Graphene- and graphite-based hybrid fillers: Synthesis, characterization, and reinforcement in Styrene Butadiene Rubber

Abstract of the thesis
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In the era of technological revolution in the nanoscale, nano-allotropes of carbon have become quintessential for modern advanced engineering. These nano-carbons, graphene in particular has become an integral component in the field of rubber nanocomposite technology as a reinforcing material. Use of pristine graphene as well as its hybrids with other nanofillers and carbon black displays enormous potential for achieving extra-ordinary properties in rubber composites and also addresses the sustainability issue. With the aim of developing facile techniques to fabricate industrially applicable graphene and its hybrids, various bottom-up and top-down approaches were explored in this thesis. Sustainable precursors like molasses and natural graphite were selected for the synthesis of graphene and graphene-carbon black hybrids in a facile pyrolytic method. Electrochemical and micro-mechanical cleavage techniques were also studied and modified to establish feasible techniques for exfoliation of graphite in presence of carbon black, resulting in unique hybrid nanostructures. All these methods were developed by stepwise structural analysis of the intermediates and understanding the plausible process mechanisms. The hybrid nanostructures thus produced, were extensively characterized by techniques such as X-ray diffraction, X-ray photoelectron and Raman spectroscopy, scanning and transmission electron microscopy, atomic force microscopy etc and the results are discussed herein. The graphene-carbon black hybrids were then incorporated into styrene butadiene rubber matrix as fillers and the properties of the rubber nanocomposites were thoroughly studied. Uncured rubber compounds were tested for bound rubber content, gel fraction and Payne effect and the hybrid fillers displayed substantial enhancement in the properties compared to pristine carbon black. The rubber vulcanizates were tested for mechanical properties by tensile test, abrasion resistance test, temperature and strain sweeps in dynamic mechanical analysis. A maximum of 86% reinforcement in tensile strength was achieved by the hybrid filler over carbon black and the hybrid fillers also enhanced typical tire properties, such as rolling resistance, ice and wet traction etc. Finally, an insight into the mechanism of reinforcement by the hybrid fillers was provided by the entanglement rubber tube model that indicated significant reduction in the rubber tube dimension and end to end distance in presence of dual filler system and explained the augmentation in the mechanical properties of the composites.

Keywords: Graphene, Hybrid fillers, Graphene-carbon black hybrids, Rubber nanocomposites, Mechanical properties