Abstract

Barrier composites containing filler particles within a polymer matrix are used to hinder the transport of moisture, gases, and liquids. The volume fraction (loading), aspect ratio, and alignment of these particles govern the overall barrier performance of such composites. Further, the experimental studies faces fabrication challenges resulting in deviation of the expected (barrier, optical , thermal and mechanical) properties as compared to the theoretical estimations. This study focuses on evaluating the effect of incorporating thin disc-shaped particles—(mainly Laponite clay and modified GO) on the barrier and optical properties of polyvinyl alcohol (PVA)-based composites.

The first objective investigates the effect of Laponite loading (volume fraction = 0.01-0.1) and their dispersion on the barrier performance of PVA membranes against the transport of dilute hydrochloric acid. Result indicates variation in permeability with increased loading, significantly influenced by the laponite dispersion. Experimental permeability ratios, compared with theoretical models, suggest that the polymer crystallinity also plays a key role in determining the overall effectiveness of barrier composites.

Further the use of high aspect ratio particles needs preprocessing to enhance their performance in composite. Graphite can be used in composite by exfoliating it to get graphene flakes with its further surface treatment using iron oxide nanoparticles (IONPs). Thus, the second objective involves synthesizing aqueous-stable IONPs exhibiting superparamagnetic behavior. Careful control of synthesis parameters is essential to obtain suitable size, composition, and aqueous stability. Further objective involves the physical exfoliation and surface modification of high aspect ratio graphite flakes using IONPs via ultrasonication process. The effectiveness of the current physical exfoliation method is compared to the chemical Hummer's process for GO synthesis.

While filler loading and aspect ratio are typically well-controlled in experimental studies, particle orientation remains less regulated. Hence, the further focus of this work is to tune the optical properties of these composites by controlling the alignment of GO flakes modified with iron oxide nanoparticles (IONPs). The final objective focuses on aligning GO-IONPs in the polymer matrix using low external magnetic fields (~3 mT) leading to their ultra-high magnetic response (UHMR).

These composites, prepared with parallel, perpendicular, and random alignments, exhibit varied optical properties analyzed via UV-Vis. Further, microscopy, and small angle x-ray spectroscopy (SAXS) analysis is used to analyze the alignment of particles in composites. Finally, the applied methodologies can be used to tune the thermal, mechanical and optical properties of composites in different applications.