Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Electrochemiluminescence sensing platform for microorganism detection

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Electrobiochemiluminescence (ECL) is a type of luminescence in which substances produced on electrode undergoes an electron transition to an excited state for light-emitting [1]. As a sensing platform, ECL instruments have been widely used in clinical diagnosis, environmental monitoring, food and water safety, biological defense and other fields benefiting from their low detection limits, extensive dynamic range, fast detection speed, and low instrument cost. In this perspective, we highlight some representative examples of microbial detection by ECL sensing platforms in biosafety and health applications.

The first example is the ECL biosensor for diagnosing COVID-19 which caused the global pandemic. Zhang et al. established an ECL platform driven by entropy to detect the RdRp-COVID, an important target of SARS-CoV-2, which was used to diagnose the COVID-19 [2] (Table 1). Instead of represented assay which applied recombinant protein representing the nucleocapsid (N) antigen for the determination of antibodies against SARS-CoV-2 such as Elecsys ® Anti-SARS-CoV-2, this ECL biosensor contains gold electrode modified DNA tetrahedron (D.T.) and Ru bipyridine $(bpy)_3^{2+}$ modified S3 DNA probe. In the presence of the target DNA, the Ru $(bpy)_3^{2+}$ modified S3 DNA probe was ligated to the linear ssDNA capture probe in the D.T., amplified reaction of target DNA in the electrode surface had occurred through the entropy-driven method, and eventually generated the signal, which was described as an "ECL on" state. Moreover, D.T. was used for the scaffold on the gold electrode and promoted the even distribution, and reduced the hybridization reactions of single-stranded DNA. Thus, the amplification reaction did not require an enzyme, which reduced the cost of mass screening of SARS-CoV-2 patients. This ECL biosensor had already done the detection of RdRp-COVID in human serum samples spiked with target DNA with both high specificity and sensitivity, which relatively reached a limit of detection (LOD) down (2.67 FM), compared with the colorimetric (0.038 nM) and fluorescence (81 pM).

Meanwhile, Hua Tang et al. designed the ECL biosensing method to detect group B streptococci (GBS) [3] (Table 1). This ECL biosensing strategy consists of CuMn-CeO_2 loading PEI-luminol complex and multi-component DNAzyme (MNAzyme) as GBS-recycling amplification. In their study, PEI was applied as a co-reactant that enhanced the luminophore efficiency through intramolecular interaction, and CuMn-CeO_2 provided a large specific surface area and promoted the capability oxidation of H_2O_2 (co-reactant) through high catalytic performance to achieve ultra-sensitivity of ECL signals. The MNAzyme system was used to specifically detect the target through circulation and amplification for a nucleic acid sequence of GBS. Notably, this ECL biosensing method was directly applied to test GBS with 51 pregnant women through vaginal/anal swabs in a clinic. Compared with traditional PCR method based on fluorescence, the ECL biosensing exhibited similar accuracy, including clinical vaginal/anal swab detection specificity and sensitivity.

Furthermore, it simplified the cascade signal amplification procedures by excluding complex biological enzymes and precision instruments. Thus, this research explored a practical application for the clinical diagnosis of bacteria. ECL was also used to kill pathogenic bacteria through produced reactive oxygen species (ROS) mediated by an activated photosensitizer, which was applied as ECL-therapeutics [4].

Another example of ECL biosensor is used for antimicrobial susceptibility testing (AST), effective technology for guiding antibiotic prescription by testing the antibiotic's sensitivity to bacteria. Fen Ma et al. designed the ECL biosensor comprised NH2-MIL-53(Al) electrode for bacterial detection [5] (Table 1). This ECL biosensor contains ruthenium complex tagged concanavalin A (Ru-Con A) as ECL probe and ruthenium (II) complex (Ru) as ECL-emitting material. In the presence of *E. coli* BL21, Ru-Con A specifically recognized the LPS secreted by *E. coli* BL21 and formed the LPS-Con A conjugate, subsequently emitting the ECL signal. After treating with different antibiotics such as β lactams (cefpirol group (CPO), imipenem (IPM), non-β lactams (tetracycline (TCY) and levofloxin hydrochloride (LVX), they found that ECL signals varied depending on the number of LPS-Con A conjugates affected by different antibiotics. Therefore, the type of clinical antibiotic and the bacterial strain being processed can be determined according to this sensor's degree of ECL signal, which provides a simple solution for clinical antibiotic stewardship. The ECL biosensor used as antimicrobial susceptibility testing also was applied to evaluate the selectivity for the other types of bacteria such as Enterococcus faecalis, streptococcus mutants, staphylococcus aureus, and salmonella pullorum. However, the results showed no significant change for the ECL signal. Moreover, we summarized some representative studies

