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Epoxy-Montmorillonite coatings for type IV high-pressure vessel applications

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Hydrogen is increasingly recognized as a central pillar of the global energy transition due to its high gravimetric energy density and its clean combustion by-product, the water. However, one of the main challenges associated with hydrogen is its safe and efficient storage under high pressure, particularly in mobile applications. Type IV composite overwrapped pressure vessels (COPVs) are currently the most advanced solution for compressed hydrogen storage. These systems combine a polymeric liner, responsible for gas containment and permeation resistance, with a fiber-reinforced composite shell that provides structural integrity. Despite their advantages in weight reduction and mechanical performance, Type IV vessels are still limited by issues such as hydrogen permeation, thermal ageing, and mechanical fatigue of the liner material.

This research project proposes the development of an internal epoxy-based nanocomposite coating for thermoplastic liners, applied through rotational molding, to enhance both barrier and mechanical performance. Epoxy systems are known for their thermal stability, chemical resistance, and strong adhesion potential. The incorporation of nanofillers like montmorillonite, MMT, aims to reduce the free volume in the polymer matrix and to increase material tortuosity, lowering hydrogen permeability and improving tensile and thermal resistance. Preliminary lap shear tests have shown that the epoxy-based system with nanofillers demonstrates superior adhesion to PA and HDPE substrates compared to unfilled systems, validating its suitability as possible liner coating.

The study includes an evaluation of the mechanical and chemical adhesion mechanisms, the effect of processing parameters on coating uniformity, and the influence of nanofiller content on adhesive integrity and performance. Mechanical and chemical characterization will be carried out to understand the adhesive-adherent behavior, including tensile and shear strength, infrared spectroscopy (FTIR), and thermal properties (DSC). The final goal is to develop a technologically viable coating solution that increases the lifespan, safety, and performance of hydrogen storage liners manufactured via rotational molding. This work contributes directly to advancing hydrogen storage technologies aligned with the demands of next-generation energy systems.