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Solutions for static control

Carbon nanotubes for static dissipation

Carbon nanotubes are electrically conductive additives with an extremely small size and a high aspect ratio. According to the manufacturer Hyperion Catalysis International Inc. the resulting morphology enables nanotubes to develop a conducting network within a polymer matrix at low percentage loadings, typically 1.5-4.5% by weight. *Plastics Additives & Compounding* looks at some recent case studies involving nanotubes for applications in the electronics and automotive industries.

While a variety of additives can be used to impart conductive and static dissipative properties to polymers, Hyperion Catalysis International says that the cleanliness and morphology of nanotubes make it possible to design finished products with a particular combination of properties. According to the company, nanotubes are produced from high purity raw materials and are chemically clean.

The advantages claimed for carbon nanotubes include electrical conductivity at low loadings - most applications only require 1.5-4.5% by weight loading.

The moulded part surface quality is said to be excellent, because the nanoscale size can give the same surface finish as neat resin. Outgassing and corrosion are minimal, meaning that the cleanliness is good.

Physical properties are retained. The company says that there is a minimal effect on neat resin properties, particularly low temperature impact strength and ductility. Nanotubes are highly isotropic and give uniform conductivity throughout the part with minimum warp. Finally, Hyperion Catalysis International says that polymers incorporating nanotubes are easy to process, because there is only a limited increase in melt viscosity.

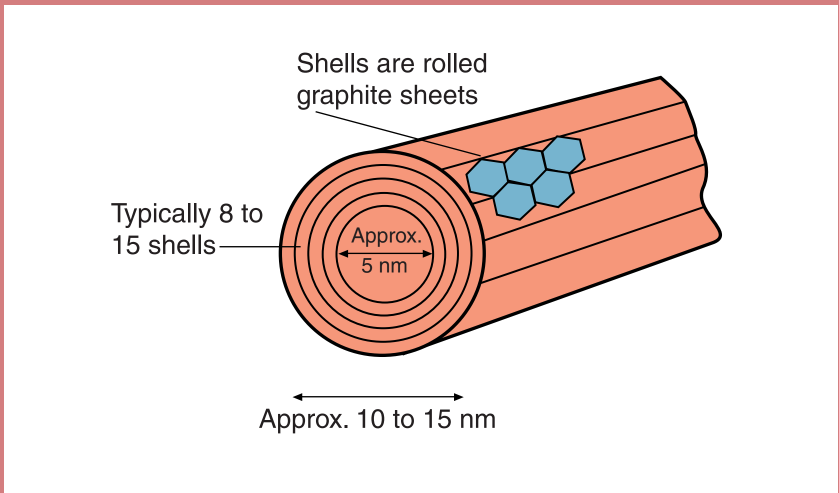

Figure 1: Structure of graphite nanotubes.

Electronics

A manufacturer supplying the electronics and semi-conductor industries was producing a static dissipative part based on a high performance polymer. In order to impart the required electrical conductivity, conventional chopped carbon fibres were incorporated into the compound.

The part was used in such a way that it came into physical contact with expensive, highly sensitive components. Due to the tendency of the relatively large carbon fibres to orient in the polymer matrix, the moulded product displayed unacceptable warping. Hyperion Catalysis says that the manufacturer evaluated nanotubes in the same polymer, which solved the problem.

The company adds that not only did the use of nanotubes solve the problem of warping, but it provided the end-user with a more uniform surface that are characteristic of nanotube-based compounds. These surfaces have a reduced tendency to slough conductive particles.

Automotive

Carbon nanotubes have also assisted a number of manufacturers of plastic automotive parts. Electrostatic spray

Designing for Electrostatic Discharge

Providing Electrostatic Discharge (ESD) protection to a device enables it to reduce a high applied voltage (up to 20,000 volts) to a level where damage is not caused (often under 1 volt), according to Hyperion Catalysis.

"This must be in a short enough time to prevent spontaneous discharge or arcing" explains John Hagerstrom, technical sales manager. "Sometimes the rate of discharge must be controlled so that it is not too fast in order to minimize the build-up of heat. Therefore, the key design considerations become the applied voltage and the rate of dissipation that is needed."

