Characterization of high-performance polymers for gas barrier applications

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Type IV hydrogen gas tanks are advanced high-pressure vessels used for hydrogen storage, featuring a polymer liner fully wrapped with carbon fiber-reinforced composite. Designed for pressures up to 700 bar, they are widely employed in fuel cell electric vehicles (FCEVs) due to their lightweight structure and high corrosion resistance. Among all tank types (I–IV), Type IV offers the best strength-to-weight ratio, making it ideal for hydrogen storage. The polymer liner is critical in minimizing hydrogen permeation. Semicrystalline polymers are increasingly used for this role, owing to their low gas permeability, processability, and tunable properties through control of crystallinity. Gas transport in these materials follows a solution-diffusion mechanism, occurring primarily in the amorphous phase, while crystalline domains act as impermeable barriers that increase tortuosity and reduce overall permeability. This study investigates the gas transport properties of two semicrystalline polyamides: polyamide 6 (PA6) and polyamide 4.10 (PA410). PA6, already used in commercial liners, is a leading alternative to high-density polyethylene (HDPE). Although it has a lower crystallinity (20–40% vs. 60–70% for HDPE), its higher amorphous phase density (1.08 g/cm³ vs. 0.85 g/cm³) results in superior hydrogen barrier performance. PA6 is also less prone to blistering, which benefits long-term tank integrity. However, its hygroscopic nature can negatively impact mechanical and barrier properties in humid conditions. This work characterizes PA6 with particular attention to humidity effects. PA410, for which limited data are currently available in the literature, is a partially bio-based polyamide offering a more sustainable alternative to conventional polymers. It combines good mechanical, thermal, and chemical resistance properties. While its slightly lower amorphous phase density (1.09 g/cm³) could increase hydrogen permeability relative to PA6, its significantly lower moisture uptake suggests improved performance under humid conditions, making it a promising liner candidate. Permeability was measured using constant-volume and constant-pressure methods across various temperatures. Water uptake behavior was assessed gravimetrically via sorption isotherms in controlled humidity environments, using saturated salt solutions to regulate relative humidity precisely. These results enhance understanding of structure–transport relationships in semicrystalline polymers and support the development of high-performance, durable materials for hydrogen storage. The data also inform ongoing multiscale modeling efforts to predict gas transport under realistic operating conditions.

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