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RECEIVED 27 August 2025

ACCEPTED 30 September 2025

PUBLISHED 22 October 2025

CITATION

Kumar S and Bhanjana G (2025) Editorial:
Nanomaterials for affordable biomedical
devices, environmental and
energy applications.
Front. Nanotechnol. 7:1693985.
doi: 10.3389/fnano.2025.1693985

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Editorial: Nanomaterials for affordable biomedical devices, environmental and energy applications

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KEYWORDS

healthcare, energy, environment, sensors, nanomaterials

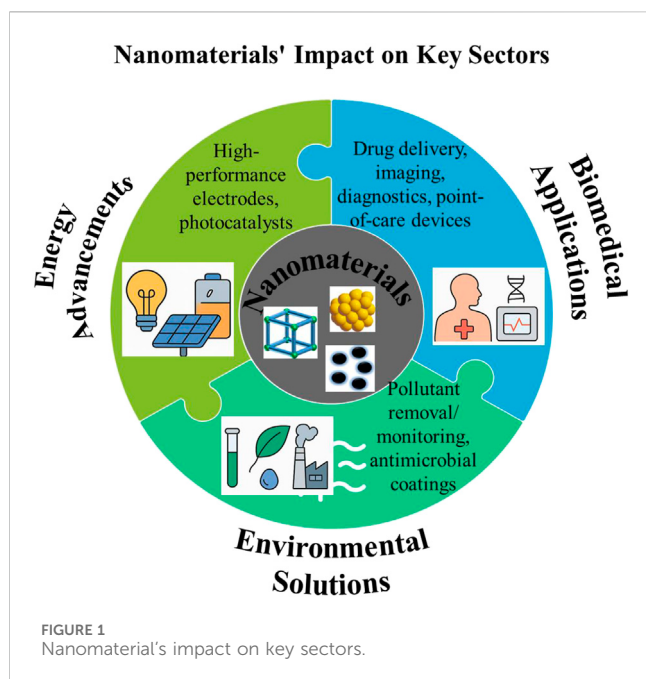
Editorial on the Research Topic

Nanomaterials for affordable biomedical devices, environmental and energy applications

In modern science, nanomaterials have become one of the most revolutionary material classes, changing the direction of research and creating new opportunities for technologically driven solutions (Schiavo et al., 2024). Nanomaterials' high surface-to-volume ratio, multifunctionality, and tailor-made physicochemical characteristics make them extremely promising for tackling some of the most important global issues in energy security, healthcare, and environmental sustainability (Thamarai et al., 2024; Kurul et al., 2025). In the biomedical field, nanomaterials have already transformed drug delivery, imaging, therapeutic monitoring, and diagnostics (Kurul et al., 2025). Nanomaterials with precise size, shape, and surface chemistry can be engineered to improve biosensor sensitivity, selectivity and provide more cost-effective point-of-care devices (Fu et al., 2024). Nanomaterial-based platforms have the potential to significantly democratise healthcare in low-resource environments where traditional diagnostic tools are still expensive and unavailable by providing portable, affordable, and user friendly devices for early identification of diseases and monitoring (Thwala et al., 2023).

Environmental applications of nanoparticles are equally important. Antibiotic resistance, air and water pollution, and climate change are complicated Research Topic that need creative solutions. For the removal of pollutants, real-time contamination monitoring, antimicrobial coatings, nanostructured materials like metal-organic frameworks, carbon-based nanomaterials, and quantum dots are being intensively investigated (Ha et al., 2025; Rezanian et al., 2024). The integration of these advanced functional materials into low-cost sensors and treatment systems could make sustainable environmental remediation feasible on a broader scale.

Additionally, nanotechnology is redefining the energy sector. Sustainable and efficient energy systems are being made possible by nanomaterials, which are used in everything from high-performance electrodes in batteries and supercapacitors to effective photocatalysts for hydrogen production and carbon dioxide reduction (Al Mahmud, 2023; Rathinam et al., 2025). More attention is being paid to scalable, affordable synthesis methods that use non-toxic, earth-



abundant precursors, promising that these technologies can transition from lab to practical uses without harming environmental safety.

