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Interpol review of the analysis and detection of explosives and explosives residues

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1. Introduction and coverage of the literature

The authors would first recommend that readers review the previous three review papers from 2013, 2016 and 2019 [22–24]. Those may have some articles on technology that laboratory managers might find useful and adaptable to their current approaches to explosives analysis and that may be of use in future real-world applications.

The international situation in 2022 is notably different from that in 2019 when the last iteration of this paper was published. There is considerably less focus on in theater devices and explosives as Allied Forces have mostly withdrawn from the Middle East and Afghanistan. Unfortunately, however, because of this withdrawal and the resulting dearth of human intelligence, people who engage in terrorist activities are less restrained in securing improvised explosives and precursors. Additionally, and dangerously, these terrorists now have access to war material left behind by withdrawing forces, including military grade explosives and munitions. A re-focused effort on traditional military high explosive detection and analysis may be needed for laboratories worldwide if these are deployed in both criminal and terrorist bombings.

Another crisis that may result in concerns for years to come for many countries is the current war in Ukraine. All wars give rise to the long-term problem of criminals and terrorists having access to excess munitions and explosives well after the war has come to a close. This was evident after the wars in Iraq and Afghanistan, but also after the wars during the breakup of former Yugoslavia. Those munitions and explosives bleed over into neighboring countries impacting the security of the region.

Beginning in 2020 the United States experienced a substantial increase in incidents of civil unrest. The criminal misuse of explosives and ignitable liquids was widespread and was recorded from large urban centers to smaller towns. While some explosives were deployed against government entities from police officers to court houses, some opportunistic individuals used the cover of riots and protests to engage in criminal bombings for monetary gain, especially by trying to breach ATM's. Almost all of the devices deployed were low explosive pyrotechnic devices and some were modified with shrapnel. Almost all of the increases in backlogs at our laboratory were from such civil unrest.

As we wrote in the last (2019) paper, "One of the most important yet difficult areas for the past ten to twenty years for the explosive analyst is the ever-changing type of explosives employed by the criminal bomber and terrorists. Restrictions on widely used commercial and military high explosives are often circumvented by the illicit production of homemade explosives. While there have been attempts to restrict chemical precursors and some oxidizers and fuels, criminal and terrorist bombings are still frequently using homemade explosives. Some of these explosive formulations are difficult to detect in chaotic and contaminated scenes, with matrices that are additionally problematic. The two biggest reasons for failure to identify a post-blast homemade explosive in some of these cases are the failure to collect samples in a timely manner and the failure to properly extract the analytes from difficult matrices. While training of first responders and others may help with the first issue, the second issue falls mostly on the explosives forensic community. There is not a lot of research in this area, but a few referenced papers do address this second issue" [24].

Introducing new techniques into the suite of analytical schemes or standard approaches has become increasingly more laborious as most laboratories are now accredited, many to ISO 17025. Accreditation standards demand more data and study before a new technique can be validated and brought online by a laboratory. This even extends to more simple transitions like swapping out columns with slightly different chemistries. Yet many laboratories do not have dedicated analytical groups to do this kind of validation work. This may add to the hesitancy of laboratory managers to adopt new techniques. If the new techniques fill a crucial need or cover a gap in overall explosives coverage those hesitancies should be put aside and efforts made to complete validations.

This review of the literature will hopefully demonstrate that there

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are many applications in the world of explosives analysis from many fields that are of interest to the forensic laboratory manager. The authors and chemists at the ATF National Laboratory Center have spent hundreds of hours of reviewing and classifying abstracts, reading papers, and selecting pertinent papers to highlight in this review. Additionally, hundreds more citations are available in the bibliography. We have drawn from explosives detection, environmental, academic, and case study articles to try to cover the range of probable areas of interest. There are still dozens of references in this area, ranging from theoretical research to applied systems that are already in field use.

There are 1004 references in this review. The bibliography portion of the paper includes numerous references not specifically highlighted in the paper which may be of interest to the reader. It starts on page 23 and follows the same category structure as the paper. Many of these references could fall into two or even three categories. They will not be presented in multiple places, so it would be advantageous for the reader to peruse all of the sections. The organization of this paper follows the same pattern as the previous reviews.

2. Review Articles

This three-year cycle includes several review publications. While some are broad schemes of analysis, others are reviews of a specific class of instrumentation or field of study. Others are self-described as reviews. Review papers are useful to give a broad overview of advances in particular aspects or categories of forensic explosive analysis.

Evans-Nguyen, K. and Hutches, K. have a book on The Forensic Analysis of Fire Debris and Explosives and is a very solid accounting of the current state in the analysis of explosives [13].

There is a brief but interesting chapter by Wolfgang Greibel on what end users on the scene of an explosion or bombing have at their disposal instrument wise and additional techniques which may be used in the future [15].

Cagan, A. and Oxley, J. have published a comprehensive Second Edition of *Counterterrorism Detection Techniques of Explosives* which covers "updated research findings that will be used for the next generation of explosive detection technologies." including the most currently employed open-source detection technologies [10]. While many techniques cannot be directly translated or used in a forensic laboratory because detection has different standards than identification, it is well worth the time reading.

Forbes, T., Krauss, S., and Gillen, G., have published a very thorough and interesting review of the challenges of analyzing for trace homemade fuel-oxidizer mixtures. It is a comprehensive front to back analysis of the current state of analysis and detection for forensic laboratories [14].

Crocombe, R.A., Leary, P.E., and Kammrath, B.W., published Volume One of the technology and instruments used in portable spectroscopy. This covers a general discussion of XRF, UV–Visible, near-infrared, mid-infrared, and Raman. In addition to traditional portable spectroscopy techniques this review also considers LIBS, NMR, and others [11].

In Volume two the above authors show how these instruments are used in various fields. They also discuss the algorithms for detection, library and method development, and the future of portable spectroscopy [11].

Sisco, E., and Forbes, T.P., reviewed the application of DART-MS to a variety of forensic samples including explosives. In addition to a thorough review of the advances for the last five years, the authors identified areas where additional research is needed to continue to advance the technique [39]. As we write below DART-MS is an increasingly useful tool in forensic chemistry.

Herweyer, D., et al. reviewed the advancements made in new "Green" primary energetic materials concentrating on potassium based energetic salts, metal-free ionic energetic salts and metal-free covalent energetic materials. The paper summarizes the "explosive performance, initiability, safety and environmental impact" of several new materials [18].

Nanoexplosives are another field where new materials continue to be developed. While this paper could be placed in novel explosives, nanoexplosive materials have been around long enough to be reviewed by Yetter, R.A. This review covers how to "… understand how to manipulate and build energetic materials at the nanoscale …" [46].

3. Explosive Standards and References, Laboratory Quality Control, Contamination Prevention

While this category is rather broad, it encompasses many references that could be highly useful in a forensic laboratory setting. As instrumentation becomes more and more sensitive having a framework for things ranging from engineering controls to standard approaches to prevent contamination is imperative.

Gareth Collett has published a fantastic report focused primarily on precursors for Homemade Explosives (HME) including recommendations for preventative actions that could limit access to the materials. It also recommends a global repository for HME based IED's and additionally links every non war zone HME IED attack with the confirmed or suspected HME used since 1970 [52]. It should be required reading for any analyst in the field.

Schachel, T.D., et al. propose a "pan-European Forensic Substance Database on Explosives" to include not just the base explosives but more importantly for sourcing and or brand identification, the additives in various products. They used a combination of HPLC-HRMS (high resolution mass spectrometry), XRD, and XRF and identified 41 additives with diagnostic potential [55].

Stein, J., did a thesis at Virginia Commonwealth University looking at transfers of explosives used in render safe procedures to device components of simulated IED's. The author considered specifically the use of a Percussion Actuated Disrupter (PAN) and a water bottle shot with detonating cord. Transfers were detected [56]. This research highlights the necessity of communication between the field and the laboratory.

ASTM International has published *ASTM* E2520-21*: Standard Practice for Measuring and Scoring Performance of Trace Chemical Detectors* and is a good resource for assessing the performance of trace explosives detectors that use swabs [49].

Also, ASTM International published ASTM E2677-20: *Standard Test Method for Estimating Limits of Detection in Trace Detectors for Explosives and Drugs of Interest* [50]. This standard may be of interest to labs establishing limits of detection for new or existing methods.

4. Sampling and Concentration of Explosive Traces

Despite the volume of research done in this category over the past several years there remain significant gaps in the field of sampling and concentrating explosive samples in the post-blast debris and trace detection realm. Ease of use and robustness of any given technique are necessary as is universality. It is the latter, universality, that is hardest to achieve because there are simply so many classes of explosives and their post-blast reaction products.

Irlam, R.C., et al. researched seven different sorbents (solid phase extraction) for recoveries of 14 types of explosives and matrices that ran the gamut from dirt to cooking oil to wastewater to determine which was the best for analyte recovery. They found that "With the exception of river water, the matrix effects were lowest using dual sorbent SPE, with little/no compromise in recovery." They report that this approach resulted in an approximate 10-fold limit of detection over the single sorbent approach. Finally, they report that Oasis HLB and Isolute ENV + yielded the best recoveries quantitative wise [68].

Additionally, Irlam, R.C., et al. have applied 3-D printed LEGO ® inspired miniature blocks for SPE extractions of explosives in a variety of matrices. It is believed that this is the first reported use of 3-D printed SPE blocks. Efficiencies of the extractions look promising [67].

In the area of ion chromatography, Mauricio F.G.M., et al. evaluated swabs and syringe filters and found that of six syringe filters only two were free of interfering analytes (such as Na, K, Mg, Ca, Cl and SO4). All "forensic" swabs had significant amounts of these as well. They further analyzed commercially available cotton swabs, cotton balls, and cotton discs and found these to have similar interferents albeit on a, surprisingly, lower level than the forensic ones. Finally, they report that all sampling materials can be cleaned of these ions through three washes [71]. The nature of post-blast analysis of inorganic explosives is such that these types of ions are often all that remains to be detected. Therefore, selection of a swabbing material that has minimal interfering analytes is advantageous and contributes to a stronger conclusion making this particularly relevant research.

While pertinent to an environmental application, Temple T., et al. researched four different types of one step extraction processes (stirring, shaking, sonication and accelerated solvent extraction (ASE)) on five different soil types and report that shaking is the most reproducible, but less efficient than stirring and ASE was the least reproducible. Also, they report that soils high in organic content (>2%) unsurprisingly affected both extraction efficiency and reproducibility [774].

Rodriquez J., and Almirall, J., demonstrated the efficiency in volatile vapor sampling using continuous capillary microextraction and reported recoveries of 3.0–89%. By comparison they reported headspace and simulated open air sampling resulted in less recoveries. The analytes were 3-NT, 2,4-DNT, DPA, EC, DBP and 2-NDPA, all compounds that can be found in smokeless powders [74].

Glackin, J.M.E., et al. published an article on coating swabs with a fluoropolymer which was then used to swab an explosive and thermally desorbed, "… causing the quenching of light emission from a thin film luminescent sensor." They first tried it with 2,4-DNT and reported an increase of three orders of magnitude in sensitivity over standard colormetric tests. Then it was used on PETN, RDX, and TNT, and even on post-blast samples [66].

Evans-Nguyen, K.M., at al reported on employing a solventless, noncontact electrostatic sampling method for drugs and explosives. They used a hand-held Van de Graaf generator and wire mesh held close to the sampling substrate. The particles transferred to the mesh and were analyzed by thermal desorption electrospray ionization and mass spectrometry [62].

Avissar, Y.Y., et al. described using hot water to extract post-blast samples. Then they conducted a liquid-liquid extraction with a very small amount of dichloromethane (DCM) before analyzing by GC-MS. They extracted several different types of substrates (metal, sponge, asphalt, gravel) and reported that this method leads to notably less sensitivity loss in the GS-MS after 40 injections than a traditional solvent extraction This extraction technique has been used successfully on real life samples [59].

Novosselov, Igor V., et al. completed a study on the recovery of certain high explosives in the swabbing of various surfaces found in security (mass transit) settings. They desorbed the analytes in various ways but found "… nylon had the lowest collection efficiency (CE%) for all cases (appx. 10%) and stainless-steel mesh had the lowest CE% for the evaluated traps" [72].

5. Identification of explosives, explosive residues and explosive properties

There are several articles describing the properties of explosives and theoretical modeling of explosive behavior. Also of interest is the area of novel explosives and proposed improvements to existing commercial and military explosives. Some of these articles also describe analytical techniques.

A. Commercial Explosives

Gao et al. reported on 3-D photopolymerization printing of a CL-20 based propellent with the goal of improve the energy content and combustion performance of propellants made with additive manufacturing techniques [106]. It is unknown if 3-D printing on a large scale will be economically feasible for mass production or more suited for quick synthesis of new combinations of materials.

Ali, F., et al. report on using waste lubricant oil as a partial substitute for fuel oil in ANFO formulations. They found that the formulations exhibited both effective explosive performance and were within the permissible limit for toxic fumes and particulate formation [78].

Lennert, E., and Bridge, C., used statistical analysis to associate smokeless powder residues from burned smokeless powder to the original smokeless powder using Sorensen-Dice similarity coefficients. The samples were run on GC/MS. They also explored the pyrolysis products of the smokeless powder constituents. Their results were mixed, stating, "The complexity of burning a mixture, such as SP, compared to burning single components may contribute to the generally low similarity coefficients observed in the comparison" [118].

Krejcir, K., Adam, J., and Buldra, R. conducted a multi-temperature study on the depletion of three common stabilizers used in smokeless powder over time. The study aims to provide background information for stability testing of smokeless powders [116].

Wang, Y., et al. explored the usage of different gases in the sensitizing microballoons in emulsion explosives and reported that the use of hydrogen gas (as opposed to helium, oxygen and nitrogen) can improve the power and energy of the emulsion explosive. Oxygen and nitrogen provide little improvement and helium is both difficult to incorporate into the explosive system and had a negative influence on performance [147].

B. Homemade Explosives

The area of Homemade Explosives (HME) is of tremendous interest to the forensic explosive's community. As we stated in our 2019 paper, "Sometimes called Improvised Explosives (as opposed to an Improvised Explosive *Device* that may or may not use HME), these explosives can, in general terms, be defined as non-factory manufactured explosives. It is uncommon, but not unheard of, however, that makers of HME will attempt to make a "commercial" type of explosive" [24].

We additionally wrote, "The actual usage of HME is constantly changing and it is difficult for forensic laboratories to have adequate protocols for every possibility" [24]. This axiom still holds true now. There is no adequate way for a regular forensic laboratory to have every possibility of HME usage covered in a post-blast situation. Intel and scene examination can help steer analysis but having the protocols in place for every eventuality, especially for a novel HME, is nearly impossible. That said, it can help if analysts keep up with current trends in HME usage worldwide.

Cory Christopher Pye reports a cautionary tale on the long-term storage of a consumer bottle of 2-propanol wherein TATP formation was noted after a dozen years past the expiration date of the product [172]. Anecdotally, the ATF lab has fielded calls where this has been found to have occurred. Fortunately, these calls are infrequent, but it is a valuable safety point for hazmat teams in particular to be aware of as well as for laboratory personnel answering questions from those in the field.

Horvath, T., and Ember, I., discuss the use of Raman and FTIR handheld instruments for on scene identification of HME and highlights the value of using the technologies in parallel [168].

Stromberg, J. and Castillo Rolon, M. conducted a study on TATP headspace using quadrapole LC/MS and found TATP was the only measurable component in the headspace, and it was noted that "the results of this study strongly suggest the proposal that diacetone alcohol and acetone are intractable components of TATP's 'vapor signature' is incorrect" [174].

D'Uva, J., et al. synthesized urea nitrate from a variety of commercially available urea sources and then analyzed the product by FTIR,

SEM/EDS, and most importantly by ICP-MS where trace elements could be determined [166]. Although chemometrics and statistical analysis were not undertaken, this proof-of-concept approach to possibly provide investigative leads etc., is very promising.

C. Other Explosives including Novel or New Explosives:

Throughout the course of history there has been a desire to develop new explosives or improve upon existing ones. The experimentation and development have been towards cheaper, more stable, more energetic, less energetic, more environmentally friendly, less susceptible to accidental initiation, more simple manufacturing processes, and more fit for immediate purpose, to name some of the objectives. Thousands of explosives have been designed and tested for decades if not centuries, but most were rejected as they did not improve upon existing explosives in the areas listed above. In this section we will include both reported improvements to existing military or commercial explosives and some unique explosives.

While not exactly novel, Yang, M., Ma, H., and Shen, Z., proposed and studied the effects of repurposing decommissioned RDX with emulsion explosive formulation. They were able to reduce the critical diameter of the original emulsion [307].

In a similar vein Cui, Q., et al. proposed a novel way of introducing TNT into porous aluminum powders and were able to simplify the method of controlling the amount of TNT through a temperature gradient [191].

Liu, Y., et al. report on a new equation on the theoretical detonation performance of aluminized RDX [251].

In the area of nanotechnology Van Riet, R., et al. report on filling nanoporous carbon with an oxidizer. While oxidizer-carbon mixtures are common, the nanostructure of the carbon is a novel report [282].

Similarly, Ma, X., et al. described improving structural control over nanoenergetic materials in an overview paper [257]. Once costs are brought down and scalability makes these products economically feasible these products will most likely find their way into the marketplace.

Li, M., et al. described the production of "photocurable energetic resin based propellants fabricated by 3D printing [242].

6. Instrumental Analysis of Explosives

A) LC/HPLC/UPLC

As was reported in 2019, "Liquid chromatography (LC), high performance liquid chromatography (HPLC), and ultra-high performance liquid chromatography (UHPLC) are all excellent separation techniques and have the advantage of being less destructive to thermally sensitive high explosives than gas chromatography techniques" [24].

Freye, C.E., et al. researched two types of liquid chromatography for measuring the aging and degradation of the PBX 9501. First low molecular weight components of the explosive were measured with HPLC while the high molecular weight compounds were measured using size exclusion chromatography (SEC) [332]. The parameters for each can be found in their paper. These tools may be useful for forensic applications such as comparisons of PBX explosives.

Steiner, A. and Lurie, I. compiled an overview on using diode array detectors (DAD) coupled with both HPLC and supercritical fluid chromatography (SFC) for a variety of analytes including explosives [332].

Veresmortean, C., explored an LCMS method development for eight selected organic high explosive compounds from wastewater. The importance of being able to extract and analyze both the original compounds (TNT, RDX, etc.) and their degradation products and optimize for both was stressed [333].

Freye, C., Nguyen, T., and Tappan, B. used UHPLC-MS/MS to explore the synthesis impurities due to the manufacturing process of ETN. They found 12 such impurities and were able to analyze for them [328].

Kotrly, M. et al. reported on using derivatization of aliphatic and aromatic amines with HPLC-fluorescent detection and having femtomole-level detection [331].

B) Ion Chromatography

The technique of ion chromatography (IC) is often used in forensic explosives analysis for the analysis of inorganic and some organic explosives. Many detectors are used including mass spectrometry. Ion chromatography has the advantage over other inorganic characterization methods because a relative profile of many anions or cations in a sample can be compared against known post-blast profiles of certain explosive types.

Hutchinson, J.P. et al. report on using two techniques for the forensic analysis of explosives and their post-blast products. Mostly exploring inorganic low explosives, they looked at using capillary electrophoresis and ion chromatography as orthogonal techniques, each instrument with its own pluses and minuses [338].

Gallidabino, M.D. et al. used ion chromatography coupled with high resolution mass spectrometry (IC-HRMS) and an ethanol-based eluent. It was interesting that their method did not detect chloride or nitrite. Their ethanol eluent-based approach was reported to be an improvement over methods using an aqueous eluent [335].

C) Gas Chromatography

Gas chromatography has been a workhorse for the qualitative oriented forensic chemist for many decades now and remains pertinent to the examination of many classes of explosives. It provides for quick separations for a variety of compounds and the methods can be relatively easily modified when required.

Qualley, A., Hughes, G.T., and Rubenstein, M.H. report on a method of improving the data in field-portable GS-MS by using the "pre-incorporation of isotopic analogues (of the target analytes) onto thermal desorption tubes in advance of field distribution …" [346].

Cruse, C. and Goodpaster, J. reported that they optimized various parameters (inlet temperatures, flow rate, and detector gas pressure) for a GC/VUV (gas chromatography-vacuum ultraviolet) system for the examination of several organic high explosives using statistical analysis called response surface methodology or RSM [343].

M. Li et al. published their work on developing a micro GC with a micro-photoionization detector which reportedly with sub-picogram detection limits on trace vapors for optimizing field GC's [345].

D) Capillary Electrophoresis

Capillary electrophoresis (CE) is a separation technique that utilizes charged fields instead of pressure to examine many types of analytes including explosives. It can be used orthogonally with Ion Chromatography or, with a mass spectrometer, as a solo technique.

Krauss, S.T. et al. demonstrated the utility of a wipe based commercial GreyScan ETD-100 capillary electrophoresis for the detection of several inorganic oxidizers including nitrate, chlorate and perchlorate and post combustion inorganic ions [351].

Rapid capillary electrophoresis screening and chemical classification of fireworks was reported by Bezemer, K. et al. The Dutch police provided samples and it should be noted the Dutch civilian use of fireworks is quite common. The detection was indirect UV-detection and the results showed that chemical classification between primarily homemade and commercial pyrotechnics was determined by $Ca2+$ and $Mg2+$ cations [349].

Krauss, S.T., Forbes, T.P., and Jobes D. reported on using gradient elution moving boundary electrophoresis (GEMBE) as a "robust electrokinetic separation technique" for the separation and detection of inorganic oxidizers frequently seen in explosives. They stated that nitrate, chlorate and perchlorate oxidizers were detected from low

explosives and that many possible inorganic and organic fuels did not interfere, and even detected and separated nitrate in post-blast samples [352].

E) General Spectroscopy: Fluorescence, Luminescence, Spectrophotometric, UV, Chemiluminescence

There are hundreds of research papers and reports in this area. They are varied in their practical application to forensic and/or security work. Some could eventually be used in commercial, military, security and law enforcement applications. Still others will prove to be too costly and are too focused on one class of explosives or even a single explosive. There are a few papers the authors wish to highlight.

F) Mass Spectrometry

Mass spectrometry continues to be the most popular technique for forensic explosives analysis and detection. It could be called the "gold standard" of post-blast explosives analysis. Even so, it remains heavily researched for a variety of reasons including sampling optimization, matrices issues because of the nature of criminal use of explosives, and the similarity of lighter compounds, especially nitrate esters, that are harder to positively identify without an orthogonal approach. Soft ionization is rigorously being examined in many publications. One of the most researched aspects in mass spectrometry in the last three years has been in quick sampling and/or screening techniques such as Direct Analysis in Real Time (DART) or similar sampling methods.

Because canines have shown a propensity to detect potassium chlorate even though the vapor pressure of chlorates at ambient temperatures is negligible and decomposition requires temperatures of 300° Celsius, Cajigas, Perez-Amodovar and De Greeff used on fiber SPME derivatization to detect the resultant chloro-2-propanol proving the outgassing of chlorine [457].

Taudte, R.V., et al. described an automated online Solid Phase Extraction (SPE) for a Triple Quadrapole direct introduction analysis for the determination of five compounds typically encountered in smokeless powders. The analytes were introduced into soil and a simulated organic GSR scenario and extracted by this automated SPE with good results. The report 8 s analysis times [484].

ShuQi An et al. published a paper on DART-MS and varied the discharge gases (helium, nitrogen and argon) and found that for TNT and 2,4-DNT the results were that using nitrogen produced mass spectra "dominated by the oxidation products" suggesting nitrogen provides for a highly oxidative environment. They also tested some substrates with thermal desorption DART-MS and reported better results than traditional DART for 14 explosive compounds [450].

Chelsea Black published a Master's Thesis on exploring the applicability of DART-MS to identify homemade explosive residues post-blast [453]. And then also published with D'Souza, T., Smith, J., and Hearns, N. a paper on using DART-MS for TATP, HMTD, and MEKP with actual (not spiked) post-blast samples of those. The method worked well with actual IED fragments, dry swabs or wet swabs, with dry swabbing producing the least interferants [454]. The fact that this was done with actual post-bast samples and not simulated or spiked ones is promising.

R. Boyea published a Master's Thesis on using multivariate statistical analysis using GC-MS to compare fired cartridge cases with unburned smokeless powder [456].

Gaiffe, G. et al. used DART-HRMS to examine 83 plastic explosives and polymer constituents that may be encountered in PBX's and post-blast samples of some PBX's. They confirmed a suite of polymeric compounds in Semtex 10. They also were able to see what the changes were post-blast noting "… the best way to describe post-blast polymer samples is that they are less oxygenated and, above all, more unsaturated than the original starting material" [466].

Using ICP-MS and principal component analysis (PCA) Joshua A. D'Uva et al. categorized 48 intact sparkler compositions by looking at 50 elements and could categorize eight distinct groups using the elements V, Co, Ni, Sr, Sn, Sb, and W [461]. It would be interesting to see if in unknown post-blast samples, the patterns could apply as well.

Similar to DART, Fowble, K.L. and Musah, R.A. used laser ablation direct analysis mass spectrometry to hyperfocus on fingerprint ridge details for a variety of illicit substances including the explosive RDX [464].

DART-MS is primarily a fast technique wherein it's use as a sample screening tool is theoretically very useful. Frazier, J., Benefield, V., and Zhang, M. test five different types of DART-MS sample introduction techniques for a suite of explosives and reported that a Dart gas stream of 200 °C as well as the addition of an acetic acid dopant to wet swabs produced the best results as other methods even including thermal desorption "failed in one aspect or another to be high-throughput, sensitive, and/or robust" [465].

Another sampling technique pre GC-MS/MS introduction is described in a paper by Galmiche, M., et al. Explosives were sampled from water using stir bar sorptive extraction (SBSE). They varied type of stir bars, ionic strength, added organic solvent as well as varied times of extraction and desorption. For those analysts seeking explosives sampling from aqueous solutions, this paper is well worth reading [467].

Gonzalez-Mendez, R., and Mayhew, C.A. published an article on using soft chemical ionization for quantitation of five additives commonly used in smokeless powders through thermal desorption and qToF-MS but all for pre-blast (i.e. intact) smokeless. A follow up study on detection post-blast with this technique might prove useful [469].

Bonnar, C., Popelka-Filcoff, R., and Kirkbride, K. used direct sample analysis ion source integrated with a ToF MS for nitroglycerin and a host of common additives found often in smokeless powders both in intact and post combustion modes with limited results on an attempt at organic gunshot residues on a shooter's hands. There is a detailed discussion of the ionization and fragmentation patterns well worth perusing [455].

Supajariyawat, P. and Gonzalez-Rodriguez J. validated explosive samples taken using the Ionscan® swabs and run on an Ionscan® system via atmospheric pressure chemical ionization (APCI) in negative ion mode and an LC-qToF mass spectrometer [483].

Kober, S., Hollert, H., and Frohme, M. used a matrix-assisted laser desorption/ionization time of flight mass spectrometry (MALDI-TOF MS) for quick analysis of TNT in soils [475].

McCulloch, R.D. and Amo-Gonzalez, M. reported picogram limits of detection for several explosives using field-free atmospheric pressure photoionization (APPI) combined with a thermal desorption introduction with differential mobility analysis (DMA) tandem mass spectrometry (MS/MS) [478].

Pavlov, J. et al. showed that 1,4-Benzoquinone is an efficient dopant for enhanced ionization and detection of nitramine explosives on a single quadrupole mass spectrometer fitted with a helium-plasma ionization source [481].

Field MS is always a bit tricky for the explosive analyst and mostly requires suitable ambient ionization and often requires operation with no power sources, gas supplies, and flow control or heating devices. Pintabona, L. et al. studied the use of surface acoustic wave nebulization (SAWN) with MS for ambient ionization suitable for filed use and report "excellent sensitivity of nitrate-based organic explosives was observed for nitrate-based explosives when operating the MS in the negative mode" [482].

Organic high explosives are frequently either light molecules with high vapor pressures or heavier and nonvolatile. Bi, L et al. developed an "ultrasonic cutter blade coupled barrier discharge ionization" method to detect ultra trace levels of nonvolatile explosives among other nonvolatile compounds [452].

G) Isotope Ratio Mass Spectrometry, IRMS

Isotope ratioing is a technique that can be used to sort or cluster products, in this case explosives, in order to possibly source the origin of

that product. For it to be successful large databases are generally required. There have been successful uses of this technique in both intelligence applications and with agricultural products wherein certain countries are under embargos. It may be useful in forensics especially as an excluder of commonality of two items but, is of limited use in definitive inclusions without the aforementioned database for that product.

Comparison of the homemade explosive erythritol tetranitrate (ETN) with its precursors was explored in a paper published by Bezemer, K et al. Keying in on carbon and nitrogen they report that "… robust linear relationships between precursor and the end product were observed for these isotopes … that support the hypothesis that a given erythritol or nitrate precursor was used to synthesis a specific ETN batch." [488].

C. Hu et al. propose a recrystallization technique to purify ammonium nitrate (AN) to achieve better results from real world AN comparisons. They found that without purification contributions from other materials mixed in with the AN can skew an isotope ratio analysis [489].

Kim, N.Y., et al. studied the propellants from nine different shotshells from several countries and clustered them by using IRMS. Adding organic component analysis as well, they were able to discriminate all nine [490]. Applying this in a post-blast or post-fired scenario might prove useful for sourcing to provide investigative leads although as always larger databases are needed.

H) FTIR

Fourier Transform Infrared Spectroscopy (FTIR) is a workhorse instrument in forensic explosives analysis. Some useful papers are included in the bibliography.

I) Raman Spectroscopy

Raman spectroscopy continues to be applied for explosives analysis in the lab as well as in the field for hazard assessment. There are numerous advantages to this technique, as we wrote in 2019, "it is fast, discriminatory, non-destructive and vetted for legal proceedings" [24]. Additionally, it does not require sample prep and is capable of sampling materials in situ, through containers, and at significant distances (stand-off).

Gulia, S. et al. reported on using spatially offset Raman spectroscopy (SORS) as a method to overcome the limitations of conventional Raman spectroscopy when applied to testing through colored glass, high density polyethylene (HDPE), Teflon etc. [512]. This will prove useful both in security settings and for examination of materials in searches.

Colob-Gonzalez, F.M., et al. described a method for detecting TNT, PETN, and RDX on a variety of hair types with non-invasive Raman spectroscopy. They found, not surprisingly, that gray hair was the best substrate for detection [505].

In a unique approach to extremely small samples Kotrly, M., and Turkova, I., used a stepped approach with SEM/FIB (focused ion beam) to get 3D reconstruction of the materials in post-blast samples, EDS/WDS for surface elemental mapping, and high-resolution Raman spectroscopy. By using this compliment of techniques, they could easily focus in on materials of interest and carry out complex analysis on microscopic particles [518]. In one regard this can be seen as a sampling technique. This combined instrument set-up could prove valuable for post-blast analysis where minimal residue is available.

J) DSC, Thermal Analysis, TG

This category is applicable to the examination of explosives and mixtures and can further characterize an unknown material. These techniques have been around for decades and while they have limited applications in the forensic lab setting, they are still useful, especially for evaluating new explosives and explosive formulations.

7. Nanotechnology

Nanotechnology can be used for the miniaturization of instrumentation which can be much more easily deployed for field analytical use. It also can significantly enhance detection of very small amounts of analytes. Also in this category is the production and manufacture of nanoexplosives which are more efficient and theoretically at least portend less environmental contamination due to the efficiency of the explosive.

Using Raman spectroscopy coupled with nanomotors Novotny, F., Plutnar, M., and Pumera, M., detected picric acid. Their synthesis of the nanomotors was done using the seeded growth wet chemical method as opposed to planar substrate methods, and they report that this method is highly scalable [551].

Bhatt, P.V., et al. also wrote about using nanotechnology as a means of tagging explosives as well as general advances in nanotechnology and a summation of the current trends [538].

8. General detection

A) Canine Explosives Detection

Canine explosive detection is both very effective, given the right training and reasoned deployment, and simultaneously the most frustrating for analysts who cannot replicate this efficiency and selectivity using man made instrumentation. Research in this area continues to try and shed light on the complexities of how canines process and detect target odors and the optimization of training aids and odor presentation. There are many considerations for training and maintaining an effective explosives detection canine team, some of which are discussed in the papers in this section.

Sacharczuk, M. et al. published a fascinating study on canine performance and selected canine olfactory receptor genes. They identified the ten canines with the best performance and the ten with the worst out of 91 drug detecting canines and 57 explosive detecting dogs. They then examined several genes in order to predict, before training, which canines would be best suited for detection work [566].

One potentially significant problem with canines is their receptiveness to handler cues. Lazarowski, L. et al. reported that responsiveness to human cues decreased with age but the ability to locate the reward increased and "Furthermore, a lack of susceptibility to deceptive social cues was predictive of future success as a detection dog" [564].

DeGreeff, L. and Peranich, K. published an article on using a Mixed Odor Delivery Device (MODD) to increase proficiency in canines for the detection of mixtures that contain a target odor. The paper finds that canines exposed to mixtures in training had more success detecting odors in a mixture than those that had not previously trained on mixtures. The odorants were verified using SPME-GC/MS for quality control [559].

Gazit, I. et al. designed an experiment to test a canine's ability to correctly alert on individual odors when previously exposed to a mixture of those odorants. They found dogs can indeed quickly recognize individual components [563].

Simon, A.G., et al. described using DART-MS to monitor in real time TATP released from a polydimethylsiloxane canine training aid and compared it to other training aids for the same analyte. They report this training aid style had similar odor output to a traditional style container with holes in the lid. The authors also used DART to assess real time odor availability from both styles of training aids in various search configurations [568].

B) LIBS Detection

Romolo, F.S. and Palucci, A. have published a review chapter on the advances with detection techniques for security purposes in the areas of laser induced breakdown spectroscopy (Stand-off) or LIBS, Raman (stand-off), surface enhanced Raman spectroscopy (SERS) and laser

photoacoustic spectroscopy They discuss the detection limits and the drawbacks of these techniques and discuss how they can be used to advance an investigation. One such example was helping to reduce the number of samples sent to the lab [577].

C) Neutron

Seman, J., Giraldo, C.H.C., and Johnson, C.E. reported on a proposed nuclear barcode to be used as a chemical detection agent. Part of the coding employs a unique combination of taggant elements at different concentration levels that could be used to provide specific information about where and when the explosive was manufactured which could provide valuable investigative leads in criminal or terrorist bombings. The paper examines the stability of the ratios over time and found that the technique could work if the concentration levels were separated at least 100 ppb [583].

D) Terahertz
E) Nuclear Techniques

Yu, P., et al. monitored the droplet size distribution in ANFO emulsion explosives at different temperature and storage conditions to assess any impact of the storage condition on the stability of the emulsion. They used Nuclear Magnetic Resonance (NMR) Pulsed Field Gradient (PFG) and found storage at 50° Celsius for 12 weeks lead to a 60% increase in mean droplet size. Adding 5% calcium nitrate to the aqueous phase suppressed this thermal degradation [602].

F) X-Ray
G) Ion Mobility Spectrometry

While Ion Mobility Spectrometry is often used in security screening settings because of its rapid sampling times and relative accuracy, it often has not been used often in forensic laboratories because of its limited ability to separate analytes, its propensity for being overloaded quickly requiring a period of cleaning of the system, and its potential for false positives. There have been advances made to allow for limited separations and quicker recovery times improving the usefulness of this technology.

Hauck B., Harden C., and McHugh V. evaluated five possible calibrants for an ion mobility time of flight instrument. They reported that di(propylene glycol) methyl ether (DPM) was the most useful and recommended against 2,4-pentanedione (PDO) and methyl salicylate (MES) [610].

Thangadurai S. and Gurusamy K. advocated for use of IMS in post-blast debris samples and reported that several explosives were detected in various matrices. They discuss sample preparation and screening and highlight the advantages and limitations of the technique for the detection of explosives [616].

Chilluwal, U. published a dissertation arguing for tandem IMS using chlorine adducts of RDX, PETN and NG for the analysis. By using tandem IMS there was a reported elimination of the false positives often encountered with IMS results due to interferents [608].

In a similar fashion, Mullen, M., and Giordano, B. used the combined technique of secondary electrospray and corona discharge ionization (SECDI) to achieve more sensitivity for TNT and 2,6-DNT [612]. These approaches that eliminate the problems inherent in IMS may prove valuable as a very rapid analytical tool.

The drift tube design for IMS was enhanced in a paper published by Smith, B. et al. They designed a flexible drift tube and report "the DT (drift tube) is constructed from a flexible printed circuit board (PCB) with a bespoke 'dog-leg' track design, that can be rolled up for ease of assembly." This design was reported to have a low cost and low footprint with limits of detection in the low nanograms [615].

Fisher, D., et al. proposed applying machine learning to IMS for a preliminary study using five nitrate explosives, AN, ANFO, Urea Nitrate, environmental pollution nitrates and blanks. Their supposition is that machine learning can enhance selectivity for actual threats [609].

Bohnhorst, A., et al. wrote about their new approach to enhancing separation by increasing the resolving power of the drift time IMS without employing higher drift voltages. Instead, they employed a moving field IMS (MOF-IMS) to use the available voltage to a smaller segmented drift region [607].

H) Novel Detection

Novel detection is a catchall category for detection that does not fall neatly into another category. It could be completely novel or it could be something based on other techniques but different enough to be included in this section of the paper or bibliography.

Filipi, J., et al. described the use of honeybees as a tool that could be used in humanitarian demining efforts. The bees can be used in passive searches to detect the present of landmines in an area or active searches of pinpointing locations. The system relies on the detection of explosives residue on the body of honey bees that were foraging [638].

Simic, M. et al. described a similar use of honeybees. As a passive system honeybees can "electrostatically collect particles from the air in the flying and foraging areas, which in conjunction with organic-based explosive vapor sensing films, placed at the entrance of a beehive, can be used as a passive explosive sensing mechanism." Furthermore, honeybees can be trained to react to certain explosives [685].

In a similar vein of using animals to detect explosives, Alsaleh, S., Barron, L., and Sturzenbaum, S. published a paper on the use of the invertebrate nematode *Caenorhabditis elegans* (worm) for the detection of ground soil perchlorate [620].

Liu, C. et al. integrated a smart phone with a urea-functionalized polyionic liquid photonic spheres to construct a colorimetric sensor array that can detect and identify five nitroaromatic explosives [660].

Lefferts, M.J., et al. used "ANFO chemiresistive vapour sensors based on polypyrrole (PPy) percolation networks to enhance" GC-MS results and reported improved sensitivity over thin film and detected "13–180 ppb of ammonia emitted by a variety of different ammonium nitrate …" mixtures [656].

Blanco, S., et al. proposed wetting TATP as they form TATP-water adducts which could then be detected by microwave spectroscopy [625].

I) Stand Off

9. Environmental

As we wrote in 2019, Environmental scientists and chemists have long sought to test and eventually remediate explosives in environmental samples. Some of these methods can be directly borrowed from this field for use in forensic laboratories. Still other research, such as degradation studies, may assist the analyst in background knowledge of the explosive in certain matrices, especially soils [24].

Nawala, J. et al. used GC-MS/MS, LC-HRMS and NMR to examine explosives excavated from the Baltic Sea. There are tons of unexploded ordinance on the sea bed, so classifying it is important. They found that most samples indicated that it was a TNT, RDX, aluminum mixture known as "torpex" [770].

Rindelaub, J.D., et al. used XRF to measure particulate matter from fireworks usage in New Zealand to postulate source material (e.g. Cl from perchlorate oxidizers) and compared air quality vis-à-vis standard environmental exposure recommendations [776].

10. Other (safety, definitions, etc.)

While this article could be placed in the review category, we have included it here. Richard Crocombe has done an extensive review of portable spectroscopy including a discussion of the future of the

technology. He looked at the deployment numbers and usage of portable IMS, XRF, FTIR and Raman instruments, most of which are deployed in security operations or with fire or police hazmat responders [823].

da Silva, L., et al. published an interesting paper on pipe bomb fragmentation with varying case (wall) thickness. They used aluminized ammonium nitrate detonated with a PETN based detonator and a 5-g booter made of PETN and nitrocellulose and noted that the size and velocity of the fragments correlated to the pipe size [825]. It would be interesting, since the quality control on the pipes and test design was well thought out, to do similar tests with a suite of low explosives and not boosted or detonated.

Amaral, M., et al. studied transfer dynamics of ammonium nitrate showing transfers "… even when contact occurs for a short duration with a relatively low force" [796]. They report a variety of test conditions which may be useful in understanding transfer in the context of crime scenes or swabbing techniques. This reference could also be placed in the sampling category.

Collett, G. et al. tackled the predictive threat assessment process for Homemade Explosives (HME) precursors, specifically the regional distribution of hydrogen peroxide, ammonium nitrate and potassium chlorate [821].

Although there were many articles published on the Beirut Port ammonium nitrate explosion, Yu, G. et al. published perhaps the most comprehensive one. By looking at many post-blast factors, measurements, and reports, they calculated the TNT equivalent of the AN explosion to be approximately 950.3 tons and the fatality radius to be 487 m from the center. They also included an evaluation other safety related considerations relating to the accident and future ammonium nitrate storage considerations [954].

Oluwoye, I., et al. used XRD and IR to examine rust on iron-based containers to show oxygen deficient Fe_2O_3 clusters can serve as an agent to reduce ignition temperatures with ammonium nitrate reactions. They report "The dihydroxylation of hydrated iron (III) oxide, present on the surfaces of rust, exposes the Fe sites that react exothermically with AN, before the material assumes the ordered Fe_2O_3 phase." It may be prudent to monitor AN storage conditions in steel storage containers, especially older ones. AN is a strong oxidizer and does not require a high percentage of fuel to react or even detonate [898].

Rettinger, R., et al. published an article on lab scale (2 g) and field scale (5 kg) testing for combinations of several oxidizers (potassium nitrate, potassium chlorate, potassium permanganate, potassium iodate, ammonium nitrate and ammonium perchlorate) mixed with sucrose and aluminum to compare explosive potentials of each [910].

Tin, D., Margus, C., and Ciottone, G., did a comprehensive review of all terrorist events for the last 50 years, including ones deploying explosives. They report 48.78% of these 168,003 events used explosives since 1970 [934]. This paper is a fitting note to end on, highlighting the continued need for research and development to combat the threat of explosives.

Final notes

We have tried to review as much literature as possible these last few years and have written here about dozens of publications. There are indeed hundreds more citations listed in the bibliography, many of which may have some useful information for your forensic laboratory and explosive analysts.

