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Editorial

Materials Science in the Quest for Sustainability

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The development of civilization has seen a revolution in materials science, with technology evolving from prehistoric stone tools to modern touchscreens. Early metallurgical practices set the stage for systematic material exploration, influencing social structures, trade, and warfare. The Industrial Revolution showcased the transformative power of materials, with steel reshaping infrastructure and synthetic chemicals coloring daily life. The 20th century witnessed polymers and semiconductors revolutionize consumer goods and global connectivity. As we navigate through the early decades of the 21st century, nanotechnology is pushing the boundaries of efficiency, while biomaterials, designed to integrate with the human body, are heralding a new frontier in healing and regeneration.

Amid the urgency of climate change and ecosystem degradation, as reiterated by the recent COP28 conference, materials science has emerged as a pivotal force in the global drive toward environmental sustainability. This era is marked by transforming the way we think about how the materials that comprise our world can be produced, used, reused, and ultimately redefined. Guided by the principles of green chemistry and the circular economy,[1,2] materials scientists are striving to reduce waste and greenhouse gases, and adopt more renewable resources. This has ushered in a new wave of eco-friendly materials and industrial processes that reduce the environmental footprint of manufacturing and offer new avenues for pollution abatement, resource recovery, and energy supply.

With the advent of big data, artificial intelligence, and high-throughput computational methods, the digitization of materials science has enabled the rapid development and deployment of advanced materials.[3] The combination of these technological advances within materials research is already expediting the discovery and refinement of more sustainable materials,[4] leading to more efficient processes and superior products.

It is within this rapidly changing landscape that this issue of *ACS Environmental Au* presents five studies that embody the transformation of materials into environmental gold (Au), each contributing to the greater narrative of global sustainability.

In their Article, Fengting Li and colleagues developed a bimetallic FeMn metal−organic framework gel (MOG) that significantly enhances peracetic acid activation for degrading the antibiotic ofloxacin. Their one-pot synthesized FeMn13BTC MOG achieved 81.85% ofloxacin degradation within an hour, outperforming peracetic acid alone. The system's hierarchical porous structure and Fe−Mn synergistic effects contribute to its high efficiency, which remains consistent even in natural water. Reactive oxygen species, primarily R−O·, were identified as the main degradation agents. This study positions MOGs as promising catalysts in water treatment and peracetic acid−based advanced oxidation processes.

Continuing with the water treatment theme, Alamgir Karim and colleagues developed a self-cross-linking MXene-intercalated graphene oxide (GO) membrane with superior antiswelling properties for water purification, addressing the swelling issue in two-dimensional membranes. The cross-linking, enabled by Ti−O−Ti bonds among others, effectively maintains ion and dye rejection performance. The durability of the membrane is confirmed through minimal swelling and consistent function after heat pressurization and thermal annealing treatments, with the membrane showing high rejection rates over a 72-h test. This innovative membrane demonstrates potential for efficient, long-term filtration applications, leveraging the hydrophilic interactions between MXene and GO for improved stability and ion-blocking capabilities.

Researching possible green materials from agriculture, Angélica M. Baena-Moncada and colleagues repurposed purple corncob (*Zea mays L.*) into a sustainable precursor for activated carbon electrodes in supercapacitors. Utilizing a KOH activation process and thermal treatment, the researchers created electrodes with a high specific surface area (728 m^2/g). These electrodes demonstrated considerable capacitances (195 F/g in H_2SO_4 and 116 F/g in KOH) and maintained 76% capacitance after 50,000 cycles. These findings highlight the potential of agricultural waste in producing cost-effective, high-performance supercapacitors, emphasizing the benefits of circular economy principles in energy storage applications.

Kurupalya Shivram Anantharaju, Periyakaruppan Karuppasamy, H. C. Ananda Murthy, and colleagues introduced a green-synthesized Ag-doped $Bi_2Zr_2O_7$ nanocomposite using pudina (*Mentha spicata L.*) extract, showing significant advancements in degrading pollutants and sensing applications. Characterized by multiple techniques, the 7 mol % Ag-doped variant demonstrated degradation of methylene blue and rose bengal dyes under visible light, with efficiencies of 98.7% and 99.3%, respectively. Additionally, it exhibited promising electrochemical sensing for lead nitrate and dextrose, and greater

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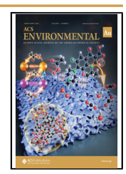

antibacterial activity against Gram-negative bacteria. These findings underscore the potential of Ag-doped $Bi_2Zr_2O_7$ in environmental and analytical applications.

Finally, the Article from William A. Tarpeh and colleagues demonstrates the efficacy of electrochemical stripping (ECS) for ammonia recovery from wastewater, achieving over 83% total ammonia nitrogen removal in a month-long operation. The process yielded high-purity ammonium sulfate close to commercial fertilizer levels. Key ECS operation parameters were identified, and findings suggest that reducing flush water and allowing complete urine hydrolysis before treatment enhanced energy efficiency. The study supports the application of ECS to various types of wastewater, potentially advancing its scale-up and promoting a circular nitrogen economy for sustainable wastewater management.

The Midas Touch for a Sustainable Future

Each paper in this issue presents new insight toward a more sustainable future. These researchers act as modern alchemists, not in search of literal gold, but in search of knowledge that can lead to a golden era of environmental stewardship. Through their efforts, we are reminded that the path to a sustainable future is paved with the materials we often overlook, waiting for the Midas touch of ingenuity to reveal their true value. As we reflect on the information and inspiration these studies provide, let us remember the alchemical motto, "*aurum nostrum non est aurum vulgi*", "our gold is not ordinary gold". The 'gold' we pursue in environmental research is the well-being of our planet and the legacy we leave for those who follow.

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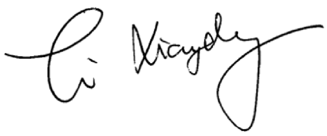

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Notes

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