

Graphene-Reinforced HDPE Nanocomposites: Trends, Challenges, and Future Directions in Mechanical Performance

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Abstract

High-density polyethylene (HDPE) is one of the most widely used thermoplastics worldwide, valued for its excellent processability, chemical resistance, and cost-effectiveness. However, its relatively modest mechanical performance often limits its use in demanding engineering applications. Recent advances in nanotechnology have highlighted graphene as a powerful reinforcing agent capable of overcoming these limitations, even at very low concentrations. This review synthesizes and critically analyzes the state of the art on HDPE/graphene nanocomposites, providing a consolidated perspective on how graphene addition alters the mechanical response of HDPE compared to its neat form. Drawing from a broad body of literature, the discussion covers tensile, flexural, and overall stiffness improvements, while also addressing the significant role of factors such as composite fabrication methods, graphene size and concentration, and the use of coupling agents and compatibilizers. Evidence from multiple studies demonstrates that significant enhancements in modulus and strength are achievable when graphene is uniformly distributed and well bonded to the polymer matrix, whereas poor dispersion or agglomeration can diminish or even reverse these gains [1, 2]. Beyond summarizing property trends, the review underscores practical aspects that are particularly relevant for researchers and industry stakeholders, including the identification of effective compounding techniques, the selection of graphene type, and guidance on optimal concentration ranges tailored to specific mechanical performance targets. By distilling these insights, the review offers a roadmap for integrating HDPE/graphene nanocomposites into both established applications, and emerging areas that demand lightweight yet mechanically robust materials. In addition, the work also highlights current challenges and research gaps, pointing to the need for scalable dispersion strategies and deeper understanding of interfacial interactions. Overall, the review provides a clear view of both the opportunities and limitations of HDPE/graphene nanocomposites, positioning them as promising candidates for next-generation polymer composite technologies.

References

- [1] Das S, Wajid AS, Shelburne JL, Liao Y-C, Green MJ, Localized In situ Polymerization on Graphene Surfaces for Stabilized Graphene Dispersions, ACS Applied Materials & Interfaces, 3 (2011) 1844-51.
- [2] Dargahi A, et al., Low-Concentration Graphene Nanoplatelet/HDPE Nanocomposites with Enhanced Dispersion and Interfacial Bonding for Improved CO₂ Barrier and Mechanical Performance at Elevated Temperatures, Industrial & Engineering Chemistry Research, 64 (2025) 5359-71.

Figures

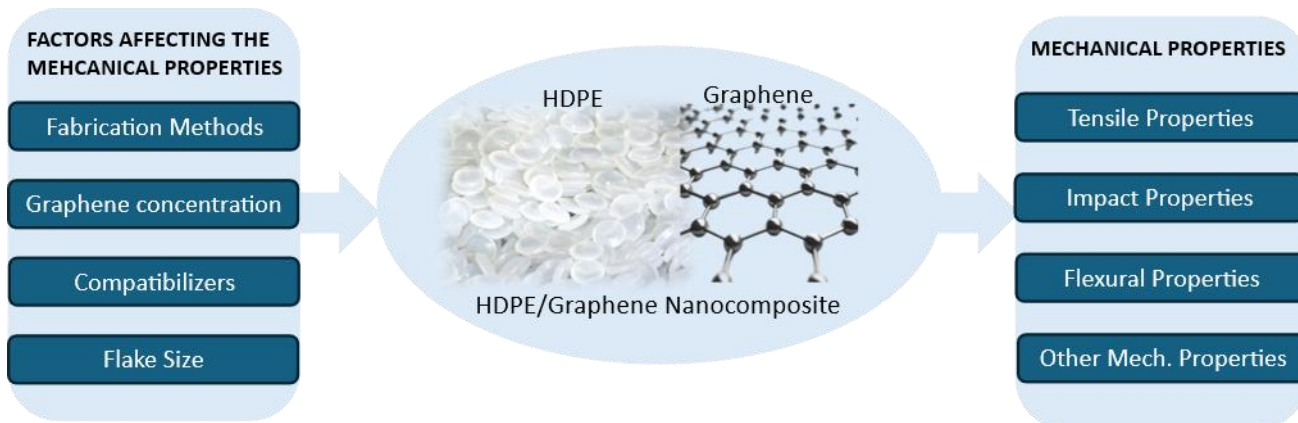


Figure 1: Schematic diagram representing the scope of the work.