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References

Review Articles

[1] O. Adegoke, N. Nic Daeid, Colorimetric optical nanosensors for trace explosive detection using metal nanoparticles: advances, pitfalls, and future perspective, Emerg. Top. Life Sci. 5 (3) (2021) 367–379, https://doi.org/10.1042/ETLS20200281.
[2] R.K.A. Amali, H.N. Lim, I. Ibrahim, N.M. Huang, Z. Zainal, S.A.A. Ahmad, Significance of nanomaterials in electrochemical sensors for nitrate detection: a review, Trends Environ. Anal. Chem. 31 (2021), e00135, https://doi.org/10.1016/j.teac.2021.e00135.
[3] R. Apak, S.D. Cekic, A. Uzer, E. CApanoglu, S.E. Celik, M. Bener, Z. Can, S. Durmazel, Colorimetric sensors and nanoprobes for characterizing antioxidant and energetic substances, Anal. Methods 12 (44) (2020) 5266–5321, https://doi.org/10.1039/D0AY01521K.
[4] V. Babrauskas, D. Leggett, Thermal decomposition of ammonium nitrate, Fire Mater. 44 (2) (2019) 250–268, https://doi.org/10.1002/fam.2797.
[5] N. Baig, & I. Kammakakam, W. Falath, Nanomaterials: a review of synthesis methods, properties, recent progress, and challenges, Mater. Adv. 2 (6) (2021) 1821–1871, https://doi.org/10.1039/D0MA00807A.
[6] S. Bell, Explosives and improvised explosive devices, in: Forensic Science: an Introduction to Scientific and Investigative Techniques, fifth ed., CRC Press, 2019, pp. 197–211.
[7] A. Benhammada, D. Trache, Thermal decomposition of energetic materials using TG-FTIR and TG-MS: a state-of-the-art review, Appl. Spectrosc. Rev. 55 (8) (2019) 724–777, https://doi.org/10.1080/05704928.2019.1679825.
[8] H. Brown, T. McDaniel, P. Fedick, C. Mulligan, The current role of mass spectrometry in forensics and future prospects, Anal. Methods 12 (32) (2020) 3974–3997, https://doi.org/10.1039/D0AY01113D.
[9] A. Brzechwa-Chodzynska, W. Drozdz, J. Harrowfield, A.R. Stefankiewicz, Fluorescent sensors: a bright future for cages, Coord. Chem. Rev. (2021), 213820, https://doi.org/10.1016/j.ccr.2021.213820.
[10] A. Cagan, J. Oxley (Eds.), Counter Terrorist *D*etection Techniques of Explosives, second ed., Elsevier Science, 2021.
[11] R.A. Crocombe, P.E. Leary, B.W. Kammrath (Eds.), Portable Spectroscopy and Spectrometry: Vol. 1: Technologies and Instrumentation, Wiley, 2021.
[12] R.A. Crocombe, P.E. Leary, B.W. Kammrath (Eds.), Portable Spectroscopy and Spectrometry: Vol. 2: Applications, Wiley, 2021.
[13] K. Evans-Nguyen, K. Hutches (Eds.), Forensic Analysis of Fire Debris and Explosives, Springer, 2019.
[14] T.P. Forbes, S.T. Krauss, G. Gillen, Trace detection and chemical analysis of homemade fuel-oxidizer mixture explosives: emerging challenges and perspectives, Trends Anal. Chem. 131 (2020), 116023, https://doi.org/10.1016/j.trac.2020.116023.
[15] W. Greibl, End user commentary on advances in the analysis of explosives, in: S. Francese (Ed.), Emerging Technologies for the Analysis of Forensic Traces, Springer, 2019, pp. 241–243, https://doi.org/10.1007/978-3-030-20542-3_16.
[16] L. Gutowski, S. Cudzilo, Synthesis and properties of novel nitro-based thermally stable energetic compounds, Defence Technol. 17 (3) (2021) 775–784, https://doi.org/10.1016/j.dt.2020.05.008.
[17] D. Herrmannsdorfer, P. Gerber, T. Heintz, M.J. Herrmann, T.M. Klapotke, Investigation of crystallization conditions to produce CL-20/HMX cocrystal for polymer-bonded explosives, Propellants, Explos. Pyrotech. 44 (6) (2019) 668–678, https://doi.org/10.1002/prep.201800332.
[18] D. Herweyer, J.L. Brusso, M. Murugesu, Modern trends in "green" primary energetic materials, New J. Chem. 45 (23) (2021) 10150–10159, https://doi.org/10.1039/D1NJ01227D.
[19] T. Horvath, J.Z. Szatai, A history of detection of explosive devices. 1 (700-1950), Rev. Acad. Fortelor Terestre 25 (3) (2020) 189–200, https://doi.org/10.2478/raft-2020-0023. Academic Complete.
[20] F. Jiang, W. Zhao, J. Zhang, Recent progress in the development of MoSe2 based chemical senors and biosensors, Microelectron. Eng. 225 (2020), 111279, https://doi.org/10.1016/j.mee.2020.111279.
[21] A. Kalsi, S. Celin, P. Bhanot, S. Sahi, J. Sharma, Microbial remediation approaches for explosive contaminated soil: critical assessment of available technologies, recent innovations and future prospects, Environ. Technol. Innovat. 18 (2020), 100721, https://doi.org/10.1016/j.eti.2020.100721.
[22] D.J. Klapec, G. Czarnopys, Analysis and detection of explosives and explosives residues review: 2010 to 2013, in: *17th Interpol International Forensic Science Managers Symposium*, Lyon 8th-10th October 2013, 2013, pp. 280–435.
[23] D.J. Klapec, G. Czarnopys, Analysis and detection of explosives and explosives residues review: 2013 to 2016, in: *18th Interpol International Forensic Science Managers Symposium*, Lyon 11th-13th October 2016, 2016, pp. 194–261.
[24] D.J. Klapec, G. Czarnopys, Analysis and detection of explosives and explosives residues review: 2016 to 2019, in: *19th Interpol International Forensic Science Managers Symposium, Lyon 8th-10th October 2019*, 2019, pp. 194–283.
[25] E. Koch, Insensitive high explosives: IV. Nitroguanidine — initiation & detonation, Defence Technol. 15 (4) (2019) 467–487, https://doi.org/10.1016/j.dt.2019.05.010.
[26] K. Koyani, M. Tharmavaram, G. Pandey, D. Rawtani, C. Hussain, Sensors for the detection of explosives and gunshots, in: D. Rawtani, C.M. Hussain (Eds.), Technology in Forensic Science: Sampling, Analysis, Data and Regulations, 2020, pp. 199–220, https://doi.org/10.1002/9783527827688.ch10.

[27] P. Li, X. Li, W. Chen, Recent advances in electrochemical sensors for the detection of 2, 4, 6-trinitrotoluene, Curr. Opin. Electrochem. 17 (2019) 16–22, https://doi.org/10.1016/j.coelec.2019.04.013.
[28] R. Liu, Z. Li, Z. Huang, K. Li, L. Yi, Biosensors for explosives: state of art and future trends, TrAC, Trends Anal. Chem. 118 (2019) 123–137, https://doi.org/10.1016/j.trac.2019.05.034.
[29] L.M. Martelo, L.F. Marques, H.D. Burrows, M.N. Berberan-Santos, Explosives detection: from sensing to response, in: B. Pedras (Ed.), Florescence in Industry, Springer, 2019, pp. 293–320.
[30] M.P.V. Matos, G.P. Jackson, Isotope ratio mass spectrometry in forensic science applications, Forensic Chem. 13 (2019), 100154, https://doi.org/10.1016/j.forc.2019.100154.
[31] S. Moazzen, A. Zarei, K. Mardi, Green sample preparation based on directly suspended droplet microextraction using deep eutectic solvent for ultra-trace quantification of nitroaromatic explosives by high performance liquid chromatography, J. Anal. Chem. 76 (11) (2021) 1296–1304, https://doi.org/10.1134/S1061934821110083.
[32] G. Musile, Y. Agard, L. Wang, E.F. De Palo, B. McCord, F. Tagliaro, Paper-based microfluidic devices: on-site tools for crime scene investigation, TrAC, Trends Anal. Chem. 143 (2021), 116406, https://doi.org/10.1016/j.trac.2021.116406.
[33] S. Patel, I. Lurie, The use of portable separation devices for forensic analysis: a review of recent literature, Forensic Chem. 26 (2021), 100365, https://doi.org/10.1016/j.forc.2021.100365.
[34] C.N. Pitman, W.R. LaCourse, Desorption atmospheric pressure chemical ionization: a review, Anal. Chim. Acta 1130 (2020) 146–154, https://doi.org/10.1016/j.aca.2020.05.073.
[35] S.V. Rao, S.A. Kalam, M.S.S. Bharathi, Photonics for explosives detection, in: *Encyclopedia of Applied Physics*, 2019, https://doi.org/10.1002/3527600434.eap826.
[36] T. Rasheed, F. Nabeel, K. Rizwan, M. Bilal, T. Hussain, S. Shehzad, Conjugated supramolecular architectures as state-of-the-art materials in detection and remedial measures of nitro based compounds: a review, TrAC, Trends Anal. Chem. (2020), https://doi.org/10.1016/j.trac.2020.115958.
[37] W. Raza, D. Kukkar, H. Saulat, N. Raza, M. Azam, A. Mehmmod, K. Kim, Metal-organic frameworks as an emerging tool for sensing various targets in aqueous and biological media, TrAC, Trends Anal. Chem. 120 (2019), 115654, https://doi.org/10.1016/j.trac.2019.115654.
[38] J. Sabatini, E. Johnson, A short review of nitric esters and their role in energetic materials, ACS Omega 6 (18) (2021) 11813–11821, https://doi.org/10.1021/acsomega.1c01115.
[39] E. Sisco, T.P. Forbes, Forensic applications of DART-MS: a review of recent literature, Forensic Chem. 22 (2021), 100294, https://doi.org/10.1016/j.forc.2020.100294.
[40] F. Tambo, D. Ablateye, A review on the role of emerging revolutionary nanotechnology in forensic investigations, J. Appl. Nat. Sci. 12 (4) (2020) 582–591, https://doi.org/10.31018/jans.v12i4.2415.
[41] K.C. To, S. Ben-Jaber, I.P. Parkin, Recent developments in the field of explosive trace detection, ACS Nano 14 (9) (2020) 10804–10833, https://doi.org/10.1021/acsnano.0c01579.
[42] Y. Tverjanovich, A. Tverjanovich, A. Averyanov, M. Panov, M. Ilyshin, M. Balmakov, Interaction of laser radiation with explosives, application and perspectives, in: K. Yamanouchi, S. Tunik, V. Makarov (Eds.), Progress in Photo Science, Springer, 2019, pp. 493–511.
[43] T. Wasilewski, J. Gebicki, Emerging strategies for enhancing detection of explosives by artificial olfaction, Microchem. J. 164 (2021), 106025, https://doi.org/10.1016/j.microc.2021.106025.
[44] T. Wasilewski, J. Gebicki, W. Kamysz, Bio-inspired approaches for explosives detection, TrAC, Trends Anal. Chem. 142 (2021), 116330, https://doi.org/10.1016/j.trac.2021.116330.
[45] B.P. Wheeler, L.J. Wilson, Experiment 24: explosive residue examination, in: Practical Forensic Microscopy: a Laboratory Manual, second ed., Wiley, 2021, pp. 337–345, https://doi.org/10.1002/9781119154525.ch24.
[46] R.A. Yetter, Progress towards nanoengineered energetic materials, Proc. Combust. Inst. 38 (1) (2021) 57–81, https://doi.org/10.1016/j.proci.2020.09.008.
[47] Q. Yu, Z. Li, Q. Cao, S. Qu, Q. Ja, Advances in luminescent metal-organic framework sensors based on post-synthetic modification, TrAC, Trends Anal. Chem. 129 (2020), 115939, https://doi.org/10.1016/j.trac.2020.115939.
[48] F. Zapata, C. Garcia-Ruiz, Chemical classification of explosives, Crit. Rev. Anal. Chem. 51 (7) (2020) 656–673, https://doi.org/10.1080/10408347.2020.1760783.

Explosive Standards and References, Laboratory Quality Control, Contamination Prevention

[49] ASTM International, *ASTM E2520-21*: Standard Practice for Measuring and Scoring Performance of Trace Explosive Chemical Detectors. Annual Book of ASTM Standards, 15.08, ASTM International, 2021, https://doi.org/10.1520/E2520-21.
[50] ASTM International, *ASTM E2677-20:* Standard Test Method for Estimating Limits of Detection in Trace Detectors for Explosives and Drugs of Interest. Annual Book of ASTM, 15.08, ASTM International, 2021, https://doi.org/10.1520/E2677-20.
[51] A. Bose, Military Pyrotechnics, CRC Press, 2022.
[52] G. Collett, An Examination of the Precursor Chemicals used in the Manufacture of Explosive Compositions Found within Improvised Explosive Devices (IEDs), Action on Armed Violence, 2021. Online at, https://cd-geneve.delegfrance.org/AOAV-Publication-of-two-reports-on-IEDs.
[53] T. Klapotke, Energetic Materials Encyclopedia, second ed., De Gruyter, 2021 https://doi.org/10.1515/9783110626810. Vols. 1-3.
[54] H. Letendre, K. Segiun, A. Grenier, V. Mousseau, L. Cadola, F. Crispino, First lessons regarding the data analysis of physicochemical traces at activity level in TTADB, J. Can. Soc. Forensic. Sci. 54 (3) (2021) 139–156, https://doi.org/10.1080/00085030.2021.1899655.
[55] T.D. Schachel, A. Stork, R. Schulte-Ladbeck, T. Viehlaber, U. Karst, Identification and differentiation of commercial and military explosives via high performance liquid chromatography – high resolution mass spectrometry (HPLC-HRMS), X-ray diffractometry (XRD) and X-ray fluorescence spectroscopy (XRF): towards a forensic substance database on explosives, Forensic Sci. Int. 308 (2020), 110180, https://doi.org/10.1016/j.forsciint.2020.110180.
[56] J. Stein, Explosive Residue Transfer from Various Explosive Ordinance Disposal (EOD) Render Safe, Master's Thesis, Virginia Commonwealth University, 2019. VCU Theses and Dissertations.
[57] M. Zarejousheghani, W. Lorenz, P. Vanninen, T. Alizadeh, M. Cammerer, H. Borsdorf, Molecularly imprinted polymer materials as selective recognition sorbents for explosives: a review, Polymers 11 (5) (2019) 888, https://doi.org/10.3390/polym11050888.

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[58] M.A. Amaral, S. Yasin, A.P. Gibson, R.M. Morgan, Sampling of explosive residues: the use of a gelatine-based medium for the recovery of ammonium nitrate, Sci. Justice 60 (6) (2020) 531–537, https://doi.org/10.1016/j.scijus.2020.07.007.
[59] Y. Avissar, A. Zelkowicz, A. Rossin, Y. Kirshenbaum, D. Tenne, A. Grafit, An efficient extraction method for post-blast traces of organic explosives, J. Forensic Ident. 71 (1) (2021) 35–48.
[60] A. Benhammda, D. Trache, M. Kesraoui, A. Tarchoun, S. Chelouche, A. Mezroua, Synthesis and characterization of α-Fe2O3 nanoparticles from different precursors and their catalytic effect on the thermal decomposition of nitrocellulose, Thermochim. Acta 686 (2020), 178570, https://doi.org/10.1016/j.tca.2020.178570.
[61] R.M. Cardoso, S.V.F. Castro, M.N.T. Silva, A.P. Lima, M.H.P. Santana, E. Nossol, R. A.B. Silva, E.M. Richter, T.R.L.C. Paixao, R.A.A. Munoz, 3D-printed flexible device combining sampling and detection of explosives, Sensor. Actuator. B Chem. 292 (2019) 308–313, https://doi.org/10.1016/j.snb.2019.04.126.
[62] K.M. Evans-Nguyen, A. Rivera, J. Fontanez-Adames, F. Li, B. Musselman, Solvent-free noncontact electrostatic sampling for rapid analysis with mass spectrometry: application to drugs and explosives, J. Am. Soc. Mass Spectrom. 31 (11) (2020) 2237–2242, https://doi.org/10.1021/jasms.0c00286.
[63] M. Galaburda, V. Bogatyrov, W. Tomaszewski, B. Charmas, O. Mischanchuk, O. Oranksa, V. Gun'ko, M. Zybert, Synthesis and structural properties of carbon/alumina composites: practical application in solid phase extraction of explosives, Microporous Mesoporus Mater. 300 (2020), 110159, https://doi.org/10.1016/j.micromeso.2020.110159.
[64] A. Garzon-Serrano, C. Sierra, O. Rodriguez-Bejarano, D. Sinuco, Volatile organic compounds, spectral characterization and morphology of ammonium nitrate fuel oil (ANFO) samples, J. Forensic Sci. 65 (4) (2020) 1085–1093, https://doi.org/10.1111/1556-4029.14312.
[65] B.C. Giordano, D.C. Ratchford, K.J. Johnson, P.E. Pehrsson, Silicon nanowire arrays for the preconcentration and separation of trace explosives vapors, J. Chromatogr. A 1597 (2019) 54–62, https://doi.org/10.1016/j.chroma.2019.03.045.
[66] J.M.E. Glackin, R.N. Gillanders, F. Eriksson, M. Fjallgren, J. Engblom, S. Mohammed, I.D.W. Samuel, G.A. Turnvull, Explosives detection by swabbing improvised explosive detection, Analyst 145 (2020) 7956–7963, https://doi.org/10.1039/D0AN01312A.
[67] R. Irlam, C. Hughes, M. Parkin, M. Beardah, M. O'Donnell, D. Brabazon, L. Barron, Trace multi-class organic explosives analysis in complex matrices enabled using LEGO®-inspired clickable 3D-printed solid phase extraction block arrays, J. Chromatogr. A (2020), https://doi.org/10.1016/j.chroma.2020.461506.
[68] R.C. Irlam, M.C. Parkin, D.P. Brabazon, M.S. Beardah, M. O'Donnell, L.P. Barron, Improved determination of femtogram-level organic explosives in multiple matrices using dual-sorbent solid phase extraction and liquid chromatography-high resolution accurate mass spectrometry, Talanta 203 (2019) 65–76, https://doi.org/10.1016/j.talanta.2019.05.047.
[69] K. Kottapalli, I.V. Novosselov, Aerodynamic resuspension and contact removal of energetic particles from smooth, rough, and fibrous surfaces, Talanta 231 (2021), 122356, https://doi.org/10.1016/j.talanta.2021.122356.
[70] H.P.H. Liddell, M.H. Merrill, In situ visualization of particle motions during wipe sampling of explosives and other race particulate materials, ACS Appl. Mater. Interfaces 11 (26) (2019) 23780–23788, https://doi.org/10.1021/acsami.9b06761.
[71] F.G.M. Mauricio, V.R.M. Abritta, R. de Lacerda Aquino, J.C. Laboissiere, L.P. L. Lograd, I.T. Weber, Evaluation of interferers in sampling materials used in explosive residue analysis by ion chromatography, Forensic Sci. Int. 307 (2019), 109908, https://doi.org/10.1016/j.forsciint.2019.109908.
[72] I. Novosselov, C. Coultas-McKenney, L. Miroshnik, K. Kttapalli, B. Ockerman, T. Manley, M. Gardner, R. Lareau, J. Brady, M. Sweat, A. Smith, M. Hargather, S. Beaudoin, Trace explosives sampling for security applications (TESSA) study: evaluation of procedures and methodology for contact sampling efficiency, Talanta 234 (2021), 122633, https://doi.org/10.1016/j.talanta.2021.122633.
[73] L. Pacheco-Londono, J. Ruiz-Caballero, M. Ramirez-Cedeno, R. Infante-Castillo, N. Galan-Freyle, S. Hernandez-Rivera, Surface persistence of trace level deposits of

highly energetic materials, Molecules 24 (19) (2019) 3494, https://doi.org/10.3390/molecules24193494.
[74] J. Rodriguez, J. Almirall, Continuous vapor sampling of volatile organic compounds associated with explosives using capillary microextraction of volatiles (CMV) coupled to a portable GC-MS, Forensic Chem. 26 (2021), 100380, https://doi.org/10.1016/j.forc.2021.100380.
[75] T. Temple, S. Cipullo, E. Galante, M. Ladyman, N. Mai, T. Parry, F. Coulon, The effect of soil type on the extraction of insensitive high explosive constituents using four conventional methods, Sci. Total Environ. 668 (2019) 184–192, https://doi.org/10.1016/j.scitotenv.2019.02.359.
[76] X. Yan, X. Ma, D. Zhong, Y. Li, D. Wu, Bar adsorptive microextraction device coated with polyimide microsphere assembled by nanosheets combined with thermal desorption-gas chromatography for trace analysis of nitroaromatic explosives in environmental waters, J. Chromatgraphy A 1624 (2020), 461193, https://doi.org/10.1016/j.chroma.2020.461193.
[77] A.A. Zelkowicz, D. Tenne, Y. Kirshenbaum, A. Rossin, T. Mishraki-Berkowtiz, A method for rapid separation of perchlorate and nitrate salts in pyrotechnics and improvised explosive mixtures, J. Forensic Ident. 70 (2) (2020) 231–244.

Commercial Explosives:

[78] F. Ali, M. Roy, B. Pingua, R. Mukherjee, L. Agarwal, P. Singh, Utilization of waste lubricant oil in fuel phase of ANFO explosives: its field applications and environmental impact, Propellants, Explos. Pyrotech. 46 (9) (2021) 1397–1404, https://doi.org/10.1002/prep.202100011.
[79] E. Anderson, C. Chiquete, S. Jackson, R. Chicas, M. Short, The comparative effect of HMX content on the detonation performance characterization of PBX 9012 and PBX 9501 high explosives, Combust. Flame 230 (2021), 111415, https://doi.org/10.1016/j.combustflame.2021.111415.
[80] A. Artyukhov, K. Berladir, J. Krmela, Technological basis for the production of ammonium nitrate with a nanoporous surface and near-surface structure in combined flow motion devices [Paper presentation], in: 2020 IEEE 10th International Conference Nanomaterials: Applications & Properties (NAP), Sumy, Ukraine, 2020, November 9-13, https://doi.org/10.1109/NAP51477.2020.9309534.
[81] Z. Arumugachamy, P. Pandian, J. Kadarkaraithangam, Experimentation on minimum ignition temperature for boron blended fireworks flash powder dust cloud at normal and inert environmental conditions, Fire Mater. 46 (2) (2022) 410–419, https://doi.org/10.1002/fam.2977.
[82] Bao, P., Li, J., Han, Z., Ma, H., & Wang, Comparing the impact safety between two HMX-based PBX with different binders. FirePhysChem, 1(3), 139-145. https://doi.org/10.1016/j.fpc.2021.08.002.
[83] W.P. Bassett, B.P. Johnson, D.D. Dlott, Hot spot chemistry in several polymer-bound explosives under nanosecond and shock conditions, Propellants, Explos. Pyrotech. 45 (2) (2020) 338–346, https://doi.org/10.1002/prep.201900249.
[84] L. Bauer, M. Benz, T. Klapotke, T. Lenz, J. Stierstorfer, Polyazido-methyl derivatives of prominent oxadiazole and isoxazole scaffolds: synthesis, explosive properties, J. Org. Chem. 86 (9) (2021) 6371–6380, https://doi.org/10.1021/acs.joc.1c00216.
[85] S. Bekhouche, D. Trache, S. Chelouche, A. Abdelaziz, A. Tarchoun, W. Benchaa, S. Benameur, A. Mezroua, Investigation of the thermal aging behavior of pyrotechnic tracer composition by spectroscopic techniques coupled with principal component analysis, Propellants, Explos. Pyrotech. 46 (7) (2021) 1155–1166, https://doi.org/10.1002/prep.202100019.
[86] V.M. Bel'skiy, D.V. Milchenko, A.L. Mikhaylov, Dependence of the detonability of high explosives on the defectiveness of the explosive filler crystals, Russ. J. Phys. Chem. B 15 (2) (2021) 285–290, https://doi.org/10.1134/S1990793121020159.
[87] P. Bhanot, A. Kalsi, S. Celin, S. Sahai, R. Tanwar, Advances in the photo-oxidation of nitro-organic explosives present in the aqueous phase, in: M. Shah (Ed.), Removal of Refractory Pollutants from Wastewater Treatment Plants, 2021, pp. 233–248, https://doi.org/10.1201/9781003204442.
[88] H. Bian, Z. Shao, J. Liu, X. Zhang, Preparation and characterization of RDX based composite energetic materials with a cellulose matrix, J. Appl. Polym. Sci. 138 (18) (2021), 50329, https://doi.org/10.1002/app.50329.
[89] R. Bouriche, S. Tazibet, Y. Boutillara, R. Melouki, F. Benaliouche, Y. Boucheffa, Characterization of titanium (IV) oxide nanoparticles loaded onto activated carbon for the adsorption of nitrogen oxides produced from the degradation of nitrocellulose, Anal. Lett. 54 (12) (2021) 1929–1942, https://doi.org/10.1080/00032719.2020.1829637.
[90] H. Cao, X. Li, K. Jin, Q. Duan, H. Chai, J. Sun, Experimental and theoretical study of the effect of typical halides on thermal decomposition products and energy release of ammonium nitrate based on microcalorimetry and FTIR, Chem. Eng. J. 410 (2021), 128405, https://doi.org/10.1016/j.cej.2021.128405.
[91] Z.M. Cao, W.J. Zong, C.L. He, J.H. Huang, W. Liu, Z.Y. Wei, Thermal safety model of HMX-based explosives in diamond turning, Mater. Des. 205 (2021), 109698, https://doi.org/10.1016/j.matdes.2021.109698.
[92] T. Chatterjee, Chemical Kinetic Investigation of the Thermal Decomposition of Energetic Materials: Ammonia Borane, Ammonium Perchlorate & hmx-Tagzt, Doctoral dissertation, Pennsylvania State University, 2020. Penn State Electronic Theses and Dissertations for Graduate School, https://etda.libraries.psu.edu/catalog/18893tkc5157.
[93] B. Chauhan, A. Thakur, P. Soni, M. Kumar, Recrystallization of CL-20 to ε-polymorphic form, IOP Conf. Ser. Mater. Sci. Eng. 1033 (2021), 012056. https://iopscience.iop.org/article/10.1088/1757-899X/1033/1/012056/pdf.
[94] J. Chen, W. Zhang, Y. Chen, Y. Chen, M. Xian, J. Wang, C. Song, J. Xu, C. Yu, G. Yang, Safe preparation of CuN_3 for improved ignition performance of Ni-Cr bridge wire electric initiating explosive devices, Chem. Eng. J. 424 (2021), 130352, https://doi.org/10.1016/j.cej.2021.130352.
[95] C. Chiquete, S. Jackson, Detonation performance of the CL-20-based explosive LX-19, Proc. Combust. Inst. 38 (3) (2021) 3661–3669, https://doi.org/10.1016/j.proci.2020.07.089.
[96] A.J. Claydon, Resonant Acoustic Mixing of Polymer Bonded Explosives, Doctoral Dissertation, Cranfield University, 2020. Cranfield CERES, http://dspace.lib.cranfield.ac.uk/handle/1826/16337.
[97] K.M. de Souze, M.J.S. de Lemos, Detailed numerical modeling and simulation of Fe_2O_3−Al thermite reaction, Propellants, Explos. Pyrotech. 46 (5) (2021) 806–824, https://doi.org/10.1002/prep.202000290.
[98] L. Du, S. Jin, Z. Liu, Z. Li, L. Li, M. Wang, P. Nie, J. Wang, Shock initiation investigation of a pressed Trinitrotoluene explosive, Propellants, Explos. Pyrotech. 46 (11) (2021) 1717–1722, https://doi.org/10.1002/prep.202100071.
[99] S. Duan, F. Ding, H. Sun, C. Xiao, S. Li, Q. Zhu, Construction of CL-20 surface layer with different wetting properties and its effect on slurry rheological behavior and mechanical sensitivities, Propellants, Explos. Pyrotech. 46 (12) (2021) 1837–1843, https://doi.org/10.1002/prep.202100129.
[100] E. Elbasuney, M. Yehia, A. Hamed, M. Mokhtar, M. Gobara, A. Saleh, E. Elsaka, G. El-Sayyad, Synergistic catalytic effect of thermite nanoparticles on HMX thermal decomposition, J. Inorg. Organomet. Polym. Mater. 31 (6) (2021) 2293–2305, https://doi.org/10.1007/s10904-021-01916-3.
[101] A.P. Ershov, I.A. Rubtsov, Detonation of low-density explosives, Combust. Explos. Shock Waves 55 (1) (2019) 114–120, https://doi.org/10.1134/S0010508219010131.
[102] A.P. Ershov, V.V. Andreev, A.O. Kashkarov, Y.L. Luk'yanov, D.A. Medvedev, E. R. Pruuel, I.A. Rubtsov, N.P. Satonkina, S.A. Solov'ev, Detonation of ultrafine explosives, Combust. Explos. Shock Waves 57 (3) (2021) 356–363, https://doi.org/10.1134/S0010508219010131.
[103] H. Fang, Y. Cheng, C. Tao, H. Su, Y. Gong, Y. Cheng, Z. Shen, Effects of content and particle size of cenospheres on the detonation characteristics of emulsion explosives, J. Energetic Mater. 39 (2) (2021) 197–214, https://doi.org/10.1080/07370652.2020.1770896.
[104] Z.T. Fondren, N.S. Fondren, B.G. McKenna, B.L. Weeks, Crystallization kinetics of pentaerythritol tetranitrate (PETN) thin films on various materials, Appl. Surf. Sci. 522 (2020), 146350, https://doi.org/10.1016/j.apsusc.2020.146350.
[105] H.G. Gallagher, J.N. Sherwood, R.M. Vrcelj, Microhardness indentation studies of 2-4-6 Trinitrotoluene, Propellants, Explos. Pyrotech. 46 (11) (2021) 1733–1739, https://doi.org/10.1002/prep.202100132.
[106] Y. Gao, W. Yang, R. Hu, J. Zhou, Y. Zhang, Validation of CL-20-based propellant formulation for photopolymerization 3D printing, Propellants, Explos. Pyrotech. 46 (12) (2021) 1844–1848, https://doi.org/10.1002/prep.202100196.
[107] A. Giam, W. Toh, V. Ben Chye Tan, Numerical review of Jones-Wilkins-Lee parameters for trinitrotoluene explosive in free-air blast, J. Appl. Mech. 87 (5) (2020), https://doi.org/10.1115/1.4046243, 051008.
[108] P.E. Hande, A.B. Samui, Determination of Diphenyl Amine (DPA) stabilizer in propellants- a mini review, Propellants, Explos. Pyrotech. 46 (11) (2021) 1638–1644, https://doi.org/10.1002/prep.202100210.
[109] M. Herman, C. Woznick, S. Scott, J. Tisdale, J. Yeager, A. Duque, Composite binder, processing, and particle size effects on mechanical properties of non-hazardous high explosive surrogates, Powder Technol. 391 (2021) 442–449, https://doi.org/10.1016/j.powtec.2021.06.009.
[110] M.L. Hobbs, M.J. Kaneshige, S. Coronel, Vented and sealed cookoff of powdered and pressed ε-CL-20, J. Energetic Mater. 39 (4) (2021) 432–451, https://doi.org/10.1080/07370652.2020.1814448.
[111] S. Hosseini, M. Nouri, M. Bahri, E. Bazrafshan, Investigation of the effective parameters on the preparation of ammonium perchlorate particles using a cooling crystallization process, Propellants, Explos. Pyrotech. 46 (7) (2021) 1060–1069, https://doi.org/10.1002/prep.202000307.
[112] E. Iglesias, T. Rowe, K. Fernandez, S. Chocron, J. Wilkerson, Mechanical response of carbon nanotube reinforced particulate composites with implications for polymer bonded explosives, J. Compos. Mater. (2021), https://doi.org/10.1177/0021998321990863.
[113] E. Koch, Insensitive high explosives: V. Ballistic properties and vulnerability of nitroguanidine based propellants, Propellants, Explos. Pyrotech. 46 (2) (2021) 174–206, https://doi.org/10.1002/prep.202000220.
[114] B. Koroglu, J. Crowhurst, E. Kahl, J. Moore, A. Racoveanu, H. Mason, D. Weisz, J. Reynolds, A. Burnham, Experimental investigation of the thermal decomposition pathways and kinetics of TATB by isotopic substitution, Propellants, Explos. Pyrotech. 46 (9) (2021) 1352–1366, https://doi.org/10.1002/prep.202100082.
[115] A. Korotkikh, I. Sorokin, Effect of Me/B-powder on the ignition of high-energy materials, Propellants, Explos. Pyortech. 46 (11) (2021) 1709–1716, https://doi.org/10.1002/prep.202100180.
[116] K. Krejcir, J. Adam, R. Buldra, Modeling of smokeless powders shelf life using results of multi-temperature study on stabilizer consumption, in: [Conference Presentation]. 2021 International Conference on Military Technologies (ICMT), Brno, Czech Republic, 2021, https://doi.org/10.1109/ICMT52455.2021.9502810.
[117] K. Lee, A. Hernandez, D. Stewart, S. Lee, Data-driven blended equations of state for condensed-phase explosives, Combust. Theor. Model. 25 (3) (2021) 413–435, https://doi.org/10.1080/13647830.2021.1887524.

[118] E. Lennert, C. Bridge, Correlation and analysis of smokeless powder, smokeless powder residues, and lab generated pyrolysis products via GC–MS, Forensic Chem. 23 (2021), 100316, https://doi.org/10.1016/j.forc.2021.100316.
[119] M. Li, Y. Gao, R. Hu, Q. Wang, W. Yang, Thermal study of APNIMMO/CL-20 based propellants fabricated by 3D printing, Thermochim. Acta 706 (2021), 179072, https://doi.org/10.1016/j.tca.2021.179072.
[120] D. Liu, P. Zhao, S. Chan, H. Hng, L. Chen, Effects of nano-sized aluminum on detonation characteristics and metal acceleration for RDX-based aluminized explosive, Defence Technol. 17 (2) (2021) 327–337, https://doi.org/10.1016/j.dt.2020.12.001.
[121] J. Liu, Y. Dong, X. An, P. Ye, Q. Sun, Q. Gao, Reaction degree of composition B explosive with multi-layered compound structure protection subjected to detonation loading, Defence Technol. 17 (2) (2020) 315–326, https://doi.org/10.1016/j.dt.2020.02.004.
[122] E. Lobry, J. Berthe, J. Hubner, F. Achnell, D. Spitzer, Tuning the oxygen balance of energetic composites: crystallization of AND/secondary explosives mixtures by spray flash evaporation, Propellants, Explos. Pyrotech. 46 (3) (2021) 398–412, https://doi.org/10.1002/prep.202000090.
[123] D. Luscher, M. Cawkwell, K. Ramos, R. Sandberg, C. Bolme, Interpreting experimental results from shock impacts on single crystal PETN in the context of continuum models, Propellants, Explos. Pyrotech. 45 (2) (2020) 284–294, https://doi.org/10.1002/prep.201900228.
[124] X. Mao, Y. Zheng, F. Shen, Y. Wang, X. Wang, Y. Li, A method for calculating the JWL equation of state parameters for the detonation products of CL-20-based aluminized explosives, J. Energetic Mater. 40 (2) (2020) 182–205, https://doi.org/10.1080/07370652.2020.1854370.
[125] F. Marrs, V. Manner, A. Burch, J. Yeager, G. Brown, L. Kay, R. Buckley, C. Anderson-Cook, Cawkwell, Sources of variation in drop-weight impact sensitivity testing of the explosive pentaerythritol tetranitrate, Ind. Eng. Chem. Res. 60 (13) (2021) 5024–5033, https://doi.org/10.1021/acs.iecr.0c06294.
[126] J. Meng, Y. Luo, G. Niu, H. Wang, F. Yang, Effect of additives on the interface binding strength of DNAN/HMX melt-cast explosives, J. Energetic Mater. 38 (4) (2020) 467–482, https://doi.org/10.1080/07370652.2020.1734689.
[127] P. Mertuszka, K. Fulawka, M. Pytlik, M. Szastok, The influence of temperature on the detonation velocity of selected emulsion explosives, J. Energetic Mater. 38 (3) (2020) 336–347, https://doi.org/10.1080/07370652.2019.1702739.
[128] C. Miller, E. Johnson, R. Sausa, J. Orlicki, J. Sabatini, A safer synthesis of the explosive precursors 4-Aminofurazan-3-Carboxylic acid and its ethyl ester derivative, Org. Process Res. Dev. 24 (4) (2020) 599–603, https://doi.org/10.1021/acs.oprd.0c00068.
[129] N. Mohan, D. Luscher, M. Cawkwell, F. Addessio, K. Ramos, Modeling microstructural effects on heterogeneous temperature fields within polycrystalline explosives, Propellants, Explos. Pyrotech. 46 (5) (2021) 713–722, https://doi.org/10.1002/prep.202000282.
[130] K. Morrison, E. Denis, M. Nims, A. Broderick, R. Fausey, H. Rose, P. Gongwer, R. G. Ewing, Vapor pressures of RDX and HMX explosives measures at and near room temperature: 1,3,5-Trinitro-1,3,5-triazinane and 1,3,5,7-Tetranitro-1,3,5,7-tetrazocane, J. Phys. Chem. A 125 (5) (2021) 1279–1288, https://doi.org/10.1021/acs.jpca.0c10409.
[131] E. Novitskaya, J.P. Kelly, S. Bhaduri, O.A. Graeve, A review of solution combustion synthesis: an analysis of parameters controlling powder characteristics, Int. Mater. Rev. 66 (3) (2021) 188–214, https://doi.org/10.1080/09506608.2020.1765603.
[132] G.R. Parker, D.S. Eastwood, M. Storm, K. Vitharana, E.M. Heatwole, I. Lopez-Pulliam, R.M. Broilo, P.M. Dickson, A. Martinez, C. Rau, N.K. Bourne, 4D micro-scale, phase-contrast X-ray imaging and computed tomography of HMX-based polymer-bonded explosives during thermal runaway, Combust. Flame 226 (2021) 478–489, https://doi.org/10.1016/j.combustflame.2020.12.025.
[133] G. Plassart, D. Picart, M. Gratton, A. Frachon, M. Caliez, Quasistatic mechanical behavior of HMX- and TATB-based plastic-bonded explosives, Mech. Mater. 150 (2020), 103561, https://doi.org/10.1016/j.mechmat.2020.103561.
[134] Q. Pontalier, J. Loiseau, S. Goroshin, F. Zhang, D.L. Frost, Blast enhancement from metalized explosives, Shock Waves 31 (3) (2021) 203–230. https://link.springer.com/article/10.1007/s00193-021-00994-z.
[135] J. Quaresma, L. Deimling, J. Campos, R. Mendes, Characterization of the detonation pressure of a PETN based PBX with the optical active method, Propellants, Explos. Pyrotech. 46 (6) (2021) 875–882, https://doi.org/10.1002/prep.202000195.
[136] M. Samsonov, J. Rysavy, A. Ruzicka, R. Matyas, Investigation of intramolecular interactions in the crystals of tetrazene explosive and its salts, Cryst. Growth Des. 21 (11) (2021) 6567–6575, https://doi.org/10.1021/acs.cgd.1c01044.
[137] D.Q. Sang, N.T. Anh, Several explosion behaviours of the emulsion explosives sensitized by cenospheres, Vietnam J. Chem. 58 (3) (2020) 380–385, https://doi.org/10.1002/vjch.202000003.
[138] S. Selvakumar, G. Sreenivasa, K.A. Reddy, Diffusion of labile chemical species in HTPB and HTPB-XT solid propellants and its effect over solid rocket moto properties on aging- a study, Propellants, Explos. Pyrotech. 46 (5) (2021) 782–790, https://doi.org/10.1002/prep.202000253.
[139] P.A. Shirbhate, M.D. Goel, A critical review of TNT equivalence factors of various explosives, in: S.K. Saha, M. Mukherjee (Eds.), Recent Advances in Computational Mechanics and Simulations, 2020, pp. 471–478, https://doi.org/10.1007/978-981-15-8138-0_36.
[140] A. Singh, P. Singla, S. Sahoo, P. Soni, Compatibility and thermal decomposition behavior of an epoxy resin with some energetic compounds, J. Energetic Mater. 38 (4) (2020) 432–444, https://doi.org/10.1080/07370652.2020.1727997.
[141] M. Suceska, C.H.Y. Serene, Z. Qingling, M. Dobrilovic, B. Stimac, Predication of cylinder wall velocity profiles for ANFO explosives combining thermochemical calculation, gurney model, and hydro-code, Propellants, Explos. Pyrotech. 46 (2) (2021) 253–261, https://doi.org/10.1002/prep.202000215.
[142] R. Togashi, M. Kohga, Preparation of fine ammonium perchlorate by employing dual-sonic premixer: freeze-drying method, Propellants, Explos. Pyrotech. 46 (6) (2021) 855–859, https://doi.org/10.1002/prep.202100033.
[143] D. Trache, A. Tarchoun, S. Chelouche, K. Khimeche, New insights on the compatibility of nitrocellulose with Aniline-based compounds, Propellants, Explos. Pyrotech. 44 (8) (2019) 970–979, https://doi.org/10.1002/prep.201800269.
[144] J.W. Tringe, D.M. Stobbe, G.R. Parker, L. Smilowitz, B.F. Henson, M.R. De Have, A.J. Ruch, B.W. White, J.E. Reaugh, K.S. Vandersall, Observation of asymmetric explosive density evolution in the deflagration-to-detonation transition for porous explosives, J. Appl. Phys. 129 (3) (2021), https://doi.org/10.1063/5.0031340, 035901.
[145] E. Wainwright, S. Dean, S. Lakshman, T. Weihs, J. Gottfried, Evaluating compositional effects on the laser-induced combustion and shock velocities of Al/Zr-based composite fuels, Combust. Flame 213 (2020) 357–368, https://doi.org/10.1016/j.combustflame.2019.12.009.
[146] T. Wang, H. Gao, J. Shreeve, Functionalized tetrazole energetics: a route to enhanced performance, Zeitschrift fur anorganische und allgemeine Chemie 647 (4) (2021) 157–191, https://doi.org/10.1002/zaac.202000361.
[147] Y. Wang, H. Ma, Z. Shen, J. Chen, L. Huang, Influence of different gases on the performance of gas-storage glass microballoons in emulsion explosives, Propellants, Explos. Pyrotech. 45 (10) (2020) 1566–1572, https://doi.org/10.1002/prep.202000105.
[148] F. Xiao, Z. Liu, T. Liang, R. Yang, J. Li, P. Luo, Establishing the interface layer on the aluminum surface through the self-assembly of tannic acid (TA): improving the ignition and combustion properties of aluminum, Chem. Eng. J. 420 (Part 3) (2021), 130523, https://doi.org/10.1016/j.cej.2021.130523.
[149] Y. Xiao, L. Chen, K. Yang, D. Geng, J. Lu, J. Wu, Mechanism of the improvement of the energy of host–guest explosives by incorporation of small guest molecules: HNO_3 and H_2O_2 promoted C–N bond cleavage of the ring of ICM-102, Sci. Rep. 11 (2021), 10559, https://doi.org/10.1038/s41598-021-89939-1.
[150] W. Xu, F. Guo, X. Liang, T. Yan, Y. Xu, J. Deng, Y. Li, J. Wang, Dynamic response properties of polymer bonded explosives under different excitation by deceleration, Mater. Des. 206 (2021), 109810, https://doi.org/10.1016/j.matdes.2021.109810.
[151] W. Xu, C. Wang, J. Yuan, W. Goh, T. Li, Investigation on energy output structure of explosives near-ground explosion, Defence Technol. 16 (2) (2020) 290–298, https://doi.org/10.1016/j.dt.2019.08.004.
[152] W. Yang, R. Hu, M. Li, M. Xu, Z. Yang, L. Meng, Thermal decomposition of photocurable energetic APNIMMO polymer, Propellants, Explos. Pyrotech. 46 (12) (2021) 1767–1771, https://doi.org/10.1002/prep.202100239.
[153] X. Yang, X. Tian, K. Zhao, J. Dong, Y. Huang, B. Feng, X. Wang, Study on the explosion field temperature and gas products of FOX-7/RDX based aluminized explosives, J. Phys. Conf. 1721 (2021), https://doi.org/10.1088/1742-6596/1721/1/012016, 012016.
[154] Y. Yang, Z. Duan, L. Zhang, Z. Zhang, Z. Ou, F. Huang, Measurements of reaction zone and determination of the equation of state parameters of DNAN-based melt-cast aluminized explosive, J. Energetic Mater. 38 (2) (2020) 240–251, https://doi.org/10.1080/07370652.2019.1679280.
[155] Z. Yang, P. Zhu, Q. Zhang, J. Shi, K. Wang, R. Shen, Microcrystalline PETN prepared using microfluidic recrystallization platform and its performance characterization, Propellants, Explos. Pyrotech. 46 (7) (2021) 1097–1106, https://doi.org/10.1002/prep.202000298.
[156] C. Zeng, Z. Yang, Y. Wen, W. He, J. Zhang, J. Wang, C. Huang, F. Gong, Performance optimization of core-shell HMX@(Al@GAP) aluminized explosives, Chem. Eng. J. 407 (2021), 126360, https://doi.org/10.1016/j.cej.2020.126360.
[157] W. Zhang, H. Xia, R. Yu, J. Zhang, K. Wang, Q. Zhang, Synthesis and properties of 3,6-Dinitropyrazolo[4,3-c]-pyrazole (DNPP) Derivatives, Propellants, Explos. Pyrotech. 45 (4) (2020) 546–553, https://doi.org/10.1002/prep.201900205.
[158] W. Zhang, H. Xia, R. Yu, J. Zhang, K. Wang, Q. Zhang, Synthesis and properties of 3,6-Dinitropyrazolo[4,3-c]-pyrazole (DNPP) Derivatives, Propellants, Explos. Pyrotech. 45 (4) (2020) 546–553, https://doi.org/10.1002/prep.201900205.
[159] X. Zhao, Z. Wang, X. Qi, S. Song, S. Huang, K. Wang, Q. Zhang, Hunting for energetic complexes as hypergolic promoters for green propellants using hydrogen peroxide as oxidizer, Inorg. Chem. 60 (22) (2021) 17033–17039, https://doi.org/10.1021/acs.inorgchem.1c02149.
[160] Y. Zhao, Z. Mei, F. Zhao, S. Xu, X. Ju, Atomic perspectives revealing the evolution behavior of aluminum nanoparticles in energetic materials, Appl. Surf. Sci. 563 (2021), 150296, https://doi.org/10.1016/j.apsusc.2021.150296.
[161] X. Zhou, Y. Mao, D. Zheng, L. Zhong, R. Wang, B. Gao, D. Wang, 3D printing of RDX-based aluminized high explosives with gradient structure, significantly altering the critical dimensions, J. Mater. Sci. 56 (15) (2021) 9171–9182, https://doi.org/10.1007/s10853-021-05869-3.
[162] Z. Zhou, J. Chen, H. Yuan, J. Nie, Influence of Al content and surrounding medium on the energy output of cyclotrimethylenetrinitramine (RDX)/Al/wax explosives, J. Appl. Phys. 129 (7) (2021), https://doi.org/10.1063/5.0032963, 074904.
[163] N. Zohari, S. Roosta, A. Shariati, The new descriptors effective on the detonation performance of aluminized explosives, Zeitschrift fur anorganische und allgemeine (2020), https://doi.org/10.1002/zaac.202000068.

