Electromagnetic Scattering from Carbon Nanotubes in the Tumbleweed Configuration

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Carbon nanotubes (CNT) clusters with morphologies that resemble desert tumbleweeds have recently been studied (see, for example, F. Vargas-Lara and J.F. Douglas, Soft Matter, 11, 4888-4898, 2015 and R.M. Mutiso and K.I. Winey, Progress in Polymer Science, 40, 63–84, 2015). The reason for this interest is that many commercial CNT samples are composed of domains that resemble the tumbleweed configuration. Therefore, it is important to model the interaction of electromagnetic waves with CNT tumbleweeds.

Several hundred CNTs in the tumbleweed configuration, with different individual and cluster shapes, were considered in this work. The CNTs were generated using a coarse-grained molecular dynamics simulator and were designed to exhibit tumbleweed shapes by confining them within a radius of 66 nm. Also, all the CNTs were assumed to have the same length of 96 nm and the classical Drude model conductivity of a (9,9) armchair metallic CNT. For simplicity, all the CNTs within a single tumbleweed cluster were constructed to be non-overlapping. In order to calculate the electromagnetic response of each tumbleweed, the Method of Moment (MOM) formulation for Arbitrary Thin Wires (ATW) was employed.

The computations show that the number of resonances in the total extinction coefficient increases as the number of CNTs in the tumbleweed increases. Since all the CNTs simulated had the same length and electrical properties, these resonances arise due to the interaction and differences in shape between the individual CNTs within a tumbleweed. The number of resonances and the frequency bandwidth where they occur were quantified as a function of the number of CNTs per tumbleweed. The evaluation of how the resonances vary with the properties of CNT tumbleweeds can be used to establish electromagnetic metrology of CNT composites.