ABSTRACT

This thesis aims at to understand the effect of hybrid nanostructures on properties of bromobutyl (BIIR) based rubber blend nanocomposites containing carbon black and platelet-type nanofillers. The influence of hybrid nanostructures and its structure-property relationship on the nanocomposites were investigated. All the nanocomposites were prepared by adapting the melt-compounding technique. The developed nanocomposites were characterized for morphology, mechanical properties, barrier properties, electrical properties, thermal properties, and adhesion properties. Highly impermeable nanocomposites based on bromobutyl (BIIR)/ polyepichlorohydrin (CO) rubber blends were developed and characterized. Platelet-type nanofillers such as organically modified montmorillonite nanoclay (Cloisite 20A)/graphene nanoplatelets (GNP) were used along with carbon black to understand the structural effects on properties described above of BIIR-CO nanocomposites with special reference to the barrier properties. TEM photomicrographs reveal a high degree of dispersion of nanoclay with the formation of hybrid nanostructures. Rheological behavior of the nanocomposites reflects shear thinning nature and significant reduction in die swell is observed with increase in the dosage of platelet-type nanofiller. It also drastically reduces the air permeability, increases electrical conductivity and thermal conductivity of the rubber nanocomposites. These unique attributes were found to stem from the fundamental viscoelastic characteristics, i.e., increase in entanglement density due to the hybrid nanostructures. The development of hybrid nanostructures and its significant contribution to the improvement of properties are explained schematically. A successful attempt has been made to predict the water vapor transmissibility by combining the tortuous effect of nanoplatelets and polar factor of rubber using a basic schematic model. A unique correlation between water vapor transmissibility and gas permeability has been derived systematically, and it has been successfully validated. Interestingly, it signifies the dependency of water vapor transmission characteristics on polar constituent in addition to the tortuous permeation offered by the hybrid nanostructures. We have investigated the effect of graphene nanoplatelets (GNP) and its tailoring mechanism on properties of BIIR-CO nanocomposites. Instead of using graphene oxide and modified graphene, which is limited by a high cost due to oxidation and modification respectively, we have exploited the cost effective GNP in our study. Effect of GNP on the barrier properties of the nanocomposite is extensively studied. A successful attempt has been made to analyze the structural effect of GNP on WVTR systematically in the rubber nanocomposites using the developed WVTR schematic model. Dispersion of GNP is pivotal in impacting the overall performance of the nanocomposites. High performance, cost-effective nanocomposites were also developed based on bromobutyl (BIIR) / epoxidized natural (ENR) rubber blends for barrier applications. Extensive insight on the effect of organically modified bentonite nanoclay (Cloisite 20) and its structure-property relationship in rubber blend nanocomposites were analyzed systematically. The effect of layered clay platelets on transport properties invokes drastic reduction in the air permeability, water vapor transmission rate, and increment in the electrical conductivity and thermal conductivity of the rubber nanocomposites. Mechanical properties register increase in the tensile modulus and tear strength of the nanocomposites. The adhesion strength between nanocomposites and rubberized fabric corroborates the lower elastic modulus and found to be good in the nanocomposite having a lower dosage of nanoclay. A basic simulation has been performed to determine the efficiency of the nanocomposites for improving the barrier properties with special reference to tire inner liner materials. It is noticed that there is a reduction in the tire air loss in the developed nanocomposites up to 17%. The findings lead to a unique methodology in predicting the air permeability in the tire which is pivotal in improving the tire durability. The prediction gives a possibility to improve the quality of inner liner compound developed proactively. In a nutshell, the drastic improvement in the functional properties invokes the possibility of application of these materials in new generation tire inner liners, tubes, highly impermeable membranes and durable bladders.

Keywords: Nanocomposites; Hybrid nanostructure; TEM; Morphology; Air permeability; WVTR model; Mechanical properties; Electrical properties; Thermal properties; Adhesion properties; FEA simulation.