Scalability, reproducibility, long-term stability, and safety evaluation are some of the issues that still need to be resolved as the area develops in order to convert laboratory progress into commercially viable goods (Khatoon et al., 2023). Moreover, affordability is the key to ensuring equitable access to nanomaterial-based devices across both developed and developing regions. This Research Topic brings together research and perspectives highlighting innovations in nanomaterials that are not only cutting-edge but also designed with affordability and sustainability in mind. Our goal is to demonstrate how nanomaterials may revolutionise energy technologies, environmental monitoring, and biomedical devices in ways that are significant, affordable, and applicable worldwide by connecting fundamental research with real-world applications. Our goal is to demonstrate how nanomaterials may revolutionize energy technologies, environmental monitoring, and biomedical devices in ways that are significant, affordable, and applicable worldwide by connecting fundamental research with real-world applications (Figure 1).

Kumar et al. isolated plant growth-promoting bacterium (AW5) that could produce iron and zinc nanoparticles which improved bacterial activity, root structure, and nutrient uptake. Bacterium AW5-mediated Fe and Zn nanoparticles significantly boosted wheat growth, yield, and nutrient uptake. The PGPR-NP synergy offers a long-term option for biofortification and agricultural production. Wadhwa et al. created binder-free $\text{NiCo}_2\text{S}_4/\text{Ni-Co}$ MOF composite electrodes on Ni foam using a dual-step solvothermal technique. These electrodes had outstanding electrochemical performance, demonstrating a high specific capacitance ($2,150.3 \text{ F g}^{-1}$), energy density (199.6 Wh kg^{-1}), and cycling stability (89% after 10,000 cycles). The low charge-transfer resistance confirms their

potential as efficient supercapacitor electrode materials. A study by Almosa et al. showed that, in comparison to traditional adhesives, adding silver nanoparticles to orthodontic adhesives greatly decreased the depth of enamel demineralisation and increased shear bond strength. Additionally, AgNP-modified adhesives displayed a more favourable failure mode distribution, suggesting improved orthodontic application performance.

Suliman and Tahir provided a comprehensive review that emphasise date palm waste as an economical and sustainable carbon source for the manufacture of graphene, with high adsorption capabilities and exceptional features for environmental applications. A roadmap for the advancement of environmentally friendly graphene production and use is provided by comparing synthesis methods and properties.

In order to effectively remove ciprofloxacin from water, Sikri et al.'s work created a GO-ZnAlNi LDH composite using co-precipitation and hydrothermal ageing. The adsorbent was a viable platform for antibiotic remediation since it demonstrated a high adsorption capacity (106.97 mg/g), accomplished over 80% removal in just 1 hour, and remained stable and reusable over several cycles. Lamba et al. reported an electrochemical sensor based on an Ag-doped Co_3O_4 nanochip (Ag@CNC) for quick and accurate lithium detection. The sensor offered a reliable and economically viable monitoring method by demonstrating excellent sensitivity ($78.66 \mu\text{A mM}^{-1} \text{ cm}^{-2}$), a low detection limit ($5 \mu\text{M}$), and the ability to directly quantify lithium in field samples without any pre-treatment. An environmentally friendly electrochemical sensor for *in-situ* testosterone detection is presented by Tortolini et al. using a graphene electrode modified with AuNPs/MOF. With a low detection limit of 0.5 nM and a broad linear range of $1\text{--}50 \text{ nM}$, the sensor demonstrated exceptional sensitivity. Its effective integration with a smartphone-based potentiostat shows great promise for doping control and clinical diagnostics. Bhattacharyya et al. created a silver-modified ZIF-8 derived heterostructure (Ag/ZnO/C) that, when exposed to visible light, degraded ciprofloxacin by 98% in 60 min, thanks to the combined impacts of Ag nanoparticles and MOF-derived structure. Its outstanding photocatalytic activity is highlighted by its high-rate constant and the dominant roles of h^+ and O_2^- . Defeo et al. provided a thorough analysis of the difficulties in nitrate monitoring, highlighting the shortcomings of the currently used techniques in terms of affordability, accuracy, and portability. The FOCUS (form factor, operational robustness, cost, user interface, and sensitivity) framework-guided user-centred lab-to-field transfer is emphasised, and nanomaterial-based sensors are highlighted as a possible option.

We extend our gratitude to the authors, reviewers, and editorial team for their contributions to this Research Topic. We hope this Research Topic of research articles inspires further exploration and commercialization of nanostructured materials for affordable healthcare and environmental applications.

Author contributions

SK: Conceptualization, Formal Analysis, Methodology, Supervision, Visualization, Writing – original draft. GB:

Formal Analysis, Investigation, Methodology, Writing – review and editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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