Homemade Explosives:

[164] J. Baldaino, D. Ommen, Saunders, J. Hietpas, J. Buscaglia, Characterization and differentiation of aluminum powders used in improvised explosive devices. Part 1: proof of concept of the utility of particle micromorphometry, J. Forensic Sci. 66 (1) (2021) 83–95, https://doi.org/10.1111/1556-4029.14564.

[165] K. Bezemer, L. McLennan, L. van Duin, C. Kuijpers, M. Koeberg, J. van den Elshout, A. van der Heijden, T. Busby, A. Yevdokimov, P. Schoenmakers, J. Smith, J. Oxley, A. can Asten, Chemical attribution of the home-made explosive ETN – Part I: liquid chromatography-mass spectrometry analysis of partially nitrated erythritol impurities, Forensic Sci. Int. 307 (2020), 110102, https://doi.org/10.1016/j.forsciint.2019.110102.

[166] J. D'Uva, D. DeTata, R. Fillingham, R. Dunsmore, S.W. Lewis, Synthesis and characterisation of homemade urea nitrate explosive from commercial sources of urea, Forensic Chem. 26 (2021), 100369, https://doi.org/10.1016/j.forc.2021.100369.

[167] C. Freye, W. Kinman, C. Tiemann, D. McDonald, V. Manner, P. Bowden, B. Tappan, M. Greenfield, Linking chemical precursors to the synthesis of Erythritol Tetranitrate, Forensic Chem. (2020), https://doi.org/10.1016/j.forc.2020.100246.

[168] T. Horvath, I. Ember, Characteristics of homemade explosive materials and their possibilities of their identification, Rev. Acad. Fortelor Terestre 26 (2) (2021) 100–107, https://doi.org/10.2478/raft-2021-0015.

[169] L. Li, W. Gu, B. Laiwang, J. Jiang, J. Jiang, C. Shu, Effects of 1-butyl-3-metylimidazolium tetrafluoroborate on the thermal hazard of triacetone triperoxide (TATP), Process Saf. Environ. Protect. 149 (2021) 518–525, https://doi.org/10.1016/j.psep.2020.11.008.

[170] R. Matyas, J. Chylkova, Study of TATP: impact of TATP sumblimation on the content of residual acid in TATP crystals and on TATP's properties, Propellants, Explos. Pyrotech. 45 (5) (2020) 833–836, https://doi.org/10.1002/prep.201900375.

[171] I. Oluwoye, M. Altarawneh, J. Gore, B.Z. Dlugogorski, Burning properties of redox crystals of ammonium nitrate and saccharides, Combust. Flame 213 (2020) 132–139, https://doi.org/10.1016/j.combustflame.2019.11.030.

[172] C.C. Pye, Chemical safety: TATP formation in 2-Propanol, ACS Chem. Health Saf. 27 (5) (2020), https://doi.org/10.1021/acs.chas.0c00061, 279-279.

[173] K. Stark, J. Bascooke, C. Gibson, C. Lenehan, C. Bonnar, M. Fitzgerald, K. Kirkbridge, Xylitol pentanitrate—its characterization and analysis, Forensic Sci. Int. (2020), https://doi.org/10.1016/j.forsciint.2020.110472.

[174] J. Stromberg, M. Castillo Rolon, TATP headspace study, Propellants, Explos. Pyrotech. 47 (2) (2022), e202100255, https://doi.org/10.1002/prep.202100255.

[175] L. Tang, H. Li, Y. Tan, T. Liu, Z. Yang, Solution chemistry and phase solubility diagrams of CL-20/MTNP energetic cocrystals, CrystEngComm 22 (12) (2020) 2173–2182, https://doi.org/10.1039/C9CE01724K.

[176] J. Zhou, L. Ding, F. Zhao, B. Wang, J. Zhang, Thermal studies of novel molecular perovskite energetic material $(C_6H_{14}N_2)[NH_4(ClO_4)_3]$, Chin. Chem. Lett. 31 (2) (2020) 554–558, https://doi.org/10.1016/j.cclet.2019.05.008.

Other Explosives including Novel or New Explosives:

[177] B.M. Abraham, G. Waitheeswaran, From van der Waals interactions to structures and properties of 3,-dinitro-5,-bis-1,2,4-triazole-1,-diolate based energetic materials, Mater. Chem. Phys. 240 (2020), 122175, https://doi.org/10.1016/j.matchemphys.2019.122175.

[178] B.M. Abraham, N. Yedukondalu, G. Vaitheeswaran, High-pressure structural and electronic properties of potassium-based green primary explosives, J. Electron. Mater. 50 (4) (2021) 1581–1590, https://doi.org/10.1007/s11664-020-08262-z.

[179] J. Agrawal, V. Dodke, Some novel high energy materials for improved performance, Zeitschrift fur anorganische und allgemeine Chemie 647 (19) (2021) 1856–1882, https://doi.org/10.1002/zaac.202100144.

[180] E. Anderson, C. Chiquete, S. Jackson, Experimental measurement of energy release from an initiating layer in an insensitive explosive, Proc. Combust. Inst. 38 (3) (2021) 3733–3740, https://doi.org/10.1016/j.proci.2020.07.150.

[181] M. Anniyappan, K. Varma, R. Amit, J. Nair, 1-methyl-2,4,5-trinitroimidazole (MTNI), a melt-cast explosive: synthesis and studies on thermal behavior in presence of explosive ingredients, J. Energetic Mater. (2019), https://doi.org/10.1080/07370652.2019.1669735.

[182] J. Bai, E. Yao, L. Xiao, J. Zhou, Y. Ren, F. Zhao, W. Shen, Synthesis, thermal behavior and energy performance of nitroguanidyl-functionalized energetic materials, Propellants, Explos. Pyrotech. 46 (8) (2021) 1276–1285, https://doi.org/10.1002/prep.202000338.

[183] Z. Bai, Z. Duan, L. Wen, Z. Zhang, Z. Ou, F. Huang, Embedded manganin gauge measurements and modeling of shock initiation in HMX-based PBX explosives with different particle sizes and porosities, Propellants, Explos. Pyrotech. 45 (6) (2020) 9089–9920, https://doi.org/10.1002/prep.201900376.

[184] L. Bao, P. Lv, T. Fei, Y. Liu, C. Sun, S. Pang, Crystal structure and explosive performance of a new CL-20/benzaldehyde cocrystal, J. Mol. Struct. 1215 (2020), 128267, https://doi.org/10.1016/j.molstruc.2020.128267.

[185] H. Bian, J. Wei, Y. Zhou, J. Liu, Z. Shao, B. Wang, Z. Li, Preparation and characterization of cellulose/RDX composite aerogel spheres, Propellants, Explos. Pyrotech. 44 (12) (2019) 1613–1620, https://doi.org/10.1002/prep.201900108.

[186] S. Bondarchuk, Modeling of explosives: 1,4,2,3,5,6-dioxatetrazinane as a new green energetic material with enhanced performance, J. Phys. Chem. Solid. 142 (2020), 109458, https://doi.org/10.1016/j.jpcs.2020.109458.

[187] W. Cao, Q. Song, D. Gao, Y. Han, S. Xu, X. Lu, X. Guo, Detonation characteristics of an aluminized explosive added with boron and magnesium hydride, Propellants, Explos. Pyrotech. 44 (11) (2019) 1393–1399, https://doi.org/10.1002/prep.201900164.

[188] L. Chen, X. Cao, Y. Chen, Q. Li, Y. Wang, X. Wang, Y. Qin, X. Cao, J. Liu, Z. Shao, W. He, Biomimetric-inspired one-step strategy for improvement of interfacial interactions in cellulose nanofibers by modification of the surface of nitramine explosives, Langmuir 37 (28) (2021) 8486–8497, https://doi.org/10.1021/acs.langmuir.1c00874.

[189] L. Chen, X. Cao, J. Gao, W. He, J. Liu, Y. Wang, X. Zhou, J. Shen, B. Wang, Y. He, D. Tan, Nitrated bacterial cellulose-based energetic nanocomposites as propellants and explosives for military applications, ACS Appl. Nano Mater. 4 (2) (2021) 1906–1915, https://doi.org/10.1021/acsanm.0c03263.

[190] Y. Cheng, X. Chen, N. Yang, Y. Zhang, H. Ma, Z. Guo, Sandwich-like low-sensitive nitroamine explosives stabilized by hydrogen bonds and π–π stacking interactions, CrystEngComm 23 (9) (2021) 1953–1960, https://doi.org/10.1039/D0CE01882A.

[191] Q. Cui, J. Liu, H. Ren, X. Jiang, Preparation of explosive/porous aluminum and its detonation property, Ferroelectrics 549 (1) (2019) 296–303, https://doi.org/10.1080/00150193.2019.1592512.

[192] X. Deng, B. Wang, Peridynamic modeling of dynamic damage of polymer bonded explosive, Comput. Mater. Sci. 173 (2020), 109405, https://doi.org/10.1016/j.commatsci.2019.109405.

[193] A.M. Djerdjev, P. Priyananda, J. Gore, J.K. Beattie, C. Neto, B.S. Hawkett, Safer emulsion explosives resulting from NO_x inhibition, Chem. Eng. J. 403 (2020), 125713, https://doi.org/10.1016/j.cej.2020.125713.

[194] Y. Du, Z. Qu, H. Wang, H. Cui, X. Wang, Review on the synthesis and performance for 1,3,4-Oxadiazole-based energetic materials, Propellants, Explos. Pyrotech. 46 (6) (2021) 860–874, https://doi.org/10.1002/prep.202000318.

[195] S. Duan, D. Wang, Q. Jiang, C. Xiao, H. Liu, Y. Guo, S. Li, Q. Zhu, Oxidant-accelerated polydopamine modification process for the fast fabrication of PDA on HMX with improved mechanical stability, Propellants, Explos. Pyrotech. 46 (5) (2021) 751–757, https://doi.org/10.1002/prep.202000095.

[196] W. Dunju, G. Changping, W. Ruihao, Z. Baojui, G. Bing, N. Fude, Additive manufacturing and combustion performance of CL-20 composites, J. Mater. Sci. 55 (7) (2020) 2836–2845, https://doi.org/10.1007/s10853-019-04209-w.

[197] S. Elbasuney, A.M.A. Elghafour, M. Radwan, A. Fahd, H. Mostafa, R. Sadek, A. Motaz, Novel aspects for thermal stability studies and shelf life assessment of modified double-base propellants, Defence Technol. 15 (3) (2019) 300–305, https://doi.org/10.1016/j.dt.2018.09.005.

[198] S. Elbasuney, A. Hamed, S. Ismael, M. Mokhtar, M. Gobara, Novel high energy density material based on metastable intermolecular nanocomposite, J. Inorg. Organomet. Polym. Mater. 30 (10) (2020) 3980–3988, https://doi.org/10.1007/s10904-020-01539-0.

[199] S. Elbasuney, M. Yehia, A. Hamed, M. Mokhtar, M. Gobara, A. Saleh, E. Elsaka, G. El-Sayyad, Synergistic catalytic effect of thermite nanoparticles on HMX thermal decomposition, J. Inorg. Organomet. Polym. Mater. 31 (6) (2021) 2293–2305, https://doi.org/10.1007/s10904-021-01916-3.

[200] A. Elbeih, A.K. Hussein, T. Elshenawy, S. Zeman, S.M. Hammad, A. Baraka, M. A. Elsayed, M. Gobara, H. Tantawy, Enhancing the explosive characteristics of a Semtex explosive by involving admixtures of BCHMX and HMX, Defence Technol. 16 (2) (2019) 487–492, https://doi.org/10.1016/j.dt.2019.05.012.

[201] M.A. Englert-Erickson, M.D. Holmes, G.R. Parker, C.C. Schmidt, B.A. Meyer, Gas transport in the insensitive high explosives PBX 9502, Propellants, Explos. Pyrotech. 45 (6) (2020) 942–949, https://doi.org/10.1002/prep.201900337.

[202] H. Fang, Y. Cheng, C. Tao, Y. Yao, H. Ma, T. Han, Z. Shen, Y. Chen, Synthesis and characterization of pressure agent with double-layer core/shell hollow-structure for emulsion explosive, Propellants, Explos. Pyrotech. 45 (5) (2020) 798–806, https://doi.org/10.1002/prep.201900288.

[203] N.S. Fondren, Z.T. Fondren, D.K. Unruh, A. Maiti, A. Cozzolino, Y.J. Lee, L. Hope-Weeks, B.L. Weeks, Study of physicochemical and explosive properties of a 2,4,6-Trinitrotoluene/Aniline Cocrystal Solvate, Cryst. Growth Des. 20 (1) (2020) 116–129, https://doi.org/10.1021/acs.cgd.9b00779.

[204] E. Forrest, R. Knepper, M. Brumbach, M. Rodrigeuz, K. Archuleta, M. Marquez, A. Tappan, Engineering the microstructure and morphology of explosive films via control of interfacial energy, ACS Appl. Mater. Interfaces 13 (1) (2021) 1670–1681, https://doi.org/10.1021/acsami.0c10193.

[205] J. Fronabgarger, J. Pattison, M. Williams, Alternatives to existing primary explosives, Int. J. Energ. Mater. Chem. Propuls. 20 (3) (2021) 65–79, https://doi.org/10.1615/intjenergeticmaterialschemprop.2021038576.

[206] E.B.F. Galante, N. Mai, M.K. Ladyman, P.P. Gill, T.J. Temple, F. Coulon, Evaluation of small-scale combustion of an insensitive high explosive formulation containing 3-nitro-1,2,4-triazol-5-one (NTO), 2,4-dinitroanisole (DNAN), and 1,3,5-trinitroperhydro-1,3,5-triazine (RDX), J. Energetic Mater. 39 (1) (2020) 85–99, https://doi.org/10.1080/07370652.2020.1762798.

[207] G. George, S. Jones, J. Buchanan, M. Cuddy, E. Alberts, R. Crouch, T. Thornell, L. Moores, Physicochemical parameters of insensitive munition constituent MethyInitroguanidine (MeNQ) of importance to environmental fate and transport, Propellants, Explos. Pyrotech. 46 (8) (2021) 1180–1187, https://doi.org/10.1002/prep.202100053.

[208] M. Gettings, M. Zeller, E. Byrd, D. Piercey, Synthesis and characterization of salts of the 3,6-Dinitro-[1,2,4]triazolo[4,3-b][1,2,4]triazolate Anion: insensitive energetic materials available from economical precursors, Zeitschrift fur anorganische und allgemein Chemie 645 (20) (2019) 1197–1204, https://doi.org/10.1002/zaac.201900164.

[209] A. Gezerman, B. Corbacioglu, Development of a new ammonium nitrate composition: an attempt to prevent misuse of explosives for antisocial activities, J. Chin. Inst. Eng. 43 (1) (2020) 101–110, https://doi.org/10.1080/02533839.2019.1676650.
[210] I.D. Giles, G.H. Imler, J.R. Deschamps, Structure and properties of 1,4-bis (Trinitromethyl)Benzene, Propellants, Explos. Pyrotech. 45 (9) (2020) 1487–1489, https://doi.org/10.1002/prep.201900394.
[211] J.L. Gottfried, *Higher Time Resolution LASEM, Part Iii: Influence of Laser-Induced Plasma Chemistry on the Laser-Induced Shock Waves of Aluminized Explosives* (ARL-TR-9205), Army Research Laboratory, 2020. https://apps.dtic.mil/sti/citations/AD1108551.
[212] M. Gratzke, S. Cudzlio, Energetic derivatives of nitroguanidine- synthesis and properties, Propellants, Explos. Pyrotech. 46 (10) (2021) 1509–1525, https://doi.org/10.1002/prep.202100092.
[213] H. Gu, G. Cheng, H. Yang, Tricyclic nitrogen-rich explosives with a planar backbone: bis(1,2,4-triazolyl)-1,2,3-triazoles as potential stable green gas generants, New J. Chem. 45 (17) (2021) 7758–7765, https://doi.org/10.1039/D1NJ00076D.
[214] P. Guerieri, B. Fuchs, W. Churaman, Feasibility of detonation in porous Silicon nanoenergetics, Propellants, Explos. Pyrotech. 46 (8) (2021) 1260–1275, https://doi.org/10.1002/prep.202000311.
[215] H. Guo, S. Xu, H. Gao, X. Geng, C. An, C. Xu, J. Wang, CL-20 based ultraviolet curing explosive composite with high performance, Propellants, Explos. Pyrotech. 44 (8) (2019) 935–940, https://doi.org/10.1002/prep.201900133.
[216] L. Gutowswki, T. Golofit, W. Trzcinski, M. Szala, Synthesis and energetic properties of 1,3,7,9-Tetranitrobenzo[c]Cinnoline-5-Oxide (TNBCO), Propellants, Explos. Pyrotech. 44 (12) (2019) 1509–1514, https://doi.org/10.1002/prep.201900183.
[217] B.W. Hamilton, Krooblawd, M.M. Islan, A. Strachan, Sensitivity of the shock initiation threshold of 1,3,5-Triamino-2,4,6-trinitrobenzene (TATB) to nuclear quantum effects, J. Phys. Chem. C 123 (36) (2019) 21969–21981, https://doi.org/10.1021/acs.jpcc.9b05409.
[218] G. Hao, H. Li, C. Mao, Y. Hu, L. Xiao, G. Zhang, J. Liu, W. Jiang, Preparation of Nano-Cu-Fe composite metal oxides a mechanical grinding method and its catalytic performance for the thermal decomposition of ammonium perchlorate, Combust. Sci. Technol. 193 (6) (2021) 987–1004, https://doi.org/10.1080/00102202.2019.1679125.
[219] S. He, K. Tan, Q. Song, G. He, W. Cao, Thermally stable and low-sensitive aluminized explosives with improved detonation performance, Propellants, Explos. Pyrotech. 46 (9) (2021) 1428–1435, https://doi.org/10.1002/prep.202100047.
[220] Z. He, T. Meng, Y. Wang, Z. Guo, G. Liu, Z. Liu, Effect of 2,4,6-Triamino-3,5-Dinitropyridine-1-Oxide on the properties of 1,3,5-Trinitro-1,3,5-Triazinane-based PBX explosives, Propellants, Explos. Pyrotech. 46 (4) (2021) 530–536, https://doi.org/10.1002/prep.202000278.
[221] M. Hermann, U. Forter-Barth, Thermal behavior and micro structure of TKX-50, Propellants, Explos. Pyrotech. 46 (2) (2021) 262–266, https://doi.org/10.1002/prep.202000257.
[222] A. Hu, H. Zou, W. Shi, A. Pang, S. Cai, Preparation, microstructure and thermal property of ZrAl3/Al composite fuels, Propellants, Explos. Pyrotech. 44 (11) (2019) 1454–1465, https://doi.org/10.1002/prep.201900012.
[223] Y. Hu, S. Yuan, X. Li, M. Liu, F. Sun, G. Hao, W. Jiang, Preparation and Characterization of Nano-CL-20/TNT cocrystal explosives by mechanical ball-milling method, ACS Omega 5 (28) (2020) 17761–17766, https://doi.org/10.1021/acsomega.0c02426.
[224] A. Hussein, S. Zeman, A. Elbeih, Cis-1,3,4,6-Tetranitrooctahydroimidazo-[4,5-d] Imidazole (BCHMX) as a part of low sensitive compositions based on DATB or HNAB, Propellants, Explos. Pyrotech. 46 (2) (2021) 322–328, https://doi.org/10.1002/prep.202000160.
[225] S.I. Jackson, A pressure- or velocity-dependent acceleration rate law for the shock-to-detonation transition process in PBX 9502 high explosive, Combust. Flame 213 (2013) 98–106, https://doi.org/10.1016/j.combustflame.2019.11.036.
[226] S.K. Jangid, S. Radhakrishnan, V.J. Solanki, M.K. Singh, G. Pandit, R. Vijayalakshmi, R.K. Sinha, Evaluation studies on partial replacement of RDX by spherical NTO in HTPB-based insensitive sheet explosive formulation, J. Energetic Mater. 37 (3) (2019) 320–330, https://doi.org/10.1080/07370652.2019.1613457.
[227] S. Jing, Z. Jiang, Q. Jiao, Z. Li, Y. Liu, L. Yang, 3,5-difluoro-2,4,6-trinitroanisole: promising melt-cast insensitive explosives instead of TNT, J. Energetic Mater. (2021), https://doi.org/10.1080/07370652.2020.1859645.
[228] M.H. Keshavarz, L. Makvandi, S. Damiri, Assessment of thermal stability and detonation performance of 4-Amino-1,2,4-triazolium Nitrate compared to 2,4,6-Trinitrotoluene for Melt-cast explosives, Zeitschrift fur anorganische und allgemine Chemie 646 (6) (2020) 323–327, https://doi.org/10.1002/zaac.202000072.
[229] N. Kim, B. Lee, H.J. Shin, J.H. Park, K. Kwon, S. Kim, Y.G. Kim, Bis(4-azido-3,5-dinitro-1H-pyrazol-1-yl)methane as a new green primary explosive, Bull. Kor. Chem. Soc. 41 (9) (2020) 913–917, https://doi.org/10.1002/bkcs.12087.
[230] T. Klapotke, TKX-50: a highly promising secondary explosive, in: D. Trache, F. Benaliouche, A. Mekki (Eds.), Materials Research and Applications: Selected Papers from JCH8-2019, Springer, Singapore, 2021, pp. 1–91. https://link.springer.com/chapter/10.1007/978-981-15-9223-2_1.
[231] E. Koch, M. Suceska, Analysis of explosive properties of tetrasulafur tetranitrde, S_4N_4, Z. Anorg. Allg. Chem. 647 (4) (2021) 192–199, https://doi.org/10.1002/zaac.202000406.
[232] M. Kohga, S. Togo, Catalytic effect of added Fe2O3 amount on thermal decomposition behaviors and burning characteristics of ammonium nitrate/ammonium perchlorate propellants, Combust. Sci. Technol. 192 (9) (2019) 1668–1681, https://doi.org/10.1080/00102202.2019.1620736.
[233] N. Kumar, A. Dixit, Nanotechnology-driven explosives and propellants, in: Nanotechnology for Defence Applications, Springer, 2019, pp. 81–115. https://link.springer.com/chapter/10.1007/978-3-030-29880-7_3.
[234] G. Lan, S. Jin, M. Chen, J. Li, L. Du, J. Wang, J. Chen, L. Li, Preparation and thermal properties study of HNIW/FOX-7 based high energy polymer bonded explosive (PBX) with low vulnerability to thermal stimulations, J. Energetic Mater. 38 (1) (2020) 83–97, https://doi.org/10.1080/07370652.2019.1665146.
[235] G. Lan, S. Jin, B. Jing, Y. Chen, D. Wang, J. Li, M. Chen, Investigation into the temperature adaptability of HNIW-based PBXs, Propellants, Explos. Pyrotech. 44 (3) (2019) 327–336, https://doi.org/10.1002/prep.201800261.
[236] P.R. Lee, A theoretical method to compare relative bulk thermal sensitivities of several common high explosives, Propellants, Explos. Pyrotech. 45 (8) (2020) 1300–1305, https://doi.org/10.1002/prep.202000048.
[237] W.H. Lee, K. Kwon, Safe synthesis of TKX-50 using an insensitive intermediate, Propellants, Explos. Pyrotech. 44 (11) (2019) 1478–1481, https://doi.org/10.1002/prep.201900171.
[238] C. Lei, H. Yang, H. Xiong, G. Cheng, The unique synthesis of green metal-free primary explosive: 3,3′-azo-5,5′-diazido-1,2,4-triazole, Propellants, Explos. Pyrotech. 45 (3) (2020) 416–421, https://doi.org/10.1002/prep.201900283.
[239] R. Lewczuk, J. Recko, S. Wojtulewski, Crystal structure and properties of an energetic perchlorate complex compound with copper and cytosine, Propellants, Explos. Pyrotech. 46 (5) (2021) 737–741, https://doi.org/10.1002/prep.202000304.
[240] J. Li, F. Chen, H. Yang, K. Lu, Optimization of the process parameters for the synthesis of high purity 4,6-Dinitrobenzofuroxan (4,6-DNBF), Propellants, Explos. Pyrotech. 45 (7) (2020) 1102–1111, https://doi.org/10.1002/prep.201900413.
[241] J. Li, F. Chen, H. Yang, K. Lu, Study on synthesis and characterization of primary explosive KDNBG with different morphologies, Propellants, Explos. Pyrotech. 45 (8) (2020) 1313–1325, https://doi.org/10.1002/prep.202000052.
[242] M. Li, W. Yang, M. Xu, R. Hu, L. Zheng, Study of photcurable energetic resin based propellants fabricated by 3D printing, Mater. Des. 207 (2021), 109891, https://doi.org/10.1016/j.matdes.2021.109891.
[243] Q. Li, C. An, J. Peng, C. Xu, H. Guo, S. Wang, B. Ye, J. Wang, Formulation of CL-20k-based explosive ink and its detonating transfer performance in micro-size charge, Propellants, Explos. Pyrotech. 44 (11) (2019) 1432–1439, https://doi.org/10.1002/prep.201900015.
[244] S. Li, C. Chang, K. Lu, Optimization of the synthesis parameters and analysis of the impact sensitivity for tretrazene explosive, Cent. Eur. J. Energ. Mater. 17 (1) (2020) 5–19, https://doi.org/10.22211/cejem/118512.
[245] Y. Li, J. Wu, L. Yang, D. Geng, M. Sultan, L. Chen, Polymerization effects on the decomposition of a Pyrazolo-Triazine at high temperatures and pressures, ChemistryOpen 9 (4) (2020) 470–479, https://doi.org/10.1002/open.202000006.
[246] P. Lian, C. Kang, Y. Zhang, S. Chen, W. Lai, Theoretical study on new high energetic density compounds with high power and specific impulse, FirePhysChem 1 (2) (2021) 103–108, https://doi.org/10.1016/j.fpc.2021.04.006.
[247] D. Liu, D. Geng, K. Yang, J. Lu, S.H.Y. Chan, C. Chen, H.H. Hng, L. Chen, Decomposition and energy-enhancement mechanism of the energetic binder glycidyl azide polymer at explosive detonation temperatures, J. Phys. Chem. 124 (27) (2020) 5542–5554, https://doi.org/10.1021/acs.jpca.0c02950.
[248] W. Liu, Z. Xu, R. Wang, C. Zhang, Q. Yan, Z. Meng, Synthesis, hydrolysis, reducting on and nitrolysis of lycoluril-derived precursors: another attempt toward the synthesis of nitramine explosives, ChemistrySelect 4 (12) (2019) 3474–3478, https://doi.org/10.1002/slct.201900204.
[249] W. Liu, C. Yang-Fan, H. Fang, Y. Yao, C. Tao, Y. Chen, Z. She, Fabrication and characterization of PMMA/TiH2 energetic microcapsules with a hollow structure, J. Energetic Mater. 38 (4) (2020) 406–417, https://doi.org/10.1080/07370652.2020.1726527.
[250] Y. Liu, P. Lv, C. Sun, S. Pang, Syntheses, crystal structures, and properties of two novel CL-20-based cocrystals, Z. Anorg. Allg. Chem. 645 (8) (2019) 656–662, https://doi.org/10.1002/zaac.201900017.
[251] Y. Liu, H. Wang, F. Bai, F. Huang, T. Hussain, A new equation of state for detonation products of RDX-based aluminized explosives, Propellants, Explos. Pyrotech. 44 (10) (2019) 1293–1301, https://doi.org/10.1002/prep.201800126.
[252] Z. Liu, W. Zhu, Theoretical studies on surface-induced energetic, electronic, and vibrational properties of Triamino-trinitrobenzene nanoparticles, J. Cluster Sci. 32 (4) (2021) 887–897, https://doi.org/10.1007/s10876-020-01850-3.
[253] B. Long, H. Wang, S. Gao, Study on the fracture properties of HTPM propellant at low temperature, Propellants, Explos. Pyrotech. 45 (1) (2020) 136–140, https://doi.org/10.1002/prep.201900277.
[254] J. Ma, Y. Tang, G. Cheng, G. Imler, D. Parrish, J. Shreeve, Energetic derivatives of 8-Nitropyrazolo[1,5-*a*] [1,3,5]triazine-2,4,7-triamine: achieving balanced explosives by fusing Pyrazole with Triazine, Org. Lett. 22 (4) (2020) 1231–1235, https://doi.org/10.1021/acs.orglett.9b04642.
[255] Q. Ma, G. Zhang, J. Li, Z. Zhang, H. Lu, L. Liao, G. Fan, F. Nie, Pyrazol-triazole energetic hybrid with high thermal stability and decreased sensitivity: facile synthesis, characterization and promising performance, Chem. Eng. J. 379 (2020), 122331, https://doi.org/10.1016/j.cej.2019.122331.
[256] Q. Ma, Z. Zhang, W. Yang, W. Li, J. Ju, G. Fan, Strategies for constructing melt-castable energetic materials: a critical review, Energ. Mater. Front. 2 (1) (2021) 69–85, https://doi.org/10.1016/j.enmf.2021.01.006.

[257] X. Ma, Y. Li, I. Husuuain, R. Shen, G. Yang, K. Zhang, Core-shell structured nanoenergetic materials: preparation and fundamental properties, Adv. Mater. 32 (30) (2020), 20001291, https://doi.org/10.1002/adma.202001291.
[258] S. Manzoor, Q. Tariq, J. Zhang, Nitro-tetrazole based high performing explosives: recent overview of synthesis and energetic properties, Defence Technol. 17 (6) (2021) 1995–2010, https://doi.org/10.1016/j.dt.2021.02.002.
[259] M.C. Marshall, A. Fernandez-Panella, T.W. Myers, J.H. Eggert, D.J. Erskine, S. Bastea, L.E. Fried, L.D. Leininger, Shock Hugoniot measurements of single-crystal 1,3,5-triamino-2,4,6-trinitrobenzene (TATB) compressed to 83 GPa, J. Appl. Phys. 127 (18) (2020), 185901, https://doi.org/10.1063/5.0005818.
[260] S. Nair, S. Matthew, C.P. Reghunadhan Nair, High energy materials as thermal decomposition modifiers of Ammonium perchlorate, Mater. Today Proc. 25 (2) (2020) 144–147, https://doi.org/10.1016/j.matpr.2019.12.203.
[261] M. Negri, M. Wilhelm, H.K. Ciezki, Thermal ignition of AND-based propellants, Propellants, Explos. Pyrotech. 44 (9) (2019) 1096–1106, https://doi.org/10.1002/prep.201900154.
[262] T.D. Ngugen, J.M. Veauthier, G.F. Angeles-Tamayo, D.E. Chavez, E. Lapsheva, T. W. Myers, T.R. Nelson, E.J. Scheleter, Correlating mechanical sensitivity with spin transition in the explosive spin crossover complex [Fe(Htrz)3]n[ClO4]2n, J. Am. Chem. Soc. 142 (10) (2020) 4842–4851, https://doi.org/10.1021/jacs.9b13835.
[263] X. Nie, C. Lei, H. Xiong, G. Cheng, H. Yang, Methylation of a triazole-fused framework to create novel insensitive energetic materials, Energ. Mater. Front. 1 (3–4) (2020) 165–171, https://doi.org/10.1016/j.enmf.2020.11.004.
[264] K. Okada, Y. Saito, M. Akiyoshi, T. Endo, T. Matsunaga, Preparation and characterization of nitrocellulose nanofiber, Propellants, Explos. Pyrotech. 46 (6) (2021) 962–968, https://doi.org/10.1002/prep.202000240.
[265] H.R. Pouretedal, S. Damiri, Z. Bighamian, The non-isothermal gravimetric method for study the thermal decomposition kinetic of HNBB and HNS explosives, Defence Technol. 16 (1) (2019) 251–256, https://doi.org/10.1016/j.dt.2019.06.006.
[266] R. Rajan, T.R. Ravindran, R.R. Madhavan, R. Asuvathraman, S. Chandra, V. Venkatesan, A.A. Vargeese, Thermal expansion of energetic material TEX obtained from x-ray diffraction and first principles calculations, J. Mol. Struct. 1195 (2019) 859–862, https://doi.org/10.1016/j.molstruc.2019.06.054.
[267] M. Reichel, D. Dosch, Klapotke, K. Karaghiosoff, Correlation between structure and energetic properties of three nitroaromatic compounds: bis(2,4-dinitrophenyl) ether, bis(2,4,6-trinitrophenyl) ether, and bis(2,4,6-trinitrophenyl) thioether, J. Am. Chem. Soc. 141 (50) (2019) 19911–19916, https://doi.org/10.1021/jacs.9rb11086.
[268] J. Ren, W. Zhang, T. Zhang, Y. Yin, L. Wang, Z. Li, Q. Zeng, T. Zhang, 3-Nitramino-6-hydroxy-1,2,4,5-tetrazine and its alkaline earth metal salts: an effective strategy to balance energy density and safety of energetic compounds, J. Energetic Mater. 39 (1) (2020) 48–59, https://doi.org/10.1080/07370652.2020.1754968.
[269] M. Reynaud, R. Sorin, V. Dubois, N. Desbiens, WGT: a mesoscale-informed reactive burn model, J. Appl. Phys. 127 (6) (2020), 065901, https://doi.org/10.1063/1.5135362.
[270] R. Roohzadeh, M. Mahdavi, Prediction of explosive properties of newly synthesized amino nitroguanidine-based energetic complexes via density functional theory, J. Mol. Model. 26 (5) (2020) 104, https://doi.org/10.1007/s00894-020-04377-6.
[271] C. Sang, S. Jim, G. Li, Y. Luo, Preparation of copper ferrite by sol–gel method and the synergistic catalytic for the thermal decomposition of ammonium perchlorate, J. Sol-Gel and Technol. 98 (3) (2021) 559–567, https://doi.org/10.1007/s10971-021-05509-x.
[272] U. Schaller, T. Keicher, V. Weiser, J. Hurttlen, 4-Amino-1-Butyl-1,2,4-Triazolium nitrate – synthesis and characterization, Propellants, Explos. Pyrotech. 44 (9) (2019) 1119–1128, https://doi.org/10.1002/prep.201900233.
[273] V. Sinditskii, V. Serushking, V. Kolesov, On the question of the energetic performance of TKX-50, Propellants, Explos. Pyrotech. 46 (10) (2021) 1504–1508, https://doi.org/10.1002/prep.202100173.
[274] C.J. Snyder, G.H. Imler, D.E. Chavez, D.A. Parrish, Synergetic explosive performance through cocrystallization, Cryst. Growth Des. 21 (3) (2021) 1401–1405, https://doi.org/10.1021/acs.cgd.0c01267.
[275] R. Soldaini de Oliverira, I. Borges, Correlation between molecular charge densities and sensitivity of nitrogen-rich heterocyclic nitroazole derivative explosives, J. Mol. Model. 25 (10) (2019) 314, https://doi.org/10.1007/s00894-019-4195-0.
[276] X. Song, Q. Huang, B. Jin, R. Peng, Fabrication and characterization of CL-20/PEI/GO composites with enhanced thermal stability and desensitization via electrostatic self-assembly, Appl. Surf. Sci. (2021), 149933, https://doi.org/10.1016/j.apsusc.2021.149933.
[277] E.N. Stepurko, A.V. Blokhin, S.V. Kohut, G.J. Kabo, Thermodynamic properties of 1-Methyl-4-nitro-1,2,3-triazole, Thermochim. Acta 686 (2020), 178534, https://doi.org/10.1016/j.tca.2020.178534.
[278] Synthesis and properties of lead-free primary explosives: potassium 5-(2,2-Diamino-1-nitrovinyl)tetrazolate. Propellants, Explos. Pyrotech., 46(7), 1150-1154. https://doi.org/10.1002/prep.202100079.
[279] D. Tan, X. Wei, D. Zhang, F. Chen, W. He, Z. Wang, Process optimization of supercritical CO_2 foamed SF-3 double-base propellant, Propellants, Explos. Pyrotech. 45 (1) (2020) 20–25, https://doi.org/10.1002/prep.201900216.
[280] C. Tao, Y. Cheng, H. Fang, Y. Yao, Y. Wang, H. Ma, Z. Shen, Y. Chen, Fabrication and characterization of a novel underground mining emulsion explosive containing thickening microcapsules, Propellants, Explos. Pyrotech. 45 (6) (2020) 932–941, https://doi.org/10.1002/prep.201900351.
[281] J. Tao, X.F. Wang, K. Zhang, X. Feng, Theoretical calculation and experimental study on the interaction mechanism between TKX-50 and AP, Defence Technol. 16 (4) (2019) 825–833, https://doi.org/10.1016/j.dt.2019.10.007.
[282] R. Van Riet, E. Amayuelas, P. Lodewyckx, M. Lefebvre, C. Ania, Novel opportunities for nanoporous carbons as energetic materials, Carbon 164 (2020) 129–132, https://doi.org/10.1016/j.carbon.2020.03.061.
[283] J.V. Viswanath, B. Shanigaram, P. Vijayadarshan, T.V. Chowadar, A. Gupta, K. Bhanuprakash, S.R. Niranjana, A. Venkataraman, Studies of theoretical optimization of CL-20: RDX cocrystal, Propellants, Explos. Pyrotech. 44 (12) (2019) 1570–1582, https://doi.org/10.1002/prep.201900126.
[284] O. Vodochodsky, M. Kunzel, R. Matyas, J. Kucera, J. Pachman, Tetraammine copper Perchlorate (TACP): explosive properties, Propellants, Explos. Pyrotech. 46 (2) (2021) 280–285, https://doi.org/10.1002/prep.202000131.
[285] G. Wang, Z. Fu, H. Yin, F. Chen, Synthesis and properties [1,2,4]Triazolo[4,3-b][1,2,4,5]Tetrazine N-oxide explosives, Propellants, Explos. Pyrotech. 44 (8) (2019) 1010–1014, https://doi.org/10.1002/prep.201900014.
[286] J. Wang, Cao, J. Cao, Y. Yang, L. Chen, D. Cao, Synthesis, characterization and decomposition of 4-Diazo-2,6-dinitrophenol, Propellants, Explos. Pyrotech. 46 (9) (2021) 1388–1396, https://doi.org/10.1002/prep.202100005.
[287] J. Wang, W. Cao, X. Guo, B. Cheng, L. Zhao, R. Liu, X. Chen, Effect of microstructure on short pulse duration shock initiation of TATB and initial response mechanism, Defence Technol. 16 (2) (2020) 374–380, https://doi.org/10.1016/j.dt.2019.06.001.
[288] J. Wang, S. Chen, S. Jin, Q. Shu, X. Zhang, R. Shi, Thermal behavior, compatibility study and safety assessment of diammonium 5,5′-bistetrazole-1,1′-diolate (ABTOX), J. Therm. Anal. Calorim. 139 (3) (2020) 1771–1777, https://doi.org/10.1007/s10973-019-08605-x.
[289] Q. Wang, L. Zhang, W. He, L. Yang, C. Zhang, Z. Wang, R. Zhang, J. Chen, S. Wang, S. Zang, T.C.W. Mak, High-performance primary explosives derived from copper thiolate cluster-assembled materials for micro-initiating device, Chem. Eng. J. 389 (2020), 124455, https://doi.org/10.1016/j.cej.2020.124455.
[290] S. Wang, L. Yang, J. Han, Z. Yan, MOF as the rigid shell to improve the mechanical sensitivity of nitramine explosives, Mater. Lett. 306 (2022), 130940, https://doi.org/10.1016/j.matlet.2021.130940.
[291] T. Wang, X. Wang, Z. Yi, W. Cao, W. Dong, Y. Bi, S. Zhu, J. Zhang, Competitive coordination of azide groups: synthesis of solvent-free and chlorine-free primary explosives based on 3-Amino-1-nitroguanidine, Cryst. Growth Des. 21 (12) (2021) 7002–7007, https://doi.org/10.1021/acs.cgd.1c00926.
[292] T. Wang, J. Zhou, Q. Zhang, L. Zhang, S. Zhu, Y. Li, Novel 3D cesium(i)-based EMOFs of nitrogen-rich triazole derivatives as “green” orange-light pyrotechnics, New J. Chem. 44 (4) (2020) 1278–1284, https://doi.org/10.1039/C9NJ03577J.
[293] W. Wang, H. Li, Q. Liu, F. Liu, Z. Liu, High-pressure characterization of the cage-structured explosive TEX by dispersion-corrected DRF calculations, Phys. Status Solidi(B) 258 (2) (2020), 2000329, https://doi.org/10.1002/pssb.202000329.
[294] Y. Wang, J. Ye, N. Yang, H. Ma, Y. Zhang, Z. Guo, Strong intermolecular interaction induced methylene-bridged asymmetric heterocyclic explosives, CrystEngComm 23 (43) (2021) 7635–7642, https://doi.org/10.1039/D1CE01083B.
[295] L.A. Wingard, R.C. Sausa, P.E. Guzman, R. Pesce-Rodrigeuz, J. Sabatini, G. W. Drake, Synthesis of bis-Isoxazole-bis-Ethylene Dinitrate and bis-Isoxazole-tetra-Ethylene Tetranitrate: potential energetic plasticizer, Propellants, Explos. Pyrotech. 44 (5) (2019) 617–622, https://doi.org/10.1002/prep.201800315.
[296] H. Woods, A. Boddorff, E. Ewaldz, Z. Adams, M. Ketcham, D.J. Jang, E. Sinner, N. Thadhani, B. Brettmann, Rheological considerations for binder development in direct ink writing of energetic materials, Propellants, Explos. Pyrotech. 45 (1) (2020) 26–35, https://doi.org/10.1002/prep.201900159.
[297] D.R. Wozniak, B. Salfter, M. Zeller, E.F.C. Byrd, D.G. Piercey, Sensitive energetics from the N -amination of 4-nitro-1,2,3-triazole, ChemistryOpen 9 (8) (2020) 806–811, https://doi.org/10.1002/open.202000053.
[298] W. Wu, W. Feng, Q. Lin, S. Wang, Z. Guo, L. Chen, W. Chen, Synthesis and thermal decomposition of TNPG, Thermochim. Acta 683 (2020), 178396, https://doi.org/10.1016/j.tca.2019.178396.
[299] F. Xiao, M. Stone, C. Stennett, Pulsed laser irradiation of a nanoparticles sensitised RDX crystal, Combust. Flame 214 (2020) 387–393, https://doi.org/10.1016/j.combustflame.2020.01.009.
[300] R. Xu, Z. Li, Y. Chen, J. Pei, J. Zhang, Enthalpy of formation of p(BAMO)-b-GAP and energetic characteristics of solid propellants based on the copolymer, Propellants, Explos. Pyrotech. 46 (6) (2021) 969–974, https://doi.org/10.1002/prep.202000244.
[301] Y. Xue, H. Xiong, J. Tang, G. Cheng, H. Yang, Exploring application of 1,2,4-Triazole energetic salts: gas generating agent, propellant and explosive compositions, Propellants, Explos. Pyrotech. 46 (7) (2021) 1070–1078, https://doi.org/10.1002/prep.202000316.
[302] Z. Xue, B. Huang, H. Li, Q. Yan, Nitramine-Based energetic cocrystals with improved stability and controlled reactivity, Cryst. Growth Des. 20 (12) (2020) 8124–8147, https://doi.org/10.1021/acs.cgd.0c01122.
[303] F. Yan, P. Zhu, S. Zhao, J. Shi, Y. Mu, H. Xia, R. Shen, Microfluidic strategy for coating and modification of polymer-bonded nano-HNS explosives, Chem. Eng. J. 428 (2022), 131096, https://doi.org/10.1016/j.cej.2021.131096.
[304] T. Yan, J. Ma, H. Yang, G. Cheng, Introduction of energetic bis-1,2,4-triazoles bridges: a strategy towards advanced heat resistant explosives, Chem. Eng. J. 429 (2022), 132416, https://doi.org/10.1016/j.cej.2021.132416.
[305] Z. Yan, L. Yang, J. Han, H. Li, Molding fabrication of copper azide/porous graphene with high electrostatic safety by self-assembly of graphene oxide, Nanotechnology 32 (38) (2021), 385704, https://doi.org/10.1088/1361-6528/abc7d5.

