# Carbon Nanotube/Polymer Nanocomposites

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Carbon nanotubes can be combined with polymer matrices to produce nanocomposites with higher performance metrics, as well as new multifunctional properties that the original polymer did not display. This entry aims to act as a brief introduction to the factors and concepts of importance for carbon nanotube/polymer nanocomposites.

carbon nanotubes polymer nanocomposites

Carbon nanotubes (CNTs) are well known for their physio-mechanical properties at the individual level [1][2]. However, they are produced industrially in forms which often do not allow direct structural applications [3][4]. Polymeric materials are one of the most commonly used structural and structural support materials but lack long term physio-mechanical properties in themselves [5]. Combining the two allows the development of multifunctional properties in polymer matrices (mechanical improvement, electrical conductivity, piezoresistive response, etc.) and the usage of CNTs in industrial and structural environments [6][7][8].

CNTs were first explored as a homogeneously dispersed mechanical reinforcement in both thermoset and thermoplastic polymer matrices [9]. Early works showed that the addition improved mechanical performance, and analysis indicated that factors such as CNT type [10], aspect ratio [11], concentration [12] and dispersion degree [13] influenced final nanocomposite performance. As integration route development progressed, alignment of the CNT [14], compounding with secondary reinforcement phases [15][16], the scale of the CNTs themselves (powders, macrostructures) [17] and the presence of magneto-electrical fields [18] also showed influence on final performance parameters.

From the polymer matrix point of view, viscosity [19][20], processability [21], integration route [22] and the presence of chemical compounds [23] were identified as factors of influence. Lower viscosity polymers, typically thermoset in nature, allowed better homogeneous dispersion with simpler techniques (mechanical mixing, ultrasonication) [24]. High shear mixing of such polymers, using techniques such as homogenization and three-roll milling, result in better degrees of dispersion. Higher viscosity polymers typically required more energy intensive techniques centering around shear force (such as single- and twin-screw extrusion) to create similar homogeneously dispersed CNT/polymer nanocomposites [25].

A higher degree of dispersion is generally considered to be better, as it allows the minimum amount of CNT addition required to create a percolation network [26]. Higher dispersion degree also alleviates issues caused by bundling and agglomeration of the CNTs, usually cited as being stress concentration and inhomogeneity of properties [27]. The formation of the network in such composites is necessary since it builds the electrically and thermally conductive bridges within the volume of the nanocomposite from one end to another [28]. Simultaneously,

the better the dispersion allows the CNTs to occupy a maximized volume, which negatively influences to inherent failure mechanisms of the matrix and reinforcement the material though inhibition of crack propagation, crack bridging and energy consumption through the failure of the CNTs themselves [29].

The percolation network is considered to consist of two main types of connections between the CNTs in homogeneously dispersed polymer nanocomposites. Ohmic connections are considered to be physical connections where the CNTs are “touching” and direct charge carrier transfer may take place [30]. Tunneling connections are those where the transfer of these charge carriers through a thin layer of polymer present between the CNTs may take place [31]. Tunneling phenomenon are affected by the electrical properties of the polymer and typical distances are reported to be below a few micrometers [32][33]. Electrical conductivity of the nanocomposite may be achieved over a critical concentration where this network becomes stable and well developed (known and the critical percolation threshold) throughout the volume [34].

Chemical or physical stimuli which are able to change this network, either by increasing or decreasing the number of connections, though changing their ratio, or physical dimensional changes of the network, cause a change in the ability to carry electric change [35][36]. This property is known as piezoresistive response, and often follows a linear response region before exponential increases take place [37]. This response allows usage of CNT/polymer nanocomposites as sensors for various scenarios and applications, and the response to stimuli is highly dependent on the polymer matrix [38]. The development of the same network induced further multifunctionality, also dependent on the degree of dispersion; hydrophobicity [39], flame retardancy [40], thermal property changes [41], corrosion resistance augmentation [42], electromagnetic shielding [43], electrostatic dissipation [44], capacitance changes [45] and thermoelectric property development [2].

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