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EDITORIAL

Chirality in nanomaterials

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Chirality at the nanoscale has emerged as a key area of interest in materials science and engineering, with significant implications for various fields such as spintronics, photonics, optoelectronics, quantum computing, and biomedicine. With their unique properties such as enantioselective interactions with light and spin-polarized electron transport, chiral nanomaterials are opening a new window of opportunities for the design of advanced functional devices. This editorial provides an overview of the current state of research in chirality in nanomaterials. We also showcase several papers from this collection that exemplify the breadth of current work, offering insights into the future directions of this rapidly evolving field.

Chirality, the property of an object being non-superimposable on its mirror image, is a phenomenon observed across scales—from the smallest molecules to the largest cosmic structures[1,2] In nanomaterials research, chirality has gained prominence due to its potential to influence the optical, electronic, magnetic and mechanical properties of materials in profound ways[3–7] With applications spanning spintronics, photonics, catalysis, biosensing, and quantum technologies, the ability to harness and control chirality at the nanoscale is becoming increasingly critical[8–13].

Recent years have seen an explosion of interest in chiral nanomaterials, driven by advances in materials synthesis, computational modeling, machine learning, and characterization techniques.[14–22]. This collection of papers on Chirality in Nanomaterials reflects the diversity of approaches and innovations that are pushing the boundaries of what is possible in this field. In this editorial, we provide a snapshot of the state of chirality research, while highlighting key contributions from this collection that exemplify important trends and future directions.

Chirality at the nanoscale

Chiral nanomaterials exhibit unique optical properties, such as circular dichroism, where left- and right-handed circularly polarized light are absorbed differently[6,7,23,24] This has led to significant developments in areas such as chiral photonics. Another important aspect of chiral nanomaterials is their potential in spintronics[25]. The chirality-induced spin selectivity effect has opened exciting opportunities for the development of new types of spintronic devices and quantum information technologies[26,27] From a synthesis perspective, one of the key challenges is to create well-defined chiral nanostructures with high enantioselectivity[28,29].

Selected contributions from the collection

Several papers in this collection showcase the cutting-edge work being done in these areas. Together, they provide a window into the future of chiral nanomaterials research. One of the standout papers, by Petronijevic et al.[7] reports on the use of nanosphere lithography to fabricate asymmetric plasmonic metasurfaces and nanohole arrays. These structures exhibit rich extrinsic chiral optical properties, including broadband handedness- and angle-dependent extinction in the near-infrared range. This work exemplifies how low-cost, scalable methods can be used to create chiral plasmonic nanostructures with tunable optical responses, paving the way for new applications in chiral photonics.

The intersection of chirality and relativistic physics is explored in a paper by Whittam et al., which investigates the effect of relativistic motion on the circular dichroism of chiral biomolecules[1] By simulating the transmission circular dichroism of molecules moving at relativistic speeds, based on chiral quantum properties, this study offers insights into how chirality could manifest in extreme conditions. The potential applications of this work in

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the search for extraterrestrial life are particularly compelling, as they suggest new methods for detecting chiral molecules across interstellar distances.

In the realm of soft materials, Gust et al. present a study on the chiroptical properties of copolymer thin films, showing how annealing temperature can influence supramolecular chirality[6] Their findings highlight the importance of temperature control in tuning the chiral properties of organic films, which has important implications for the design of optoelectronic devices, such as organic light-emitting diodes. The use of transient circular dichroism spectroscopy to track these changes in real-time provides a powerful tool for probing the dynamic behavior of chiral materials under external stimuli.

Sadeqian et al. take a more device-oriented approach by studying the time delay in zigzag graphene nanoscrolls (ZGNSs) used in complementary metal-oxide-semiconductors[13] Their research demonstrates how the chiral properties of ZGNSs can be harnessed to improve the speed and efficiency of integrated circuits. This work bridges the gap between fundamental materials research and practical applications in nanoelectronics, offering a path forward for the development of faster, more efficient electronic devices based on chiral nanomaterials.

Kandiah et al. provide a new mathematical framework for controlling gravitational spinners and waves in chiral waveguides[2] By linking gyroscopic actions with gravity, they offer a fresh perspective on the dynamic response of chiral metamaterials to external loads. This work highlights the potential of chiral materials for applications in mechanical and aerospace engineering, where the control of wave propagation and rotational motion could have far-reaching implications.

Finally, the paper by Dunlap-Shohl et al. investigates how electron-donating functional groups in ligands can enhance chiral imprinting on $CsPbBr_3$ quantum dots[12] This study provides valuable design principles for creating chiral perovskite nanostructures with enhanced optical activity, which are of great interest for next-generation spintronic and optoelectronic devices. By demonstrating the importance of ligand chemistry in modulating chiral properties, this work offers a roadmap for the rational design of chiral materials with tailored functionalities.

Conclusion

Chirality in nanomaterials is a field that is both dynamic and diverse, with implications for a wide range of scientific and technological disciplines. The contributions in this special issue of *Scientific Reports* reflect the richness of current research, while pointing toward exciting future directions. As guest editors, we are pleased to present this collection and hope that it will inspire further exploration and innovation in the field of chiral nanomaterials.

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Author contributions

Y. Zheng drafted the main manuscript. R. Matassa and S. C. Ray contributed to revisions. All authors reviewed and approved the final version of the manuscript.

Declarations

Competing interests

The authors declare no competing interests.

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