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Effect of 2D Nanomaterials on Gas Permeability and Mechanical Properties of Thermoplastic Polyurethane Nanocomposites

Abstract: Thermoplastic polyurethanes (TPU) are highly versatile polymers as they close the gap between rubber and hard thermoplastics. They possess a unique combination of properties, such as, high wear resistance, good resistance to oils, greases and solvents, and extremely good weather stability, combined with high elasticity. However, in their neat forms, they are unsuitable for packaging and storage applications due to their high gas permeability. In the past, many efforts have been dedicated to improve gas barrier properties in TPU nanocomposites by incorporating different 2D nanomaterials such as nanoclays [1], graphene oxides [2] and graphene nanoribbons [3]. The incorporated 2D nanofillers create a tortuous path for gas molecules within the polymer matrix [4], thus making it difficult for gas to diffuse and get transported across the membranes, as illustrated in Figure 1. In particular, graphene filled TPU nanocomposites exhibit substantial improvements in gas barrier properties as well as mechanical, electrical and thermal properties. Graphene, with impermeable 2D structure and high aspect ratio, provides superior gas barrier properties in the prepared nanocomposites as compared to its spherical counterparts (like nanoparticles) [4]. In this study, we investigate the effect of different aspect ratios of graphene on the gas barrier properties of the TPU nanocomposites, where the nanofillers have been incorporated. TPU nanocomposites were prepared by solvent casting technique, using different types of graphene powders dispersed into chloroform, with the help of sonication. The as prepared TPU nanocomposites demonstrated significant improvements in the gas barrier properties with respect to the pure polymer matrix, which depend on their aspect ratios. In particular, a reduction of 70 % in the gas permeability was observed at 6.0 wt.% concentration of graphene having lateral size and thickness of 415 nm and 5.3 nm, respectively. Their corresponding aspect ratio is 78.30. The normalized gas permeability rate was reduced from 144,846.44 mL.micron/m^2/day for the neat TPU films, to 42,508.53 mL.micron/m2/day at 6.0 wt.% graphene mass loading. This can be attributed to the good dispersion of the graphene flakes into chloroform solvent [5] and packing of the graphene flakes into TPU nanocomposites. Likewise, mechanical properties (Young's modulus) of the as prepared nanocomposites were improved at similar mass fractions. In particular the Young's modulus was increased from 5.16 MPa (for neat TPU) to 11.84 MPs making the TPU nanocomposites more resistant to deformations. The prepared nanocomposites have been also characterized using SEM, TEM and Raman spectroscopy. Future work will involve preparation of solvent-free TPU/graphene nanocomposites with enhanced properties using twin screw extruder and a pelletizer.

References

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Figures

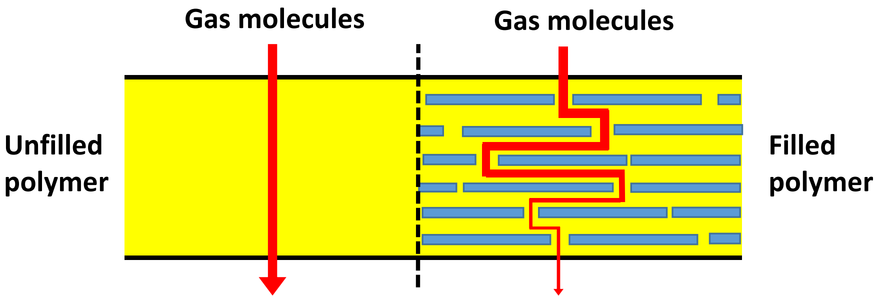

Figure 1: Mechanism of gas molecule's absorption and transportation through a neat polymer film and graphene filled polymer nanocomposite.