[306] L. Yang, M. Yan, S. Huang, J. Xu, J. He, X. He, X. Cao, Y. Liu, Porous structure and reduced sensitivity of 2,2',4,4',6,6'-hexanitrostilbene (HNS) prepared by different solvation and desolvation methods, J. Energetic Mater. 38 (1) (2020) 35–47, https://doi.org/10.1080/07370652.2019.1658825.
[307] M. Yang, H. Ma, Z. Shen, Effect of RDX powders on detonation characteristics of emulsion explosives, J. Energetic Mater. 37 (4) (2019) 459–474, https://doi.org/10.1080/07370652.2019.1637480.
[308] R. Yang, Z. Dong, Z. Ye, Tetrazolium nitrate anion based salts as potential melt-castable explosives, ChemistrySelect 4 (48) (2019) 14208–14213, https://doi.org/10.1002/slct.201903408.
[309] X. Yang, K. Zhao, X. Tian, Z. Chen, X. Fang, Q. Xiao, X. Li, J. Dong, Y. Hang, X. Wang, An efficient energy characteristics and explosion heat improving method of FOX-7-based aluminized explosives, FirePhysChem 1 (1) (2021) 1–7, https://doi.org/10.1016/j.fpc.2021.02.003.
[310] Y. Yao, Y. Cheng, R. Liu, F. Hu, Q. Zhang, Xia, Y. Chen, Effects of micro-encapsulation treatment on the thermal safety of high energy emulsion explosives with boron powders, Propellants, Explos. Pyrotech. 46 (3) (2021) 389–397, https://doi.org/10.1002/prep.202000130.
[311] C. Young, S. Volaric, Synthesis, iodometric analysis, and IR spectroscopy of the peroxide double salt $[Zn(NH_3)_4][Mo(O_2)_4]$, J. Chem. Educ. 97 (4) (2020) 1120–1122, https://doi.org/10.1021/acs.jchemed.9b01113.
[312] S. Yuan, Z. Li, Q. Luo, X. Duan, C. Pei, Preparation and thermal decomposition properties of nitrated graphene oxide (NGO)/RDX nano-energetic composites, J. Therm. Anal. Calorimetery 139 (3) (2020) 1671–1679, https://doi.org/10.1007/s10973-019-08613-x.
[313] M.G. Zaky, A. Elbeih, T. Elshenawy, Review of nano-thermites: a pathway to enhanced energetic materials, Cent. Eur. Energ. Mater. 18 (1) (2021) 63–86, https://doi.org/10.22211/cejem/134953.
[314] J. Zhang, B. Jin, X. Li, W. Hao, T. Huang, B. Lei, Z. Guo, J. Shen, R. Peng, Study of H2AzTO-based energetic metal-organic frameworks for catalyzing the thermal decomposition of ammonium perchlorate, Chem. Eng. J. 404 (2021), 126287, https://doi.org/10.1016/j.cej.2020.126287.
[315] M. Zhang, Y. Tan, X. Zhao, J. Zhang, S. Huang, Z. Zhai, Y. Liu, Z. Yang, Seeking a novel energetic co-crystal strategy through the interfacial self-assembly of CL-20 and HMX nanocrystals, CrystEngComm 22 (1) (2020) 61–67, https://doi.org/10.1039/C9CE01447K.
[316] T. Zhang, Y. Li, D. Cao, Y. Liu, J. He, C. Zou, Experimental study and thermodynamic modeling of a novel heat-resistant explosive in different mono solvents, J. Mol. Liq. 311 (2020), 113056, https://doi.org/10.1016/j.molliq.2020.113056.
[317] C. Zhao, Y. Chi, Q. Peng, F. Yang, J. Zhou, X. Wang, J. Sun, A study on the comprehension of differences in specific kinetic energy of TKX-50 and HMX from the perspective of gas products, Phys. Chem. Chem. Phys. 21 (12) (2019) 6600–6605, https://doi.org/10.1039/C8CP07487A.
[318] C. Zhao, Z. Zhang, Q. Yu, F. Yang, G. Fan, K. Yu, Comparative study of the decomposition mechanism and kinetics of biimidazole-based energetic explosives, J. Phys. Chem. A 124 (18) (2020) 3672–3678, https://doi.org/10.1021/acs.jpca.0c01820.
[319] G. Zhao, P. Yin, Staples, J. Shreeve, One-step synthesis to an insensitive explosive: N,N′-bis((1H-tetrazol-5-yl)methyl)nitramide (BTMNA), Chem. Eng. J. 412 (2021), 128697, https://doi.org/10.1016/j.cej.2021.128697.
[320] N. Zhao, H. Ma, E. Yao, Z. Yu, T. An, F. Zhao, X. Yu, Influence of tailored CuO and Al/CuO nanothermites on the thermocatalytic degradation of nitrocellulose and combustion performance of AP/HTPB composite propellant, Cellulose 28 (13) (2021) 8671–8691, https://doi.org/10.1007/s10570-021-04060-w.
[321] P. Zhao, L. Chen, K. Yang, D. Geng, J. Lu, J. Wu, Effect of temperature on shock initiation of RDX-based aluminized explosives, Propellants, Explos. Pyrotech. 44 (12) (2019) 1562–1569, https://doi.org/10.1002/prep.201900092.
[322] K. Zhong, L. Hiu, G. Li, C. Zhang, Crack mechanism of $Al@Al_2O_3$ nanoparticles in hot energetic materials, J. Phys. Chem. C 125 (4) (2021) 2770–2778, https://doi.org/10.1021/acs.jpcc.0c10479.
[323] D. Zhu, L. Zhou, X. Zhang, Rheological behavior of DNAN/HMX melt-cast explosives, Propellants, Explos. Pyrotech. 44 (12) (2019) 1583–1589, https://doi.org/10.1002/prep.201900117.
[324] W. Zhu, M.I. Papadaki, S. Horsch, M. Krause, C.V. Mashuga, Calorimetric studies on the thermal stability of 2-Nitrotoluene explosives with incompatible substances, Ind. Eng. Chem. Res. 58 (29) (2019) 13366–13375, https://doi.org/10.1021/acs.iecr.9b01823.
[325] S. Zlotin, A. Churakov, M. Egorov, L. Feshtat, M. Klenov, I. Kuchurov, N. Makhova, G. Smirnow, Y. Tomilov, V. Tartakovsky, Advanced energetic materials: novel strategies and versatile applications, Mendeleev Commun. 31 (6) (2021) 731–749, https://doi.org/10.1016/j.mencom.2021.11.001.

Instrumental Analysis of ExplosivesLC/HPLC/UPLC

[326] J. Chen, H. Ding, J. Li, Y. Chen, Y. Liu, X. Zhao, Development and validation of HPLC method for DAAF and its application in quality control and environmental monitoring, Propellants, Explos. Pyrotech. 45 (10) (2020) 1580–1589, https://doi.org/10.1002/prep.202000018.
[327] H. Ding, H. Zhao, J. Chen, Z. Zhang, Y. Liu, Development and validation of a HPLC-UV method for DATNBI and its' application in quality control, J. Liq. Chromatogr. Relat. Technol. 44 (3–4) (2021) 220–228, https://doi.org/10.1080/10826076.2021.1884569.
[328] C. Freye, T. Nguyen, B. Tappan, Investigation of the impurities in erythritol tetranitrate (ETN) using UHPLC-QTOF, Propellants, Explos. Pyrotech. 46 (10) (2021) 1555–1560, https://doi.org/10.1002/prep.202100193.
[329] C.E. Freye, N. Lease, G.W. Brown, B.C. Tappan, D.G. Thompson, C.J. Rosales, S. A. Larson, Identification of blue discoloration in PBX 9404 using ultrahigh pressure liquid chromatography with quadrupole time-of-flight mass spectrometry, Propellants, Explos. Pyrotech. 46 (3) (2021) 355–359, https://doi.org/10.1002/prep.202000230.
[330] C.E. Freye, C.J. Rosales, D.G. Thompson, G.W. Brown, S.A. Larson, Development of comprehensive two-dimensional liquid chromatography for investigating aging of plastic bonded explosives, J. Chromatogr. A 1611 (2019), 460580, https://doi.org/10.1016/j.chroma.2019.460580.
[331] M. Kotrly, A. Eisner, I. Beroun, I. Turkova, New data for analyze improvised explosives in forensic practice, in: Proceedings SPIE Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XXVI, 11750, 2021, https://doi.org/10.1117/12.2587987, 1175008.
[332] A. Steiner, I. Lurie, Applicability of liquid and supercritical fluid chromatographic separation techniques with diode array ultraviolet detection for forensic analysis, Forensic Chem. 26 (2021), 100359, https://doi.org/10.1016/j.forc.2021.100359.
[333] C. Veresmortean, Development of an LCMS Analytical Method with Applicability to Determination of Trace Level Explosives in Environmental Waters, PhD, City University of New York, 2021, https://academicworks.cuny.edu/gc_etds/4574/.

Ion Chromatography

[334] S. Beal, S. Taylor, R. Crouch, A. Bednar, *Environmental Analysis of Aqueous 3-nitro-1,2,4-Triazol-5-One (NTO) by Ion Chromatography with Conductivity Detection* (ERDC TR-20-13), U.S. Army Corps of Engineers, 2020, https://doi.org/10.21079/11681/37415.
[335] M.D. Gallidabino, R.C. Irlam, M.C. Salt, M. O'Donnell, M.S. Beardah, L.P. Barron, Targeted and non-targeted forensic profiling of black powder substitutes and gunshot residue using gradient ion chromatography – high resolution mass spectrometry (IC-HRMS), Anal. Chim. Acta 1072 (2019) 1–14, https://doi.org/10.1016/j.aca.2019.04.048.
[336] M.A.C. Hartel, T.M. Klapotke, J. Stierstorfer, L. Zehetner, Vapor pressure of linear nitrate esters determined by transpiration method in combination with VO-GC/MS, Propellants, Explos. Pyrotech. 44 (4) (2019) 484–492, https://doi.org/10.1002/prep.201800133.
[337] A. Harvey, Detection and Identification of Chemical Warfare Agents and Explosives in Complex Matrices, Doctoral Dissertation, University of York, 2019.
[338] J.P. Hutchinson, C. Johns, G.W. Dicinoski, L. Jones, M.C. Breadmore, P. R. Haddad, Identification of improvised inorganic explosives devices by analysis of postblast residues using ion chromatography and capillary electrophoresis, in: Encyclopedia of Analytical Chemistry: Applications, Theory and Instrumentation, Wiley, 2020, https://doi.org/10.1002/9780470027318.a9031.pub2.
[339] H.R. Pouretedal, S. Damiri, A.R. Sharifi, Statistical optimization for determination of trace amounts of RDX in matrix of HMX using GC-ECD, SN Appl. Sci. 1 (457) (2019) 1–9, https://doi.org/10.1007/s42452-019-0477-5.
[340] P. Suppajariyawat, M. Elie, M. Baron, J. Gonzalez-Rodriguez, Classification of ANFO samples based on their fuel composition by GC–MS and FTIR combined with chemometrics, Forensic Sci. Int. 301 (2019) 415–425, https://doi.org/10.1016/j.forsciint.2019.06.001.

Gas Chromatography

[341] C. Cruse, J. Goodpaster, Optimization of gas chromatography/vacuum ultraviolet (GC/VUV) spectroscopy for explosive compounds and application to post-blast debris, Forensic Chem. 26 (2021), 100362, https://doi.org/10.1016/j.forc.2021.100362.
[342] C. Cruse, J. Pu, J. Goodpaster, Identifying thermal decomposition products of nitrate ester explosives using gas chromatography-vacuum ultraviolet spectroscopy: an experimental and computation study, Appl. Spectrosc. (2020), https://doi.org/10.1177/0003702820915506.
[343] C.A. Cruse, J.V. Goodpaster, Thermal and spectroscopic analysis of nitrated compounds and their breakdown products using gas chromatography/vacuum UV spectroscopy (GC/VUV), Anal. Chim. Acta 1143 (2021) 117–123, https://doi.org/10.1016/j.aca.2020.11.041.
[344] I. Lara-Ibeas, A. Cuevas, S. Le Calve, Recent developments and trends in miniaturized gas preconcentrators for portable gas chromatography systems: a review, Sensor. Actuator. B Chem. 346 (2021), 130449, https://doi.org/10.1016/j.snb.2021.130449.
[345] M. Li, A. Ghosh, A. Venkatasubramanin, R. Sharma, X. Huang, X. Fan, High-sensitivity micro-gas chromatograph-photoionization detector for trace vapor detection, ACS Sens. 6 (6) (2021) 2348–2355, https://doi.org/10.1021/acssensors.1c00482.
[346] A. Qualley, G.T. Hughes, M.H. Rubenstein, Data quality improvement for field-portable gas chromatography-mass spectrometry through the use of isotopic analogues for in-situ calibration, Environ. Chem. 17 (1) (2020) 28–38, https://doi.org/10.1071/EN19134.
[347] R. Reiss, B. Gruber, S. Klingbeil, T. Groger, S. Ehlert, R. Zimmermann, Evaluation and application of gas chromatography - vacuum ultraviolet spectroscopy for drug- and explosive precursors and examination of non-negative matrix factorization for deconvolution, Spectrochim. Acta Mol. Biomol. Spectrosc. 219 (2019) 129–134, https://doi.org/10.1016/j.saa.2019.04.032.
[348] C. Wang, L. Heraty, H. Li, M. Fuller, P. Hatzinger, N. Sturchio, Method for derivatization and isotopic analysis of the insensitive munition compound 3-nitro-

1,2,4-triazol-5-one (NTO), J. Hazard. Mater. Lett. 2 (2021), 1000044, https://doi.org/10.1016/j.hazl.2021.100044.

Capillary Electrophoresis

[349] K. Bezemer, L. van Duin, C. Martin-Alberca, G. Somsen, P. Schoenmakers, R. Haselberg, A. van Asten, Rapid forensic chemical classification of confiscated flash banger fireworks using capillary electrophoresis, Forensic Chem. 16 (2019), 100187, https://doi.org/10.1016/j.forc.2019.100187.

[350] K.D.B. Bezemer, T.P. Forbes, A.W.C. Hulsbergen, J. Verkouteren, S.T. Krauss, M. Kobeberg, P.J. Schoenmakers, G. Gillen, A.C. van Asten, Emerging techniques for the detection of pyrotechnic residues from seized postal packages containing fireworks, Forensic Sci. Int. 308 (2020), 110160, https://doi.org/10.1016/j.forsciint.2020.110160.

[351] S.T. Krauss, T.P. Forbes, D. Jobes, Inorganic oxidizer detection from propellants, pyrotechnics, and homemade explosive powders using gradient elution moving boundary electrophoresis, Electrophoresis 42 (3) (2020) 279–288, https://doi.org/10.1002/elps.202000279.

[352] S.T. Krauss, T.P. Forbes, J.A. Lawrence, G. Gillen, J.R. Verkouteren, Detection of fuel-oxidizer explosives utilizing portable capillary electrophoresis with wipe-based sampling, Electrophoresis 41 (16–17) (2020) 1482–1490, https://doi.org/10.1002/elps.202000094.

General Spectroscopy: Fluorescence, Luminescence, Spectrophotometric, UV, Chemiluminescence

[353] O. Abuzalat, D. Wong, S. Park, S. Kim, Highly selective and sensitive fluorescent zeolitic imidazole frameworks sensor for nitroaromatic explosive detection, Nanoscale 12 (25) (2020) 13523–13530, https://doi.org/10.1039/D0NR01653E.

[354] A.J. Agranat, Y. Kabessa, B. Shemer, E. Shpigel, O. Schwartsglass, L. Atammneh, Y. Uziel, M. Ejzenberg, Y. Mizrachi, Y. Garcia, G. Perepelitsa, S. Belkin, An autonomous bioluminescent bacterial biosensor module for outdoor sensor networks, and its application for the detection of buried explosives, Biosens. Bioelectron. 185 (2021), 113253, https://doi.org/10.1016/j.bios.2021.113253.

[355] M.N. Ahamad, M. Shahid, M. Ahmad, F. Sama, Cu(II) MOFs based on Bipyridyls: topology, magnetism, and exploring sensing ability toward multiple nitroaromatic explosives, ACS Omega 4 (4) (2019) 7738–7749, https://doi.org/10.1021/acsomega.9b00715.

[356] S. Anju, R. Anjana, N. Vijila, A. Aswathy, J. Jayakrishna, B. Anjitha, S. Adhya, S. George, Tb-doped BSA–gold nanoclusters as a bimodal probe for the selective detection of TNT, Anal. Bioanal. Chem. 412 (17) (2020) 4165–4172, https://doi.org/10.1007/s00216-020-02654-0.

[357] D.G. Babar, S.S. Garje, Nitrogen and phosphorus co-doped carbon dots for selective detection of nitro explosives, ACS Omega 5 (6) (2020) 2710–2717, https://doi.org/10.1021/acsomega.9b03234.

[358] A. Butler, D. Amondson, H. Krier, N. Glumac, Spectral emission signatures from cased high-explosive charge, Appl. Spectrosc. 75 (11) (2021) 1410–1418, https://doi.org/10.1177/00037028211042646.

[359] S. Chaudhary, P. Sonkusre, A. Chopra, K.K. Bahsin, C.R. Suri, UV-FIA: UV-induced fluoro-immunochemical assay for ultra-trace detection of PETN, RDX, and TNT, Anal. Chim. Acta 1077 (2019) 266–272, https://doi.org/10.1016/j.aca.2019.05.048.

[360] Q. Chen, L. Yang, K. Guo, J. Yang, J. Han, Expedite fluorescent sensor prototype for hydrogen peroxide detection with long-life test substrates, ACS Omega 6 (17) (2021) 11447–11457, https://doi.org/10.1021/acsomega.1c00471.

[361] C. Cheng, M. Nawaz, C. Liu, S. Shahzad, H. Zhou, C. Yu, X. Jin, Phenothiazine and BN-doped AIE probes integrated fluorescence sensor array for detection and discrimination of nitro explosives, Chin. J. Anal. Chem. 48 (7) (2020), https://doi.org/10.1016/S1872-2040(20)60034-2 e370075-e20080.

[362] J. Delente, D. Umadevi, K. Byrne, W. Schmitt, G. Watson, T. Gunnlaugsson, S. Shanmugaraju, Hyper-crosslinked 4-amino-1,8-naphthalimide Tröger's base containing pyridinium covalent organic polymer (COP) for discriminative fluorescent sensing of chemical explosives, Supramol. Chem. 32 (9) (2020) 508–517, https://doi.org/10.1080/10610278.2020.1825715.

[363] S. Devi, S. Shaswat, V. Kumar, A. Sachdev, P. Gopinath, S. Tyagi, Nitrogen-doped carbon quantum dots conjugated isoreticular metal-organic framework-3 particles based luminescent probe for selective sensing of trinitrotoluene explosive, Microchim. Acta 187 (9) (2020) 536, https://doi.org/10.1007/s00604-020-04496-0.

[364] L. Diaz, M. Munoz, Paredes-Gil, N. Snejko, B. Gomez-Lor, E. Gutierrez-Puebla, A. Monge, The effect of auxiliary nitrogenated linkers on the design of new cadmium based coordination polymers as sensors for detection of explosives materials, Chem.–Eur. J. (2021), https://doi.org/10.1002/chem.202005166.

[365] S. Elbasuney, A. Baraka, Y. El-Sharkawy, G. El-Sayyad, Superior spectral fluorescence signature of novel illuminated melamine resin for industrial explosive detection, Opt Laser. Technol. 140 (2021), 107066, https://doi.org/10.1016/j.optlastec.2021.107066.

[366] S. Elbasuney, A. Baraka, M. Gobara, Y.H. El-Sharkawy, 3D spectral fluorescence signature of cerium(III)-melamine coordination polymer: a novel sensing material for explosive detection, Spectrochim. Acta Mol. Biomol. Spectrosc. 245 (2021), 119841, https://doi.org/10.1016/j.saa.2020.118941.

[367] M. Faheem, S. Aziz, X. Jing, T. Ma, J. Du, F. Sun, Y. Tian, G. Zhu, Dual luminescent covalent organic frameworks for nitro-explosive detection, J. Mater. Chem. (2019), https://doi.org/10.1039/C9TA09497K.

[368] J. Fan, Z. Meng, X. Dong, M. Xue, L. Qiu, X. Liu, F. Zhong, X. He, Colorimetric screening of nitramine explosives by molecularly imprinted photonic crystal array, Microchem. J. 158 (2020), 105143, https://doi.org/10.1016/j.microc.2020.105143.

[369] F. Feng, Y. Peng, L. Zhang, W. Huang, Imine organic cages derived from tetraphenylethylene dialdehydes exhibiting aggregation-induced emission and explosives detection, Dyes Pigments 194 (2021), 109657, https://doi.org/10.1016/j.dyepig.2021.109657.

[370] E. Gao, D. Liu, J. Xing, Y. Feng, J. Su, J. Liu, H. Zhao, N. Wang, Z. Jia, X. Zhang, V. P. Fedin, M. Zhu, A recyclable bi-functional luminescent zinc (II) metal-organic framework as highly selective and sensitive sensing probe for nitraromatic explosives and Fe3+ ions, Appl. Organomet. Chem. 33 (9) (2019), e5109, https://doi.org/10.1002/aoc.5109.

[371] George, G., Edwards, C.S., Hayes, J.I., Yu, L., Ede, S.R., Wen, J.G., Luo, & Z.P. A novel reversible fluorescent probe for the highly sensitive detection of nitro and peroxide organic explosives using electrospun BaWO4 nanofibers. J. Mater. Chem. C, 7(47), Pages 14949-14961. https://doi.org/10.1039/C9TC05068J.

[372] K. Gholivand, S. Tizhoush, A. Kozakiewicz, Two new micro-isostructural metal–organic polymers based on mixed-ligand copper(I): structures and selective sensing of nitro explosives in water, Appl. Organomet. Chem. 34 (8) (2020), e5701, https://doi.org/10.1002/aoc.5701.

[373] R. Gillanders, J. Glackin, J. Filipi, N. Kezi, I. Samuel, G. Turnbull, June 23-27). Fluorescence-based sensors and preconcentration techniques for buried explosives detection [Conference session], in: European Conference on Lasers and Electro-Optics, Munich, Germany, 2019. https://www.osapublishing.org/abstract.cfm?uri=CLEO_Europe-2019-ch_9_5.

[374] P. Guo, S. Zheng, Y. Wang, Q. Zhuang, Y. Ni, Synthesis of fluorescent tremalle-like carbon nanosheets and their application for sensing of 2,4,6-trinitrophenol, Anal. Lett. 53 (1) (2020) 72–83, https://doi.org/10.1080/00032719.2019.1636809.

[375] H. Hao, H. Luo, A. Yi, C. Liu, B. Xu, G. Shi, Z. Chi, A multifunctional luminescent network film electrochemically deposited from a new AIEE emitter for OLEDs and explosive detection, Org. Electron. 69 (2019) 281–288, https://doi.org/10.1016/j.orgel.2019.03.029.

[376] J. Harwell, J. Glackin, N. Davis, R. Gillanders, D. Credgington, G. Turnbull, I. Samuel, Sensing of explosive vapor by hybrid perovskites: effect of dimensionality, Apl. Mater. 8 (7) (2020), 071106, https://doi.org/10.1063/5.0011229.

[377] Y. Henshke, B. Shemer, S. Belkin, The Escherichia coli azoR gene promoter: a new sensing element for microbial biodetection of trace explosives, Curr. Res. Biotechnol. 3 (2021) 21–28, https://doi.org/10.1016/j.crbiot.2021.01.003.

[378] E. Hussain, Y. Li, C. Cheng, H. Zhuo, S. Shahzad, S. Ali, M. Ismail, H. Qi, C. Yu, Benzo[ghi]perylene and coronene as ratiometric fluorescence probes for the selective sensing of nitroaromatic explosives, Talanta 207 (2020), 120316, https://doi.org/10.1016/j.talanta.2019.120316.

[379] M. Jurcic, W.J. Peveler, C.N. Savory, D. Bucar, A.J. Kenyon, D.O. Scanlon, I. P. Parking, Sensing and discrimination of explosives at variable concentrations with a large-pore MOF as part of a luminescent array, ACS Appl. Mater. Interfaces 11 (12) (2019) 11618–11626, https://doi.org/10.1021/acsami.8b22385.

[380] N. Kalva, C.H. Tran, M.W. Lee, R. Augstine, S.J. Lee, I. Kim, Aggregation-induced emission-active hyperbranched polymers conjugated with tetraphenylethylene for nitroaromatic explosive detection, Dyes Pigments 194 (2021), 109617, https://doi.org/10.1016/j.dyepig.2021.109617.

[381] S. Kanwal, S. Jahan, F. Mansoor, An ultrasonic-assisted synthesis of leather-derived luminescent graphene quantum dots: catalytic reduction and switch on–off probe for nitro-explosives, RSC Adv. 10 (39) (2020) 22959–22965, https://doi.org/10.1039/D0RA03715J.

[382] Z. Kayhomayun, K. Ghani, K. Zargoosh, Template-directed synthesis of $Sm_2Ti_2O_7$ nanoparticles: a FRET-based fluorescent chemosensor for the fast and selective determination of picric acid, New J. Chem. 44 (38) (2020) 16442–16451, https://doi.org/10.1039/D0NJ04219F.

[383] Z. Kayhomayun, K. Ghani, K. Zatgoosh, Surfactant-assisted synthesis of fluorescent SmCrO3 nanopowder and its application for fast detection of nitroaromatic and nitramine explosives in solution, Mater. Chem. Phys. 247 (2020), 122899, https://doi.org/10.1016/j.matchemphys.2020.122899.

[384] S. Khan, A. Hazra, B. Dutta, Akhtaruzzaman, M. Raihan, J. Raihan, P. Banerjee, M. Mir, Strategic design of anthracene-decorated highly luminescent coordination polymers for selectives and rapid detection of TNP: an explosive nitro derivative and mutagenic pollutant, Cryst. Growth Des. 21 (6) (2021) 3344–3354, https://doi.org/10.1021/acs.cgd.1c00145.

[385] M. Kose, H. Kirpik, A. Kose, Fluorimetric detections of nitroaromatic explosives by polyaromatic imine conjugates, J. Mol. Struct. 1185 (2019) 369–378, https://doi.org/10.1016/j.molstruc.2019.03.003.

[386] I.S. Kovalev, L.K. Sadieva, O.S. Taniya, V.M. Yurk, A.S. Minin, S. Santra, G. V. Zyryanov, V.N. Charushin, O.N. Chupakhin, M.V. Tsurkan, Computer vision vs. spectrofluorometer-assisted detection of common nitro-explosive components with bola-type PAH-based chemosensors, RSC Adv. 11 (42) (2021) 25850–25857, https://doi.org/10.1039/D1RA03108B.

[387] P.A. Kulharni, V. Nandre, N. Kumbhar, R. Khade, T. Urmode, K.M. Kodam, M. A. More, NTO sensing by fluorescence quenching of a pyoverdine siderophore—a mechanistic approach, ACS Omega 5 (17) (2020) 9668–9673, https://doi.org/10.1021/acsomega.9b03844.

[388] A. Kumar, C. Lu, W. Tseng, Two in one: poly(ethyleneimine)-modified MnO_2 nanosheets for ultrasensitive detection and catalytic reduction of 2,4,6-Trinitro-toluene and other nitro aromatics, ACS Sustain. Chem. Eng. 9 (3) (2021) 1142–1151, https://doi.org/10.1021/acssuschemeng.0c06224.

[389] Kumar, V., Choudhury, N., Kumar, A., De, P., & Satapathi, S. Poly-tryptophan/carbazole based FRET-system for sensitive detection of nitroaromatic explosives. Opt. Mater., 100, 109710. https://doi.org/10.1016/j.optmat.2020.109710.

[390] V. Kumar, S.K. Saini, N. Choudhury, A. Kumar, A. Kumar, B. Maiti, P. De, M. Kumar, S. Sataphathi, Highly sensitive detection of nitro compounds using a fluorescent copolymer-based FRET system, ACS Appl. Polym. Mater. 3 (8) (2021) 4017–4026, https://doi.org/10.1021/acsapm.1c00540.
[391] J.Y. Lee, H.D. Root, R.A.W. An, V.M. Lynch, S. Bahring, I.S. Kim, J.L. Sessler, J. S. Park, Ratiometric turn-on fluorophore displacement ensembles for nitroaromatic explosives detection, J. Am. Chem. Soc. 142 (46) (2020) 19579–19587, https://doi.org/10.1021/jacs.0c08106.
[392] M. Li, H. Chen, S. Li, G. Wang, Wei, X. Guo, H. Tu, Active self-assembled monolayer sensors for trace explosive detection, Langmuir 36 (6) (2020) 1462–1466, https://doi.org/10.1021/acs.langmuir.9b03742.
[393] X. Li, C. Wang, W. Song, C. Meng, C. Zuo, Y. Xue, W. Lai, W. Huang, Electron-rich π-extended Diindolotriazatruxene-based chemosensors with highly selective and rapid responses to nitroaromatic explosives, ChemPlusChem 84 (10) (2019) 1623–1629, https://doi.org/10.1002/cplu.201900347.
[394] Y. Li, Y. Zhang, Y. Zhanag, Z. Wang, H. Yang, H. Yao, T. Wei, Q. Lin, Tripodal naphthalimide assembled novel AIE supramolecular fluorescent sensor for rapid and selective detection of picric acid, Dyes Pigments 181 (2020), 108563, https://doi.org/10.1016/j.dyepig.2020.108563.
[395] X. Liang, L. Wen, Y. Mi, J. Guo, B. Yu, M. Tao, Z. Cao, Z. Zhao, Highly cross-linked polymeric nanoparticles with aggregation-induced emission for sensitive and recyclable explosive detection, Dyes Pigments 191 (2021), 109369, https://doi.org/10.1016/j.dyepig.2021.109369.
[396] K. Liu, Z. Wang, C. Shang, X. Li, H. Peng, R. Miao, L. Ding, J. Liu, T. Liu, Y. Fang, Unambiguous discrimination and detection of controlled chemical vapors by a film-based fluorescent sensor array, Adv. Mater. Technol. 4 (7) (2019), 1800644, https://doi.org/10.1002/admt.201800644.
[397] W. Liu, H. Ai, Z. Meng, L. Isaacs, Z. Xu, M. Xue, Q. Yang, Interactions between acyclic CB[n]-type receptors and nitrated explosive materials, Chem. Commun. 55 (71) (2019) 10635–10638, https://doi.org/10.1039/C9CC05117A.
[398] A. Loch, D. Stoltzfus, P. Burn, P. Shaw, High-sensitivity Poly(dendrimer)-based sensors for the detection of explosives and taggant vapors, Macromolcules 53 (5) (2020) 1652–1664, https://doi.org/10.1021/acs.macromol.0c00060.
[399] S. Lu, W. Fan, H. Liu, L. Gong, Z. Xiang, H. Wang, C. Yang, Four imidazole derivative AIEE luminophores: sensitive detection of NAC explosives, New J. Chem. 45 (15) (2021) 6889–6894, https://doi.org/10.1039/D0NJ06007K.
[400] Y. Ma, X. Yang, M. Niu, W. Hao, D. Shi, D. Schipper, High-nuclearity CD(II)-Nd (III) nanowheel with NIR emission sensing of metal cations and nitro-based explosives, Cryst. Growth Des. 21 (5) (2021) 2821–2827, https://doi.org/10.1021/acs.cgd.0c01742.
[401] F. Mauricio, J. Silva, M. Talhavini, S. Alves Jr., I. Weber, Luminescent sensors for nitroaromatic compound detection: investigation of mechanism and evaluation of suitability of using in screening test in forensics, Microchem. J. 150 (2019), 104037, https://doi.org/10.1016/j.microc.2019.104037.
[402] F. Mitri, A. De Iacovo, De Santis, C. Giansante, G. Sotgiu, L. Colace, Chemiresistive device for the detection of nitroaromatic explosives based on colloidal PbS quantum dots, ACS Appl. Electron. Mater. 3 (7) (2021) 3234–3239, https://doi.org/10.1021/acsaelm.1c00401.
[403] D. Modafferi, V. Zazubovich, L. Kalman, Bound detergent molecules in bacterial reaction centers facilitate detection of tetryl explosive, Phtosynthesis Res. 145 (2) (2020) 145–157, https://doi.org/10.1007/s11120-020-00770-7.
[404] F. Nabeel, T. Rasheed, M.F. Mahmood, S.U. Khan, Hyperbranched copolymer based photoluminescent vesicular probe conjugated with tetraphenylethene: synthesis, aggregation-induced emission and explosive detection, J. Mol. Liq. 308 (2020), 113034, https://doi.org/10.1016/j.molliq.2020.113034.
[405] O. Nanda, N. Gupta, R. Grover, A.M. Biradar, K. Saxena, Detection of 2, 4, 6-Trinitrotoluene traces in water using fluorescent conjugated polymer based on Photoluminescence and Raman Spectroscopy, in: K. Singh, A.K. Gupta, S. Khare, N. Dixit, Kamal Pant (Eds.), ICOL-2019: Proceedings of the International Conference on Optics and Eletro-Optics, Springer, Dehradun, India, 2021, pp. 829–832. https://link.springer.com/chapter/10.1007/978-981-15-9259-1_191.
[406] M. Nawaz, L. Meng, H. Zhou, J. Ren, S. Shahzad, A. Hayat, C. Yu, Tetraphenylethene probe based fluorescent silica nanoparticles for the selective detection of nitroaromatic explosives, Anal. Methods 13 (6) (2021) 825–831, https://doi.org/10.1039/D0AY01945C.
[407] M. Niu, X. Yang, Y. Ma, X. Leng, W. Hao, Y. Chen, Z. Chen, D. Schipper, Construction of a nanoscale Yb(III) Schiff base complex with NIR luminescence response to anions and nitro explosives, J. Lumin. 231 (2021), 117807, https://doi.org/10.1016/j.jlumin.2020.117807.
[408] M. Niu, X. Yang, Y. Ma, D. Shi, D. Schipper, Triangular Cd(II)-Sm(III) base complex with dual visible and near-infrared luminescent responses to nitro explosives, J. Phys. Chem. A 125 (1) (2020) 251–257, https://doi.org/10.1021/acs.jpca.0c09758.
[409] E. Ozcan, S.O. Tumay, G. Kesan, S. Yesilot, B. Cosut, The novel anthracene decorated dendrimeric cyclophosphazenes for highly selective sensing of 2,4,6-trinitrotoluene (TNT), Spectrochim. Acta Part A: Mol. Biomol. Spectrosc. 220 (2019), 117115, https://doi.org/10.1016/j.saa.2019.05.020.
[410] M. Panchal, A. Kongor, M. Athar, K. Modi, C. Patel, S. Dey, M. Vora, K. Bhadresha, R. Rawal, P. Jha, V. Jain, Structural motifs of oxacalix[4]arene for molecular recognition of nitroaromatic explosives: experimental and computational investigations of host-guest complexes, J. Mol. Liq. 306 (2020), 112809, https://doi.org/10.1016/j.molliq.2020.112809.
[411] B. Prusti, M. Chakravarty, An electron-rich small AIEgen as a solid platform for the selective and ultrasensitive on-site visual detection of TNT in the solid, solution and vapor states, Analyst 145 (5) (2020) 1687–1694, https://doi.org/10.1039/C9AN02334H.
[412] T. Qiao, S. Kim, W. Lee, H. Lee, An enhanced fluorescence detection of a nitroaromatic compound using bacteria embedded in porous poly lactic-co-glycolic acid microbeads, Analyst 146 (14) (2021) 4615–4621, https://doi.org/10.1039/D1AN00510C.
[413] Z. Qiu, S. Fan, C. Xing, M. Zong, M. Song, Z. Nie, L. Xu, X. Zhang, L. Wang, S. Zhang, B. Li, Facile fabrication of an AIE-active metal-organic framework for sensitive detection of explosives in liquid and solid phases, ACS Appl. Mater. Interfaces 12 (49) (2020) 55299–55307, https://doi.org/10.1021/acsami.0c17165.
[414] A. Saravanan, M. Maruthapandi, P. Das, S. Gaguly, S. Margel, J. Luong, A. Gedanken, Applications of n-doped carbon dots as antimicrobial agents, antibiotic carriers, and selective fluorescent probes for nitro explosives, ACS Appl. Bio Mater. 3 (11) (2020) 8023–8031, https://doi.org/10.1021/acsabm.0c01104.
[415] S. Saravanan, R. Ahmad, S. Kasthuri, K. Pal, S. Ravietja, P. Nagaraaj, R. Hoogenboom, V. Nutalapati, S. Maji, Pyrazoloanthrone-functionalized fluorescent copolymer for the detection and rapid analysis of nitroaromatic, Mater. Chem. Front. 5 (1) (2021) 238–243, https://doi.org/10.1039/D0QM00563K.
[416] E. Scorsone, R. Manai, K. Cali, M. Ricatti, S. Farno, K. Persaud, C. Mucignat, Biosensor array based on ligand binding proteins for narcotics and explosives detection, Sensor. Actuator. B Chem. 334 (2021), 129587, https://doi.org/10.1016/j.snb.2021.129587.
[417] D. Sengottuvelu, V. Kachwal, P. Raichure, T. Raghav, I. Laskar, Aggregation-induced enhanced emission (AIEE)-active conjugated mesoporous oligomers (CMOs) with improved quantum yield and low-cost detection of a trace amount of nitroaromatic explosives, ACS Appl. Mater. Interfaces 12 (88) (2020) 31875–81886, https://doi.org/10.1021/acsami.0c05273.
[418] G. Shan, W. Li, Z. Zhijia, L. Rui, W. Qiang, W. Guojun, W. Hao, O. Xiao, Ultrasensitive and portable fluorescence polyurethane indicator paper for real-time, visual and selective detection of 2,4,6-trinitrophenol, Chem. Eng. J. Adv. 5 (2021), 100069, https://doi.org/10.1016/j.ceja.2020.100069.
[419] M. Sharafizadeh, J. Mokhtari, H. Saeidian, Z. Mirjafary, Urea metal-organic frameworks as a highly selective fluorescent sensor for the explosive nitroaromatics and carbonyl compounds, J. Porous Mater. 27 (2020) 603–609, https://doi.org/10.1007/s10934-019-00842-7.
[420] B. Shemer, E. Shpigel, C. Hazan, Y. Kabessa, A. Agranat, S. Belkin, Detection of buried explosives with immobilized bacterial bioreporters, Microb. Biotechnol. 14 (1) (2021) 251–261, https://doi.org/10.1111/1751-7915.13683.
[421] B. Shin, H. Sohn, Heavy atom effect of metallole nanoaggregates and their explosive sensing applications, J. Nanosci. Nanotechnol. 20 (9) (2020) 5599–5603, https://doi.org/10.1166/jnn.2020.17638.
[422] E. Shpigel, B. Shemer, T. Elad, A. Glozman, S. Belkin, Bacterial bioreporters for the detection of trace explosives: performance enhancement by DNA shuffling and random mutagenesis, Appl. Microbiol. Biotechnol. 105 (10) (2021) 4329–4337, https://doi.org/10.1007/s00253-021-11290-2.
[423] R. Siegel, S. Glazier, TNT sensor: Stern-Volmer analysis of luminescence quenching of ruthenium bipyridine, J. Chem. Educ. 98 (8) (2021) 2643–2648, https://doi.org/10.1021/acs.jchemed.0c01221.
[424] R. Singhaal, L. Tashi, Z. ul Nisa, N.A. Ashashi, C. Sen, S. Devi, H.N. Sheikh, PEI functionalized $NaCeF_4$:Tb^{3+}/Eu^{3+} for photoluminescence sensing of heavy metal ions and explosive aromatic nitro compounds, RSC Adv. 11 (32) (2021) 19333–19350, https://doi.org/10.1039/D1RA02910J.
[425] S.M. Tawfik, A.A. Elaal, Y. Lee, Selective dual detection of Hg2+ and TATP based on amphiphilic conjugated polythiophene-quantum dot hybrid materials, Analyst 146 (9) (2021) 2894–2901, https://doi.org/10.1039/D1AN00166C.
[426] A.C. Tella, V.T. Olayemi, F.A. Adekola, A.C. Oladipo, V.O. Adimula, J.O. Ogar, E. C. Hosten, A.S. Ogunlaja, S.P. Argent, R. Mokaya, Synthesis, characterization and density functional theory of copper(II) complex and cobalt(II) coordination polymer for detection of nitroaromatic explosives, Inorg. Chim. Acta. 515 (2021), 120048, https://doi.org/10.1016/j.ica.2020.120048.
[427] R. Tian, P. Ji, L. Wang, H. Zhang, J. Sun, TNT sensor based on accumulation layer and effective distance of FRET mechanism with ultra-high sensitivity, Microchem. J. 160 (Part B) (2021), 105706, https://doi.org/10.1016/j.microc.2020.105706.
[428] A.P. Vargas, J. Almeida, F. Gamez, J. Roales, C. Queiros, M. Rangel, T. Lopes-Costa, A.M.G. Silva, J.M. Pedrosa, Synthesis of a highly emissive carboxylated pyrrolidine-fused chlorin for optic sensing of TATP vapours, Dyes Pigments 195 (2021), 109721, https://doi.org/10.1016/j.dyepig.2021.109721.
[429] E. Verbitskiy, G. Rusinov, O. Chupakhin, V. Charushin, Design of fluorescent sensors based on azaheterocyclic push-pull systems towards nitroaromatic explosives and related compounds: a review, Dyes Pigments 180 (2020), 108414, https://doi.org/10.1016/j.dyepig.2020.108414.
[430] N.S. Vijila, M. Athira, S.M. Anju, A.O. Aswathy, J. Jayakrishna, M. Sreekumar, J. S.A. Devi, B. Anjitha, S. George, Folic acid as a bimodal optical probe for the detection of TNT, J. Fluoresc. 31 (4) (2021) 933–940, https://doi.org/10.1007/s10895-021-02713-4.
[431] D. Wang, S. Lou, Y. Ying, Z. Guo, L. Wang, Assembly of two isostructural metal-organic frameworks based on Hetero-N,O donor ligand for detecting nitro explosives, Chem. Res. Chin. Univ. 35 (5) (2019) 762–766, https://doi.org/10.1007/s10895-021-02713-4.
[432] K. Wang, E. Ma, Z. Hu, H. Wang, Rapid synthesis of self-propelled tubular micromotors for "ON-OF"" fluorescent detection of explosives, Chem. Commun. 57 (81) (2021) 10528–10531, https://doi.org/10.1039/D1CC03899K.

