Resolving Hierarchical Structures in Carbon Nanotube Networks Using Small and Ultra-Small Angle Neutron Scattering

Mehran Tehrani[a,*] Tusitha Nanda Bandara Etampawala[b,c], Mark Dadmun[c,d] and Mohammad Abir Hossain[a]

[a] Advanced Structural and Energy Materials Laboratory, Department of Mechanical Engineering, University of New Mexico, Albuquerque, New Mexico, Unite States

[b] Center for Instrumentation Facility, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

[c] Chemistry Department, University of Tennessee, Knoxville, Tennessee, United States

[d] Chemical Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, United States

[*] Corresponding author. Tel: 505 277-6298. E-mail: mtehrani@unm.edu (Mehran Tehrani)

Abstract

Resolving hierarchical structures in carbon nanotube (CNT) composites is crucial for their performance optimization. We report here that self-consistent analyses of small- and ultra-small-angle neutron scattering (SANS and USANS, respectively) patterns can be used to extract both the size and morphology of the hierarchical structures in carbon nanotube networks. In particular, this study investigates the correlation of structure and electrical conductivity of CNT-PEDOT:PSS (poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate)) composite films where distinguishable dispersion states of nanotubes in the PEDOT:PSS matrix were achieved by varying the CNT concentration, duration of sonication, and addition of ethylene glycol (EG) to the pre-deposition solutions. It was concluded that five hierarchical levels of structure, spanning a few nanometers to tens of microns, exist in all samples. The results suggest a strong variation in the structure of the nanocomposites at larger length scales and, to a lesser extent, at smaller length scales with the variation in processing. Electrical conductivity of samples was largely affected by the morphological changes at larger scales. The EG addition affected the electrical conductivity by both increasing the matrix conductivity and improving CNT dispersion. The presented analysis is also useful for the characterization of structures in pure CNT and low CNT composite samples.