ABSTRACT

In recent times, materials that harvest solar radiation and transform it into other forms of energy are of considerable interest. The ease of processibility of reduced graphene oxide (rGO) and its composites provide fascinating optical, electronic, mechanical properties that are presently being explored for photonic, energy harvesting, and advanced electronics applications. Graphene-based devices, an alternative to inorganic semiconductors, are widely being used due to low cost, light weight, flexible, and tunability of energy band gap. A clear understanding of charge transport properties (such as charge carrier mobility (μ), conductivity, trap state density, charge transport mechanism, etc.) of these systems that can make an impact on device performances is very important in device fabrication. In this dissertation, we have investigated the electrical transport, magnetic, and optoelectronic properties of rGO, rGO - metal chalcogenide composites (rGO-zinc selenide (ZnSe), rGO-zinc telluride (ZnTe)). The samples have been synthesized by solvothermal method and the detailed morphological, structural properties of all the samples are studied by various spectroscopic as well as microscopic techniques.

It is observed from dc measurements that the charge transport mechanism follows Mott variable range hopping both for rGO and different rGO-ZnSe composites at lower temperatures (84K-280K), whereas Arrhenius-like transport behavior was observed in 290K-473K. AC conductivity suggests Debye-like relaxation process caused by quantum mechanical tunneling between localized states for rGO-ZnSe films in the whole temperature range. Electron paramagnetic resonance spectra and magnetization data indicate paramagnetic behavior of the composites, in contrast to the diamagnetism of pure rGO and ZnSe. Temperature dependent (84K-473K) current density-voltage ($J-V$) characteristics of pure rGO, rGO-ZnSe, and rGO-ZnTe show a transition from Ohmic to trap dominated space charge limited current with a power law $J \sim V^m$, $m \geq 2$ for higher applied voltages.

The synergistic coupling between rGO sheets and ZnSe nanoparticles have been tested by measuring the nonlinear optical (NLO) responses with a femtosecond laser pulse (∼150 fs). Comprehensive measurements on nonlinear absorption as well as nonlinear refraction in an intensity range of 37-130 GW/cm^2 exhibit an enhancement in NLO properties of rGO-ZnSe composite than the individual counterparts. Moreover, the comparative studies on rGO-ZnSe and rGO-ZnTe composites indicate that the latter shows better optoelectronic properties as compared to the former in terms of photosensitivity (P) values, change in μ under illumination, and NLO properties. A decreasing trend in P values with increasing temperature is seen for all the samples which has been attributed to enhanced scattering of charge carriers. These studies stipulate that rGO-semiconductor composites are promising candidates for optoelectronic as well as photonic device applications.

Keywords: Charge transport process, light-matter interaction, nonlinear optical properties, graphene-based composites.