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Characterisation of Functionalised Multi-Wall Carbon Nanotube Nanocomposites with Poly(3,4-Ethylene Dioxythiophene): Polystyrene Sulfonate

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Abstract. The influence of functionalised multi-wall carbon nanotubes (f-MWCNTs) on the conductivity of conducting polymer poly (3,4-ethylene dioxythiophene)-poly (styrene sulfonate) (PEDOT: PSS) was explored by using various concentrations of MWCNTs to create a nanocomposite (PEDOT: PSS/ MWCNT) matrix. Field emission scanning electron microscopy (FE-SEM), X-ray diffraction and Fourier transform infrared spectroscopy were employed to examine the structural and morphological features of the produced nanocomposite thin films. The electrical conductivity of MWCNT and (PEDOT: PSS/ MWCNT) nanocomposites was determined using a two-point probe (lab view 2018). Results showed that the conductivity was enhanced from 6.7 s/cm for PEDOT: PSS (0.01 wt.% MWCNT) to 36.6 s/cm for PEDOT: PSS (5 wt.% MWCNT) and then decreased to 11.72 and 3.14 s/cm for 7 and 10 wt.%, respectively.

Introduction

Conjugated polymers derived from substituted thiophene are a major family of electronically conducting polymers [1] that have attracted interest over the last 25 years because of their unique electrical and optical properties originating from the p-electron delocalisation along their backbones. These materials can be used in data storage, sensors, light-emitting diodes, and rechargeable batteries. [2].

For poly (3,4-ethylene dioxythiophene) (PEDOT): PSS, its conductivity can be attributed to its polar component—the PSS unit that enhances the polymer's dispersion in water but also reduces its conductivity. This commercially accessible polymer has a conductivity of 200 S cm^{-1} but could not outperform inorganic counterparts such as indium tin oxide (ITO), fluorine-doped tin oxide (FTO) or doped zinc oxide. Various approaches, such as acid treatment, functionalisation, and integration of various nanomaterials including carbon nanotubes (CNTs), graphene and TiO_2, have been applied to improve the conductivity of PEDOT: PSS [3,4]. With acid treatment, the functionalised PSS decreases rapidly and consequently reduces the dispersibility of PEDOT: PSS in water [5].

Poly(3,4-ethylene dioxythiophene) PEDOT is a bicyclic polythiophene derivative that was first developed and commercialised. Bayer AG is developing conductive anti-electrostatic coatings [6]. Poly(3,4-ethylene dioxythiophene): polystyrene sulfonate is theoretically useful due to its facile processibility from an environmentally acceptable solvent, water, and its good film-forming characteristics. Positive charges in doped PEDOT are neutralised by the negative charges on the sulfonate groups (SO_3^-) in PSS. The additional sulfonic acid groups ($SO_3^-H^+$) give surface charges that maintain the aqueous colloidal dispersion of PEDOT: PSS complex via the Coulomb repulsion between colloidal particles [7,8].

The appropriate chemical functionalisation of CNTs, individualisation (i.e. prevention of their aggregation in solution form), In the production of a nanocomposite and its incorporation in an organic electronic application, the length shortening of tubes and optimisation of concentration in nanocomposites are all key variables [9].