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Nature-Inspired Nanomaterials

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Over the past two decades, nature-inspired nanomaterials have experienced remarkable development, yielding numerous discoveries of novel principles, materials, and innovative technologies. To showcase the latest advancements in this field, we have organized a Special Issue entitled "Nature-inspired Nanomaterials" for *Advanced Materials*. This Special Issue features 26 articles, comprising 18 Review Articles and 8 Research Articles, which cover diverse aspects of the nature-inspired nanomaterials domain. These contributions provide valuable insights into prominent frontier areas, including nature-inspired super-wettable materials, nature-inspired adhesion, lubrication, soft materials, and nature-inspired structural and mechanical materials, among others. Additionally, this Special Issue commemorates the 60th birthday of Professor Lei Jiang—a leading expert in the field of nature-inspired materials—and the 25th anniversary of his return to work in China.

Superwettability, including superhydrophilicity, superhydrophobicity, superoleophilicity, and superoleophobicity, is a unique interfacial property that can enhance interfacial interactions and mass transport, thereby playing a critical role of nanomaterials design. Mingjie Liu et al. (adma.202506058) introduce the design principles and synthesis strategies of superwetting catalysts, particularly focusing on the confinement effects and mass transport mechanisms. Superwetting catalysts are expected to expand applications in sustainable energy, environmental remediation, and industrial catalysis, solving key challenges in multiphase reaction systems. Liping Wen et al. (adma.202506029) review the recent progress in advanced nanofluidic channels, discuss the impact of external field regulation, and prospect the future of osmotic energy conversion. Inspired by natural transmembrane transport behaviors, the biomimetic nanofluidics can achieve high-selectivity and high-flux transportation, enhancing high-performance osmotic energy harvesting. Huan Liu and co-workers (adma.202505085) develop the model structures of dual-, triple-, and multi-conical fibers, which enable controllable liquid transfer. Moreover, micro-patterning devices prepared using the fibrous-guided direct-writing strategy would achieve excellent optoelectronic performance. Fengyu Li et al. (adma.202502890) discuss the ability of the *Hofmeister effect* to modulate elasticity in flexible devices through controlling surface wettability precisely. The *Hofmeister effect* modulates material properties via specific ion-surface interactions and hydration restructuring, providing a simplified mechanism to improve the performance of flexible electronics, optics, and biomedical devices.

Bio-inspired soft matter is one kind of material that tends to exhibit typical wet/lubricous/adhesive behavior, playing an irreplaceable role in medical and industrial applications. Hongbo Zeng et al. (adma.202501542) systematically discuss the nanomechanical mechanisms of underwater adhesion and self-healing capabilities of mussels, then summarize the development of mussel-inspired materials, including coacervates, coatings, and hydrogels with underwater adhesion and self-healing properties. The mussels' molecular interaction strategies provide valuable insights for the development of novel functional materials. Inspired by unique cold-adaptation mechanisms of organisms in extreme cold environments, Jianjun Wang et al. (adma.202510982) discuss the multidisciplinary strategies for tissue and organ cryopreservation, and propose an ideal "cocktail-style" cryoprotectant which shows the potential to transform transplant medicine through global organ banking and advancing regenerative therapies. Yanlei Yu et al. (adma.202509892) reveal the interplay between materials chemistry, processing, and alignment of liquid crystal polymers (LCPs), summarize the advances in LCP actuators inspired from biological muscles, and discuss the perspectives on the current challenges and potential future development trends. Xuehua Zhang et al. (adma.202509486) discuss recent advances in reactive microdroplets, which are employed as microreactors for the fabrication of functional materials, and used as reactive entities to accelerate interfacial reactions in energy and environmental fields. Thomas Scheibel et al. (adma.202508959) explore recent advances in nanostructured material surfaces inspired by spider silk, such as particles, capsules, electrospun nanofibers, films/coatings, macroscopic nanofibril-based hydrogels, and nanohydrogel coatings. Furthermore, applications of nanostructured spidroin coatings are also demonstrated, including drug delivery, cell accommodation, bioselective immobilization, and producing confined nanostructured patterns. Joanna Aizenberg et al. (adma.202507273) report a new strategy to fabricate untethered soft microactuators by taking inspiration from cell differentiation. By using liquid crystal monomer droplets as a core, soft microactuators are realized with a rich library

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of shapes, surface patterns, and molecular structures. Ximin He et al. (adma.202519669) draw inspiration from the energy-harvesting and repetitive jumping behaviors of insects to realize light-driven, electronics-free soft robots capable of self-sustained, continuous motion. Through integrating photothermal conversion, snap-through instability, and self-shadowing feedback within photoresponsive nanocomposites, these insect-scale robots autonomously harvest energy from constant light to repeatedly jump, self-right, and navigate obstacles. This work showcases how nature-inspired design can impart autonomous, long-lived functionality to soft materials and robotic systems. Feng Zhou et al. (adma.202420626) provide an overview of the common biological lubrication behaviors of natural organisms and their underlying mechanisms, and then summarize the significant works in developing biomimetic advanced lubrication materials. Natural lubrication strategies will be beneficial to design lubrication materials and reduce friction-induced energy consumption.