[433] K. Wang, W. Wang, S. Pan, Y. Fu, B. Dong, H. Wang, Fluorescent self-propelled covalent organic framework as a microsensor for nitro explosive detection, Appl. Mater. Today 19 (2020), 100550, https://doi.org/10.1016/j.apmt.2019.100550.
[434] Y. Wang, H. Niu, Q. Lu, W. Zhang, X. Qiao, H. Niu, Y. Zhang, W. Wang, From aerospace to screen: multifunctional poly(benzoxazine)s based on different triarylamines for electrochromic, explosive detection and resistance memory devices, Spectrochim. Part A: Mol. Biomol. Spectrosc. 225 (2020), 117254, https://doi.org/10.1016/j.saa.2019.117524.
[435] Y. Xiao, Q. Guan, Y. Wang, Z. You, K. Zhang, Y. Xing, F. Bai, L. Sun, A novel supramolecular silver coordination complex based on a triazole carboxylate ligand: synthesis and fluorescence sensing of colchicine and a series of nitro explosives, ChemistrySelect 4 (45) (2019) 13327–13332, https://doi.org/10.1002/slct.201904284.
[436] G. Xie, B. Liu, Fingerprinting of nitroaromatic explosives realized by aphen-functionalized titanium dioxide, Sensors 19 (10) (2019) 2407, https://doi.org/10.3390/s19102407.
[437] Y. Xu, X. Song, C. Hao, LCOFs: role of the excited state hydrogen bonding in the detection for nitro-explosives, J. Lumin. 215 (2019), 116733, https://doi.org/10.1016/j.jlumin.2019.116733.
[438] C. Yan, W. Qin, Z. Li, Y. Zhou, Y. Cui, G. Liang, Quantitative and rapid detection of explosives using an efficient luminogen with aggregation-induced emission characteristics, Sensor. Actuator. B Chem. 302 (2020), 127201, https://doi.org/10.1016/j.snb.2019.127201.
[439] J. Yang, R. Shen, P. Yan, Y. Liu, X. Li, P. Zhang, W. Chen, Fluorescence sensor for volatile trace explosives based on a hollow core photonic crystal fiber, Sensor. Actuator. B Chem. 306 (2020), 127585, https://doi.org/10.1016/j.snb.2019.127585.
[440] L. Yang, Y. Liu, C. Liu, F. Ye, A built-in self-calibrating luminescence sensor based on RhB@Zr-MOF for detection of cations, nitro explosives and pesticides, RSC Adv. 10 (33) (2020) 19149–19156, https://doi.org/10.1039/D0RA02843F.
[441] X. Yang, D. Hu, Q. Chen, L. Li, P. Li, S. Ren, M. Bertuzzo, K. Chen, D. Han, X. Zhou, X. Xia, A pyrene-cored conjugated microporous polycarbazole for sensitive and selective detection of hazardous explosives, Inorg. Chem. Commun. 107 (2019), 107453, https://doi.org/10.1016/j.inoche.2019.107453.
[442] B. Yardimci, O. Koc, A. Uzer, J. Hizal, R. Apak, Ethylenediamine-bound magnetite nanoparticles as dual function colorimetric sensor having charge transfer and nanozyme activity for TNT and tetryl detection, Microchim. Acta 188 (7) (2021) 228, https://doi.org/10.1007/s00604-021-04877-z.
[443] C. Zhang, X. Pan, S. Cheng, A. Xie, W. Dong, Pyrene Derived aggregation-induced emission sensor for highly selective detection of explosive CL-20, J. Lumin. 233 (2021), 117871, https://doi.org/10.1016/j.jlumin.2020.117871.
[444] L. Zhang, J. Hu, J. Li, J. Zhang, A thermal and pH stable fluorescent coordination polymer for sensing nitro explosives or metal ions with high selectivity and sensitivity in aqueous solution, J. Lumin. 234 (2021), 117958, https://doi.org/10.1016/j.jlumin.2021.117958.
[445] W. Zhang, B. Gao, X. Guo, W. Song, Polyfluorene based fluorescent sensor for sensitive and selective detection of picric acid, Mater. Lett. 306 (2022), 130860, https://doi.org/10.1016/j.matlet.2021.130860.
[446] X. Zhang, Y. Yan, F. Chen, G. Bai, H. Xu, S. Xu, A fluorescent titanium-based metal-organic framework sensor for nitro-aromatics detection, Zeitschrift fur anorganische und allgemeine Chemie 647 (7) (2021) 759–763, https://doi.org/10.1002/zaac.202000459.
[447] Y. Zhang, Y. Feng, Z. Zhang, M. Zhang, Highly efficient fluorescent film probe of hydrogen peroxide vapor, Microchem. J. (2020), https://doi.org/10.1016/j.microc.2020.105290.
[448] P. Zheng, A. Abdurahman, Z. Zhang, Y. Feng, Y. Zhang, X. Zi, F. Li, M. Zhang, A simple organic multi-analyte fluorescent prober: one molecule realizes the detection to DNT, TATP and Sarin substitute gas, J. Hazard Mater. (2020), https://doi.org/10.1016/j.jhazmat.2020.124500.
[449] Y. Zheng, S. Wang, R. Li, L. Pan, L. Li, Z. Qi, C. Li, Highly selective detection of nitroaromatic explosive 2,4,6-trinitrophenol (TNP) using N-doped carbon dots, Res. Chem. Intermed. 47 (6) (2021) 2421–2431, https://doi.org/10.1007/s11164-021-04410-0.

Mass Spectrometry

[450] S. An, S. Liu, J. Cao, S. Lu, Nitrogen-activated oxidation in nitrogen direct analysis in real time mass spectrometry (DART-MS0 and rapid detection of explosives using thermal desorption DART-MS, J. Am. Soc. Mass Spectrom. 30 (10) (2019) 2092–2100, https://doi.org/10.1007/s13361-019-02279-3.
[451] A.C.A. Assis, J. Caetano, M.H. Florencio, C. Cordeiro, Triacetone triperoxide characterization by FT-ICR mass spectrometry: uncovering multiple forensic evidence, Forensic Sci. Int. 301 (2019) 37–45, https://doi.org/10.1016/j.forsciint.2019.04.020.
[452] L. Bi, A. Habib, La Chen, T. Xu, L. Wen, Ultra-trace level detection of nonvolatile compounds studied ultrasonic cutter blade coupled dielectric barrier discharge ionization-mass spectrometry, Talanta 222 (2021), 121673, https://doi.org/10.1016/j.talanta.2020.121673.
[453] C. Black, Exploring Applicability of Direct Analysis in Real Time with Mass Spectrometry (DART-MS) to Identify Homemade Explosive Residues Post-blast, Master's thesis, Carleton University Research Virtual Environment, 2019, https://doi.org/10.22215/etd/2019-13644.
[454] C. Black, T. D'Souza, J. Smith, N. Hearns, Identification of post-blast explosive residues using direct-analysis-in-real-time and mass spectrometry (DART-MS), Forensic Chem. 16 (2019), 100185, https://doi.org/10.1016/j.forc.2019.100185.
[455] C. Bonnar, R. Popelka-Filcoff, K. Kirkbride, Armed with the facts: a method for the analysis of smokeless powders by ambient mass spectrometry, J. Am. Soc. Mass Spectrom. 31 (9) (2020) 1943–1956, https://doi.org/10.1021/jasms.0c00193.
[456] R. Boyea, *Association of Fire Cartridge Residues to Unburned Smokeless Powders Using GC-MS and Multivariate Statistical Procedures* (Publication No. 27744171), Master's thesis, Michigan State University, 2020.
[457] J.M.C. Cajigas, L. Perez-Almodovar, L.E. DeGreeff, Headspace analysis of potassium chlorate using on-fiber SPME derivatization coupled with GC/MS, Talanta 205 (2019), 120127, https://doi.org/10.1016/j.talanta.2019.120127.
[458] D. Carmany, C.B. Nguyen, T. Glaros, N. Manicke, E. Dhummkupt, Pressure-sensitive adhesive combined with paper spray mass spectrometry for trace surface detection of illicit drugs and explosives, in: Proceedings SPIE Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XXII, vol. 11749, 2021, https://doi.org/10.1117/12.2585936, 1174909.
[459] C. Costa, E.M. van Es, P. Sears, J. Bunch, V. Palitsin, H. Cooper, M.J. Bailey, Exploring a route a selective and sensitive portable system for explosive detection-swab spray coupled to of high-field assisted waveform ion mobility spectrometry (FAIMS), Forensic Sci. Int.: Synergy 1 (2019) 214–220, https://doi.org/10.1016/j.fsisyn.2019.07.009.
[460] C. Costa, E.M. van Es, P. Sears, J. Bunch, V. Palitsin, K. Mosegaard, M.J. Baliey, Exploring rapid, sensitive and reliable detection of trace explosives using paper spray mass spectrometry (PS-MS), Propellants, Explos. Pyrotech. 44 (8) (2019) 1021–1027, https://doi.org/10.1002/prep.201800320.
[461] J. D'Uva, D. DeTate, C. May, S. Lewis, Investigations into the source attribution of part sparklers using trace elemental analysis and chemometrics, Anal. Methods 12 (41) (2020) 4939–4948, https://doi.org/10.1039/D0AY01319F.
[462] K. Evans-Nguyen, A. Stelmark, P. Clowser, J. Holtz, C. Mulligan, Fieldable mass spectrometry for forensic science, homeland security, and defense applications, Mass Spectrom. Rev. (2021) 628–646, https://doi.org/10.1002/mas.21646.
[463] T. Forbes, J. Lawrence, C. Hao, G. Gillen, Open port sampling interface mass spectrometry of wipe-based explosives, oxidizers, and narcotics for trace contraband detection, Anal. Methods 13 (17) (2021) 3453–3460, https://doi.org/10.1039/D1AY01038G.
[464] K.L. Fowble, R.A. Musah, Simultaneous imaging of latent fingermarks and detection of analytes of forensic relevance by laser ablation direct analysis in real time imaging-mass spectrometry (LADI-MS), Forensic Chem. 15 (2019), 100173, https://doi.org/10.1016/j.forc.2019.100173.
[465] J. Frazier, V. Benefield, M. Zhang, Practical investigation of direct analysis in real time mass spectrometry for fast screening of explosives, Forensic Chem. 18 (2020), 100233, https://doi.org/10.1016/j.forc.2020.100233.
[466] G. Gaiffe, R.B. Cole, A. Sonnette, N. Floch, M.C. Bridoux, Identification of postblast residues by DART-high resolution mass spectrometry combined with multivariate statistical analysis of the Kendrick mass defect, Anal. Chem. 91 (13) (2019) 8093–8100, https://doi.org/10.1021/acs.analchem.9b00137.
[467] M. Galmiche, A. Colin, M. Clavos, C. Pallez, C. Rosin, X. Dauchy, Determination of nitroaromatic explosive residues in water by stir bar sorptive extraction-gas chromatography-tandem mass spectrometry, Anal. Bioanal. Chem. 413 (1) (2021) 159–169, https://doi.org/10.1007/s00216-020-02985-y.
[468] M.D. Gonsalves, A. Yevdokimov, A. Brown-Nash, J.L. Smith, J.C. Oxley, Paper spray ionization-high-resolution mass spectrometry (PSI-HRMS) of peroxide explosives in biological matrices, Anal. Bioanal. Chem. 413 (11) (2021) 3069–3079, https://doi.org/10.1007/s00216-021-03244-4.
[469] R. Gonzalez-Mendez, C.A. Mayhew, Applications of direct injection soft chemical ionization-mass spectrometry for the detection of pre-blast smokeless powder organic additives, J. Am. Soc. Mass Spectrom. 30 (4) (2019) 615–624, https://doi.org/10.1007/s13361-018-02130-1.
[470] A. Habib, L. Bi, L. Wen, Simultaneous detection and quantification of explosives by a modified hollow cathode discharge ion source, Talanta 233 (2021), 122596, https://doi.org/10.1016/j.talanta.2021.122596.
[471] A. Habib, B. Lei, H. Hong, L. Wen, Challenges and strategies of chemical analysis of drugs of abuse and explosives by mass spectrometry, Front. Chem. 8 (2021), 598487, https://doi.org/10.3389/fchem.2020.598487.
[472] H. Hong, A. Habib, L. Bi, L. Wen, Gas phase ion-molecule reactions of nitroaromatic explosive compounds studied by hollow cathode discharge ionization-mass spectrometry, Talanta 236 (2022), 122834, https://doi.org/10.1016/j.talanta.2021.122834.
[473] M. Huang, J. Zhu, J. Wu, Simulation of explosive detection based on APT-TOF for verifying nuclear warhead dismantlement, Appl. Radiat. Isot. 171 (2021), 109648, https://doi.org/10.1016/j.apradiso.2021.109648.
[474] N. Jurado-Campos, U. Chiluwal, G.A. Eiceman, Improved selectivity for the determination of trinitrotoluene through reactive stage tandem ion mobility spectrometry and a quantitative measure of source-based suppression of ionization, Talanta 226 (2021), 121944, https://doi.org/10.1016/j.talanta.2020.121944.
[475] S. Kober, H. Hollert, M. Frohme, Quantification of nitroaromatic explosives in contaminated soil using MALDI-TOF mass spectrometry, Anal. Bioanal. Chem. 411 (23) (2019) 5993–6003, https://doi.org/10.1007/s00216-019-01976-y.
[476] J. Lee, M.S. Kim, H.S. Kim, Y. Choe, S.G. Cho, E.M. Goh, J. Kim, Characterization of RDX and HMX explosive adduct ions using ESI FT-ICR MS, J. Mass Spectrom. 56 (4) (2020), e4632, https://doi.org/10.1002/jms.4632.
[477] C. Longo, R. Musah, MALDI-mass spectrometry imaging for touch chemistry biometric analysis: establishment of exposure to nitroaromatic explosives through chemical imaging of latent fingermarks, Forensic Chem. 20 (2020), 100269, https://doi.org/10.1016/j.forc.2020.100269.
[478] R.D. McCulloch, M. Amo-Gonzalez, Rapid detection of explosive vapors by thermal desorption-atmospheric pressure photoionization-differential mobility

analysis-tandem mass spectrometry, RCM (Rapid Commun. Mass Spectrom.) 33 (18) (2019) 1455–1463, https://doi.org/10.1002/rcm.8492.
[479] K. Moquin, A. Higgins, P. Leary, B. Kammrath, Optimized explosives analysis using portable gas chromatography-mass spectrometry for battlefield forensics, LC GC: Mass Spectrom. 18 (2) (2020) 277–290.
[480] W. Niessen, Tandem mass spectrometry of organic nitro and halogen compounds: competition between losses of molecules and of radicals, Int. J. Mass Spectrom. 460 (2021), 116496, https://doi.org/10.1016/j.ijms.2020.116496.
[481] J. Pavlov, D. Douce, S. Bajic, A. Attygalle, 1,4-Benzoquinone as a highly efficient dopant for enhanced ionization and detection of nitramine explosives on a single-quadrupole mass spectrometer fitted with a helium-plasma ionization (HePI) source, J. Am. Soc. Mass Spectrom. 30 (12) (2019), https://doi.org/10.1007/s13361-019-02339-8, 2704-1710.
[482] L. Pintabona, A. Astefanei, G. Corthals, A. van Asten, Utilizing surface acoustic wave nebulization (SAWN) for the rapid and sensitive ambient ionization mass spectrometric analysis of organic explosives, J. Am. Soc. Mass Spectrom. 30 (12) (2019) 2655–2669, https://doi.org/10.1007/s13361-019-02335-y.
[483] P. Supajariyawat, J. Gonzalez-Rodriguez, Application of LC–QTOF/MS for the validation and determination of organic explosive residues on Ionscan® swabs, Sci. Justice 61 (6) (2021) 697–703, https://doi.org/10.1016/j.scijus.2021.09.001.
[484] R.V. Taudte, C. Roux, D.P. Bishop, C. Fouracre, A. Beavis, High-throughput screening for target compounds in smokeless powders using online-SPE tandem mass spectrometry, Aust. J. Forensic Sci. 53 (1) (2019) 16–26, https://doi.org/10.1080/00450618.2019.1629019.
[485] W. Wang, F. Xu, L. Jin, C. Ding, Rapid identification of illegal drugs and explosives using resonance excitation in miniaturized photoionization ion trap mass spectrometry, Int. J. Mass Spectrom. 467 (2021), 116625, https://doi.org/10.1016/j.ijms.2021.116625.
[486] J. Xue, Y. Bai, H. Liu, Recent advances in ambient mass spectrometry imaging, TrAC, Trends Anal. Chem. 120 (2019), 115659, https://doi.org/10.1016/j.trac.2019.115659.
[487] Q. Zhang, X. Zou, Q. Liang, H. Wang, C. Huang, C. Shen, Y. Chu, Ammonia-assisted proton transfer reaction mass spectrometry for detecting triacetone triperoxide (TATP) explosive, J. Am. Soc. Mass Spectrom. 30 (3) (2019) 501–508, https://doi.org/10.1007/s13361-018-2108-6.

Isotope Ratio Mass Spectroscopy (IRMS)

[488] K. Bezemer, L. McLennan, R. Hessels, J. Schoorl, J. van den Elshout, A. van der Heijden, A. Hulsbergen, M. Koeberg, T. Busby, A. Yevdokimov, E. de Rijke, P. Schoenmakers, J. Smith, J. Oxley, A. van Asten, Chemical attribution of homemade explosive ETN- part II: isotope ratio mass spectrometry analysis of ETN and its precursors, Forensic Sci. Int. 313 (2020), 110334, https://doi.org/10.1016/j.forsciint.2020.110344.
[489] C. Hu, H. Mei, H. Guo, Z. Yu, J. Zhu, Purification of ammonium nitrate via recrystallization for isotopic profiling using isotope ratio mass spectrometry, Forensic Sci. Int. 328 (2021), 111009, https://doi.org/10.1016/j.forsciint.2021.111009.
[490] N.Y. Kim, B. Song, D. Kim, M. Jung, Preliminary stable isotope analyses for propellant discrimination in shotshells, Rapid Commun. Mass Spectrom. 35 (9) (2021), e9072, https://doi.org/10.1002/rcm.9072.

FTIR

[491] A. Banas, K. Banas, S. Lim, J. Loke, M. Breese, Broad range FTIR spectroscopy and multivariate statistics for high energetic materials discrimination, Anal. Chem. 92 (7) (2020) 4788–4797, https://doi.org/10.1021/acs.analchem.9b03676.
[492] A. Banas, K. Banas, M. Fung Lo, M. Kansiz, S. Kalaiselvi, S. Lim, J. Loke, M. Breese, Detection of high-explosive materials within fingerprints by means of optical-photothermal infrared spectromicroscopy, Anal. Chem. (2020), https://doi.org/10.1021/acs.analchem.0c00938.
[493] A.M. Colon-Mercado, K.M. Vazquez-Velez, E. Caballero-Agosto, V. Vallanueva-Lopez, R. Infante-Casstillo, S.P. Hernandez-Rivera, Detection of high explosives samples deposited on reflective and matte substrates using mid-infrared laser spectroscopy at the grazing angle of incidence assisted by multivariate analysis, Opt. Eng. 59 (9) (2020), 092011, https://doi.org/10.1117/1.OE.59.9.092011.
[494] N. He, Y. Ni, J. Teng, H. Li, L. Yao, P. Zhao, Identification of inorganic oxidizing salts in homemade explosives using Fourier transform infrared spectroscopy, Spectrochim. Acta Mol. Biomol. Spectrosc. 221 (2019), 117164, https://doi.org/10.1016/j.saa.2019.117164.
[495] H. Itozaki, Near Infrared Inspection Technology of Bottled Explosive Liquid in Airports, NIR news, 2019, https://doi.org/10.1177/0960336019889283.
[496] M. Mayfield, FLIR markets upgraded explosives detector, Natl. Defense 105 (794) (2020) 11 (EBSCO: Military & Government).
[497] P. Su, W. Liang, G. Zhang, X. Wen, H. Chang, Z. Meng, M. Xue, L. Qiu, Quantitative detection of components in polymer-bonded explosives through near-infrared spectroscopy with partial least square regression, ACS Omega 6 (36) (2021) 23163–23169, https://doi.org/10.1021/acsomega.1c02745.
[498] T. Tao, X. Sui, S. Li, N. Wang, A study on consumption and characterization of stabilizer content of NEPE propellant via FTIR, Propellants, Explos. Pyrotech. 44 (7) (2019) 889–895, https://doi.org/10.1002/prep.201800340.
[499] J. Wojtas, M. Szala, Thermally enhanced FTIR spectroscopy applied to study of explosives stability, Measurement 184 (2021), 110000, https://doi.org/10.1016/j.measurement.2021.110000.

Raman Spectroscopy

[500] W. Ahmed, O. Demirtas, M. Ozturk, A. Bek, Monolayer assembly of multispiked gold nanoparticles for surface-enhanced Raman spectroscopy-based trace detection of dyes and explosives, ACS Appl. Nano Mater. 3 (7) (2020) 6766–6773, https://doi.org/10.1021/acsanm.0c01177.
[501] M. Amin, P. Wen, W.D. Herzog, R.R. Kunz, Optimization of ultraviolet Raman spectroscopy for trace explosive checkpoint screening, Anal. Bioanal. Chem. 412 (2020) 4495–4504, https://doi.org/10.1007/s00216-020-02725-2.
[502] S. Bykov, R. Roppel, M. Mao, S. Asher, 228-nm quadrupled quasi-three-level Nd: GdVO4 laser for ultraviolet resonance Raman spectroscopy of explosives and biological molecules, J. Raman Spectrosc. 51 (12) (2020) 2478–2488, https://doi.org/10.1002/jrs.5999.
[503] Z. Chen, M. Qin, C. Xiao, Preliminary study on double enhanced Raman scattering detection of gas phase trace explosives, IEEE Access 8 (2020) 194925–194932, https://doi.org/10.1109/ACCESS.2020.3032836.
[504] W.K. Chio, W.J. Peveler, K.I. Assaf, S. Moorthy, W.M. Nau, I.P. Parkin, T. Lee, Selective detection of nitroexplosives using molecular recognition within self-assembled plasmonic nanojunctions, J. Phys. Chem. C 123 (25) (2019) 15769–15776, https://doi.org/10.1021/acs.jpcc.9b02363.
[505] F.M. Colon-Gonzalez, L.A. Perez-Almodovar, M. Barreto-Perez, G.L. Vargas-Alers, J.M. Santos-Rolon, S.P. Hernandez-Rivera, Raman scattering detection of high explosives on human hair, Opt. Eng. 59 (10) (2020), 107103, https://doi.org/10.1117/1.OE.59.10.107103.
[506] D. Diaz, D. Hahn, Raman spectroscopy for detection of ammonium nitrate as an explosive precursor used in improvised explosive devices, Spectrochim. Acta Mol. Biomol. Spectrosc. 233 (2020), 118204, https://doi.org/10.1016/j.saa.2020.118204.
[507] Y. Dwivedi, Concept and applications of standoff Raman spectroscopy techniques, in: V. Gupta, Y. Ozaki (Eds.), Molecular and Laser Spectroscopy: Advances and Applications, vol. 2, Elsevier, 2020, pp. 483–520, https://doi.org/10.1016/B978-0-12-818870-5.00014-9.
[508] E.C.A. Gallo, L.M.L. Cantu, F. Duschek, RDX remote Raman detection of NATO SET-237 samples, Eur. Phys. J. Plus 136 (4) (2021) 401, https://doi.org/10.1140/epjp/s13360-021-01336-9.
[509] R. Gao, H. Qian, C. Weng, X. Wang, C. Xie, K. Guo, S. Zhang, S. Xuan, Z. Guo, L. Luo, A SERS stamp: multiscale coupling effect of silver nanoparticles and highly ordered nano-micro hierarchical substrates for ultrasensitive explosive detection, Sensor. Actuator. B Chem. 321 (2020), 128543, https://doi.org/10.1016/j.snb.2020.128543.
[510] R. Gao, X. Song, C. Zhan, C. Weng, S. Cheng, K. Guo, N. Ma, H. Chang, Z. Cuo, L. Luo, L. Yu, Light trapping induced flexible wrinkled nanocone SERS substrate for highly sensitive explosive detection, Sensor. Actuator. B Chem. 314 (2020), 128081, https://doi.org/10.1016/j.snb.2020.128081.
[511] P. Garg, Bharti, R.K. Soni, R. Raman, Graphene oxide-silver nanocomposite SERS substrate for sensitive detection of nitro explosives, J. Mater. Sci. Mater. Electron. 31 (2) (2020) 1094–1104, https://doi.org/10.1007/s10854-019-02621-1.
[512] S. Gulia, K. Gultai, V. Gambhir, R. Sharma, Detection of explosive materials and their precursors through translucent commercial bottles using spatially offset Raman spectroscopy using excitation wavelength in visible range, Opt. Eng. 58 (12) (2019), 127102, https://doi.org/10.1117/1.OE.58.12.127102.
[513] X. He, Y. Liu, S. Cui, W. Liu, Z. Li, Controllable fabrication of Ag-NP-decorated porous ZnO nanosheet arrays with superhydrophobic properties for high performance SERS detection of explosives, CrystEngComm 22 (4) (2020) 776–785, https://doi.org/10.1039/C9CE01430F.
[514] V. Heleg-Shabtai, A. Zaltsman, M. Sharon, H. Harabi, I. Nir, D. Marder, G. Cohen, I. Ron, A. Pevzner, Explosive vapour/particles detection using SERS substrates and a hand-held Raman detector, RSC Adv. 11 (42) (2021) 26029–26036, https://doi.org/10.1039/D1RA04637C.
[515] J. Hubner, T. Deckert-Gaudig, J. Glorian, V. Deckert, D. Spitzer, Surface characterization of nanoscale co-crystals enabled through tip enhanced Raman spectroscopy, Nanoscale 2020 (12) (2020) 10306–10319, https://doi.org/10.1039/D0NR00397B.
[516] V. Kahhkaie, M. Yousefi, S. Darbani, A. Mobashery, Enhanced Raman intensity of pollutants and explosives by using 2-mercaptoethanol controlled pyramid Ag–iron nanostructure embedded graphene oxide platform, Photon. Nanostruct. Fund. Appl. 41 (2020), 100801, https://doi.org/10.1016/j.photonics.2020.100801.
[517] G.A. Khan, O. Demirtas, A.K. Demir, O. Aytekin, A. Bek, A.S. Bhatti, W. Ahmed, Fabrication of flexible, cost-effective, and scalable silver substrates for efficient surface enhanced Raman spectroscopy based trace detection, Colloids Surf. A Physicochem. Eng. Asp. 619 (2021), 126542, https://doi.org/10.1016/j.colsurfa.2021.126542.
[518] M. Kotrly, I. Turkova, New possibilities of complex analysis of explosives and post blast residues in forensic practice, Microsc. Microanal. 26 (S2) (2020) 816–817, https://doi.org/10.1017/S1431927620015949.
[519] D. Lin, R. Dong, P. Li, S. Li, M. Ge, Y. Zhang, L. Yang, W. Xe, A novel SERS selective detection sensor for trace trinitrotoluene based on meisenheimer complex of monoethanolamine molecule, Talanta 218 (2020), 121157, https://doi.org/10.1016/j.talanta.2020.121157.
[520] K. Milligan, N.C. Shand, D. Graham, K. Faulds, Detection of multiple nitroaromatic explosives via formation of a Janowsky complex and SERS, Anal. Chem. 92 (4) (2020) 3253–3261, https://doi.org/10.1021/acs.analchem.9b05062.
[521] S.S.B. Moram, A.K. Shaik, C. Byram, S. Hamad, V.R. Soma, Instantaneous trace detection of nitro-explosives and mixtures with nanotextured silicon decorated

with Ag–Au alloy nanoparticles using the SERS technique, Anal. Chim. Acta 1101 (2019) 157–168, https://doi.org/10.1016/j.aca.2019.12.026.
[522] S. Mosca, C. Conti, N. Stone, P. Matousek, Spatially offset Raman spectroscopy, Nat. Rev. Methods Prim. 1 (2021) 21, https://doi.org/10.1038/s43586-021-00019-0.
[523] T.K. Naqvi, M.S.S. Bharati, A.K. Srivastava, M.M. Kulkarni, A.M. Siddiqui, S.S. V. Rao, P.K. Dwibedi, Hierarchical laser-patterned silver/graphene oxide hybrid SERS sensor for explosive detection, ACS Omega 4 (18) (2019) 17691–17701, https://doi.org/10.1021/acsomega.9b01975.
[524] J. Ottaway, A. Allen, A. Waldron, P. Paul, S. Angel, J. Carter, Spatial Heterodyne Raman Spectrometer (SHRS) for in situ chemical sensing using sapphire and silica optical fiber Raman probes, Appl. Spectrosc. 73 (10) (2019) 1160–1171. https://opg.optica.org/as/abstract.cfm?URI=as-73-10-1160.
[525] K. Ramachandran, Kumari, J. Acharyya, A. Chaudhary, Study of photo induced charge transfer mechanism of PEDOT with nitro groups of RDX, HMX and TNT explosives using anti-Stokes and Stokes Raman lines ratios, Spectrochim. Acta Part A: Mol. Biomol. Spectrom. 251 (2021), 119360, https://doi.org/10.1016/j.saa.2020.119360.
[526] M. Sen Bishwas, M. Malik, P. Poddar, Raman spectroscopy-based sensitive, fast and reversible vapour phase detection of explosives adsorbed on metal–organic frameworks UiO-67, New J. Chem. 45 (16) (2021) 7145–7153, https://doi.org/10.1039/D0NJ04915H.
[527] K. Squire, K. Sivashanmugan, B. Zhang, J. Kraai, G. Rorrer, A. Wang, Multiscale photonic crystal enhanced core-shell plasmonic nanomaterial for rapid vapor-phase detection of explosives, ACS Appl. Nano Mater. 3 (2) (2020), https://doi.org/10.1021/acsanm.9b02399, 165 6-1665.
[528] J. Wu, Y. Feng, L. Zhang, W. Wu, Nanocellulose-based surface-enhanced Raman spectroscopy sensor for highly sensitive detection of TNT, Carbohydr. Polym. 248 (2020), 116766, https://doi.org/10.1016/j.carbpol.2020.116766.
[529] J. Wu, L. Zhang, F. Huang, X. Ji, H. Dai, W. Wu, Surface enhanced Raman scattering substrate for the detection of explosives: construction strategy and dimensional effect, J. Hazard. (2019), https://doi.org/10.1016/j.jhazmat.2019.121714.

DSC, Thermal Analysis, TG

[530] N. Galan-Fryle, L. Pacheco-Londono, A. Figueroa Navedo, W. Ortiz-Rivera, J. Castro-Suarez, S. Hernandez-Rivera, Modulated-laser source induction system for remote detection of infrared emissions of high explosives using laser-induced thermal emission, Opt. Eng. 59 (9) (2020), 092008, https://doi.org/10.1117/1.OE.59.9.092008.
[531] L. Luo, P. Guo, B. Jin, Y. Xiao, Q. Zhang, S. Chu, R. Peng, An isothermal decomposition dynamics research instrument and its application in HMX/TNT/Al composite explosive, J. Therm. Anal. Calorim. 139 (3) (2020) 2265–2272, https://doi.org/10.1007/s10973-019-08554-5.
[532] Parker, G.R., Heatwole, E.M., Holmes, M.D., Asay, B.W., Dickson, P.M., & McAfee, J.M. Deflagration-to-detonation transition in hot HMX and HMX-based polymer-bonded explosives. Combust. Flame, 215, 295-308. https://doi.org/10.1016/j.combustflame.2020.01.040.
[533] L. Patidar, M. Khichar, S.T. Thynell, A comprehensive mechanism for liquid-phase decomposition of 1,3,5,7-tetranitro-1,3,5,7-tetrazoctane (HMX): thermolysis experiments and detailed kinetic modeling, Combust. Flame 212 (2020) 67–78, https://doi.org/10.1016/j.combustflame.2019.10.025.
[534] Z. Wang, D. Cao, Z. Xu, J. Wang, L. Chen, Thermal safety study on the synthesis of HMX by nitrourea method, Process Saf. Environ. Protect. 137 (2020) 282–288, https://doi.org/10.1016/j.psep.2020.02.013.
[535] Zhang, J., Wang, S., Ma, Y., Chen, L., & Chen, W. Investigation of the decomposition kinetics and thermal hazards of 2,4-Dinitrotoluene on simulation approach. Thermochim. Acta. https://doi.org/10.1016/j.tca.2019.178350.

Nanotechnology

[536] K. Ahmad, S. Mobin, Advanced function nanomaterials for explosive sensors, in: O. Kharissova, L. Martinez, B. Kharisov (Eds.), Handbook of Nanomaterials Nanocomposites for Energy and Environmental Applications, 2020, pp. 1–22. https://link.springer.com/referenceworkentry/10.1007%2F978-3-030-11155-7_90-1.
[537] M.S.S. Bharati, B. Chandu, S.V. Rao, Explosives sensing using Ag–Cu alloy nanoparticles synthesized by femtosecond laser ablation and irradiation, RSC Adv. 9 (3) (2019) 1517–1525, https://doi.org/10.1039/c8ra08462a.
[538] P.V. Bhatt, G. Pandey, Tharmavaram, D. Tawtani, C.M. Hussain, Nanotechnology and taggant technology in forensic science, in: D. Rawtani, C.M. Hussain (Eds.), Technology in Forensic Science: Sampling, Analysis, Data and Regulations, 2020, pp. 281–301. https://onlinelibrary.wiley.com/doi/book/10.1002/9783527827688.
[539] R. Bhuvaneswari, V. Nagarajan, R. Chandiramouli, Explosive vapor detection using novel graphdiyne nanoribbons—a first-principles investigation, Struct. Chem. 31 (2) (2019) 709–717, https://doi.org/10.1007/s11224-019-01456-0.
[540] J. Cruz, E. Moraes, P. Pantoja, T. Pereira, G. Mota, M. Antonio, Sensors using the molecular dynamics of explosives in carbon nanotubes under external uniform electric fields, J. Nanosci. Nanotechnol. 19 (9) (2019) 5687–5691, https://doi.org/10.1166/jnn.2019.16510.
[541] C. Day, N. Rowe, T. Hutter, Nanoporous silica preconcentrator for vapor-phase DMNB, a detection taggant for explosives, ACS Omega 5 (29) (2020) 18073–18079, https://doi.org/10.1021/acsomega.0c01615.
[542] L. Esrafili, M. Gharib, A. Morsali, P. Retailleau, Rational morphology control of nano-scale Amide decorated metal-organic frameworks by ultrasonic method: capability to selective and sensitive detection of nitro explosives, Ultrason. Sonochem. 66 (2020), 105110, https://doi.org/10.1016/j.ultsonch.2020.105110.
[543] C. Huang, Z. Yang, Y. Li, B. Zheng, Q. Yan, L. Guan, G. Luo, S. Li, F. Nie, Incorporation of high explosives into nano-aluminum based microspheres to improve reactivity, Chem. Eng. J. 383 (2020), 123110, https://doi.org/10.1016/j.cej.2019.123110.
[544] L. Hubbard, R. Sumner, M. Liezers, T. Cell, C. Reed, N. Uhnak, C. Allen, B. Berry, H. Currah, E. Fuller, E. Kinney, N. Smith, M. Foxe, A. Carman, Rugged nanoparticle tracers for mass tracking in explosive events, MRS Commun. 10 (4) (2020) 594–599, https://doi.org/10.1557/mrc.2020.70.
[545] A. Jabbar, A. Alwan, Efficient detecting of TNT molecules using palladium nanoparticles/cross shape pores like structure porous silicon, Vib. Spectrosc. 103 (2019), 102933, https://doi.org/10.1016/j.vibspec.2019.102933.
[546] B. Keskin, A. Uzer, R. Apak, Colorimetric sensing of ammonium perchlorate using methylene Blue - modified gold nanoparticles, Talanta 206 (2020), 120240, https://doi.org/10.1016/j.talanta.2019.120240.
[547] B. Khezri, S. Mousavi, Z. Sofer, M. Pumera, Recyclable nanographene-based micromachines for the on-the-fly capture of nitroaromatic explosives, Nanoscale 11 (18) (2019) 8825–8834, https://doi.org/10.1039/C9NR02211B.
[548] J. Liu, T. Si, Z. Zhang, Mussel-inspired immobilization of silver nanoparticles toward sponge for rapid swabbing extraction and SERS detection of trace inorganic explosives, Talanta 204 (2019) 189–197, https://doi.org/10.1016/j.talanta.2019.05.110.
[549] V. Monte-Garcia, M. Squillaci, M. Diez-Castellnou, Q. Ong, F. Stellacci, P. Samori, Chemical sensing with Au and Ag nanoparticles, Chem. Soc. Rev. 50 (2) (2021) 1269–1304, https://doi.org/10.1039/D0CS01112F.
[550] N. Musayeva, T. Orujov, R. Hasanov, C. Sultanov, C. Ferrari, C. Frigeri, G. Trevisi, S. Beretta, M. Bosi, R. Verucchi, L. Aversa, F. Sansone, F. Rispoli, L. Baldini, Growth and functionalization of carbon nanotubes for nitroaromatic explosive detection, in: Today: Proceedings, 2019, https://doi.org/10.1016/j.matpr.2019.08.218.
[551] F. Novotny, J. Plutnar, M. Pumera, Plasmonic self-propelled nanometers for explosives detection via solution-based surface enhanced Raman scattering, Adv. Funct. Mater. 29 (33) (2019), 1903041, https://doi.org/10.1002/adfm.201903041.
[552] A. Panigrahi, B.P. Sahu, S. Mandani, D. Nayak, S. Giri, T.K. Sarma, AIE active fluorescent organic nanoaggregates for selective detection of phenolic-nitroaromatic explosives and cell imaging, J. Photochem. Photobiol. Chem. 364 (2019) 194–205, https://doi.org/10.1016/j.jphotochem.2019.01.029.
[553] M. Wang, C. Wang, R. Ma, Explosive detection and identification using X-ray fluorescence and thermal fingerprint of silica encapsulated nanoparticles, Colloids Surf. A Physicochem. Eng. Asp. 601 (2020), 125027, https://doi.org/10.1016/j.colsurfa.2020.125027.
[554] B. Willis, Integration of Biomolecular Recognition Elements with Solid-State Nano-Devices for Chemical Sensors with Specificity, Univ. of Connecticut Storrs United States, 2019 (N00014-16-1-2279), https://apps.dtic.mil/dtic/tr/fulltext/u2/1080221.pdf.
[555] F. Yi, G. Gillen, J. Lawrence, T.P. Forbes, M. Staymates, D.A. LaVan, Nanocalorimetry of explosives prepared by inkjet printing, Thermochim. Acta 685 (2020), 178510, https://doi.org/10.1016/j.tca.2020.178510.
[556] J. Zhang, E.P. Fahrenthold, Graphene-based sensing of gas-phase explosives, ACS Nano Mater. 2 (3) (2019) 1445–1456, https://doi.org/10.1021/acsanm.8b02330.
[557] Q. Zhu, W. Xiong, L. Cui, C. Qiu, R. Duan, J. Zhao, Y. Che, Kinetically stable nanoribbons with improved excitation migration length for detecting explosive, ACS Appl. Nano Mater. 3 (5) (2020) 4880–4885, https://doi.org/10.1021/acsanm.0c01068.