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Table 1
Summary of representative study for ECL in application, probe, and characteristic.

Detection Species	Sensor Type	Description	Ref.
Virus (RdRp-COVID)	$Ru(bpy)_3^{2+}$modified S3 DNA probe	Enzyme-free entropy-driven reaction and D.T. probe enhance the large-scale screening and sensitivity of the assays.	[2]
Virus (HPV16)	Self-assembly ssDNA	BSA platform improved the position distribution and spatial orientation of the probe.	[6]
Bacteria (GBS)	SP-MNAzyme	GBS with 51 pregnant women was detected and simplified the cascade signal amplification procedures by the ECL.	[3]
Bacteria (EAB)	None	Characteristics of O_2 and EET of EAB and without special sensor.	[7]
Bacteria (*E. coli*)	Aptasensor	Luminol/AgBr/3DNGH nanocomposites improved the intensity and stability of ECL emission.	[8]
Antibiotic (AST)	Ru-Con A	Measure bacterial and characterize the antimicrobial activities of β-lactam and non-β-lactam antibiotics.	[5]
Antibiotic (Kanamycin & neomycin)	Nanogears aptasensor	Multiple detections for kanamycin and neomycin used a single luminophore.	[9]
Tumor Biomarkers (CA15-3 & CA 125)	CA125 and CA153 antibodies	Multiplex ultrasensitive mediated by a dual signal probe and the detection of dual targets of simultaneous determination.	[10]

for ECL strategies in an application, probe, and characteristic are in Table 1.

Summary and perspectives

The ECL-based platform combines different identification sensors and has diversified application prospects due to the low detection limit, high specificity, fast detection speed, diversified detection targets, and portable instrument. For example, the Elecsys®, an ECL platform developed by Roche, was authorized by Food and Drug Administration to screen SARS-CoV-2 infection against the current worldwide pandemic, which shows that the ECL platform has established itself as a powerful tool for ultrasensitive detection of a wide range of microorganisms. However, it is still urgent to develop novel detection methods with high sensitivity, sufficient specificity, and simple instrument requirements due to the limits of sensitive detection of samples in complex environments. Therefore, new ECL sensing systems, such as aggregation-induced emission-based ECL (AIE-ECL), upconversion nanoparticles (UCNPs), hydrophilic luminol derivative, nanomaterial, and near-infrared (NIR) ECL as optimized emitters, inorganic and organic compound and nanomaterials (N.M.s) as efficient co-reaction accelerator (CRA), and stainless steel, very-high-density electrochemical sensing, and electrodes decorated by conductive polymer hydrogels (CPHs) and nanomaterial as new electrodes platform will be investigated and fully applied [11,12]. Moreover, there are growing interests in the co-detection of multiple microorganisms with high specificity and sensitivity, such as immune sensors, adaptation sensors, gene sensors, and cell sensors [13].

Furthermore, based on the characteristics of the detected substance such as electron transfer sensitivity, ECL detection platforms without a specific sensor will be designed [7]. The broad clinical requirements of the ECL sensing platform in microbial detection will facilitate new analytical applications, such as food safety, water safety, and environmental monitoring applications. Future research should develop portable, intelligent, low-cost, highly stable, high-specific, environmentally friendly ECL platforms, which may better solve various uncertain crises.

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Conflict of interest statement

The authors declare that there are no conflicts of interest.

Author contributions

Jun Li: Writing – Original Draft. **Jianliang Shen:** Writing – Review & Editing. **Ruogu Qi:** Writing – Review & Editing.

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