Over hundreds of millions of years, organisms have evolved robust structures for selected functions to adapt against a wide range of ecological pressures and predation, inspiring the design of numerous structural and mechanical nanocomposite materials. David Kisailus et al. (adma.202509281) describe the role of nanoscale architectures in biological systems, including enhancement of structural, optical, thermal, and sensing properties. In addition, Kisailus' group provides an overview of bio-inspired nanostructure developing by leveraging the synthesis-structure and structure-function relationships observed in nature. Peter Fratzl et al. (adma.202508442) reveal the primary mechanisms involved in the generation, storage, and release of internal stresses by considering examples of biological materials, and describe the phenomena of generating a function by storing elastic energy in the biological world. Moreover, Shu-Hong Yu et al. (adma.202506308) successfully fabricate a scalable porous ceramic enabled by nacre-like framework, presenting an excellent fire-resistance and maintained performance after fire. With a good combination of thermal insulation and mechanical strength, this nanostructured material shows broad potential application prospects in the thermal protection field. Furthermore, Qunfeng Cheng et al. (adma.202501932) summarize recent advances for high-performance 2D carbon nanocomposites (TDCNs) drawing inspiration from nacre, and systematically present the manufacturing strategies of TDCNs. Highly-aligned assembled and densified TDCNs exhibit extraordinary fracture toughness, demonstrating potential as a new generation of high-performance composite materials. Ruikang Tang et al. (adma.202505767) provide an overview of relevant works in artificial material-biological fusion technologies, which is inspired by biomineralization, and summarize the progress in biomedical applications consisting of cell protection and functionalization, vaccine engineering, artificial organelles, organization plugin, and disease treatment. Stanislav Gorb and co-workers (adma.202503941) elucidate the effect of hierarchical composite architecture of insect wings on damage resistance, where nanoscale chitin fiber orientations achieve an exceptional balance between lightweight flexibility and structural robustness. This biomechanical strategy provides guidance for biomimetic design of micro-aircraft and advanced fiber-reinforced materials. Lin Guo and co-workers (adma.202503537) developed a gradient enamel-mimetic composite via crisscross assembly of amorphous ZrO_2 layer-coated hydroxyapatite nanowires. This gradient design strategy provides excellent mechanical performance, especially fatigue resistance, for the structural materials, laying a foundation for the preparation of high-strength engineering materials.

In addition to the above fields, there are also many other nature-inspired materials, including separation, sensing, energy, biomedical, and interfacial materials, among others. Shutao Wang et al. (adma.202510312) present a comprehensive review on recent advances in nature-inspired particles with unique chemical and topological characteristics from natural prototypes to preparation methods. These particles are developed for various bioanalytical applications such as adsorption, separation, interaction, recognition, biological sensing, and biological imaging. Jian Jin et al. (adma.202505656) introduce the solar-driven interfacial evaporation (SDIE) technology inspired by plant transpiration mechanisms, and present the recent advancements in SDIE. With the material innovation and structural design expansion in the future, multifunctional SDIE technologies are considered to play an important role in solving water-energy-resource interdependency. Fan Xia and co-workers (adma.202505187) summarize the current synthesis methods of natural cell-inspired nanoparticles (NCINPs), present the progress, limitations, and challenges throughout the development of NCINPs, and depict the future prospects. Róisín M. Owens et al. (adma.202501985) report a type of biologically relevant 2D biomembrane-functionalized microelectrode array, integrated with host-cell-derived supported lipid bilayers and organic microelectrode arrays. This platform can function as a virus sensor by overexpressing angiotensin-converting enzyme 2 receptors on the biomembranes, enabling automated label-free assay for viral detection and inhibitor screening. Zuankai Wang and co-workers (adma.202506136) propose a torrent-like charge regulation strategy and design a charge vascular system by taking inspiration from plant vascular networks to achieve ultra-high-power output in triboelectric energy harvesters. This method allows a volumetric peak power density exceeding 10 MW m^{-3}, highlighting its practicality and flexibility for real-world applications. Zuzanna S. Siwy et al. (adma.202418987) devise heterogeneous nanopore arrays by selective modification of nanopores embedded in a silicon nitride membrane, successfully reproducing the efficient transport of biological ion channels. Zhiwu Han and co-workers (adma.202418108) review the development of bionic recognition technologies taking inspiration from biological mechanosensory systems. They summarize the design strategies and considerations for mechanical information bionic recognition technologies, and provide an outlook on potential applications in healthcare, smart devices, and virtual reality.

Finally, we express our sincere gratitude to the editorial team of *Advanced Materials*, particularly Dr. Bo Weng, for their support in publishing this Special Issue. We also extend our heartfelt thanks to all authors for their outstanding contributions. This Special Issue in *Advanced Materials* serves as a global platform for disseminating significant advancements in nature-inspired nanomaterials and their prospective applications. Furthermore, it is our aspiration that this Special Issue will inspire readers and foster greater collaboration among researchers and practitioners from diverse fields.

Conflict of Interest

The authors declare no conflict of interest.

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