DetectionCanine Explosives Detection

[558] M. DeChant, Training and Experience Factors Impacting Detection Dog Performance, PhD, Texas Tech University, 2021, https://ttu-ir.tdl.org/handle/2346/87982.
[559] L. DeGreeff, K. Peranich, Canine olfactory detection of trained explosive and narcotic odors in mixtures using a mixed odor delivery device, Forensic Sci. Int. 329 (2021), 111059, https://doi.org/10.1016/j.forsciint.2021.111059.
[560] L. DeGreeff, C.J. Katilie, R.F. Johnson, S. Vaughan, Quantitative vapor delivery for improved canine threshold testing, Anal. Bioanal. Chem. 413 (3) (2021) 955–966, https://doi.org/10.1007/s00216-020-03052-2.
[561] L.E. DeGreeff, A.G. Simon, K. Peranich, H.K. Holness, K. Frank, K.G. Furton, Generalization and discrimination of molecularly similar odorants in detection canines and the influence of training, Behav. Process. 177 (2020), 104148, https://doi.org/10.1016/j.beproc.2020.104148.
[562] S. Gallegos, E. Aviles-Rosa, N. Hall, P. Prada-Tiedemann, Headspace sampling of smokeless powder odor in a dynamic airflow context, Forensic Chem. 27 (2022), 100402, https://doi.org/10.1016/j.forc.2022.100402.
[563] I. Gazit, A. Goldblatt, D. Grinstein, J. Terkel, Dogs can detect the individual odors in a mixture of explosives, Appl. Anim. Behav. Sci. 235 (2021), 105212, https://doi.org/10.1016/j.applanim.2020.105212.
[564] L. Lazarowski, B. Rogers, L.P. Waggoner, J.S. Katz, When the nose knows: ontogenetic changes in detection dogs' (Canis familiaris) responsiveness to social and olfactory cues, Anim. Behav. 153 (2019) 61–68, https://doi.org/10.1016/j.anbehav.2019.05.002.
[565] W. MacCrehan, M. Young, M. Schantz, T.C. Angle, P. Waggoner, T. Fischer, Two-temperature preparation method for PDMS-based canine training aids for

explosives, Forensic Chem. 21 (2020), 100290, https://doi.org/10.1016/j.forc.2020.100290.
[566] M. Sacharczuk, M. Walczak, E. Adamkiewicz, A. Walasek, J. Ensminger, M. Presch, T. Jezierski, Polymorphism of olfactory and neurotransmitters receptor genes in drug and explosives detection dogs can be associated with differences in detection performance, Appl. Anim. Behav. Sci. 215 (2019) 52–60, https://doi.org/10.1016/j.applanim.2019.04.006.
[567] M. Sanford, Canine Threshold to Double Base Smokeless powder, Master of Science. Texas Tech University, 2021. https://ttu-ir.tdl.org/handle/2346/87992.
[568] A.G. Simon, L.E. DeGreeff, Variation in the headspace of bulk hexamethylene triperoxide diamine (HMTD): Part II. Analysis of non-detonable canine training aids, Forensic Chem. 13 (2019), 100155, https://doi.org/10.1016/j.forc.2019.100155.
[569] A.G. Simon, K. Van Arsdale, J. Barrow, J. Wagner, Real-time monitoring of TATP released from PDMS-based canine training aids versus bulk TATP using DART-MS, Forensic Chem. 23 (2021), 100315, https://doi.org/10.1016/j.forc.2021.100315.
[570] K. Tiira, A. Tikkanen, O. Vainio, Inhibitory control – important trait for explosive detection performance in police dogs? Appl. Anim. Behav. Sci. 224 (2020), 104942 https://doi.org/10.1016/j.applanim.2020.104942.
[571] I. Wilhelm, G. Bikelyte, M. Vittek, M. Hartel, D. Roseling, T. Klapotke, Phlegmatization of TATP and HMTD with activated charcoal as training aid for explosive detection dogs, Propellans, Explos. Pyrotechn. 4792 (2022), e202100057, https://doi.org/10.1002/prep.202100057.

LIBS Detection

[572] D.F. Andrade, E.R. Pereira-Filho, D. Amarasiriwardena, Current trends in laser-induced breakdown spectroscopy: a tutorial review, Appl. Spectrosc. Rev. 56 (2) (2021) 98–114, https://doi.org/10.1080/05704928.2020.1739063.
[573] C. Byram, S.S.B. Moram, V.R. Soma, Wavelength Effect on Gold Nanoparticles Fabrication in Picosecond Laser Ablation and Evaluation of SERA Performance in Explosive Detection, 2021, pp. 499–502, https://doi.org/10.1007/978-981-15-9259-1_114.
[574] S. Carter, R. Clough, A. Fisher, B. Gibson, B. Russell, J. Waack, Atomic spectrometry update: review of advances in the analysis of metals, chemicals and materials, J. Anal. Atomic Spectrom. 34 (11) (2019) 2159–2216, https://doi.org/10.1039/C9JA90058F.
[575] R. Junjuri, A.P. Gummadi, M.K. Gundawar, Single-shot compact spectrometer based standoff LIBS configuration for explosive detection using artificial neural networks, Optik 204 (2020), 163946, https://doi.org/10.1016/j.ijleo.2019.163946.
[576] R. Junjuri, A.P. Gummadi, M.K. Gundawar, Identification of the Explosive Mixtures Using Laser Induced Breakdown Spectroscopy (LIBS), 2021, pp. 391–394, https://doi.org/10.1007/978-981-15-9259-1_89.
[577] F.S. Romolo, A. Palucci, Advances in the analysis of explosives, in: S. Francese (Ed.), Emerging Technologies for the Analysis of Forensic Traces, Springer, 2019, pp. 207–240, https://doi.org/10.1007/978-3-030-20542-3_15.

Neutron

[578] S. Bishnoi, Patel, R. Thomas, R. Jilju, P. Sarkar, B. Hayak, Study of tagged neutron method with laboratory D-T neutron generator for explosive detection, Eur. Phys. J. Plus 135 (6) (2020) 428, https://doi.org/10.1140/epjp/s13360-020-00402-y.
[579] M. Han, S. Jing, Y. Gao, Simulation and data analysis of a portable tagged neutron system for detection of explosives hidden in packages, Radiat. Phys. Chem. 182 (2021), 109361, https://doi.org/10.1016/j.radphyschem.2021.109361.
[580] M. Han, S. Jing, Y. Gao, Y. Guo, Experiment and MCNP simulation of a portable tagged neutron inspection system for detection of explosives in a concrete wall, Nucl. Instrum. Methods Phys. Res. Sect. A Accel. Spectrom. Detect. Assoc. Equip. 929 (2019) 156–161, https://doi.org/10.1016/j.nima.2019.03.069.
[581] K. Hossny, A.H. Hossny, s. Magdi, A.Y. Soliman, M. Hossny, Detecting shielded explosives y coupling prompt gamma neutron activation analysis and deep neural networks, Sci. Rep. 10 (1) (2020), 13467, https://doi.org/10.1038/s41598-020-70537-6.
[582] A. Sardet, B. Peror, C. Carasco, G. Sannie, S. Moretto, Fontana C. Nebbia, F. Pino, Performances of C-BORD's tagged neutron inspection system for explosives and illicit drugs detection in cargo containers, IEEE Trans. Nucl. Sci. 68 (3) (2021) 346–353, https://doi.org/10.1109/TNS.2021.3050002.
[583] J. Seman, C.H.C. Giraldo, C.E. Johnson, Effects of delaying measurements of concentration using neutron activation analysis on explosive taggants, Appl. Radiat. Isot. 156 (2020), 109007, https://doi.org/10.1016/j.apradiso.2019.109007.
[584] D. Sudac, M. Pavlovic, J. Obhodas, K. Nad, Z. Orlic, M. Korolija, D. Rendic, I. Meric, H.E.S. Pettersen, V. Valkovic, Detection of *Chemical* Warfare (CW) agents and the other hazardous substances by using fast MeV neutrons, Nucl. Instrum. Methods Phys. Res. Sect. A Accel. Spectrom. Detect. Assoc. Equip. 971 (2020), 164066, https://doi.org/10.1016/j.nima.2020.164066.

Terahertz

[585] D. Ganesh, E. Rao, M. Venatesh, K. Nagarijuna, G. Vaitheesawaran, A. Sahoo, A. Chaudhary, Time-domain terahertz spectroscopy and density functional theory studies of nitro/nitrogen-rich aryl-tetrazole derivatives, ACS Omega 5 (6) (2020) 2541–2551, https://doi.org/10.1021/acsomega.8b03383.
[586] N. Khan, A. Vickers, N. Abas, A.R. Kalair, Design of an optical terahertz generator, J. Laser Sci. Fund. Theory Anal. Methods 1 (3/4) (2019) 225–252. https://www.oldcitypublishing.com/wp-content/uploads/2019/06/IJLSv1n3-4p225-252Khan.pdf.
[587] A. Kidavu, N. Nagaraju, G. Damarala, A. Chaudhary, Scattering analysis of explosive materials mixed in Teflon matrix in THz regime, in: Workshop on Recent Advances in Photonics, Guwahati, India, 2019, https://doi.org/10.1109/WRAP47485.2019.9013700.
[588] P.N. Kumar, D. Ganesh, M. Nagaraju, A.K. Chaudhary, Detection of explosives and non-explosive materials from a soil matrix using 0.5 and 1.5. THz radiation, 2021, pp. 889–893, https://doi.org/10.1007/978-981-15-9259-1_204.
[589] Q. Liu, X. Li, H. Deng, J. Sun, D. Guan, L. Luo, Y. Zhang, L. Shang, Determination of moisture content in octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine using terahertz time-domain spectroscopy, Opt. Eng. 59 (8) (2020), 084102, https://doi.org/10.1117/1.OE.59.8.084102.
[590] M. Pereira, A. Apostolakis, Terahertz (THz), Mid Infrared (MIR) and Near Infrared (NIR) Technologies for Protection of Critical Infrastructures against Explosives and CBRN, Springer, 2021.
[591] L. Quancheng, Z. Qi, L. Guilin, G. Zhicheng, H. Xiangyang, X. Chai, D. Hu, S. Liping, Terahertz spectral investigation of temperature induced polymorphic transformation of 2,2dinitroethylene-1,1-diamine, RSC Adv. 11 (11) (2021) 6247–6253, https://doi.org/10.1039/D0RA10754A.
[592] M. Seo, H.R. Park, Terahertz biochemical molecule-specific sensors, Adv. Opt. Mater. 8 (3) (2020), 1900662, https://doi.org/10.1002/adom.201900662.
[593] W. Shi, C. Dong, L. Hou, Z. Xing, Q. Sun, L. Zhang, Investigation of aging characteristics in explosive using terahertz time-domain spectroscopy, Int. J. Mod. Phys. B 33 (24) (2019), 1950272, https://doi.org/10.1142/S0217979219502722.
[594] G. Singh, I. Malhotra, Terahertz Antenna Technology for Imaging and Sensing Applications, Springer, 2021.
[595] Z. Tang, J. Miao, Q. Liu, W. Qu, L. Luo, L. Shang, H. Deng, Ammonium perchlorate moisture quantitative detection using terahertz spectroscopy combined with chemometrics, Microchem. J. 169 (2021), 106635, https://doi.org/10.1016/j.microc.2021.106635.
[596] V. Vaks, E. Domracheva, M. Chernyaeva, S. Pripolzin, V. Anfertev, A. Yablokov, I. Lukyanenk, Y. Sheikov, High-resolution terahertz spectroscopy for investigation of energetic materials during their thermal decomposition, IEEE Trans. Terahertz Sci. Technol. 11 (4) (2021) 443–453, https://doi.org/10.1109/TTHZ.2021.3074030.

Nuclear Techniques

[597] C. Chen, Nuclear Quadruple Resonance and Low-Field Nuclear Magnetic Resonance for Materials Authentication, Doctoral dissertation, Case Western Reserve University, 2020, https://etd.ohiolink.edu/pg_10?0::NO:10:P10_ACCESSION_NUM:case1567518073598426.
[598] V. Joubert, V. Silvestre, V. Ladroue, F. Besacier, P. Blondel, S. Akoka, E. Baguet, G. Remaud, Forensic application of position-specific isotopic analysis of trinitrotoluene (TNT) by NMR to determine ^{13}C and ^{15}N intramolecular isotopic profiles, Talanta 213 (2020), 120819, https://doi.org/10.1016/j.talanta.2020.120819.
[599] P. Munjal, B. Sharma, J.R. Sethi, A. Dalal, S.L. Gholap, Identification and analysis of organic explosives from post-blast debris by nuclear magnetic resonance, J. Hazard Mater. 403 (2021), 124003, https://doi.org/10.1016/j.jhazmat.2020.124003.
[600] A. Nevzorov, A. Orlov, D. Stankevich, Machine learning in NQR TNT express detection system, J. Magn. Reson. 308 (2019), 106596, https://doi.org/10.1016/j.jmr.2019.106596.
[601] E.G. Sorte, Mobile Cross-Polarized NQR: Buried Explosive Detection from a Safe Distance (SANDIA20213047), Sandia National Laboratories, 2020, https://doi.org/10.2172/1673816.
[602] P. Yu, N.N.A. Ling, E.O. Fridjonsson, M.L. John, The effect of inert salts on explosive emulsion thermal degradation, Propellants, Explos. Pyrotech. 46 (3) (2021) 360–367, https://doi.org/10.1002/prep.202000258.

X-Ray

[603] A. Manerikar, F. Li, A. Kak, DEBISim: a simulation pipeline for dual energy CT-based baggage inspection systems, J. X Ray Sci. Technol. 29 (2) (2021) 259–285, https://doi.org/10.3233/XST-200808.
[604] E.A. Miller, L.W. Campbell, N. Deshmukh, A.J. Gilbert, P. Ivanusa, R.E. Jacob, D. M. Kasparek, J.D. McCall, E. Munoz, S.L. Owsley Jr., K.L. Silvers, T.A. White, R. S. Wittman, M.A. Zalvadia, Gratings-based phase contract x-ray imaging: progress towards a prototype system for explosives detection, Proc. SPIE: Anomaly Detect. Imag. X-rays (ADIX) VI 11738 (2021), 1173802, https://doi.org/10.1117/12.2589938.

Ion Mobility Spectroscopy

[605] M. Amo-Gonzalez, S. Perez, R. Delgado, G. Arranz, I. Carnicero, Tandem ion mobility spectrometry for the detection of traces of explosives in cargo at concentrations of parts per quadrillion, Anal. Chem. 91 (21) (2019) 14009–14018, https://doi.org/10.1021/acs.analchem.9b03589.
[606] O. Anttalainen, J. Puton, A. Kontunen, M. Karjalanen, P. Kumpulainen, N. Oksala, Possible strategy to use differential mobility spectrometry in real time applications, Int. J. Ion Mobil. Spectrom. 23 (2019) 1–8, https://doi.org/10.1007/s12127-019-00251-1.

[607] A. Bohnhorst, M. Hitzemann, M. Lippman, A.T. Kirk, S. Zimmermann, Enhanced resolving power by moving field ion mobility spectrometry, Anal. Chem. 92 (19) (2020) 12967–12974, https://doi.org/10.1021/acs.analchem.0c01653.
[608] U. Chilluwal, *Reactive Tandem Ion Mobility Spectrometry for Selective Detection of Explosives in Mixtures* (Publication No. 28157920), PhD, New Mexico State University, 2020.
[609] D. Fisher, S.R. Lukow, G. Berezutskiy, I. Gil, T. Levy, Y. Zeiri, Machine learning improves trace explosive selectivity: application to nitrate-based explosives, J. Phys. Chem. A 124 (46) (2020) 9656–9664, https://doi.org/10.1021/acs.jpca.0c05909.
[610] B. Hauck, C. Harden, V. McHugh, Accurate evaluation of potential calibration standards for ion mobility spectrometry, Anal. Chem. 92 (8) (2020) 6158–6165, https://doi.org/10.1021/acs.analchem.0c00859.
[611] A. McKenzie-Coe, F. Fernandez-Lima, Influence of gas modifiers on the TIMS analysis of familiar explosives, Int. J. Ion Mobil. Spectrom. 22 (2) (2019) 71–76, https://doi.org/10.1007/s12127-019-00246-y.
[612] M. Mullen, B. Giordano, Combined secondary electrospray and corona discharge ionization (SECDI) for improved detection of explosive vapors using drift tube ion mobility spectrometry, Talanta 209 (2020), 120544, https://doi.org/10.1016/j.talanta.2019.120544.
[613] A. Pevzner, G. Feldheim, A. Zaltsman, S. Elisha, V. Heleg-Shabtai, I. Ron, Sonic-spray introduction of liquid samples to hand-held Ion mobility spectrometry analyzers, Analyst (2021), https://doi.org/10.1039/D0AN02401E.
[614] R. Schrader, B. Marsh, R. Cooks, Fourier transform-ion mobility linear ion trap mass spectrometer using frequency encoding for recognition of related compounds in a single acquisition, Anal. Chem. 92 (7) (2020) 5107–5115, https://doi.org/10.1021/acs.analchem.9b05507.
[615] B. Smith, C. Boisdon, I. Young, T. Praneenarat, T. Vilaivan, S. Maher, Flexible drift tube for high resolution ion mobility spectrometry (Flex-DT-IMS), Anal. Chem. 92 (13) (2020) 9104–9112, https://doi.org/10.1021/acs.analchem.0c01357.
[616] S. Thangadurai, K. Gurusamy, Ion mobility spectrometry: a tool in the forensic science for the post detonation residue analysis, J. Forensic Sci. Criminol. 7 (2) (2019) 201–214.

Novel Detection

[617] A. Agrawal, C. Hussain, Smartphone-based detection of explosives, in: C. Hussain (Ed.), Smartphone-based Detection Devices: Emerging Trends in Analytical Techniques, Elsevier, 2021, pp. 399–416, https://doi.org/10.1016/B978-0-12-823696-3.00013-1.
[618] L. Algharagholy, H. Sadeghi, A. Al-Backri, Selective sensing of 2,4,6-trinitrotoluene and triacetone triperoxide using carbon/boron nitride heteronanotubes, Mater. Today Commun. 28 (2021), 102739, https://doi.org/10.1016/j.mtcomm.2021.102739.
[619] A. Al-Mousawi, Magnetic Explosives Detection System (MEDS) based on wireless sensor network and machine learning, Measurement 151 (2020), 107112, https://doi.org/10.1016/j.measurement.2019.107112.
[620] S. Alsaleh, L. Barron, S. Sturzenbaum, Perchlorate detection via an invertebrate biosensor, Anal. Methods 13 (3) (2021) 327–336, https://doi.org/10.1039/D0AY01732A.
[621] M.R. Andrews, C. Collet, A. Wolff, C. Hollands, Resonant acoustic mixing: processing and safety, Propellants, Explos. Pyrotech. 45 (1) (2020) 77–86, https://doi.org/10.1002/prep.201900280.
[622] A. Arm, S. Saglam, A. Uzer, R. Apak, Direct electrochemical determination of peroxide-type explosives using well-dispersed multi-walled carbon nanotubes/polyethyleneimine-modified glassy carbon electrodes, Anal. Chem. 93 (33) (2021) 11451–11460, https://doi.org/10.1021/acs.analchem.1c01397.
[623] E. Aznar-Gadea, P. Rodriguez-Canto, J. Martinez-Pastor, A. Lopatynskyi, V. Chegel, R. Abargues, Molecularly imprinted silver nanocomposites for explosive taggant sensing, ACS Appl. Polym. Mater. 3 (6) (2021) 2960–2970, https://doi.org/10.1021/acsapm.1c00116.
[624] H. Beardsley, CRESS fielded to IBCTs: chemical reconnaissance and explosives screening sets bring detecting precursors of HMEs to the force, Infantry 109 (1) (2020) 4. https://www.benning.army.mil/infantry/magazine/issues/2020/Spring/pdf/3_News2_CRESS.pdf.
[625] June 22-26 S. Blanco, A. Macario, J. Garcia-Calvo, A. Revilla-Cuesta, T. Torroba, J.C. Lopez, *Wetting Triacetone Triperoxide allows its detection by microwave spectroscopy* [Conference presentation], in: 2020 International Symposium on Molecular Spectroscopy, Champaign-Urbana, IL, United States, 2020, https://doi.org/10.15278/isms.2021.RD07.
[626] S. Blanco, A. Macario, J. Garcia-Calvo, A. Revilla-Cuesta, T. Torroba, J.C. Lopez, Microwave detection of wet Triacetone Triperoxide (TATP): non-covalent forces and water dynamics, Chem. Eur J. 27 (5) (2020) 1680–1687, https://doi.org/10.1002/chem.202003499.
[627] Z. Cao, L. Chen, S. Li, M. Yu, Z. Li, K. Zhou, C. Liu, F. Jiang, M. Hong, A flexible two-fold interpenetrated indium MOF exhibition dynamic response to gas adsorption and high-sensitivity detection of nitroaromatic explosives, Chem. Asian J. 14 (20) (2019) 3597–3602, https://doi.org/10.1002/asia.201900458.
[628] R.M. Cardoso, D.P. Rocha, R.G. Rocha, J.S. Stegano, R.A.B. Silva, E.M. Richter, R. A.A. Munoz, 3D-printing pen versus desktop 3D-printers: fabrication of carbon black/polylactic acid electrodes for single-drop detection of 2,4,6-trinitrotoluene, Anal. Chim. Acta 1132 (2020) 10–19, https://doi.org/10.1016/j.aca.2020.07.034.
[629] V. Chegel, A. Lopatynskyi, V. Lytvyn, P. Demydov, J. Martinez-Poaster, R. Abargues, E. Gadea, S. Piletsky, Localized surface plasmon resonance nanochips with molecularly imprinted polymer coating for explosives sensing, Semicond. Phys. Quantum Electron. Optoelectron. 23 (4) (2020) 431–436, https://doi.org/10.15407/spqeo23.04.431.
[630] C. Chen, J. Jin, Surface acoustic wave vapor sensor with graphene interdigital transducer for TNT detection, Sens. Imag. 21 (1) (2020) 24, https://doi.org/10.1007/s11220-020-00287-2.
[631] S. Colreavy-Donnelly, F. Caraffini, S. Kuhn, M. Gongora, J. Florez-Lozano, C. Parra, Shallow buried improvised explosive device detection via convolutional neural networks, Integrated Comput. Aided Eng. 27 (4) (2020) 403–416, https://doi.org/10.3233/ICA-200638.
[632] A. Dettlaf, P. Jakobczyk, M. Ficek, B. Wilk, M. Szala, J. Wojtas, T. Ossowski, R. Bogdanowicz, Electrochemical determination of nitroaromatic explosives at boron-doped diamond/graphene nanowall electrodes: 2,4,6-trinitrotoluene and 2,4,6-trinitroanisole in liquid effluents, J. Hazard Mater. (2019), https://doi.org/10.1016/j.jhazmat.2019.121672.
[633] J. Dickinson, Vapor Detection of Hydrogen and Organic Peroxide, Master's Degree, Oklahoma State University, 2021, https://shareok.org/handle/11244/330907.
[634] M. Doshi, E. Fahrenthold, Functionalized metallic carbon nanotube arrays for gas phase explosives detection, Comput. Theor. Chem. 1205 (2021), 113460, https://doi.org/10.1016/j.comptc.2021.113460.
[635] L. Eisner, I. Wilhelm, G. Flachenecker, J. Hurttlen, W. Schade, Molecularly imprinted sol-gel for TNT detection with optical micro-ring resonator sensor chips, Sensors 19 (18) (2019) 3909, https://doi.org/10.3390/s19183909.
[636] S. Elbasuney, Y.H. El-Sharkawy, G.S. El-Sayyad, M. Gobara, Surface modified colloidal silica nanoparticles: novel aspect for complete identification of explosive materials, Talanta 211 (2020), 120695, https://doi.org/10.1016/j.talanta.2019.120695.
[637] J. Fan, Z. Meng, X. Dong, M. Xue, L. Qiu, X. Liu, F. Zhong, X. He, Colorimetric screening of nitramine explosives by molecularly imprinted photonic crystal array, Microchem. J. 158 (2020), 105143, https://doi.org/10.1016/j.microc.2020.105143.
[638] J. Filipi, V. Stojnic, M. Mustra, R. Fillanders, V. Jovanovic, S. Gajic, G. Turnbull, Z. Babic, N. Kezic, V. Risojevic, Honeybee-based biohybrid system for landmine detection, Sci. Total Environ. 803 (2022), 150041, https://doi.org/10.1016/j.scitotenv.2021.150041.
[639] J.E. Friedel, T.H. Holzer, S. Sarkani, Development, optimization, and validation of unintended radiation emissions processing system for threat identification, IEEE Trans. Syst. Man Cybern. Syst. 50 (6) (2020) 2208–2219, https://doi.org/10.1109/TSMC.2018.2810305.
[640] F. Ghasemi, M. Hormozi-Hezhad, Determination and identification of nitroaromatic explosives by a double-emitter sensor array, Talanta 201 (2019) 230–236, https://doi.org/10.1016/j.talanta.2019.04.012.
[641] B. Gokdere, A. Uzer, S. Durmazel, E. Ercag, R. Apak, Titanium dioxide nanoparticles–based colorimetric sensors for determination of hydrogen peroxide and triacetone triperoxide (TATP), Talanta 202 (2019) 402–410, https://doi.org/10.1016/j.talanta.2019.04.071.
[642] K. Gong, S. Xiao, S. Jing, Y. Zheng, Back propagation neural network analysis for the detection of explosives based on tagged neutron, J. Radioanal. Nucl. Chem. 326 (2020) 329–336, https://doi.org/10.1007/s10967-020-07321-3.
[643] S. Gutierrez, F. Vega, F. Gonzalez, C. Baer, J. Sachs, Application of polarimetric features and support vector machines for classification of improvised explosive devices, IEEE Antenn. Wireless Propag. Lett. 18 (11) (2019) 2282–2286, https://doi.org/10.1109/LAWP.2019.2934691.
[644] M. Harries, T. Bruno, Field demonstration of portable vapor sampling in a simulated cargo container, Forensic Chem. 16 (2019), 100182, https://doi.org/10.1016/j.forc.2019.100182.
[645] C. Hay, J. Lee, D. Silvester, A methodology to detect explosive residues using a gelled ionic liquid based field-deployable electrochemical device, J. Electroanal. Chem. 872 (2020), 114046, https://doi.org/10.1016/j.jelechem.2020.114046.
[646] C. Hay, J. Lee, D. Silvester, An electroanalytical methodology to detect explosive residues using a gelled ionic liquid based field-deployable device, J. Electroanal. Chem. 872 (2020), 114046, https://doi.org/10.1016/j.jelechem.2020.114046.
[647] N. Holubowitch, C. Crabtree, Z. Budimir, Electroanalysis and spectroelectrochemistry of nonaromatic explosives in acetonitrile containing dissolved oxygen, Anal. Chem. 92 (17) (2020) 11617–11626, https://doi.org/10.1021/acs.analchem.0c01174.
[648] K. Hossny, S. Madgi, A.Y. Soliman, A.H. Hossny, Detecting explosives by PGNAA using KNN Regressors and decision tree classifier: a proof of concept, Prog. Nucl. Energy 124 (2020), 103332, https://doi.org/10.1016/j.pnucene.2020.103332.
[649] S. Jangi, M. Akhond, G. Absalan, A field-applicable colorimetric assay for notorious explosive triacetone triperoxide through nanozyme-catalyzed irreversible oxidation of 3, 3′-diaminobenzidine, Microchim. Acta 187 (8) (2020) 431, https://doi.org/10.1007/s00604-020-04409-1.
[650] L. Jiang, J. Wu, K. Chen, Y. Zheng, G. Deng, X. Zhang, Z. Li, K.S. Chiang, Polymer waveguide Mach-Zehnder interferometer coated with dipolar polycarbonate for on-chip nitroaromatics detection, Sensor. Actuator. B Chem. 305 (2020), 127406, https://doi.org/10.1016/j.snb.2019.127406.
[651] V. Krivitsky, B. Filanovsky, T. Bourenko, E. Granot, A. Praiz, F. Patolsky, Vapor trace collection and direct ultrasensitive detection of nitro-explosives by 3D microstructured electrodes, Anal. Chem. 91 (22) (2019) 14375–14382, https://doi.org/10.1021/acs.analchem.9b02849.
[652] V. Krivitsky, B. Filanovsky, V. Naddaka, F. Patolsky, Direct and selective electrochemical vapor trace detection of organic peroxide explosives via surface decoration, Anal. Chem. 91 (8) (2019) 5323–5330, https://doi.org/10.1021/acs.analchem.9b00257.

[653] K. Lee, Y. Yoo, M. Chae, K. Hwang, J. Lee, H. Kim, D. Hur, J. Lee, Highly selective reduced graphene oxide (rGO) sensor based on a peptide aptamer receptor for detecting explosives, Sci. Rep. 9 (2019), 10297, https://doi.org/10.1038/s41598-019-45936-z.
[654] S. Lee, S. Kwak, K. Wang, W. Han, Substituent effect on Difluoroboron β-diketonate complexes: synthesis, photophysical and electrochemical properties, and application as nitro-explosive chemosensors, ECS J. Solid State Sci. Technol. 10 (8) (2021), https://doi.org/10.1149/2162-8777/ac1d60, 086007.
[655] M. Lefferts, M. Castell, Influence of soil type on chemiresistive detection of buried ANFO, Forensic Chem. 27 (2022), 100401, https://doi.org/10.1016/j.forc.2022.100401.
[656] M.J. Lefferts, L.H. Humphreys, N. Mai, K. Murugappan, B.I. Armitage, J. Pons, M. R. Castell, ANFO vapour detection with conducting polymer percolation sensors and GC/MS, Analyst 146 (7) (2021) 2168–2193, https://doi.org/10.1039/D0AN02403A.
[657] N. Leibl, L. Duma, C. Gonzato, K. Haupt, Polydopamine-based molecularly imprinted thin films for electro-chemical sensing of nitro-explosives in aqueous solutions, Bioelectrochemistry 135 (2020), 107541, https://doi.org/10.1016/j.bioelechem.2020.107541.
[658] M. Li, K. Xie, G. Wang, J. Zheng, Y. Cao, X. Cheng, Z. Li, F. Wei, H. Tu, J. Tang, An AIE-active ultrathin polymeric self-assembled monolayer sensor for trace volatile explosive detection, Macromol. Rapid Commun. 42 (23) (2021), 2100551, https://doi.org/10.1002/marc.202100551.
[659] Y. Li, W. Zhou, B. Zu, X. Dou, Qualitative detection toward military and improvised explosive vapors by a facile TiO2 nanosheet-based chemiresistive sensor array, Front. Chem. 8 (2020) 29, https://doi.org/10.3389/fchem.2020.00029.
[660] C. Liu, W. Zhang, Y. Zhao, C. Lin, K. Zhou, Y. Li, Li, Urea-functionalized poly(ionic liquid) photonic sphere for visual identification of explosives with a smartphone, ACS Appl. Mater. Interfaces 11 (23) (2019) 21078–21085, https://doi.org/10.1021/acsami.9b04568.
[661] X. Liu, Y. Hu, Y. Zhou, P. Zhang, L. Gao, B. Liu, Z. Wu, L. Zhang, PPV nanotube sensor arrays for explosives identification by excitation wavelength regulation, Macromol. Mater. Eng. 306 (10) (2021), 2100276, https://doi.org/10.1002/mame.202100276.
[662] Y. Liu, J. Li, G. Wang, B. Zu, X. Dou, One-step instantaneous detection of multiple military and improvised explosives facilitated by colorimetric reagent design, Anal. Chem. 92 (20) (2020) 13980–13988, https://doi.org/10.1021/acs.analchem.0c02893.
[663] K.J. Major, T.C. Hutchens, C.R. Wilson, M.K. Poutous, I.D. Aggarwal, J. S. Sanghera, K.J. Ewing, Discrimination between explosive materials and Isomers using a human color vision-inspired sensing method, Appl. Spectrosc. 73 (5) (2019) 520–528, https://doi.org/10.1177/0003702819828411.
[664] K.J. Major, L.B. Shaw, L. Busse, R. Gattass, D. Arnone, E. Lopez, M. Pushkarsky, J. Kane, R.J. Clewes, L. Lee, C.R. Howle, J.S. Sanghera, K.J. Ewing, Fiber optic coupled quantum cascade infrared laser system for detection of explosive materials on surfaces, Opt Laser. Technol. 119 (2019), 105635, https://doi.org/10.1016/j.optlastec.2019.105635.
[665] G. Namboodiri, M. Joseph, M. Kumar, M. Nallaperumal, K. Moideenkutty, M. Arumugam, L. Kumar, J. Jayaprakash, X-ray computed tomography and thermal neutron radiography for detection of low dense compounds inside pyro elements used in space applications, Eur. Phys. J. Plus 136 (9) (2021) 945, https://doi.org/10.1140/epjp/s13360-021-01910-1.
[666] S.K. Nandi, S.R. Chowdhury, D. Podder, P.K. Ghorai, D. Haldar, A robust tripeptide for in-field selective naked eye ultratrace detection of 2,4,6-Trinitrophenol, Cryst. Growth Des. 20 (3) (2020) 1884–1890, https://doi.org/10.1021/acs.cgd.9b01591.
[667] F. Niu, Z. Shao, L. Tao, Y. Ding, Si-doped graphene nanosheets as a metal-free catalyst for electrochemical detection of nitroaromatic explosives, J. Colloid Interface Sci. 594 (2021) 848–856, https://doi.org/10.1016/j.jcis.2021.03.091.
[668] F. Novtny, V. Urbanova, J. Putnar, M. Pumera, Preserving fine structure details and dramatically enhancing electron transfer rates in graphene 3D-printed electrodes via thermal annealing: toward nitroaromatic explosives sensing, ACS Appl. Mater. Interfaces 11 (38) (2019) 35371–35375, https://doi.org/10.1021/acsami.9b06683.
[669] J. Ognard, D. Bourhis, R. Cadieu, M. Grenier, C. Saccardy, Z. Alavi, S.D. Ben, Feasibility of use of medical dual energy scanner for forensic detection and characterization of explosives, a phantom study, Int. J. Leg. Med. 134 (2020) 1915–1925, https://doi.org/10.1007/s00414-020-02315-y.
[670] V. Palaparthy, S. Doddapujar, G. Gupta, P. Das, S. Chandorkar, S. Mukherji, M. Baghini, V. Rao, E-nose: multichannel analog signal conditioning circuit with pattern recognition for explosive sensing, IEEE Sensor. J. 20 (3) (2020) 1373–1382, https://doi.org/10.1109/JSEN.2019.2946253.
[671] V. Palaparthy, S. Doddapujar, S. Surya, S. Chandorkar, S. Mukherji, M. Baghini, V. Rao, Hybrid pattern recognition for rapid explosive sensing with comprehensive analysis, IEEE Sensor. J. 21 (6) (2021) 8011–8019, https://doi.org/10.1109/JSEN.2020.3047271.
[672] L. Pan, Z. Liu, M. Tian, B.C. Schroeder, A.E. Aliev, C.F.J. Faul, Luminescent and swellable conjugated microporous polymers for detecting nitroaromatic explosives and removing harmful organic vapors, ACS Appl. Mater. Interfaces 11 (51) (2019) 48352–48362, https://doi.org/10.1021/acsami.9b16767.
[673] S. Pollock, D.R. Crick, L.J. Winter, M.C. Kemp, Multi-sensor threat detection for screening people and their carried bags, in: Proceedings SPIE Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XXII, 11749, 2021, https://doi.org/10.1117/12.2585744, 1174908.
[674] T. Puttasakul, C. Pintavirooj, C. Sangma, W. Sukjee, Hydrogel based-electrochemical gas sensor for explosive material detection, IEEE Sensor. J. 19 (19) (2019) 8556–8562, https://doi.org/10.1109/JSEN.2019.2922170.
[675] T. Puttasakul, W. Sukjee, C. Pintavirooj, C. Sangma, IDE gas sensor based dengue virus co-imprinting for detection of 2,4,6-Trinitrotoluene, in: A. Roeksabutr (Ed.), *Proceedings of the 2021 9th International Electrical Engineering Congress (iEECON 2021)*, Institute of Electrical and Electronics Engineers, 2021, pp. 555–559, https://doi.org/10.1109/iEECON51072.2021.9440379.
[676] T. Puttasakul, C. Tancharoen, W. Sukjee, C. Pintavirooj, C. Sangma, Detection of 2,4,6-*Trinitrotoluene by MIP-composite based electrochemical sensor* [Paper presentation], in: 9th International Electrical Engineering Congress (iEECON 2021), 2021, https://doi.org/10.1109/iEECON51072.2021.9440315.
[677] K. Rejeti, G. Murali, B.S. Kumar, An accurate methodology to identify the explosives using wireless sensor networks [Paper presentation], in: *Internati*onal Conference on Sustainable Computing in Science, Technology and Management (SUSCOM), Amity University, Rajastan, Jaipur, India, 2019, February, https://doi.org/10.2139/ssrn.3362178.
[678] N. Rohaizad, Z. Sofer, M. Pumera, Boron and nitrogen dopants in graphene have opposite effects on the electrochemical detection of explosive nitroaromatic compounds, Electrochem. Commun. 112 (2020), 106660, https://doi.org/10.1016/j.elecom.2020.106660.
[679] M. Sadeghi, M. Tajdini, E. Wig, C. Rappaport, Single frequency fast dielectric characterization of concealed body-worn explosive threats, IEE Trans. Antenn. Propag. (2020), https://doi.org/10.1109/TAP.2020.3000866.
[680] D. Saha, D. Mehta, E. Altan, R. Chandak, R. Lo, P. Gupta, S. Singamaneni, S. Chakrabarty, B. Raman, Explosive sensing with insect-based biorobots, Biosens. Bioelectron. X6 (2020), 100050, https://doi.org/10.1016/j.biosx.2020.100050.
[681] E. Schultz-Fellenz, E. Swanson, A. Sussman, R. Coppersmith, R. Kelley, E. Miller, B. Crawford, A. Lavadie-Bulnes, J. Cooley, S. Vigil, M. Townsend, J. Larotonda, High-resolution surface topographic change analyses to characterize a series of underground explosions, Rem. Sens. Environ. 246 (2020), 111871, https://doi.org/10.1016/j.rse.2020.111871.
[682] B. Shemer, E. Shpigel, A. Glozman, S. Yagur-Kroll, Y. Kabessa, A. Agranat, S. Belkin, Genome-wide gene-deletion screening identifies mutations that significantly enhance explosives vapor detection by a microbial sensor, N. Biotech. 59 (2020) 65–73, https://doi.org/10.1016/j.nbt.2020.06.002.
[683] M.D. Shree, A. Sangeetha, P. Krishnan, Design and analysis of FBG sensor for explosive detection application, Plasmonics 15 (3) (2020) 813–819. https://doi.org/10.1007/s11468-019-01100-x.
[684] N. Siangdee, N. Youngvises, Smart sensor using cellulose-based material for TNT detection, Key Eng. Mater. 803 (2019) 124–128. https://doi.org/10.4028/www.scientific.net/KEM.803.124.
[685] M. Simic, R. Gillanders, A. Avramovic, S. Sajic, V. Jovanovic, V. Stojnic, V. Risojevic, J. Glackin, G. Turnbull, J. Filipi, N. Kezic, M. Mustra, Z. Babic, Honeybee activity monitoring in a biohybrid system for explosives detection, in: A. Badnjevic, R. Skrbic, L.G. Pokvic (Eds.), Proceedings of the International Conference on Medical and Biological Engineering, 16-18 May 2019, Banja Luka, Bosnia and Herzegovina, 2019, pp. 185–192, https://doi.org/10.1007/978-3-030-17971-7_29.
[686] M. Simonovic, S. Ostojic, D. Mici, M. Bisercic-Savic, T. Mix, M. Glumac, B. Pejin, A novel and effective natural product-based immunodetection tool for TNT-like compounds, Nat. Prod. Res. (2020), https://doi.org/10.1080/14786419.2020.1806269.
[687] B. Stromer, Bednar, M. Janjic, S. Becker, T. Kylloe, J. Allen, T. Trapani, J. Hargrove, J. Hargrove, *Traces explosives Detection by Cavity Ring-Down Spectroscopy (CRDS)* (Report No. ERDC/EL TR-21-5), US Army Corps of Engineers Engineer Research and Development Center, 2021. https://erdc-library.erdc.dren.mil/jspui/handle/11681/41520.
[688] S. Sun, F. Wang, Y. Sun, X. Guo, R. Ma, M. Zhang, T. Hu, Construction of a dual-function metal-organic framework: detection of Fe3+, Cu2+, nitroaromatic explosives, and a high second-harmonic generation response, Ind. Eng. Chem. Res. 58 (38) (2019) 17784–17791, https://doi.org/10.1021/acs.iecr.9b02949.
[689] Sundaram, G. & Udayan, A.P.M. (2021). Method to make scalable ultrathin hexagonally faceted metal-organic framework (MOF) and method of using same for detecting explosives and other nitro-aromatic compounds (U.S. Patent No. 2021/0101914 A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20210101914A1/en.
[690] C. Tancharoen, W. Sukjee, P. Yenchitsomanus, A. Panya, P. Lieberzeit, C. Sangma, Selectivity enhancement of MIP-composite sensor for explosive detection using DNT-dengue virus template: a co-imprinting approach, Mater. Lett. 285 (2021), 129201, https://doi.org/10.1016/j.matlet.2020.129201.
[691] V. Taranto, M. Ueland, S.L. Forbes, L. Blanes, The analysis of nitrate explosive vapour samples using Lab-on-a-chip instrumentation, J. Chromatogr. A 1602 (2019) 467–473, https://doi.org/10.1016/j.chroma.2019.06.003.
[692] J. Torres-Tello, A.V. Guaman, S. Ko, Improving the detection of explosives in a MOX chemical sensors array with LSTM network, IEEE Sensor. J. 20 (23) (2020) 14302–14309, https://doi.org/10.1109/JSEN.2020.3007431.
[693] M. Trachioti, D. Hemzal, J. Hrbac, M. Prodromidis, Generation of graphite nanomaterials from pencil leads with the aid of a 3D positioning sparking device: application to the voltammetric determination of nitroaromatic explosives, Sens. Actuators, B 310 (2020), 127871, https://doi.org/10.1016/j.snb.2020.127871.
[694] Trammell, S.A., Myers-Ward, R.L., Hangarter, S.C., Zabetakis, D., Stenger, D.A., Gaskill, D.K., & Walton, S.G. (2021). Plasma modified epitaxial fabricated graphene on SiC for electrochemical trace detection of explosives (U.S. Patent and Trademark Office No. 10,928,351 B2). https://patents.google.com/patent/US10928351B2/en..

