Frontiers in Materials

TYPE Editorial
PUBLISHED 22 July 2024
DOI 10.3389/fmats.2024.1447573

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OPEN ACCESS

EDITED AND REVIEWED BY
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RECEIVED 11 June 2024
ACCEPTED 18 June 2024
PUBLISHED 22 July 2024

CITATION
Ren L, Peng Z, Kwon J and Li H (2024), Editorial: Multifunctional, flexible, polymeric materials with controlled nanostructures. *Front. Mater.* 11:1447573. doi: 10.3389/fmats.2024.1447573

Editorial: Multifunctional, flexible, polymeric materials with controlled nanostructures

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KEYWORDS

polymeric materials, composites, multifunctional, structure-properties correlations, nanostructures

Editorial on the Research Topic
Multifunctional, flexible, polymeric materials with controlled nanostructures

The ongoing research in flexible polymeric materials with controlled nanostructures holds great promise for advancing a wide range of applications. By focusing on the structure-properties correlations, researchers can design materials with enhanced mechanical, electrical, thermal, and optical properties. The recent advances in synthesis and assembly techniques have paved the way for the development of functional materials with tailored nanostructures. Overcoming the challenges in this field will enable the integration of these materials into practical devices, driving innovation in areas such as energy storage and conversion, electrochemical sensing, thermal conduction or insulation.

In the quest for sustainable and efficient solutions, the realm of materials science has witnessed remarkable strides towards multifunctional, flexible polymeric materials with controlled nanostructures due to their unique properties, such as lightweight, mechanical flexibility, and easy processability (Feng et al., 2021; Li et al., 2021; Ren et al., 2021). Understanding the structure-property correlations through the design of controlled nanostructures is highly significant (Roberts and Knackstedt, 1996; Tong et al., 2019). The properties of nanomaterials are influenced not only by their composition (Ai et al., 2020; Ren et al., 2022) but also by their nanostructures, such as nanoparticle dispersion and hierarchical design (Wang et al., 2015; Zhang et al., 2018; Vargo et al., 2023; Li et al., 2024). The amalgamation of advanced synthesis techniques and innovative applications has paved the way for transformative developments in various fields ranging from energy to environmental sustainability (Tabone et al., 2010; Giussi et al., 2019; DelRe et al., 2021; Homer et al., 2023; Hua et al., 2023).

This Research Topic aims to provide a comprehensive overview of recent advancements in developing flexible polymeric materials with controlled nanostructures, and to showcase intriguing research results that will inspire future advancements in both fundamental science and applied research, paving the way for promising devices and systems. The focus will be on structure-property correlations, emphasizing the impact of controlled nanostructures on the materials' multi-physical properties. We are delighted to present five valuable research findings on this Research Topic, including advancements in organic polymeric and inorganic composites, improvements in multi-physical performance and preparation methods, as well as the exploration of structure-property correlations.

Organic polymers, composed of repeating monomer units, are essential materials with diverse structures and applications (McCrum et al., 1997). Han et al. delved into the enhancement of organic solar cells through the modification of poly (3,4-ethylenedioxythiophene)-poly (styrene sulfonate) (PEDOT:PSS) hole transport layer. By addressing the intrinsic limitations of PEDOT:PSS, such as low conductivity and surface roughness, the study achieved a remarkable power conversion efficiency of 18.13% in PM6:Y6 devices. In the realm of thermal insulation, Liu et al. leveraged the thermal properties of polyimide (PI) aerogel and the reinforcement of aramid fiber and prepared flexible PI aerogel/aramid fiber composites with enhanced mechanical strength and thermal insulation capabilities successfully. In consideration of environmental sustainability, waterborne phenol-formaldehyde epoxy resins with superior performance and environmental friendliness were explored extensively. Through meticulous optimization of synthesis methods and the introduction of nano-silica modifiers, Lu et al. obtained stable phenol-formaldehyde epoxy resin emulsions with a prolonged storage lifespan.

In addition, some contributions cover the exploration of nanocomposites with tailored nanostructures. Hasheena et al. presented a facile synthetic strategy for the fabrication of graphene oxide-nickel sulfide quantum dots, offering a versatile platform for electrochemical sensing. The nanocomposite-coated electrode exhibited excellent stability and sensitivity, enabling the simultaneous detection of dopamine and tyrosine. Also based on graphene oxide (GO), Armstrong et al. introduced silver-graphene oxide (Ag-GO) hybrid nanofluid to heat exchanging equipment. By tuning the molarity of Ag-GO hybrid nanoparticles, uniformly embedded quazicubical Ag nanoparticles over an amorphous, worm-like silky veil of GO nanostructures were formed, achieving significant enhancements in heat transfer coefficient and thermal performance index in a double pipe heat exchanger.

Collectively, these articles underscored the pivotal role of controlled nanostructures in unlocking the multifunctionality and flexibility of organic-inorganic hybrid materials across diverse applications. From renewable energy to environmental remediation, these advancements epitomized the convergence of materials science, nanotechnology, and sustainability, offering solutions to pressing global challenges. Through this collection of articles, we aim to ignite greater research enthusiasm and push the potential of multifunctional materials to new frontiers in future applications.

