Lecture 9. Mechanical Properties of Carbon Nanofibers. Applications of Carbon Nanofiber.

The purpose of the lecture: to provide information on the mechanical properties and applications of carbon nanofibers.
Expected results: to be able to distinguish features of the mechanical properties and applications of carbon nanofibers.

Unfortunately, direct measurement of the tensile properties of a single VGCNF is not possible experimentally and no data has therefore been reported. However, direct measurements by earlier workers of the macroscopic vapor-grown carbon fibers have given values of 2.9 GPa for the tensile strength and 240 GPa for the tensile modulus, values comparable to a medium grade of PAN-based carbon fiber. An indirect method could be the reinforcement of VGCNF in any matrix and measure mechanical properties of the resulting composites. However, to extract intrinsic fiber mechanical properties from composite properties would require that fiber position and orientation within the composite, and its coupling with the matrix is controlled optimally.

Applications of Carbon Nanofiber

Introduction of a new material is typically limited by a number of technical barriers. In the case of VGCNF, these barriers include surface functionalization for bonding to selected matrices, dispersion, and orientation of the VGCNF in the composite. Even though vigorous efforts of numerous researchers have overcome several of these barriers and have established a foundation of rules for composite synthesis needed for the emergence of commercial applications, much work remains before such composite technology is firmed up to standard industrial practice.

Carbon Nanofiber Composites

CNF can be incorporated into commercially available thermoplastics, thermosets, and elastomers and can be used directly in existing high volume molding processes without any significant new manufacturing development. Because of its extraordinary intrinsic properties, particularly its strength and elastic modulus, CNF is expected to enable a reduction in the material required to produce a given strength and/or stiffness, thus providing net weight and cost savings.

The necessity of going beyond conventional compounding techniques has created opportunity for the emergence of a supply chain producing VGCNF compounded materials.

Resins are now available that contain 20% by weight loadings of VGCNF that can be utilized in a variety of formulated epoxy systems including pre-pregs, molding compounds, adhesives, and coatings (nanosperse.com). Such formulations are intended for use in conductive adhesives with high-strength characteristics, structural composite panels to replace metal for weight savings and corrosion resistance, and components for medical, aerospace, and electronics applications. Use of VGCNF has been reported for improved mechanical properties of liner-less composite pressure vessels, where performance improvement is attributed to the development of high strain, microcrack-resistant resins, and the inclusion of VGCNF at the ply interfaces. These materials eliminate microcracking as the first failure mode and improve the laminate failure strain to a level that nearly equals that of the reinforcing carbon fiber. Compounded with thermoplastics or thermosets, VGCNF can more than triple the resin's tensile modulus and strength. Compressive strength is generally improved by an even larger margin. Preliminary research gives some hope that a practical method may be found to improve the orientation of VGCNF to achieve even greater improvements.

Conductive Thermoplastic Composites

Since virtually all of the electrical conductivity in carbon fiber–polymer composites is through the network of carbon fibers, it is clear that good fiber dispersion, small fiber diameter, and large aspect ratio will all aid in achieving high composite conductivity. There are really two goals to be sought in fabricating CNF–polymeric composites. The first is a low percolation threshold; it is achieved when a small volume fraction of fibers first establishes this conducting network. The second goal is achieving sufficient conductivity at high fiber loading to meet more ambitious high conductivity goals, such as radio frequency interference shielding and superior mechanical properties of the resulting composites. Recent work by Zhang et al. illustrates the promise of making sensors for organic vapors from VGCNF–polystyrene composites, as the electrical resistivity of such composites rises sharply on exposure to organic vapors. Data from three different types of fibers are plotted and compared to a simple superposition model for graphitized or as-grown fibers in Figure 1. In contrast to structural changes induced in carbon black composites, VGCNF composites reproduce cyclability in vapors such as tetrahydrofuran (THF) or benzene.

Finally, the availability of a thermal grease composed of a silicon-free carrier material incorporating VGCNF as the thermal conductor has also been announced (electrovac.com). Here the nanoscale filler enables accurate thin film application and decreases thermal resistance.

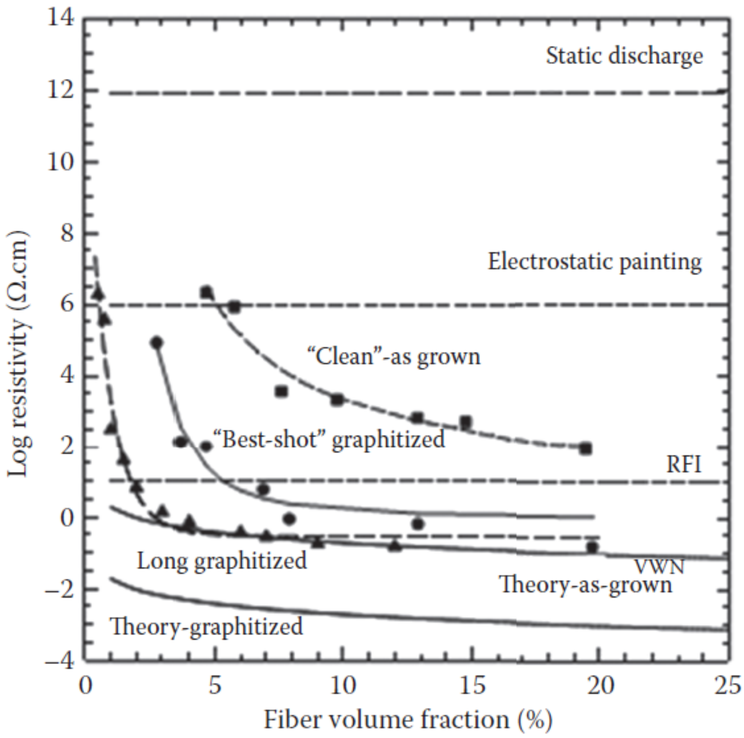

FIGURE 1. Resistivities of some polypropylene–VGCNF composites. Approximate resistivity values required for static discharge, electrostatic painting, and radio frequency interference shielding are indicated