Advancing Graphene Derivatives: From Scalable Synthesis to High-Performance Industrial Applications

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Abstract

The industrial translation of graphene technologies has increasingly shifted from pristine graphene toward engineered graphene derivatives that offer superior processability, functional tunability, and system-level compatibility with large-scale manufacturing environments. At TACC Limited, our development strategy is centered on mission-specific graphene derivative platforms, where material chemistry, morphology, and surface functionality are tailored to meet the performance requirements of targeted industrial applications rather than pursuing conventional, one-size-fits-all graphene products. Our work focuses on the scalable synthesis and application-driven engineering of graphene oxide (GO), reduced graphene oxide (rGO), and graphene nanoplatelets (GNPs), produced through controlled chemical and physical routes that enable precise modulation of oxygen functional groups, defect density, layer thickness, lateral dimensions, and surface energy. These parameters are systematically optimized to achieve application-relevant properties such as dispersibility, interfacial bonding, electrical and thermal conductivity, mechanical reinforcement efficiency, and chemical stability.

TACC has developed a portfolio of application-specific graphene derivatives in the form of dry powders, aqueous and solvent-based dispersions, and pre-functionalized concentrates, designed for direct integration into industrial value chains. These materials are being deployed and evaluated across multiple sectors including cement and construction materials, energy storage systems, elastomers and polymers, advanced coatings, technical textiles, thermal interface materials, and multifunctional composites. In construction and infrastructure, GO is engineered as nano-additives to enhance cement hydration kinetics, microstructural densification, mechanical performance, and durability, enabling material efficiency and potential clinker reduction. In energy systems, rGO-based architectures are developed as conductive frameworks and active components for electrodes and composite current collectors. In polymers, rubbers, and coatings, surface-modified graphene derivatives act as multifunctional fillers providing percolative electrical conductivity, thermal transport, barrier performance, and mechanical reinforcement at ultra-low loadings.

Ongoing R&D efforts emphasize process scalability, reproducibility, and techno-economic optimization, with a strong focus on synthesis scale-up, dispersion engineering, surface chemistry control, and industrial quality consistency. This mission-oriented materials design paradigm represents a shift from laboratory-grade graphene toward application-engineered graphene derivatives, positioning these materials as commercially viable advanced functional additives for high-volume and high-impact industrial sectors.