[695] D.W.J.M. van de Wouw, F.B. teer Haar, G. Dubbelman, P.H.N. de With, Development and analysis of a real-time system for automated detection of improvised explosive device indicators from ground vehicles, J. Electron. Imag. 28 (4) (2019) 1–16, https://doi.org/10.1117/1.JEI.28.4.043009.
[696] V. Villanueva-Lopez, A.M. Colon-Mercado, K.M. Vazquez-Velez, J.R. Castro-Suarez, L.C. Pacheco-Londono Rivera, S.P. Hernandez-Rivera, Trace detection of C-4 on aluminum using mid-infrared reflection-absorption quantum cascade laser spectroscopy, in: A. Rocha, C. Hernan Fajardo-Toro, J.M.R. Rodriguez (Eds.), Developments and Advances in Defense and Security: Proceedings of MICRADS 2021, Springer, 2022, pp. 227–239, https://doi.org/10.1007/978-981-16-4884-7_18.
[697] G. Wang, Z. Cai, X. Dou, Colorimetric logic design for rapid and precise discrimination of nitrate-based improvised explosives, Cell Rep. Phys. Sci. 2 (2) (2021), 100317, https://doi.org/10.1016/j.xcrp.2020.100317.
[698] G. Wang, Y. Li, Z. Cai, X. Dou, A colorimetric artificial olfactory system for airborne improvised explosive identification, Adv. Mater. 32 (14) (2020), 1907043, https://doi.org/10.1002/adma.201907043.
[699] J. Wang, M. Tanaka, M. Okochi, Quartz crystal microbalance sensor based on peptide anchored single-walled carbon nanotubes for highly selective TNT explosive detection [conference session], in: 2020 IEE Sensors, Rotterdam, Netherlands, 2020, https://doi.org/10.1109/SENSORS47125.2020.9278670.
[700] X. Wang, T. Qin, Y. Qin, A.H. Abdelrahamn, R.S. Witte, H. Xin, Microwave-induced thermoacoustic imaging for embedded explosives detection in high-water content medium, IEEE Trans. Antenn. Propag. 67 (7) (2019) 4803–4810, https://doi.org/10.1109/TAP.2019.2908267.
[701] G. Wen, W. Wu, F. Wang, X. Wang, J. Rong, Y. Wang, An excellent thermostable dual-functionalized 3D fsx-type Cd(ii) MOF for the highly selective detection of Fe3+ ions and ten nitroaromatic explosives, CrystEngComm 23 (35) (2021) 6171–6179, https://doi.org/10.1039/D1CE00939G.
[702] J. Wojtas, R. Bogdanowicz, A.K. Duda, B. Pietrzyk, M. Sobaszek, P. Prasula, A. Dettlaff, K. Achtenberg, Fast-response optoelectronic detection of explosives' residues from the nitroaromatic compounds detonation: field studies approach, Measurement 162 (2020), 107925, https://doi.org/10.1016/j.measurement.2020.107925.
[703] J. Wu, M. Fan, G. Deng, C. Gong, K. Chen, J. Luo, K.S. Chiang, Y. Rao, Y. Gong, Optofluidic laser explosive sensor with ultralow detection limit and large dynamic range using donor-acceptor-donor organic dye, Sensor. Actuator. B Chem. 298 (2019), 126830, https://doi.org/10.1016/j.snb.2019.126830.
[704] S. Yang, W. Fan, H. Cheng, Z. Gong, D. Wang, M. Fan, B. Huang, A dual functional cotton swab sensor for rapid on-site naked-eye sensing of nitro explosives on surfaces, Microchem. J. 159 (2020), 105398, https://doi.org/10.1016/j.microc.2020.105398.
[705] A.N. Yumang, A.C. Paglinawan, J.S. Andres, R.J. De Lon, J.C. Dela Cruz, C. K. Floresta, February 14-16). Electronic nose of Acetone as a potential precursor in Triacetone Triperoxide (TATP)-based improvised explosive devices (IEDs), in: M. Kavakli (Ed.), *Proceedings of 2020 12th International Conference on Computer and Automation Engineering*, Association for Computing Machinery, 2020, pp. 52–55, https://doi.org/10.1145/3384613.3384625 (Chair).
[706] G. Zhang, X. Zou, H. Li, Y. He, Visual colorimetric detection of triacetone triperoxide based on a Fe(ii)-promoted thermal decomposition process, Analyst 146 (20) (2021) 6187–6192, https://doi.org/10.1039/D1AN01480C.
[707] J. Zhang, E. Fahrenthold, Graphene nanoribbons as flexible docks for chemiresistive sensing of gas phase explosives, Nanoscale 12 (19) (2020) 10730–10736, https://doi.org/10.1039/D0NR01237H.
[708] S. Zhang, Y. Sun, Y. Sun, H. Wang, Y. Shen, Semiquantitative immunochromatographic colorimetric biosensor for the detection of dexamethasone based on up-conversion fluorescent nanoparticles, Microchim. Acta 187 (8) (2020) 447, https://doi.org/10.1007/s00604-020-04418-0.
[709] W. Zhang, Z. Wu, J. Hu, Y. Cao, J. Guo, M. Long, H. Duan, D. Jia, Flexible chemiresistive sensor of polyaniline coated filter paper prepared by spraying for fast and non-contact detection of nitroaromatic explosives, Sensor. Actuator. B Chem. (2019), https://doi.org/10.1016/j.snb.2019.127233.
[710] W. Zhang, Z. Wu, J. Hu, Y. Cao, J. Guo, M. Long, H. Duan, D. Ji, Flexible chemiresistive sensor of polyaniline coated filter paper prepared by spraying for fast and non-contact detection of nitroaromatic explosives, Sensor. Actuator. B Chem. 304 (2020), 127233, https://doi.org/10.1016/j.snb.2019.127233.
[711] Y. Zhang, Y. Ma, L. Wang, Simple copper nanoparticle/polyfurfural film modified electrode for the determination of 2, 4, 6-Trinitrotoluene (TNT), Anal. Lett. 53 (16) (2020) 2671–2684, https://doi.org/10.1080/00032719.2020.1751182.
[712] Q. Zhu, G. Zhang, W. Yuan, S. Wang, L. He, F. Yong, G. Tao, Handy fluorescent paper device based on a curcumin derivative for ultrafast detection of peroxide-based explosives, Chem. Commun. 55 (91) (2019) 13661–13664, https://doi.org/10.1039/C9CC06737J.

Stand Off

[713] H. Ayoub, A. El-Sherif, A. Elbeih, Hyperspectral imaging and remote trace detection of cis-1,3,4,6-tetranitrooctahydroimidazo-[4,5 d] imidazole (BCHMX) compared with traditional explosives using laser induced fluorescence, Defence Technol. 17 (5) (2021) 1609–1616, https://doi.org/10.1016/j.dt.2020.09.008.
[714] C.J. Breshike, C.A. Kendziora, R. Furstenberg, T.J. Huffman, V.K. Nguyen, N. Budack, Y. Yoon, R.A. McGill, Hyperspectral imaging using active infrared backscatter spectroscopy for detection of trace explosives, Opt. Eng. 59 (9) (2020), 092009, https://doi.org/10.1117/1.OE.59.9.092009.
[715] P.G. Datskos, M. Morales-Rodriguez, L.R. Senesac, Standoff imaging of trace RDX using quantum cascade lasers, IEEE Sensor. J. 20 (1) (2020) 149–154, https://doi.org/10.1109/JSEN.2019.2940883.
[716] E. Gallo, L. Cantu, F. Duschek, Remote Raman spectroscopy of explosive precursors, Opt. Eng. 60 (8) (2021), 084108, https://doi.org/10.1117/1.OE.60.8.084108.
[717] C. Gasser, M. Goschl, J. Ofner, B. Lendl, Stand-off hyperspectral Raman imaging and random decision forest classification: a potent duo for the fast remote identification of explosives, Anal. Chem. 91 (12) (2019) 7712–7718, https://doi.org/10.1021/acs.analchem.9b00890.
[718] R. Gillanders, J. Glackin, Z. Babic, M. Mustra, M. Simic, N. Kezi, G. Turnbull, J. Filipi, Biomonitoring for wide area surveying in landmine detection using honeybees and optical sensing, Chemosphere 273 (2021), 129646, https://doi.org/10.1016/j.chemosphere.2021.129646.
[719] A. Goyal, D. Wood, V. Lee, J. Rollag, P. Schwarz, L. Zhu, G. Santora, Laser-based long-wave-infrared hyperspectral imaging system for the standoff detection of trace surface chemicals, Opt. Eng. 59 (9) (2020), https://doi.org/10.1117/1.OE.59.9.092003, 092003.
[720] K.K. Gulati, S. Gulia, N. Kumar, A. Kumar, S. Kumari, V. Gambhir, M.N. Reddy, Real-time stand-off detection of improvised explosive materials using time-gated UV–Raman spectroscopy, Pramana - J. Phys. 92 (2) (2019) 1–5, https://doi.org/10.1007/s12043-018-1688-9.
[721] Gunes, H., Bicakci, S., Citak, H., Coramik, M., & Ege, Y. Buried magnetic material detection system: an SVM algorithm application. IEEE Trans. Magn., 57(7), 6500509. https://doi.org/10.1109/TMAG.2021.3077864.
[722] V. Gupta, Y. Ozaki, *Molecular and Laser Spectroscopy*: Advances and Applications, vol. 2, Elsevier, 2020, https://doi.org/10.1016/C2018-0-04226-7.
[723] L.A. Horsfall, *Modification of N-type and P-type Semiconducting Metal Oxide Gas Sensors for the Purpose of Explosive Detection* [Doctoral Dissertation, University College London], UCL Discovery, 2020. https://discovery.ucl.ac.uk/id/eprint/10107642/.
[724] K.T. Hufziger, *The Development of Photonic Crystal Optics and Wide-field Raman Imaging Spectrometers for Trace Explosive Detection* [Unpublished Doctoral Dissertation], University of Pittsburgh, 2019.
[725] M. Jindal, S. Veeraburhiran, Mainuddin, A. Razdan, Integrated path DIAL for standoff detection of acetone vapors under topographic target condition, Opt Laser. Technol. 143 (2021), 107299, https://doi.org/10.1016/j.optlastec.2021.107299.
[726] J. Johny, S. Karnik, R. Prabhu, *Investigations of Hollow-Core Photonic Crystal Fibres (HC-PCF) for Trace Explosive Vapour Detection* [Poster Presentation], SPIE SECURITY & DEFENSE, United Kingdom, 2020, https://doi.org/10.1117/12.2574356. Online Only.
[727] A. Koz, Ground-based hyperspectral image surveillance systems for explosive detection: part I—state of the art and challenges, IEEE J. Sel. Top. Appl. Earth Obs. Rem. Sens. 12 (12) (2019) 4746–4753, https://doi.org/10.1109/JSTARS.2019.2957484.
[728] V. Lazi, A. Palucci, L. De Dominicis, M. Nuvoli, M. Pistilli, I. Menicucci, F. Colao, S. Almviva, Integrated laser sensor (ILS) for remote surface analysis: application for detecting explosives in fingerprints, Sensors 19 (19) (2019) 4269, https://doi.org/10.3390/s19194269.
[729] M. Mann, A.S. Rao, R.C. Sharma, Remote mid IR Photoacoustic Spectroscopy for the detection of explosive materials, Chem. Phys. Lett. 765 (2021), 138231, https://doi.org/10.1016/j.cplett.2020.138231.
[730] A.K. Misra, T.E. Acosta-Maeda, J.N. Porter, M.J. Egan, M.W. Sandford, T. Oyama, J. Zhou, Remote Raman detection of chemicals from 1752m during afternoon daylight, Appl. Spectrosc. 74 (2) (2020) 233–240, https://doi.org/10.1177/0003702819875437.
[731] Otagaki, Y., Miyato, Y., Barras, J., Sato-Akaba, H., & Kosmas, P. Development of a low-cost, portable NQR spectrometer for RDX explosives detection. IEEE Sensor. J., 21(5), 6922-6929. https://doi.org/10.1109/JSEN.2020.3038158.
[732] P.P. Ricci, O.J. Gregory, Continuous monitoring of TATP using ultrasensitive, low-power sensors, IEEE J. 20 (23) (2020) 14058–14064, https://doi.org/10.1109/JSEN.2020.3008254.
[733] A. Shaik, V. Soma, Standoff discrimination and trace detection of explosive molecules using femtosecond filament induced breakdown spectroscopy combined with silver nanoparticles, OSA Continuum 2 (3) (2019) 554–562, https://doi.org/10.1364/OSAC.2.000554.
[734] A.K. Shaik, V.R. Soma, Femtosecond filaments for standoff detection of explosives, Defense Sci. J. 70 (4) (2020) 359–365, https://doi.org/10.14429/dsj.70.14962.
[735] R.C. Sharma, S. Kumar, S. Kumar, M. Mann, M.M. Sharma, Photoacoustic remote sensing of suspicious objects for defence and forensic applications, Spectrochim. Acta Mol. Biomol. Spectrosc. 224 (2020), 117445, https://doi.org/10.1016/j.saa.2019.117445.
[736] R.C. Sharma, S. Kumar, A. Parmar, M. Mann, S. Prakash, S.N. Thakur, Standoff pump-probe photothermal detection of hazardous chemicals, Sci. Rep. 10 (2020), 15053, https://doi.org/10.1038/s41598-020-71937-4.
[737] S.K. Sharma, B.M. Howe, A.K. Misra, M.R. Rognstad, J.N. Porter, T.E. Acosta-Maeda, M.J. Egan, Underwater time-gated standoff Raman sensor for in situ chemical sensing, Appl. Spectrosc. 75 (6) (2021) 739–746, https://doi.org/10.1177/00037028211001923.
[738] N. Simin, Y. Park, D. Lee, T. Thundat, S. Kim, Enhanced nanoplasmonic heating in standoff sensing of explosive residues with infrared reflection-absorption spectroscopy, Opt Lett. 45 (8) (2020) 2144–2147, https://doi.org/10.1364/OL.387653.

[739] S. Thongrom, P. Kalasuwan, P. van Dommelen, C. Daengngam, Development of a cost-effective remote explosives detection system based on Raman spectroscopy, J. Phys. Conf. 1719 (2021), 012080, https://doi.org/10.1088/1742-6596/1719/1/012080.
[740] D. Wild, C. Theiß, G. Holl, Contact-free and fast detection of energetic materials in containments, Eur. Phys. J. Plus 136 (4) (2021) 437, https://doi.org/10.1140/epjp/s13360-021-01406-y.
[741] G. Xie, X. Lv, P. Zhang, B. Liu, L. Gao, J. Duan, B. Ma, Z. Wu, Uncontactless detection of improvised explosives TATP realized by Au NCs tailored PPV flexible photoelectric Schottky sensor, NanoSelect 1 (4) (2020) 419–431, https://doi.org/10.1002/nano.202000044.
[742] C. Yang, F. Jin, S. Trivedi, U. Hommerich, L. Nemes, A. Samuels, A novel standoff simultaneous UVN + LWIR laser induced breakdown spectroscopy (LIBS) detection system for rapid in-situ chemical analysis, in: Proc. SPIE: Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XXV, vol. 11418, 2020, https://doi.org/10.1117/12.2565159, 114180I.

Environmental

[743] T. Ariyarathna, M. Ballentine, P. Vlahos, R. Smith, C. Cooper, J. Bojlke, T. Groshens, C. Tobias, Degradation of RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine) in contrasting coastal marine habitats: subtidal non-vegetated (sand), subtidal vegetated (silt/eel grass), and intertidal marsh, Sci. Total Environ. (2020), https://doi.org/10.1016/j.scitotenv.2020.140800.
[744] H. Avellaneda, Z. Arbeli, W. Teran, F. Roldan, Transformation of TNT, 2,4-DNT, and PETN by Raoultella planticola M30b and Rhizobium radiobacter M109 and exploration of the associated enzymes, World J. Microbiol. Biotechnol. 36 (12) (2020) 190, https://doi.org/10.1007/s11274-020-02962-8.
[745] R. Behera, T. Biswal, R. Panda, in: S. Acharya, D. Mishra (Eds.), Current Advances in Mechanical Engineering: Select Proceedings of ICRAMERA 2020, Springer, 2021, pp. 305–315, https://doi.org/10.1007/978-981-33-4795-3_29.
[746] T.J. Boyd, R.H. Cuenca, Y. Hagimoto, M.M. Michalsen, C. Tobias, J. Popovic, Stable Carbon Isotopes for Trace in Situ RDX Remediation (NRL/6180/MR—2021/1), U.S. Naval Research Laboratory, 2021, https://apps.dtic.mil/sti/citations/AD1122062.
[747] T. Cary, E. Rylott, L. Zhang, R. Routsong, A. Palazzo, S. Strand, N. Bruce, Field trial demonstrating phytoremediation of the military explosive RDX by XplA/XplB-expressing switchgrass, Nat. Biotechnol. 39 (2021) 1216–1219, https://doi.org/10.1038/s41587-021-00909-4.
[748] J. Chandra, R. Xalxo, N. Pandey, S. Keshavkant, Biodegradation of explosives by transgenic plants, in: M. Hasanuzzaman, M.N. Vara Prasad (Eds.), Handbook of Bioremediation: Physiological, Molecular, and Biotechnological Interventions, Academic Press, 2021, pp. 657–675, https://doi.org/10.1016/B978-0-12-819382-2.00042-9.
[749] S. Cho, C. Park, J. Lee, B. Lyu, I. Moon, Finding the best operating condition in a novel process for explosive waste incineration using fluidized bed reactors, Comput. Chem. Eng. 142 (2020), 107054, https://doi.org/10.1016/j.compchemeng.2020.107054.
[750] M. D'Alexxio, J. Lichwa, C. Ray, Transport of explosive chemicals in fire-affected Hawaiian topsoil, J. Hazard. Toxic, Radioact. Waste 25 (1) (2021), https://doi.org/10.1061/(ASCE)HZ.2153-5515.0000567.
[751] N. Estoppey, J. Mathieu, E. Diez, E. Sapin, O. Delemont, P. Esseiva, L. Felippe de Alencastro, S. Coudret, P. Folly, Monitoring of explosive residues in lake-bottom water using Polar Organic Chemical Integrative Sampler (POCIS) and chemcatcher: determination of transfer kinetics through Polyethersulfone (PES) membrane is crucial, Environ. Pollut. 252 (A) (2019) 767–776, https://doi.org/10.1016/j.envpol.2019.04.087.
[752] W. Fawcett-Hirst, T.J. Temple, M.K. Ladyman, F. Coulon, A review of treatment methods for insensitive high explosive contaminated wastewater, Heliyon 7 (7) (2021), e07438, https://doi.org/10.1016/j.heliyon.2021.e07438.
[753] G. Jenness, S. Giles, M. Shukla, Thermodynamic adsorption states of TNT and DNAN on corundum and hematite, J. Phys. Chem. C 124 (25) (2020) 13837–13844, https://doi.org/10.1021/acs.jpcc.0c04512.
[754] A. Kalsi, S. Celin, J. Sharma, Aerobic biodegradation of high explosives hexahydro-1,3,5- trinitro-1,3,5-triazine by Janibacter cremeus isolated from contaminated soil, Biotechnol. Lett. (2020), https://doi.org/10.1007/s10529-020-02946-6.
[755] A. Kalsi, S. Celin, P. Bhanot, S. Sahai, J. Sharma, A novel egg shell-based bio formulation for remediation of RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) contaminated soil, J. Hazard Mater. 401 (2021), 123346, https://doi.org/10.1016/j.jhazmat.2020.123346.
[756] M. Khan, S. Yadav, R. Sharma, M. Dalela, S. Celin, A. Sharma, S. Sharma, Augmentation of stimulated Pelomonas aquatica dispersible granules enhances remediation of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) contaminated soil, Environ. Technol. Innovat. 17 (2020), 100594, https://doi.org/10.1016/j.eti.2019.100594.
[757] B. Khezri, K. Villa, F. Novotny, Z. Sofer, M. Pumera, Smart dust 3D-printed graphene-based Al/Ga robots for photocatalytic degradation of explosives, Small 16 (33) (2020), 2002111, https://doi.org/10.1002/smll.202002111.
[758] T. Klapotke, R. Scharf, J. Stierstorfer, C.C. Unger, Toxicity assessment of energetic materials by using the luminescent bacteria inhibition test, Propellants, Explos. Pyrotech. 46 (1) (2021) 114–123, https://doi.org/10.1002/prep.202000044.
[759] D. Koske, K. Straumer, N.I. Goldenstrin, R. Hanel, T. Lang, U. Kammann, First evidence of explosives and their degradation products in dab (Limanda limanda L.) from a munition dumpsite in the Baltic Sea, Mar. Pollut. Bull. 155 (2020), 111131, https://doi.org/10.1016/j.marpolbul.2020.111131.
[760] K. Lata, A. Kushwaha, G. Ramanathan, Bacterial enzymatic degradation and remediation of 2,4,6-trinitrotoluene, in: S. Das, H. Ranjan (Eds.), Microbial and Natural Macromolecules: Synthesis and Applications, 2021, pp. 623–659, https://doi.org/10.1016/B978-0-12-820084-1.00024-7.
[761] J. Lauf, W. Rusow, R. Zimmermann, Nitrogen Based Propellants as Substitute for Carbon Containing Fuels, NATO Energy Security Centra of Excellence, 2021. https://enseccoe.org/data/public/uploads/2021/04/nato-ensec-coe-nitrogen-based-propellants-as-substitute-for-carbon-containing-fuels-jutta-lauf-wsewolod-rusow-reiner-zimmermann.pdf.
[762] J. Li, Q. Zhou, M. Li, Y. Liu, Q. Song, Monodisperse amino-modified nanosized zero-valent iron for selective and recyclable removal of TNT: synthesis, characterization, and removal mechanism, J. Environ. Sci. 103 (2021) 69–79, https://doi.org/10.1016/j.jes.2020.10.009.
[763] X. Li, F. Zhang, C. Zeng, C. Li, Z. Zhang, H. Zheng, Y. Yang, An instant reused luminescent mixed matrix membrane sensor for convenient phenolic nitro-explosives detection, J. Photochem. Photobiol. Chem. 370 (2019) 51–57, https://doi.org/10.1016/j.jphotochem.2018.10.029.
[764] X. Liu, Y. Deng, C. Zhang, X. Bai, J. Li, Optimizing degradation conditions of treatment of TATB explosive wastewater by γ-Fe2O3 nanoparticles and UV synergistic degradation, Can. J. Chem. 99 (4) (2021) 362–367, https://doi.org/10.1139/cjc-2020-0278.
[765] G.R. Lotufo, K.A. Gust, M.L. Ballentine, L.C. Moores, A.J. Kennedy, N.D. Barker, Q. Ji, P. Chappenll, Comparative toxicology evaluation of uv-degraded versus parent-insensitive munition compound 1-Methyl-3-Nitroguanidine in fathead minnow, Environ. Toxicol. Chem. 39 (3) (2020) 612–622, https://doi.org/10.1002/etc.4647.
[766] C. Madeira, W. Kadoya, G. Li, S. Wong, R. Sierra-Alvarez, J. Field, Reductive biotransformation as a pretreatment to enhance in situ chemical oxidation of nitroaromatic and nitroheterocyclic explosives, Chemosphere 222 (2019) 1025–1032, https://doi.org/10.1016/j.chemosphere.2019.01.178.
[767] L. Madeira, A. Alemeida, M. Teixeira, A. Prazeres, H. Chaves, F. Carvalho, Immediate one-step lime precipitation and atmospheric carbonation as pre-treatment for low biodegradable and high nitrogen wastewaters: a case study of explosives industry, J. Environ. Chem. Eng. 8 (3) (2020), 103808, https://doi.org/10.1016/j.jece.2020.103808.
[768] L. Madeira, F. Carbalho, M.R. Teixeira, C. Ribeiro, A. Almeida, Vertical flow constructed wetland as a green solution for low biodegradable and high nitrogen wastewater: a case study of explosives industry, Chemosphere 272 (2021), 129871, https://doi.org/10.1016/j.chemosphere.2021.129871.
[769] S. Nagar, S. Anand, S. Chatterjee, C.D. Rawat, J. Lamba, P.K. Rai, A review of toxicity and biodegradation of octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) in the environment, Environ. Technol. Innovat. 23 (2021), 101750, https://doi.org/10.1016/j.eti.2021.101750.
[770] J. Nawala, M. Szala, D. Dziedzic, D. Gordon, B. Dawidziuk, J. Fabisiak, S. Popiel, Analysis of samples of explosives excavated from the Baltic Sea floor, Sci. Total Environ. 708 (2020), 135198, https://doi.org/10.1016/j.scitotenv.2019.135198.
[771] B. Nhi, Research on regeneration activated carbon in 2,4,6-Trinitrotoluene (TNT) explosives manufacturing industry by microwave radiation and ionized nitrogen, Propellants, Explos. Pyrotech. 46 (1) (2021) 7–12, https://doi.org/10.1002/prep.202000166.
[772] J. Niedzwiecka, K. McGee, K. Finneran, Combined biotic-abiotic 2,4-dinitroanisole (DNAN) degradation in the presence of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), Environ. Sci. Technol. 54 (17) (2020) 10638–10645, https://doi.org/10.1021/acs.est.0c02363.
[773] C.M. Oral, M. Ussia, M. Pumera, Self-propelled activated carbon micromotors for "one-the-fly" capture of nitroaromatic explosives, J. Phys. Chem. C 125 (32) (2021) 18040–18045, https://doi.org/10.1021/acs.jpcc.1c05136.
[774] A.A. Otaiku, A.I. Alhaji, Characterization of microbial species in the biodegradation of explosives, military shooting range, Kaduna, Nigeria, J. Appl. Biotechnol. Bioeng. 7 (3) (2020) 128–147, https://doi.org/10.15406/jabb.2020.07.00226.
[775] J. Qin, Y. Huang, M. Shi, H. Wang, M. Han, x. Yang, F. Li, L. Ma, Aqueous-phase detection of antibiotics and nitroaromatic explosives by an alkali-resistant Zn-MOF directed by an ionic liquid, RSC Adv. 10 (3) (2020) 1439–1446, https://doi.org/10.1039/C9RA08733H.
[776] J.D. Rindelaub, P.K. Davy, N. Talbot, W. Pattinson, G.M. Miskelly, The contribution of commercial fireworks to both local and person air quality in Auckland, New Zealand, Environ. Sci. Pollut. Control Ser. 28 (17) (2021) 21650–21660, https://doi.org/10.1007/s11356-020-11889-4.
[777] L. Shi, N. Li, D. Wang, M. Fan, S. Zhang, Z. Gong, Environmental pollution analysis based on the luminescent metal organic frameworks: a review, Trac. Trends Anal. Chem. 134 (2021), 116131, https://doi.org/10.1016/j.trac.2020.116131.
[778] Y. Shim, S. Ha, E. Yoo, H. Jang, A. Kim, S. Ramakrishnan, D. Yoo, Recovery of ammonium perchlorate from obsolete ammunition and its application in synthesis of lithium perchlorate, Propellants, Explos. Pyrotech. 46 (4) (2021) 612–617, https://doi.org/10.1002/prep.202000235.
[779] J.S. Strehse, M. Brenner, M. Kisiela, E. Maser, The explosive trinitrotoluene (TNT) induces gene expression of carbonyl reductase in the blue mussel (Mytilus spp.): a new promising biomarker for sea dumped war relicts, Arch. Toxicol. 94 (12) (2020) 4043–4054, https://doi.org/10.1007/s00204-020-02931-y.
[780] J.S. Strehse, M. Brenner, M. Kisiela, E. Maser, Correction to: the explosive trinitrotoluene (TNT) induces gene expression of carbonyl reductase in the blue mussel (Mytilus spp.): a new promising biomarker for sea dumped war relicts? Archiv. Toxciol. 95 (8) (2021) 2893, https://doi.org/10.1007/s00204-021-03088-y.

[781] H.M. Tauqeer, A. Karczewska, K. Lewinska, M. Fatima, S.A. Khan, M. Farhad, V. Turan, P.M.A. Ramzani, M. Iqbal, Environmental concerns associated with explosives (HMX, TNT, and RDX), heavy metals and metalloids from shooting range soils: prevailing issues, leading management practices, and future perspectives, in: M. Hasanuzzaman, M.N. Var Prasad (Eds.), Handbook of Bioremediation: Physiological, Molecular, and Biotechnological Interventions, Academic Press, 2021, pp. 569–590, https://doi.org/10.1016/B978-0-12-819382-2.00036-3.
[782] S. Via, Phytoremediation of explosives, in: B. Shmaefsky (Ed.), Phytoremediation: In-Situ Applications, Springer, 2020, pp. 261–284, https://doi.org/10.1007/978-3-030-00099-8_8.
[783] J. Warner, Enschede cries—restoring ontological security after a fireworks disaster, Int. J. Disaster Risk Reduc. 59 (2021), 102171, https://doi.org/10.1016/j.ijdrr.2021.102171.
[784] J. Yan, B. Jin, P. Zhao, R. Peng, Facile fabrication of BiOCl nanoplates with high exposure {001} facets for efficient photocatalytic degradation of nitro explosives, Inorg. Chem. Front. 8 (3) (2021) 777–786, https://doi.org/10.1039/D0QI01218A.
[785] X. Yang, J. Lai, Y. Zhang, X. Luo, M. Han, S. Zhao, Microbial community structure and metabolome profiling characteristics of soil contaminated by TNT, RDX, and HMX, Environ. Pollut. 285 (2021), 117478, https://doi.org/10.1016/j.envpol.2021.117478.
[786] Y. Ying, J. Plutnar, M. Pumera, Six-Degree-of-Freedom Steerable Visible-Light-Driven microsubmarines using water as a fuel: application for explosives decontamination, Small 17 (23) (2021), 2100294, https://doi.org/10.1002/smll.202100294.
[787] Y. Ying, A. Pourrahimi, C. Manzanares-Palenzuela, F. Novtny, Z. Sofer, M. Pumera, Light-driven ZnO brush-shaped self-propelled micromachines for nitroaromatic explosives decomposition, Small 16 (27) (2020), 1902944, https://doi.org/10.1002/smll.201902944.
[788] A.M. Zainullin, Increasing the environmental safety of the initiating explosives production, IOP Conf. Ser. Earth Environ. Sci. 815 (2021), 012005, https://doi.org/10.1088/1755-1315/815/1/012005.
[789] J. Zhao, B. Jin, R. Peng, New core-shell hybrid material IR-MOF3@COF-LZU1 for highly efficient visible-light photocatalyst degrading nitroaromatic explosives, Langmuir 36 (20) (2020) 5665–5670, https://doi.org/10.1021/acs.langmuir.9b03786.

Other (Safety, Definitions, Etc):

[790] M.H. Abraham, W.E. Acree, X. Liu, Descriptors for high-energy nitro compounds: estimation of thermodynamic, physicochemical and environmental properties, Propellants, Explos. Pyrotech. 46 (2) (2021) 267–279, https://doi.org/10.1002/prep.202000117.
[791] B. Aduev, D. Nurmukhametov, I. Liskov, A. Zvekov, RDX-Al and PETN-Al composites' glow spectral kinetics at the explosion initiated with laser pulse, Combust. Flame 223 (2021) 376–381, https://doi.org/10.1016/j.combustflame.2020.10.016.
[792] B.P. Aduev, D.R. Nurmukhametov, I.Y. Liskov, A.V. Tupitsyn, G.M. Belokurov, Laser pulse initiation of RDX-al and PETN-Al composites explosion, Combust. Flame 216 (2020) 468–471, https://doi.org/10.1016/j.combustflame.2019.10.037.
[793] M.V. Ageev, Y.N. Vedernikov, G.G. Zegrya, A.S. Mazur, U.M. Poberezhnaya, V. K. Popov, G.G. Savenkov, Properties of two and three-component explosive compositions based on porous silicon, Russ. J. Phys. Chem. B 15 (2) (2021) 259–265, https://doi.org/10.1134/S1990793121020020.
[794] S. Al-Hajj, H.R. Dhaini, S. Mondello, H. Kaafarani, F. Kobeissy, R.G. DePalma, Beirut ammonium nitrate blast: analysis, review, and recommendations, Front. Public Health 9 (2021), 657996, https://doi.org/10.3389/fpubh.2021.657996.
[795] F. Ali, B. Pingua, A. Dey, A. Roy, P. Singh, Surface functionalized ammonium nitrate prills with enhanced water resistance property: characterizations and its application as commercial explosives, Propellants, Explos. Pyrotech. 46 (1) (2021) 78–83, https://doi.org/10.1002/prep.202000158.
[796] M. Amaral, E. Hatten, A. Gibson, R. Morgan, The impact of force, time, and rotation on the transfer of ammonium nitrate: a reductionist approach to understanding evidence dynamics, Sci. Justice 62 (2) (2022) 129–136, https://doi.org/10.1016/j.scijus.2021.12.006.
[797] A. Anfinson, N. Al-Dayel, Landmines and improvised explosives devices: the lingering terror of the Islamic state, Stud. Conflict Terrorism (2020), https://doi.org/10.1080/1057610X.2020.1751998.
[798] Vytenis Babrauskas, Fire safety is the key to ammonium nitrate explosion safety, Process Saf. Prog. 39 (2020), https://doi.org/10.1002/prs.12200.
[799] Z. Bai, Z. Duan, X. Wang, F. Huang, A statistical hot spot reaction rate model for shock initiation of polymer-bonded explosives, Propellants, Explos. Pyrotech. 46 (11) (2021) 1723–1732, https://doi.org/10.1002/prep.202100106.
[800] Bai, Z., Duan, Z., Wen, L., Zhang, Z., Ou, Z., & Huang, F. (2019). Comparative analysis of detonation growth characteristics between HMX- and TATB-based PBXs. Propellants, Explos. Pyrotech.,44(7) , 858-869. https://doi.org/10.1002/prep.201800390.
[801] Bai, Z., Duan, Z., Wen, L., Zhang, Z., Ou, Z., & Huang, F. Shock initiation of multi-component insensitive PBX explosives: experiments and MC-DZK mesoscopic reaction rate model. J. Hazard Mater., 369, 62-69. https://doi.org/10.1016/j.jhazmat.2019.02.028.
[802] I.A. Balagansky, A.A. Bataev, I.A. Bataev, Explosion Systems with Inert High-Modulus Components: Increasing the Efficiency of Blast Technologies and Their Applications, Wiley, 2019.
[803] G. Baldino, C. Stassi, C. Mondello, A. Bottari, S. Vanin, E.V. Spagnolo, Forensic investigative issues in a fireworks production factory explosion, Int. J. Leg. Med. 135 (4) (2021) 1647–1654, https://doi.org/10.1007/s00414-021-02564-5.
[804] R. Bari, A.A. Denton, Z.T. Fondren, G.B. McKenna, S.L. Simon, Acceleration of decomposition of CL-20 explosive under nanoconfinement, J. Therm. Anal. Calorim. 140 (6) (2020) 2649–2655, https://doi.org/10.1007/s10973-019-09027-5.
[805] B. Barnes, K. Leiter, J. Larentzos, J. Brennan, Forging of hierarchical multiscale capabilities for simulation of energetic materials, Propellants, Explos. Pyrotech. 45 (2) (2020) 177–195, https://doi.org/10.1002/prep.201900187.
[806] O. Bedair, Review of blast analysis and design for industrial/residential buildings and ammunition storage facilities, Multidiscip. Model. Mater. Struct. 17 (2) (2021) 437–450, https://doi.org/10.1108/MMMS-03-2020-0052.
[807] Y. Borisov, A. Makarenkov, S. Kiselev, E. Kononova, A. Ponomaryov, M. Budnik, V. Ol'shevkaya, Prediction of energetic properties of carboranyl tetrazoles based on DFT study, Mater. Chem. Phys. 240 (2020), 122209, https://doi.org/10.1016/j.matchemphys.2019.122209.
[808] M.K. Boulkadid, M.H. Lefebvre, L. Leunieau, A. Dejeaifve, Burning rate of artificially aged solid double-base gun propellants, J. Energetic Mater. 38 (1) (2020) 1–19, https://doi.org/10.1080/07370652.2019.1657204.
[809] R. Bouma, T. Griffiths, I. Tuukkanen, The development of a future chemical compatibility standard for energetic materials, Thermochim. Acta 676 (2019) 13–19, https://doi.org/10.1016/j.tca.2019.03.012.
[810] C. Cao, W. Chen, W. Jhang, Y. Chung, L. Wei-Cheng, Thermal decomposition and evaluation thermokinetic parameters for explosive type, J. Therm. Anal. Calorim. 144 (2) (2021) 443–454, https://doi.org/10.1007/s10973-020-10475-7.
[811] W. Cao, W. Guo, T. Ding, Y. Han, M. Li, D. Gao, X. Guo, Laser ablation of aluminized RDX with added ammonium perchloreate or ammonium perchlorate/boron/magnesium hydride, Combust. Flame 221 (2020) 194–200, https://doi.org/10.1016/j.combustflame.2020.07.045.
[812] M.J. Cawkwell, V.W. Manner, Ranking the drop-weight impact sensitivity of common explosives using Arrhenius chemical rates computed from quantum molecular dynamics simulations, J. Phys. Chem. A 124 (1) (2020) 74–81, https://doi.org/10.1021/acs.jpca.9b10808.
[813] S. Cazares, J.A. Snyder, J. Cartier, F. Sallis-Peterson, J. Fregeau, A Monte Carlo tradeoff analysis to guide resource investment in threat detection systems: from forensic to prospective investigations, J. Defense Model. Simulat. Appl. Methodol. Technol. 16 (3) (2019) 297–320, https://doi.org/10.1177/1548512917694966.
[814] A. Chafin, J. Bottaro, K. Rosenkoetter, The evaluation of secondary amine protecting group of nitration, Propellants, Explos. Pyrotech. 44 (10) (2019) 1226–1232, https://doi.org/10.1002/prep.201900115.
[815] N. Chandrasekaran, C. Oommen, V. Kumar, A. Lukin, V. Abrokov, D. Anufrieva, Prediction of detonation velocity of N-O composition of high energy C-H-N-O explosives by means of artificial neural networks, Propellants, Explos. Pyrotech. 44 (5) (2019) 579–587, https://doi.org/10.1002/prep.201800325.
[816] J. Chen, D. Feng, G. Wang, F. Gao, C. Peng, Numerical simulation of detonation and Brisance performance of aluminized HMX using density-adaptive SPH, Propellants, Explos. Pyrotech. 46 (12) (2021) 1800–1814, https://doi.org/10.1002/prep.202100214.
[817] J. Chen, T. Yan, C. Wang, R. Gao, S. Xu, G. Fan, W. Zhao, Y. Liu, The photostability and degradation pathways of TKX-50 as a representative of nitrogen-rich energetic salts in aqueous solution, J. Photochem. Photobiol. Chem. 411 (2021), 113178, https://doi.org/10.1016/j.jphotochem.2021.113178.
[818] X. Chen, Z. Wang, Y. Liu, A whole explosive dispersion process prediction model for fuel clouds, Propellants, Explos. Pyrotech. 45 (6) (2020) 950–965, https://doi.org/10.1002/prep.201900318.
[819] M. Chiquito, R. Castedo, L. Lopez, A. Santos, J. Mancilla, J. Yenes, Blast wave characteristics and TNT equivalent of improvised explosive device at small-scaled distances, Defence Sci. J. 69 (4) (2019) 328–335. https://www.doi/org/10.14429/dsj.69.13637.
[820] M. Chouai, M. Mustefa, M. Mimi, CH-Net: deep adversarial autoencoders for semantic segmentation in X-ray images of cabin baggage screening at airports, J. Transport. Secur. 13 (1) (2020) 71–89. https://www.doi/org/10.1007/s12198-020-00211-5.
[821] G. Collett, M. Ladyman, R. Hazael, T. Temple, The use of a predictive threat analysis to propose revisions to exist risk assessments for precursor chemicals used in the manufacture of home-made explosives (HME), Heliyon 7 (12) (2021), e08343, https://doi.org/10.1016/j.heliyon.2021.e08343.
[822] S.A. Coronel, M.J. Kaneshige, Response of PETN detonators to elevated temperatures, Proc. Combust. Inst. 38 (3) (2021) 4271–4279, https://doi.org/10.1016/j.proci.2020.06.265.
[823] R. Crocombe, The future of portable spectroscopy, Spectroscopy 35 (7) (2020, July) 12–14. https://www.spectroscopyonline.com/view/future-portable-spectroscopy.
[824] A. Cuesta, O. Abreu, A. Balboa, D. Alvear, A new approach to protect soft-targets from terrorist attacks, Saf. Sci. 120 (2019) 877–885, https://doi.org/10.1016/j.ssci.2019.08.019.
[825] L. da Saliva, S. Johnson, R. Critchley, J. Clements, K. Norris, C. Stennett, Experimental fragmentation of pipe bombs with varying case thickness, Forensic Sci. Int. (2019), https://doi.org/10.1016/j.forsciint.2019.110034.
[826] A. Dandekar, Z. Roberts, S. Paulson, W. Chen, S. Son, M. Koslowski, The effect of the particle surface and binder properties on the response of polymer bonded explosives at low impact velocities, Comput. Mater. Sci. 166 (2019) 170–178, https://doi.org/10.1016/j.commatsci.2019.04.033.
[827] H. Deng, L. Wang, D. Tang, Y. Zhang, Y. Zhang, L. Zhang, Review on the laser-induced performance of photothermal materials for ignition application, Energ.