We extend our gratitude to all the authors who contributed to this Research Topic, as well as the journal editors and staff who helped compile this outstanding collection.

Author contributions

LR: Writing–original draft, Writing–review and editing. ZP: Writing–review and editing. JK: Writing–review and editing. HL: Writing–review and editing.

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.

Publisher's note

References

Ai, D., Li, H., Zhou, Y., Ren, L., Han, Z., Yao, B., et al. (2020). Tuning nanofillers in *in situ* prepared polyimide nanocomposites for high-temperature capacitive energy storage. *Adv. Energy Mater.* 10 (16), 1903881. doi:10.1002/aenm.201903881

DelRe, C., Jiang, Y., Kang, P., Kwon, J., Hall, A., Jayapurna, I., et al. (2021). Near-complete depolymerization of polyesters with nano-dispersed enzymes. *Nature* 592 (7855), 558–563. doi:10.1038/s41586-021-03408-3

Feng, Q. K., Zhong, S. L., Pei, J. Y., Zhao, Y., Zhang, D. L., Liu, D. F., et al. (2021). Recent progress and future prospects on all-organic polymer dielectrics for energy storage capacitors. *Chem. Rev.* 122 (3), 3820–3878. doi:10.1021/acs.chemrev.1c00793

Giussi, J. M., Cortez, M. L., Marmisollé, W. A., and Azzaroni, O. (2019). Practical use of polymer brushes in sustainable energy applications: interfacial nanoarchitectonics for high-efficiency devices. *Chem. Soc. Rev.* 48 (3), 814–849. doi:10.1039/c8cs00705e

Homer, J. A., Xu, L., Kayambu, N., Zheng, Q., Choi, E. J., Kim, B. M., et al. (2023). Sulfur fluoride exchange. *Nat. Rev. Methods Prim.* 3 (1), 58. doi:10.1038/s43586-023-00241-y

Hua, M., Peng, Z., Guha, R., Ruan, X., Ng, K. C., Demarteau, J., et al. (2023). Mechanochemically accelerated deconstruction of chemically recyclable plastics. *ChemRxiv*. doi:10.26434/chemrxiv-2023-rf93d

Li, H., Vargo, E., Xie, Z., Ma, L., Pieters, P. F., Shelton, S. W., et al. (2024). Multilaminate energy storage films from entropy-driven self-assembled supramolecular nanocomposites. *Adv. Mater.* 2401954, e2401954. doi:10.1002/adma.202401954

Li, H., Zhou, Y., Liu, Y., Li, L., Liu, Y., and Wang, Q. (2021). Dielectric polymers for high-temperature capacitive energy storage. *Chem. Soc. Rev.* 50 (11), 6369–6400. doi:10.1039/d0cs00765j

McCrum, N. G., Buckley, C. P., and Bucknall, C. B. (1997). *Principles of polymer engineering*. Oxford; New York: Oxford University Press.

Ren, L., Li, H., Xie, Z., Ai, D., Zhou, Y., Liu, Y., et al. (2021). High-temperature high-energy-density dielectric polymer nanocomposites utilizing inorganic core–shell nanostructured nanofillers. *Adv. Energy Mater.* 11 (28), 2101297. doi:10.1002/aenm.202101297

Ren, L., Qiao, J., Wang, C., Zheng, W., Li, H., Zhao, X., et al. (2022). Role of bandgap and permittivity of nanofiller in the energy storage performance of PEI-based nanocomposites. *Mater. Today Energy* 30, 101161. doi:10.1016/j.mtener.2022.101161

Roberts, A. P., and Knackstedt, M. A. (1996). Structure-property correlations in model composite materials. *Phys. Rev. E* 54 (3), 2313–2328. doi:10.1103/physreve.54.2313

Tabone, M. D., Cregg, J. J., Beckman, E. J., and Landis, A. E. (2010). Sustainability metrics: life cycle assessment and green design in polymers. *Environ. Sci. Technol.* 44 (21), 8264–8269. doi:10.1021/es101640n

Tong, H., Ahmad, A., Fu, J., Xu, H., Fan, T., Hou, Y., et al. (2019). Revealing the correlation between molecular structure and dielectric properties of carbonyl-containing polyimide dielectrics. *J. Appl. Polym. Sci.* 136 (34), 47883. doi:10.1002/app.47883

Vargo, E., Ma, L., Li, H., Zhang, Q., Kwon, J., Evans, K. M., et al. (2023). Functional composites by programming entropy-driven nanosheet growth. *Nature* 623 (7988), 724–731. doi:10.1038/s41586-023-06660-x

Wang, Y., Cui, J., Yuan, Q., Niu, Y., Bai, Y., and Wang, H. (2015). Significantly enhanced breakdown strength and energy density in sandwich-structured barium titanate/poly (vinylidene fluoride) nanocomposites. *Adv. Mater.* 27 (42), 6658–6663. doi:10.1002/adma.201503186

Zhang, X., Jiang, J., Shen, Z., Dan, Z., Li, M., Lin, Y., et al. (2018). Polymer nanocomposites with ultrahigh energy density and high discharge efficiency by modulating their nanostructures in three dimensions. *Adv. Mater.* 30 (16), 1707269. doi:10.1002/adma.201707269