Advanced Nanocomposites for Hydrogen Storage: From Material Design to Processability

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The transition toward sustainable mobility and reduced environmental impact has driven significant research into alternative energy carriers. Hydrogen is increasingly recognized as a viable solution to reduce reliance on fossil fuels, particularly in the transportation sector. Nevertheless, the challenge of safely and efficiently storing hydrogen remains a critical technological barrier. Lightweight, high-performance polymer composite vessels offer an attractive solution for storing hydrogen in both compressed and cryogenic forms, especially in mobile applications [1]. Carbon fiber reinforced composites are ideal for Type V tanks, which are linerless vessels that rely on their composite structure for strength and hydrogen containment. These tanks are at the technological frontier of hydrogen storage, though the absence of an internal liner places significant demands on the matrix material, particularly in terms of gas barrier performance, limiting commercial uptake. This study investigates epoxy-based composites enhanced with expanded graphite as a potential matrix material for Type V hydrogen storage vessels. Epoxy resins are extensively used in aerospace due to their processability and mechanical properties. The integration of nanofillers, especially those with high aspect ratios such as expanded graphite, has been shown to significantly enhance gas barrier properties, as well as mechanical resistance and thermal conductivity [2]. A key objective of this research is to develop a rheological framework to evaluate the processability of these nanocomposites using traditional manufacturing methods such as filament winding and prepreg compression moulding [3]. The viscosity profile of the resin system is critically assessed to determine its suitability for large-scale manufacturing, while also correlating the nanofiller loading with changes in barrier and functional performance. The work contributes to the broader field of chemical engineering by advancing material solutions that support decarbonized energy systems, particularly through sustainable and scalable hydrogen storage technologies. The findings aim to bridge the gap between material development and process engineering, facilitating the deployment of Type V tanks in transportation sectors and thus accelerating the hydrogen economy.

Keywords: *hydrogen storage, lightweight, polymer composite*

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