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Editorial: Ordered structures of nanomaterials in advanced composites

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Editorial on the Research Topic
Ordered structures of nanomaterials in advanced composites

Nanomaterials, including nanoparticles, nanowires, nanosheets, etc., exhibit unique physicochemical properties distinct from their bulk counterparts due to nanoscale effects and exceptionally high specific surface areas. Since the late 20th century, these nanomaterials have attracted extensive global research attention for their potentials in composites, electronic devices, biomedicine and other advanced technological applications. In the context of composite materials, the deliberate structural design of nanomaterials is emerging as an essential strategy, enabling them to serve as functional fillers that not only utilize intrinsic properties but also enhance nanofiller loading efficiency. For novel composites incorporated with pre-assembled structures of nanomaterials, the synergistic interactions between particles and with the matrix can significantly improve the overall performance. Notably, the morphology of microstructures and interfacial characteristics are critical determinants of these interactions.

This Research Topic features 4 insightful studies that explore the processing and structural optimization of nanomaterials to enhance their reinforcing efficiency in advanced composites. Innovative strategies were proposed to address persistent challenges such as particle agglomeration and limited interfacial compatibility. These advancements have led to application-specific breakthroughs, including the development of aerogel-based thermal insulators, high-performance sunscreen formulations, and graphene-based devices, thus contributing both theoretical insights and technological solutions for the design of next-generation composites.

Mechanical treatment is a facile method to modify the microstructure of nanomaterials. Yang et al. employed fine grinding techniques to reduce the aggregation of oxide particles in a zinc oxide (ZnO) and titanium dioxide (TiO_2) hybrid system, achieving a homogenous slurry containing sub-micron powders. The treated slurry demonstrated an increased sun protection factor (SPF) and reduced free radical generation, highlighting the efficacy of particle size control in the formulation of sunscreen products. Li et al. comprehensively investigated the impact of mechanical grinding on mesoporous silica aerogels, analyzing changes in particle size, tap density, pore architecture, thermal conductivity, and hydrophobicity. By correlating microstructural evolution, such as skeleton collapse and pore restructuring, with macroscopic performance metrics, their study provides a broader understanding of property modulation beyond particle size alone. The identification of grinding speed as a key parameter offers valuable data for optimizing aerogel particles used in thermal barrier coatings and composite systems. Arf et al. examined the effect of ethanol-assisted mixing on diverse mechanical properties of PMMA-based composites reinforced with MgO and Ag nanoparticles. Their findings demonstrate that ethanol-mediated dispersion effectively reduces nanoparticle agglomeration and stress concentration, thereby enhancing flexural strength, impact resistance, microhardness and compressive strength of the composites.

Large-area graphene as the representative atomic-thin nanostructure has drawn considerable attention in composite applications. The cleanliness of transferred graphene is crucial for harnessing its exceptional properties. Liu et al. proposed replacing conventional acetone with acetic acid for PMMA removal during the transfer process. They achieved evident reduction in surface residues, thus significantly improve the electrical performance of graphene. This simple yet effective approach offers promising applicability in layered composites, electronic devices and energy storage devices.

Collectively, the contributions in this Research Topic showcase interdisciplinary innovations in nanomaterial processing, characterization, and application. They address critical bottlenecks and pave the way for practical deployment of structured nanomaterials in high-performance and functional composite materials.

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