Mater. Front. 2 (3) (2021) 201–217, https://doi.org/10.1016/j.enmf.2021.08.001.
[828] E. Denis, K. Morrison, S. Wharton, S. Phillips, S. Myers, M. Foxe, R. Ewing, Trace explosive residue detection of HMX and RDX in post-detonation dust from an open-air environment, Talanta 227 (2021), 122124, https://doi.org/10.1016/j.talanta.2021.122124.
[829] J.M. Dewey, Studies of the TNT equivalence of propane, propane/oxygen, and ANFO, Shock Waves 30 (5) (2020) 483–489, https://doi.org/10.1007/s00193-020-00949-w.
[830] J.M. Dewey, The TNT and ANFO equivalences of the Beirut explosion, Shock Waves 31 (1) (2021) 95–99, https://doi.org/10.1007/s00193-021-00992-1.
[831] I. Edri, H. Grisaro, D. Yankelevsky, TNT equivalency in an internal explosion event, J. Hazard Mater. 374 (2019) 248–257, https://doi.org/10.1016/j.jhazmat.2019.04.043.
[832] M. El Sayed, Beirut ammonium nitrate explosion: a man-made disaster in times of COVID-19 Pandemic, Disaster Med. Public Health Prep. (2020), https://doi.org/10.1017/dmp.2020.451.
[833] J. Essel, A. Nelson, L. Smilowitz, B. Henson, L. Merriman, D. Turnbaugh, K. Shermer, Investigating the effect of chemical ingredient modifications on the slow cook-off violence of ammonium perchlorate solid propellants on the laboratory scale, J. Energetic Mater. (2019), https://doi.org/10.1080/07370652.2019.1672831.
[834] K. Evans-Nguyen, Forensic Chem. Am. Chem. Soc. (2021), https://doi.org/10.1021/acsinfocus.7e5009.
[835] X. Fan, L. Zhang, X. Wang, Study on theoretical calculation of quasi-static pressure for aluminized explosive in confined space, J. Phys. Conf. 1721 (2021), 012023, https://doi.org/10.1088/1742-6596/1721/1/012023.
[836] Z. Fan, L. Fan, R. Ma, Forensic fingerprint intelligence analysis: technology status and prospect, Forensic Sci. Technol. 45 (5) (2020) 441–447, https://doi.org/10.16467/j.1008-3650.2020.05.001.
[837] L. Figuli, Z. Kubikova, M. Ivanco, Safety assessment and blast protection of select soft target, Interdiscip. Descr. Complex Syst. 17 (1-A) (2019) 58–66, https://doi.org/10.7906/indecs.17.1.8.
[838] J. Foltynski, N. Al-Shebah, L. Moy, Slow heating testing of high density polyethylene foam dunnage for 40-mm M431A1 grenade packaging (Technical Report ARESI-TR-19002). U.S. Army Combat Capabilities Development Command Armaments Center. https://apps.dtic.mil/sti/pdfs/AD1127907.pdf, 2021.
[839] T. Forbes, G. Gillen, DART-MS spectral similarity of infrared thermally desorbed solid particulate and solution cast propellant samples, J. Am. Soc. Mass Spectrom. 32 (4) (2021) 1033–1040, https://doi.org/10.1021/jasms.1c00015.
[840] D. Frem, Estimating the Metal Acceleration Ability of High Explosives, Defence Technology, 2019, https://doi.org/10.1016/j.dt.2019.07.002.
[841] D. Freudenmann, H. Ciezki, ADN and HAN-based monopropellants – a mini review on compatibility and chemical stability in aqueous media, Propellants, Explos. Pyrotech. 44 (9) (2019) 1084–1089, https://doi.org/10.1002/prep.201900127.
[842] D. Frost, J. Clemenson, S. Goroshin, F. Zhang, M. Soo, Thermocuple temperature measurements in metalized explosive fireballs, Propellants, Explos. Pyrotech. 46 (6) (2021) 899–911, https://doi.org/10.1002/prep.202000328.
[843] H. Gao, F. Chen, R. Cai, S. Ye, F. Tan, W. Xiong, Y. Yi, W. Hu, The diffusion of components from propellant and linear at the interfaces of EPDM insulation, Propellants, Explos. Pyrotech. 46 (3) (2021) 460–467, https://doi.org/10.1002/prep.202000270.
[844] B.C. Giordano, L.E. DeGreeff, M. Malito, M. Hammond, C. Katiillie, M. Mullen, G. E. Collins, S.L. Rose-Pehrsson, Trace vapor generator for explosives and narcotics (TV-Gen), Rev. Sci. Instrum. 91 (8) (2020), 085112, https://doi.org/10.1063/1.5142385.
[845] M. Gonsalves, Making Energetic Materials Safe (Publication No. 28255637), PhD. University of Rhode Island, 2020.
[846] M. Gonsalves, J. Smith, J. OxLey, Characterization of encapsulated energetic materials for trace explosives aids for scent (TEAS), J. Energetic Mater. (2021), https://doi.org/10.1080/07370652.2020.1867937.
[847] M.S. Gruhne, M. Lonnel, M.H.H. Wurzenberger, N. Szimhardt, T.M. Klapotke, J. Stierstorfer, OZM ball drop impact tester (BIT-132) vs. BAM standard method-a comparative investigation, Propellants, Explos. Pyrotech. 45 (1) (2020) 147–153, https://doi.org/10.1002/prep.201900286.
[848] I. Gunduz, Microscopic imaging and optical pressure measurements of detonations, Propellants, Explos. Pyrotech. 46 (9) (2021) 1378–1387, https://doi.org/10.1002/prep.202000337.
[849] B.W. Hamilton, B.A. Steele, M.N. Sakano, M.P. Kroonblawd, I.W. Kuo, A. Strachan, Predicted reaction mechanisms, product speciation, kinetics, and detonation properties of the insensitive explosive2,6-Diamino-3,5-dinitropyrazine-1-oxide (LLM-105), J. Phys. Chem. A 125 (8) (2021) 1766–1777, https://doi.org/10.1021/acs.jpca.0c10946.
[850] M. Hariri, K. Ghani, S. Damiri, Purification of 2,4,6-trinitrotoluene by digestion with sodium sulfite and determination of its impurities by gas chromatography–electron capture detector (GC-ECD), J. Iran. Chem. Soc. 16 (11) (2019) 2401–2408, https://doi.org/10.1007/s13738-019-01709-z.
[851] H. Harris, H. Lee, Arson and explosives, in: H.A. Harris, H.C. Lee (Eds.), Introduction to Forensic Science and Criminalistics, second ed., CRC Press, 2019, pp. 289–325, https://doi.org/10.4324/9781315119175.
[852] Z. He, W. Weng, Synergic effects in the assessment of multi-hazard coupling disasters: fires, explosions, and toxicant leaks, J. Hazard Mater. 388 (2020), 121813, https://doi.org/10.1016/j.jhazmat.2019.121813.
[853] Z. He, Y. Huang, G. Ji, J. Chen, Q. Wu, Electron properties and thermal decomposition behaviors for HMX/HTPB plastic-bonded explosives, J. Phys. Chem. C 123 (39) (2019) 23791–23799, https://doi.org/10.1021/acs.jpcc.9b04759.
[854] D. Herrmannsdorfer, T.M. Klaptke, High-precision density measurements of energetic materials for quality assessment, Propellants, Explos. Pyrotech. 46 (3) (2021) 413–427, https://doi.org/10.1002/prep.202000272.
[855] M. Hobbs, J. Brown, M. Kaneschige, C. Sviles-Ramos, A micromechanics pressurization model for cookoff, Propellants, Explos. Pyrotech. 47 (2) (2022), e202100155, https://doi.org/10.1002/prep.202100155.
[856] M. Hobbs, J. Brown, M. Kaneshige, C. Aviles-Ramos, Cookoff of powdered and pressed explosives using a micromechanics pressurization model, Propellants, Explos. Pyrotech. 47 (2) (2022), e202100156, https://doi.org/10.1002/prep.202100156.
[857] M. Hobbs, M. Kaneshige, W. Erikson, J. Brown, M. Anderson, S. Todd, D. Moore, Cookoff experiments of a melt cast explosive (Comp-B3), Combust. Flame 213 (2020) 268–278, https://doi.org/10.1016/j.combustflame.2019.12.004.
[858] Q. Huang, X. Liu, Y. Xiao, L. Luo, G. Luo, B. Jin, R. Peng, S. Chu, Isothermal thermal decomposition of the HMX-based PBX explosive JOL-1, J. Energetic Mater. (2020), https://doi.org/10.1080/07370652.2020.1737988.
[859] D. Huegli, S. Merks, A. Schwainger, Automation reliability, human–machine system performance, and operator compliance: a study with airport security screeners supported by automated explosives detection systems for cabin baggage screening, Appl. Ergon. 86 (2020), 103094, https://doi.org/10.1016/j.apergo.2020.103094.
[860] E. Ioannou, N. Nikiforakis, Multiphysics modeling of the initiating capability of detonators. I. The underwater test, J. Appl. Phys. 129 (2) (2021), 025902, https://doi.org/10.1063/5.0030478.
[861] E. Ioannou, Numerical Study of Detonation in Solid Explosives under Hydrodynamic and Elastic-Plastic Confinement, PhD, University of Cambridge, 2019, https://www.repository.cam.ac.uk/handle/1810/296704.
[862] D.G. Itkis, M.A. Bohn, Simulation of heat flow curves of NC-based propellants-part 1: determination of reaction enthalpies and other characteristics of the reactions of NC and stabilizer DPA using quantum mechanical methods, Propellants, Explos. Pyrotech. 46 (8) (2021) 1188–1203, https://doi.org/10.1002/prep.202000314.
[863] D.G. Itkis, M.A. Bohn, Simulation of heat flow curves of NC-based propellants-part 2: application of DPA stabilized propellants, Propellants, Explos. Pyrotech. 46 (8) (2021) 1204–1215, https://doi.org/10.1002/prep.202000313.
[864] J. James, Explosives Experimentation: a Holistic View of Fireballs: infrared Spectroscopy Facilitates the Acquisition of Continuous Chemical Data from Explosions, Analytical Scientist, 2019. https://theanalyticalscientist.com/fields-applications/under-fire-explosive-experimentation.
[865] F. Jiang, X. Wang, Y. Huang, B. Feng, X. Tian, Y. Niu, K. Zhang, Effect of particle gradation of aluminum on the explosion field pressure and temperature of RDX-based explosives in vacuum and air atmosphere, Defence Technol. 15 (6) (2019) 844–852, https://doi.org/10.1016/j.dt.2019.06.007.
[866] G. Kang, Y. Ning, P. Chen, K. Ni, Meso-structure construction and effective modulus simulation of PBXs, J. Energetic Mater. (2019), https://doi.org/10.1080/07370652.2019.1684594.
[867] N. Kerschen, J. Drake, C. Sorensen, Z. Guo, J. Mares, K. Fezzaa, T. Sun, S. Son, W. Chen, X-ray phase contrast imaging of the impact of the multiple HMX particles in a polymeric matrix, Propellants, Explos. Pyrotech. 45 (4) (2020) 607–614, https://doi.org/10.1002/prep.201900217.
[868] E. Kim, D. Hong, M. Han, S. Moon, Desensitization of high explosives by encapsulation in metal-organic frameworks, Chem. Eng. J. 407 (2021), 127882, https://doi.org/10.1016/j.cej.2020.127882.
[869] C. Knox, D. Linskey, J. Tyler, Preparing officers to build a culture of preparedness: a case study of the Boston Marathon Bombings, in: M. Landahl, T. Thornton (Eds.), The Role of Law Enforcement in Emergency Management and Homeland Security, Emerald Publishing, 2021, pp. 203–215, https://doi.org/10.1108/S2040-726220210000024011.
[870] E. Koch, High Explosives, Propellants, Pyrotechnics, De Gruyter, 2021.
[871] M. Kohga, D. Shigi, M. Beppu, Detonation properties of ammonium nitrate/nitramine-based composite propellants, J. Energetic Mater. 37 (3) (2019) 309–319, https://doi.org/10.1080/07370652.2019.1607921.
[872] S. Konar, A. Michalchuk, N. Sen, C. Bull, C. Morrison, C. Pulham, High-pressure study of two polymorphs of 2,4,6-Trinitrotoluene using neutron powder diffraction and density functional theory methods, J. Phys. Chem. C 123 (43) (2019) 26095–26105, https://doi.org/10.1021/acs.jpcc.9b07658.
[873] O. Kudryashova, A. Pavlenko, S. Titov, A. Vorozhtsov, A mathematical model for evaporation of explosive thin film, J. Energetic Mater. (2020), https://doi.org/10.1080/07370652.2020.1806947.
[874] K. Lee, A. Hernandez, D. Stewart, Well-posed equations of states for condensed-phase explosives, Propellants, Explos. Pyrotech. (2019), https://doi.org/10.1002/prep.201900121.
[875] D. Lewis, J. Padfield, S. Connors, I. Wilson, J. Akhavan, Further insights into the discoloration of TATB under ionizing radiation, J. Energetic Mater. 38 (3) (2020) 362–376, https://doi.org/10.1080/07370652.2020.1716109.
[876] S. Li, J. Xu, Y. Liu, Characterization of interfacial micro-structures of explosive-binder composites by gas permeation, Propellants, Explos. Pyrotech. 44 (9) (2019) 1160–1166, https://doi.org/10.1002/prep.201900050.
[877] Z. Li, Y. Sun, L. Xu, N. Zhang, J. Liu, H. Wang, Q. Zhao, Explosion scene forensic image interpretation, J. Forensic Sci. 64 (4) (2019) 1221–1229, https://doi.org/10.1111/1556-4029.13996.

[878] Z. Liang, B. Chen, Y. Nan, J. Jiang, L. Ding, Research on the computing method for the forming velocity of circumferential multiple explosive formed projectiles, J. Defense Model. Simulat.: Appl. Methodol. Technol. 17 (2) (2020) 125–136, https://doi.org/10.1177/1548512919833187.
[879] H. Lin, Q. Zhu, C. Huang, D. Yang, N. Lou, S. Zhu, H. Li, Dinitromethyl, fluorodinitromethyl derivatives of RDX and HMX as high energy density materials: a computational study, Struct. Chem. 30 (6) (2019) 2401–2408, https://doi.org/10.1007/s11224-019-01366-1.
[880] J. Liu, C. He, R. Zhang, H. Zhao, Q. Wang, Study on a method to determine the transverse impact strength of propellants based on impact absorbing energy, Propellants, Explos. Pyrotech. 46 (11) (2021) 1645–1652, https://doi.org/10.1002/prep.202100084.
[881] K. Liu, M. Wang, M. Xu, Z. Meng, H. Chang, G. Zhang, Z. Chen, L. Zhang, Determination of the component mass ratio and moisture in BTTN/NG nitrate ester mixture simultaneously by qNMR and method validation, Microchem. J. 152 (2020), 104337, https://doi.org/10.1016/j.microc.2019.104337.
[882] Y. Liu, J. Yin, Z. Wang, Study on overdriven detonation of double-layer shaped charge, Propellants, Explos. Pyrotech. 44 (11) (2019) 1410–1422, https://doi.org/10.1002/prep.201900105.
[883] R. Lodes, H. Krier, N. Glumac, Spectrally- and temporally-resolved optical depth measurements in high explosive post-detonation fireballs, Propellants, Explos. Pyrotech. 45 (3) (2020) 406–415, https://doi.org/10.1002/prep.201900225.
[884] C. Lopez-Munoz, F. Velasco, J. Carcia-Cascales, R. Mur, R. Oton-Martinez, Validation of a multi-dimensional model for unsteady combustion of AP/HTPB propellants, Propellants, Explos. Pyrotech. 44 (11) (2019) 1482–1493, https://doi.org/10.1002/prep.201900032.
[885] E. Lozano, G.S. Jackson, V. Petr, An Eulerian multimaterial framework for simulating high-explosive aquarium tests, Comput. Fluids 205 (2020), 104524, https://doi.org/10.1016/j.compfluid.2020.104524.
[886] K. Lv, K. Yang, B. Zhou, F. Zhang, J. Guo, C. Han, Y. Tian, The densification and mechanical behaviors of large-diameter polymer-bonded explosives processed by ultrasonic-assisted powder compaction, Mater. Des. 207 (2021), 109872, https://doi.org/10.1016/j.matdes.2021.109872.
[887] V. Manner, C. Tiemann, J. Yeager, L. Kay, N. Lease, M. Cawkwell, G. Brown, S. Anthony, D. Montanari, Examining explosives handling sensitivity of trinitrotoluene (TNT) with different particle sizes, AIP Conf. Proc. 2272 (2020), https://doi.org/10.1063/12.0001125, 050015.
[888] J.O. Mares, Z.A. Roberts, I.E. Gunduz, N.D. Parab, T. Sun, K. Fezzaa, W.W. Chen, J.F. Son, J.F. Rhoads, In-situ X-ray observations of ultrasound-induced explosive decomposition, Appl. Mater. Today 15 (2019) 286–294, https://doi.org/10.1016/j.apmt.2019.01.009.
[889] N. Marks, M. Stewart, M. Netherton, C. Stirling, Airblast variability and fatality risks from a VBIED in a complex urban environment, Reliab. Eng. Syst. Saf. 209 (2021), 107459, https://doi.org/10.1016/j.ress.2021.107459.
[890] J. Meng, C. Wang, M. Cheng, S. Zhang, R. Gou, Y. Chen, Y. Li, The thermal decomposition behavior of the TNT-RDX-Al explosive by molecular kinetic simulation, Int. J. Quant. Chem. 121 (11) (2021), e26635, https://doi.org/10.1002/qua.26635.
[891] C. Miller, D. Kittell, C. Yarrington, M. Zhou, Prediction of probabilistic detonation threshold via millimeter-scale microstructure-explicit and void-explicit simulation, Propellants, Explos. Pyrotech. 45 (2) (2020) 254–269, https://doi.org/10.1002/prep.201900214.
[892] S.B. Mishra, S. Marutheeswaran, S.C. Roy, V. Natarajan, P.K. Rai, B.R.K. Nanda, Adsorption and degradation mechanism of 2,4,6-trinitrotoluene on TiO2 (110) surface, Surf. Sci. 713 (2021), 121902, https://doi.org/10.1016/j.susc.2021.121902.
[893] T. Moorthy, M. Baskaran, Suicide bombing in a money lending shop—a rare non-terrorist explosion scene report, Indian J. Forensic Med. Toxicol. 15 (2) (2021) 1138–1141.
[894] G.M. Nazin, B.L. Korsunskiy, Determination of the thermal stability of explosives, Russ. J. Phys. Chem. B 15 (2) (2021) 271–277, https://doi.org/10.1134/S1990793121020093.
[895] C. Nell, P. Sable, Short pulse initiation of an RDX-based explosive using large diameter flyer-plate impacts, Propellants, Explos. Pyrotech. 45 (12) (2020) 1894–1897, https://doi.org/10.1002/prep.202000089.
[896] T. Nguyen, Switchable compound for safer explosives, C&EN Global Enterprise 98 (8) (2020) 9–10. https://pubs.acs.org/doi/10.1021/cen-09808-scicon7.
[897] I. Oluwoye, S. Mosallanejad, G. Soubans, M. Altarawneh, J. Gore, B. Dlugogorski, Thermal decomposition of ammonium nitrate on rust surface: risk of low-temperature fire, Fire Saf. J. 120 (2021), 103062, https://doi.org/10.1016/j.firesaf.2020.103063.
[898] T. Owolabi, Determination of the velocity of detonation of primary explosives using genetically optimized support vector regressions, Propellants, Explos. Pyrotech. 44 (10) (2019) 1282–1292, https://doi.org/10.1002/prep.201900077.
[899] H.J. Pasman, C. Fouchier, S. Park, N. Quddus, D. Laboureur, Beirut ammonium nitrate explosion: are not we really learning anything? Process Saf. Prog. 39 (4) (2020), e12203 https://doi.org/10.1002/prs.12203.
[900] G. Pfister, J. Murison, A. Grosset, A. Duhoux, E. Lapeyre, B. Bauer, L. Mathieu, Blast injury of the hand related to warfare explosive devices: experience from the French Military Health Service, BMJ Mil. Health (2020), https://doi.org/10.1136/jramc-2019-001326.
[901] M.C. Phillips, B.E. Bernacki, S.S. Harilal, B.E. Brumfield, J.M. Schwallier, N. G. Glumac, Characterization of high-explosive detonations using broadband infrared external cavity quantum cascade laser absorption spectroscopy, J. Appl. Phys. 126 (9) (2019), 093102, https://doi.org/10.1063/1.5107508.
[902] H. Pouretedal, S. Damiri, A. Sharifi, Study of triplet kinetic of thermal decomposition reaction and sensitivity to impact and electrostatic discharge of HMX polymorphs, J. Therm. Anal. Calorim. 139 (3) (2020) 545–553, https://doi.org/10.1007/s10973-019-08411-5.
[903] D.B. Powers, E.D. Rodriguez, Characteristics of ballistic and blast injuries, in: A. H. Dorafashar, E.D. Rodriguez, P.N. Manson (Eds.), Facial Trauma Surgery: from Primary Repair to Reconstruction, 2020, pp. 261–272, https://doi.org/10.1016/B978-0-323-49755-8.00028-1.
[904] T. Prescott, Accidental sulfur mustard exposure from explosive ordnance in a UK military service person, BMJ Mil. Health 167 (4) (2021) 287–288, https://doi.org/10.1136/bmjmilitary-2020-001687.
[905] H. Qin, M. Stewart, Casualty risks induced by primary fragmentation hazards from high-explosive munitions, Reliab. Eng. Syst. Saf. 215 (2021), 107874, https://doi.org/10.1016/j.ress.2021.107874.
[906] J. Quaresma, L. Deimling, J. Campos, R. Mendes, Active and passive optical metrology for detonation velocity measurements, Propellants, Explos. Pyrotech. 45 (6) (2020) 921–931, https://doi.org/10.1002/prep.201900197.
[907] K. Ramamurthi, in: Modeling Explosions and Blast Waves, third ed., Springer, 2021. https://link.springer.com/book/10.1007/978-3-030-74338-3.
[908] E. Reinke, *Human Cell Line Activation Test of the Novel Energetic N,N'- Bis(4 Nitro 1,2,5 Oxadiazol 3 Yl)-Methanediamine (MBANF) February-March 2020,* (Toxicity Study No. 0070548-19), U.S. Army Public Health Center, 2020. https://apps.dtic.mil/sti/citations/AD1099566.
[909] R. Rettinger, M. Porter, J. Canaria, J. Smith, J. Oxley, Fuel-oxidizer mixtures: a lab and field study, J. Energetic Mater. 38 (2) (2020) 170–190, https://doi.org/10.1080/07370652.2019.1679282.
[910] S. Rigby, C. Osborne, G. Langdon, S. Cooke, D. Pope, Spherical equivalence of cylindrical explosives: effect of charge shape on deflection of blast-loaded plates, Int. J. Impact Eng. 155 (2021), 103892, https://doi.org/10.1016/j.ijimpeng.2021.103892.
[911] I. Rubtsov, K. Ten, E. Pruuel, A. Kashkarov, S. Kremenko, M. Voronin, B. Tolochko, Methods to restore the dynamics of carbon condensation during the detonation of high explosives, J. Phys. Conf. 1147 (1) (2019), https://doi.org/10.1088/1742-6596/1147/1/012038, 012038.
[912] T. Rudisill, K. Preamble, C. Pilkerton, The liberalization of fireworks legislation and its effects on firework-related injuries in West Virginia, BMC Publ. Health 20 (1) (2020) 137, https://doi.org/10.1186/s12889-020-8249-0.
[913] L. Safatly, M. Baydoun, Alipour, A. Al-Takach, K. Atab, M. Al-Husseini, A. El-Hajj, H. Ghaziri, Detection and classification of landmines using machine learning applied to metal detector data, J. Exp. Theor. Artif. Intell. 33 (2) (2021) 203–226, https://doi.org/10.1080/0952813X.2020.1735529.
[914] M. Santaspirt, Improvised Explosive Devices: Assessing the Global Risk for Use in Terrorism, Doctoral dissertation, Rutgers University, 2020, https://rucore.libraries.rutgers.edu/rutgers-lib/64147/.
[915] N.P. Satonkina, Influence of the grain size of high explosives on the duration of a high conductivity zone at the detonation, Sci. Rep. 9 (2019), 12256, https://doi.org/10.1038/s41598-019-48807-9.
[916] A. Schmid (Ed.), Handbook of Terrorism Prevention and Preparedness, ICCT Press, 2020. https://icct.nl/handbook-of-terrorism-prevention-and-preparedness.
[917] Y. Sha, X. Zhang, Impact sensitivity and moisture adsorption on the surface of CL-20/TNT cocrystal by molecular dynamics simulation, Appl. Surf. Sci. 483 (2019) 91–97, https://doi.org/10.1016/j.apsusc.2019.03.231.
[918] J. Shi, P. Zhu, S. Zhao, C. Xu, F. Yan, R. Shen, H. Xia, H. Jiang, S. Xu, F. Zhao, Continuous spheroidization strategy for explosives with micro/nano hierarchical structure by coupling microfluidics and spray drying, Chem. Eng. J. 412 (2021), 128613, https://doi.org/10.1016/j.cej.2021.128613.
[919] Q. Shi, B. Chen, C. Nie, Z. Zhao, J. Zhang, S. Si, S. Cui, J. Gu, A novel model of blast induced traumatic brain injury caused by compressed gas produced sustained cognitive deficits in rats: involvement of phosphorylation of tau at the Thr205 epitope, Brian Res. Bull. 157 (2020) 149–161, https://doi.org/10.1016/j.brainresbull.2020.02.002.
[920] M. Short, E.K. Anderson, C. Chiquete, S.I. Jackson, Experimental and modeling analysis of detonation in circular arcs of the conventional high explosive PBX 9501, Proc. Combust. Inst. 38 (3) (2021) 3683–3690, https://doi.org/10.1016/j.proci.2020.07.107.
[921] V. Siditskii, A. Smirnova, T. Vu, S. Filatov, V. Serushkin, G. Rudakov, Thermal decomposition of 1,3,5,5-Tetranitrohexahydro-Pyrimidine: a new type of autocatalysis that persists at high temperatures, Propellants, Explos. Pyrotech. 46 (1) (2021) 150–158, https://doi.org/10.1002/prep.202000259.
[922] P. Sieloicki, M. Stewart, T. Gajewski, M. Malendowski, P. Peksa, H. Al-Rifaie, R. Studzinski, W. Sumelka, Field test and probabilistic analysis of irregular steel debris casualty risks from a person-borne improvised explosive device, Defence Technol. 17 (6) (2020) 1852–1963, https://doi.org/10.1016/j.dt.2020.10.009.
[923] S. Sivaraman, S. Varadharajan, Investigative consequence analysis: a case study research of beirut explosion accident, J. Loss Prev. Process. Ind. 69 (2021), 104387, https://doi.org/10.1016/j.jlp.2020.104387.
[924] B. Sreekanth, S. Anand, V.R. Ikkurthi, P. Chaudhury, B. Sapra, Y.S. Mayya, S. Chaturvedi, Evolution of particle metric in a buoyant aerosol cloud from explosive release, Aerosol Sci. Technol. 54 (6) (2020) 656–667, https://doi.org/10.1080/02786826.2020.1723788.
[925] K. Stauffer, C. Mestre, Long-term risk management tools for protocols for residual explosive ordnance mitigation: a pretest in Vietnam, J. Conventional Weapons Destruction 23 (3) (2020) 18–21. https://commons.lib.jmu.edu/cisr-journal/vol23/iss3.

[926] A. Sudhakar, The Behavior of sUASs under Explosive Loading Conditions and Implications for Safe Operating Procedures (Publication No. 27547442), Doctoral Dissertation, Missouri University of Science and Technology, 2019.
[927] Y. Sugiyama, K. Wakabayashi, T. Matsumura, Y. Nakayama, Numerical study of the effect of high-explosive storage facility shape on the azimuthal distribution of blast-wave pressures, Eur. J. Mech. B Fluid 79 (2020) 153–164, https://doi.org/10.1016/j.euromechflu.2019.09.008.
[928] X. Sun, S. Lu, Effect of large-scale perturbation on the critical condition of detonation formation in stoichiometric CH4-2O2 mixtures, Process Saf. Environ. Protect. Trans. Inst. Chem. Eng. Part B 130 (2019) 86–93, https://doi.org/10.1016/j.psep.2019.07.022.
[929] L. Szleszkowski, A. Thannhauser, K. Szwagrzyk, M. Kuliczkowski, T. Jurek, Blast injuries found on the exhumed remains of Polish postwar partisans killed by the Polish security service in 1946, Leg. Med. 42 (2020), 101659, https://doi.org/10.1016/j.legalmed.2019.101659.
[930] M. Tahtabasi, S. Er, M. Kalayci, Imaging findings in patients after the bomb explosion in Somalia on December 28, 2019, Clin. Imag. 78 (2021) 230–239, https://doi.org/10.1016/j.clinimag.2021.05.018.
[931] J. Teitelbaum, The yule bomber, Forensic Sci. Rev. 32 (3) (2020) 97–100.
[932] K.A. Thorn, ^{13}C and ^{15}N NMR identification of product compound classes from aqueous and solid phase photodegradation of 2,4,6-trinitrotoluene, PLoS One 14 (10) (2019), e0224114, https://doi.org/10.1371/journal.pone.0224112.
[933] D. Tin, C. Margus, G. Ciottone, Half-a-century of terrorist attacks: weapons selection, casualty outcomes, and implications for counter-terrorism medicine, Prehospital Disaster Med. 36 (5) (2021) 526–530, https://doi.org/10.1017/S1049023X21000868.
[934] C. Todd, Explosive: Bringing the World's Deadliest Bombers to Justice, Headline Publishing Group, 2021.
[935] J. Tringe, D. Stobbe, G. Parker, L. Smilowitz, B. Henson, M. De Haven, A. Ruch, B. White, J. Reaugh, K. Vandersall, Observation of asymmetric explosive density evolution in the deflagration-to-detonation transition for porous explosives, J. Appl. Phys. 129 (3) (2021), 035091, https://doi.org/10.1063/5.0031340.
[936] J. Wang, L. Yang, W. Zheng, J. Zhang, Study on comparative performance of CL-20/RDX-based CMDB propellants, Propellants, Explos. Pyrotech. 44 (9) (2019) 1175–1182, https://doi.org/10.1002/prep.201900029.
[937] L. Wang, H. Du, H. Xu, Compensation method for infrared temperature measurement of explosive fireball, Themochim. Acta 680 (2019), 178432, https://doi.org/10.1016/j.tca.2019.178342.
[938] R. Wei, Z. Fei, M. Yoosefian, Water molecules can significantly increase the explosive sensitivity of Nitrotriazolone (NTO) in storage and transport, J. Mol. Liq. 336 (2021), 116372, https://doi.org/10.1016/j.molliq.2021.116372.
[939] S.D. Wilkinson, Numerical Modelling of Detonation and Ignition of Condensed Phase Explosives (Doctoral dissertation, University of Cambridge), Apollo, University of Cambridge Repository, 2019, https://www.repository.cam.ac.uk/handle/1810/297692.
[940] N. Wingborg, Heat of formation of ADN-based liquid monopropellants, Propellants, Explos. Pyrotech. 44 (9) (2019) 1090–1095, https://doi.org/10.1002/prep.201900142.
[941] R. Wolstenholme, S. Jickells, S. Forbes (Eds.), Analytical Techniques in Forensic Science, John Wiley & Sons, 2021, https://doi.org/10.1002/9781119373421.
[942] Y. Wong, L. Khoo, M. Ibrahim, M. Noor, M. Mahmood, The first case of C4-Blast related death in Malaysia: a multidisciplinary approach illustrated with emphasis on conjoint anthropologic and radiologic expertise in forensic identification of skeletal remains, J. Forensic Legal Med. 83 (2021), 102253, https://doi.org/10.1016/j.jflm.2021.102253.
[943] S. Wongwattanaporn, T. Phienthrakul, January 21-24). *Machine learning for explosive detection form electronic nose datasets* [Paper presentation], in: 13th International Conference on Knowledge Smart Technology (KST), Bagsaen, Chonbur, Thailand, 2021, https://doi.org/10.1109/KST51265.2021.9415845.
[944] Y. Wu, H. Duan, K. Yang, H. Guo, F. Huang, Ignition and combustion developments of granular explosives (RDX/HMX) in response to mild-impact loading, Propellants, Explos. Pyrotech. (2020), https://doi.org/10.1002/prep.201900365.
[945] W. Xiao, M. Andrae, N. Gebbeken, Air blast TNT equivalence factors of high explosive materials PETN for bare charges, J. Hazard Mater. 377 (2019) 152–162, https://doi.org/10.1016/j.jhazmat.2019.05.078.
[946] W. Xiao, K. Chen, M.F. Yang, X.W. Hong, H.W. Li, B.L. Wang, Effects of the particle size and gas environment on after burning reactions and explosion performance of aluminized HMX-based explosives, Combust. Explos. Shock Waves 57 (2) (2021) 222–231, https://doi.org/10.1134/S0010508221020118.
[947] X. Xie, Y. Fen, S. Liu, J. Zhu, Thermal behavior and stability of emulsion explosives in the presence of ferrous ion, J. Therm. Anal. Calorim. 139 (2) (2020) 999–1006, https://doi.org/10.1007/s10973-019-08494-0.
[948] H. Xu, W. Li, W. Li, Y. Wang, Experimental studies of explosion energy output with different igniter mass, Defence Technol. 15 (2019), https://doi.org/10.1016/j.dt.2019.05.010.
[949] L. Xu, H. Xu, X. Li, M. Pan, A defect inspection for explosive cartridge using an improved visual attention and image-weighted eigenvalue, IEEE Trans. Instrum. Meas. 69 (4) (2020) 1191–1204, https://doi.org/10.1109/TIM.2019.2912237.
[950] C. Yang, P. Cronin, A. Agambayev, S. Ozev, A. Cetin, A. Orailoglu, A crowd-based explosive detection system with two-level feedback sensor calibration, in: Y. Xie (Ed.), *ICCAD '20: Proceedings of the 39th International Conference on Computer-Aided Design*, Association for Computing Machinery, New Youk, 2020, pp. 1–9, https://doi.org/10.1145/3400302.3415670.
[951] H. Yang, H. Li, M. Zhou, M. Wei, T. Wei, C. Tang, L. Liu, Y. Zhou, X. Long, A relationship between membrane permeation and partitioning of nitroaromatic explosives and their functional groups. A computational study, Phys. Chem. Chem. Phys. 22 (16) (2020) 8791–8799, https://doi.org/10.1039/D0CP00549E.
[952] Z. Yang, C. Lin, F. Gong, C. Zeng, J. Zhang, F. Huang, Effects of crystal quality and morphology on the mechanical performance of LLM-105 based PBXs, Propellants, Explos. Pyrotech. 44 (10) (2019) 1219–1225, https://doi.org/10.1002/prep.201900106.
[953] G. Yu, Y. Wang, L. Zheng, J. Huang, J. Li, L. Gong, R. Chen, W. Li, J. Huang, Y. Duh, Comprehensive study on the catastrophic explosion of ammonium nitrate stored in the warehouse of Beirut port, Process Saf. Environ. Protect. 152 (2021) 201–219, https://doi.org/10.1016/j.psep.2021.05.030.
[954] J. Yuan, Liu, Y. Zhou, Y. Zhou, Y. Zhang, K. Cen, Thermal decomposition and combustion characteristics of Al/AP/HTPB propellant, J. Therm. Anal. Calorim. (2020), https://doi.org/10.1007/s10973-020-09297-4.
[955] W. Yuan, J. Dudley, A. Slutsky-Ganesh, J. Leach, P. Scheifele, M. Altaye, K. Barber Foss, J. Diekfuss, C. Rhea, G. Myer, White matter alteration following SWAT explosive breaching training and the moderating effect of a neck collar device: a DTI and NODDI study, Mil. Med. 186 (11–12) (2021) 1183–1190, https://doi.org/10.1093/milmed/usab168.
[956] T. Zeng, R. Yang, D. Li, D. Li, J. Li, X. Guo, P. Luo, Reactive molecular dynamics study on the effect of H_2O on the thermal decomposition of ammonium dinitramide, Propellants, Explos. Pyrotech. 45 (10) (2020) 1590–1599, https://doi.org/10.1002/prep.201900309.
[957] B. Zhang, H. Liu, Theoretical prediction model and experimental investigation of detonation limits in combustible gaseous mixtures, Fuel 258 (2019), 116132, https://doi.org/10.1016/j.fuel.2019.116132.
[958] B. Zhang, L. Zhang, H. Wang, X. Wang, Lessons learned from the explosion that occurred during the synthesis of diaminomethanesulfonic acid: discussion and preventative strategies, ACS Chem. Health Saf. 28 (4) (2021) 244–249, https://doi.org/10.1021/acs.chas.1c00021.
[959] W. Zhang, L. Salavati, M. Akhtar, D. Dlott, Shock initiation and hop spots in plastics-bonded 1,3,5-triamino-2,4,6-trinitrobenzene (TATB), Appl. Phys. Lett. 116 (12) (2020), 124102, https://doi.org/10.1063/1.5145216.
[960] W. Zhang, X. Zhou, T. Bao, L. Deng, D. Gao, Evaluation of mechanical properties of composite solid propellant by genetic engineering of materials: part a, Propellants, Explos. Pyrotech. 44 (9) (2019) 1167–1174, https://doi.org/10.1002/prep.201800385.
[961] Y. Zhang, C. Hou, C. Li, X. Zhang, Y. Tan, J. Wang, Rapid assembly and preparation of energetic microspheres LLM-105/CL-20, Propellants, Explos. Pyrotech. 45 (8) (2020) 1269–1274, https://doi.org/10.1002/prep.201900389.
[962] Z. Zhang, X. Fu, H. Yu, W. Tao, C. Mao, J. Chen, M. Wu, P. Chen, Enhanced the thermal conductivity of hydroxyl-terminated polybutadiene (HTPB) composites by graphene-silver hybrid, Compos. Commun. 24 (2021), 100661, https://doi.org/10.1016/j.coco.2021.100661.
[963] Z. Zhang, B. Wu, Z. Yang, P. Xiao, W. Zhang, H. Li, A flexible Rayleigh wave transducer for surface cracks detection on heterogeneous composite explosives, Instrum. Exp. Tech. 64 (3) (2021) 420–426, https://doi.org/10.1134/S0020441221030325.
[964] C. Zhao, Y. Chi, Q. Yu, X. Wang, G. Fan, K. Yu, A comprehensive study of the interaction and mechanism between Bistetrazole ionic salt and Ammonium Nitrate explosive in thermal decomposition, J. Phys. Chem. C (2019), https://doi.org/10.1021/acs.jpcc.9b05728.
[965] P. Zhao, L. Chen, K. Yang, Y. Xiao, K. Zhang, J. Lu, J. Wu, Shaped-charge jet-initiation of covered RDX-based aluminized explosives and effect of temperature, Propellants, Explos. Pyrotech. 45 (9) (2020) 1443–1453, https://doi.org/10.1002/prep.201900378.
[966] Y. Zhao, F. Zhao, S. Xu, X. Ju, Molecular reaction dynamics simulation of thermal decomposition for aluminiferous RDX composites, Comput. Mater. Sci. 177 (2020), 109556, https://doi.org/10.1016/j.commatsci.2020.109556.
[967] M. Zhou, S. Chen, H. Zou, J. Wang, K. Chen, Y. Yu, G. Zhang, J. Li, M. Chen, Investigation on the thermal decomposition performance and long-term storage performance of HNIW-based PBXs through accelerated aging tests, J. Energetic Mater. (2019), https://doi.org/10.1080/07370652.2019.1663564.
[968] C. Zhu, S. Tang, Z. Li, X. Fang, Dynamic study of critical factors of explosion accident in laboratory based on FTA, Saf. Sci. 130 (2020), 104877, https://doi.org/10.1016/j.ssci.2020.104877.
[969] R. Zito, Accelerated age testing of explosives and propellants, in: Mathematical Foundations of System Safety Engineering, 2019, pp. 237–255, https://doi.org/10.1007/978-3-030-26241-9_16.

Final Notes (Patents etc)

[970] Afilani, T. (2020). Dynamic selective polarization matching for remote detection smokeless gunpowder (U.S. Patent 2020191747A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20200191747A1/en.
[971] Alexander, T.B. & Price, D.W. (2020). High energy reduced sensitivity tactical explosives (U.S. Patent No. 20200062671A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20200062671A1/en..
[972] Apblett, A.W., Materer, N.F., & Shaikh, S. (2019). *Explosive-containing porous materials as non-detonable training aid* (U.S. Patent No. 2,019,018,687,8A1). Washington, DC: U.S. Patent and Trademark Office. https://patents.google.com/patent/US20190186878A1/en.
[973] Bell, W.T. & Rairigh, J.G. (2020). *Mini-severing and back-off tool with pressure balanced explosives* (U.S. Patent No. 10,538,984 B2). U.S. Patent and Trademark Office. https://www.lens.org/images/patent/US/10538984/B2/US_10538984_B2.pdf.

[974] Blaha, J., Dupac, J., Zastera, M., & Mazl, R. (2020). Explosives detector and method for detecting explosives (U.S. Patent No. 10551304B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10551304B2/en.
[975] Boronse, A.W. (2021). *Device for detecting explosive materials, or weapons or firearms, or knives or substances* (U.S. Patent No. 10,948,581 B1). U.S. Patent and Trademark Office. https://www.lens.org/images/patent/US/10948587/B1/US_10948587_B1.pdf.
[976] Brogden, M. & Duffy, S. (2021). High fidelity sheet explosive simulants (U.S. Patent 10941085B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10941085B2/en.
[977] Burn, P., Shaw, P., & Fan, S. (2020). Detection method (U.S. Patent 20200172561A1). U.S. Patent and Trademark Office. http://www.freepatentsonline.com/y2020/0172561.html.
[978] Deline, J. (2021). Development of dry-deposit trace explosives detection test standards, solutions and methods for deposition (U.S. Patent No. 11079369B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US11079369B2/en.
[979] Gorski, B. (2020). Devices and methods for detecting an explosive substance (U.S. Patent No. 10,746,717). U.S. Patent and Trademark Office. https://www.lens.org/images/patent/US/10746717/B2/US_10746717_B2.pdf.
[980] Hanumanthappa, S.H. & Jayaramakrishnan, S. (2021). System and method for determining a location of an explosive device (U.S. Patent No. 20210225148A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20210225148A1/en.
[981] Hgyuyen, D.H. (2020). Detection of nitrogen containing and nitrogen free explosives (U.S. Patent No. 10641752B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10641752B2/en.
[982] Hower, B. (2021). *Defeat system for vehicle attached improvised explosive devices* (U.S. Patent No. 10,935,349 B1). U.S. Patent and Trademark Office. https://www.lens.org/images/patent/US/10935349/B1/US_10935349_B1.pdf.
[983] Huber, H. & Lee, R. (2020). Mass spectrometer method and apparatus for monitoring for TATP (U.S. Patent No. 10725006B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10725006B2/en.
[984] Laktas, J.M., Stochl, I.D., Place, G.J., Jelliss, P., Chung, S., & Buckner, S.W. (2020). *Nano-enhanced explosive material* (U.S. 10,766,832 B1). U.S. Patent Trademark Office. https://www.lens.org/images/patent/US/10766832/B1/US_10766832_B1.pdf.
[985] Marsh, B.D. (2021). Energetic charge for propellant fracturing (U.S. Patent No. 10907460B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10907460B2/en.
[986] Miklaszewski, E. & Dilger, J. (2021). Systems and methods for modifying and enhancing explosives by irradiating a reaction zone (U.S. Patent No. 10883805B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10883805B2/en.
[987] Morton, D. & Tan, S.N. (2020). *Conveying of emulsion explosive* (U.S. Patent No. 10,557575 B2). U.S. Patent and Trademark Office. https://www.lens.org/images/patent/US/10557575/B2/US_10557575_B2.pdf.
[988] Nesveda, J. (2021). *Method for producing ecological explosive for primer compositions of ammunition* (U.S. Patent No. 20210163376A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20210163376A1/en.
[989] Park, I. & Kim, J.H. (2021). System for detecting explosives *(U.S. Patent No. 10,921,098 B2)*. U.S. Patent and Trademark Office. https://www.lens.org/images/patent/US/10921098/B2/US_10921098_B2.pdf.
[990] Pettersen, J., McPhail, E., & Gore, J. (2021). *Explosive compositions for use in reactive ground and related methods (U.S. Patent No. 2021/0094889 A1)*. U.S. Patent and Trademark Office. https://patents.google.com/patent/US20210094889A1/en.
[991] Reynolds, J., Leininger, L., & Myers, T. (2021). *Enhanced colorimetric apparatus and method for explosives detection using ionic liquids (U.S. Patent No. 20210010941A1)*. U.S. Patent and Trademark Office. https://patents.google.com/patent/US20210010941A1/en.
[992] Shaffer, G.D. (2020). Explosive detection in cargo containers and packages (U.S. Patent No. 20200041474). U.S. Patent and Trademark Office. http://www.freepatentsonline.com/y2020/0041474.html.
[993] Shkolnikov, V. & Barcelo, S. (2021). Photoacoustic explosives detectors (U.S. Patent No. 202100184466A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20210018466A1/en..
[994] Smith, Z., Griggs, B., Gore, J., & Paris, N. (2020). Explosive compositions with reduced fume (U.S. Patent No. 20200216369A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20200216369A1/en..
[995] Splitzer, D., Pichot, V., & Risse, E. (2021). *Methods for manufacturing nanoparticles by detonation* (U.S. Patent No. 10,906,016 B2). U.S. Patent and Trademark Office. https://www.lens.org/images/patent/US/10906016/B2/US_10906016_B2.pdf..
[996] Steed, D. (2021). Methods of training to detect powdered explosives-detection training aids (U.S. Patent No. 20210316924A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20210316924A1/en..
[997] Steed, D.J. (2020). Packaging for powdered explosive-detection training aids and uses thereof (U.S. Patent 20200262629A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20200262629A1/en..
[998] Tang, Q. (2020). Method and device for emulsifying emulsion explosive (U.S. Patent No. 10,610,838 B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10610838B2/en..
[999] Tortoriello, V. & Picolli, R. (2020). Acoustic frequency based system with crystalline transducer module for non-invasive detection of explosives, contraband, and other elements (U.S. Patent No. 10,684,646). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10634646B2/en..
[1000] Vabnick, I. (2020). Penetrator projectile for explosive device neutralization (U.S. Patent No. 2020173761A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20200173761A1/en..
[1001] Wald, L.B. & Keen, S.L. (2020). Fluorescence-based chemical detection (U.S. Patent 10830764 B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10830764B2/en.
[1002] Widmann, S., Sinn, G., & Mittenzwey, K. (2020). Portable device for detecting explosive substances comprising a device for generating and measuring the emission of an indicator (U.S. Patent No. 10605732B2). U.S. Patent and Trademark Office. https://patents.google.com/patent/US10605732B2/en..
[1003] Zaharia, S., Apostol, M., Ionita, S., Iana, V., Monea, C., Ionescu, L., Constantin, D., Ilie, M., & Varga, A. (2020). Mobile detector and method for detecting potentially explosive substances, explosives and drugs by nuclear quadrupole resonance (nqr) (U.S. Patent No. 20200182810A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20200182810A1/en.
[1004] Zussman, E., Eshed, Y., & Gal-Oz, R. (2021). *Composition and method for detection of molecules of interest* (U.S. Patent No. 202010109077A1). U.S. Patent and Trademark Office. https://patents.google.com/patent/US20210109077A1/en.