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Mini Review

Future Perspectives on Nanomaterials: Emerging Applications in Biology and Technology

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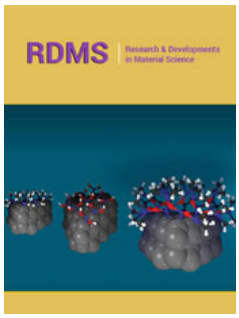

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Abstract

Nanomaterials have transformed scientific fields due to their unique physicochemical properties. This review highlights recent advances in synthesis and characterization techniques, with a focus on applications in energy, medicine-particularly cancer immunotherapy-and environmental remediation. Future challenges and directions are also addressed.

Introduction

Nanomaterials, typically <100nm in size, exhibit high surface area, quantum effects, and enhanced reactivity. These properties enable their use in catalysis, drug delivery, biosensing, and energy storage [1].

Synthesis and Characterization

Modern techniques such as green synthesis, atomic layer deposition, and electrospinning allow precise control over nanomaterial morphology. Tools like TEM, AFM, and XRD reveal structure–property relationships essential for functional optimization [2].

Applications

Energy

A. Nanostructured electrodes improve lithium-ion battery performance.

B. Quantum dots enhance solar cell efficiency via superior light absorption [3].

Medicine

Targeted drug delivery: Liposomes and polymeric nanoparticles deliver drugs directly to tumor cells, minimizing side effects.

Imaging: Gold and iron oxide nanoparticles enhance MRI and CT contrast.

Cancer Immunotherapy:

a) Nanoparticles deliver immune checkpoint inhibitors (e.g., anti-PD-1, anti-CTLA-4) to tumor sites, reducing systemic toxicity.

b) Lipid nanoparticles are used in mRNA-based cancer vaccines,

c) stimulating antigen-specific immunity [2,3].

Diagnosis:

a) Nanobiosensors detect disease biomarkers with high sensitivity.

b) Lab-on-a-chip devices enable rapid diagnostics for infectious diseases.

c) Quantum dots and SERS amplify signals in molecular assays [1].

Therapeutics:

a) Gold nanoshells enable photothermal therapy.

b) Iron oxide nanoparticles induce magnetic hyperthermia.

c) Nanocarriers improve chemotherapy delivery and RNA-based gene modulation [3].

Environment

Nanomaterials contribute to water purification, pollutant degradation, and air filtration, offering sustainable solutions for environmental challenges [1].

Challenges and Future Outlook

Key challenges include scalability, biocompatibility, and regulatory approval. Future efforts should focus on eco-friendly synthesis, long-term safety, and integration into clinical and industrial platforms [2].

Conclusion

Nanomaterials are reshaping science and technology. With interdisciplinary collaboration and responsible innovation, their full potential can be realized across medicine, energy, and environmental sectors.

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