The rate of charge dissipation is not just a function of the material's resistivity, which is governed by the following equation.

$\tau = \rho\varepsilon$

where τ is the time constant for rate of charge dissipation, ρ is the resistivity of the material and ε is the permittivity of the material, which is the ability of the material to store electrical potential energy.

For unfilled polymers $\varepsilon \cong 3$

For perfect conductors $\varepsilon \cong \times$

For conductive additives $\varepsilon \cong$ very large

Therefore, a filled polymer's permittivity increases with filler loading.

Hyperion Catalysis says that the high aspect ratio of Fibril™ nanotubes enables the formation of a conductive network at very low loadings compared with other fillers (see Figure 2). The nanotubes give a low resistivity at low loadings, with the low loadings providing low permittivity.

John Hagerstrom adds: "In all filled polymers, direct particle-particle contacts are rare, since each particle is surrounded by polymer. Therefore, electrical conduction in filled polymers is a combination of ohmic and quantum mechanisms."

Ohmic refers to conduction within the additive itself, which results in a linear relationship between conductivity (current) and voltage. Quantum refers to conduction via electron hopping and tunnelling across the gaps, which results in a non-linear relationship between conductivity (current) and voltage.

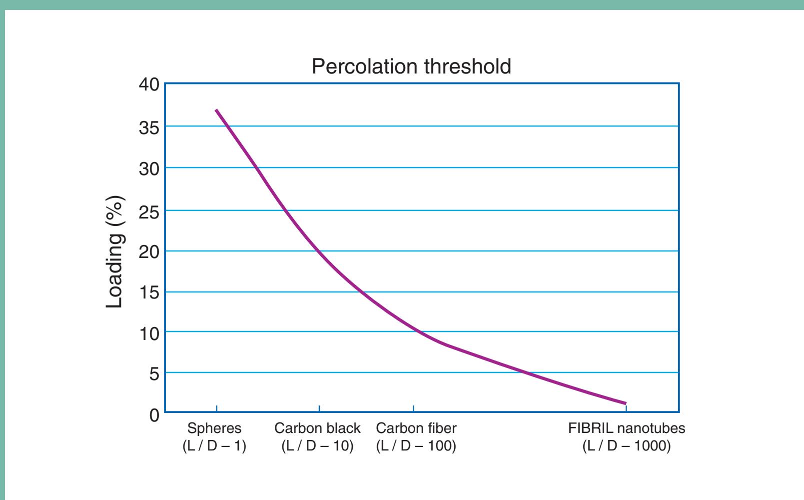

Figure 2: Percolation threshold.

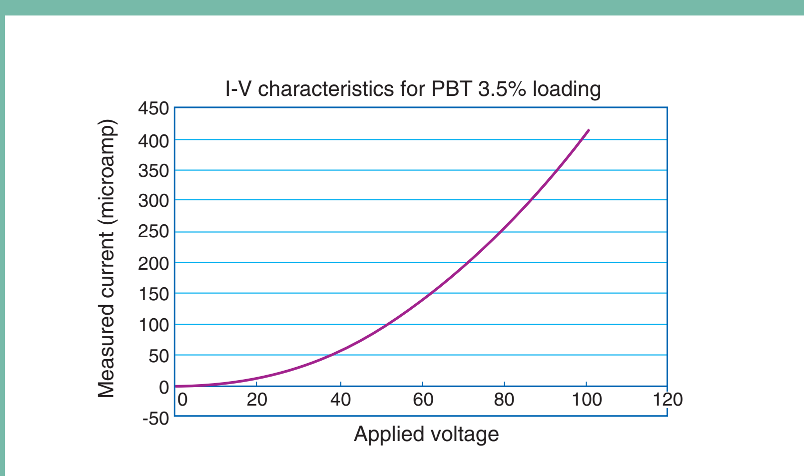

Figure 3: Current/voltage characteristics for PBT with a 3.5% loading of carbon nanotubes.

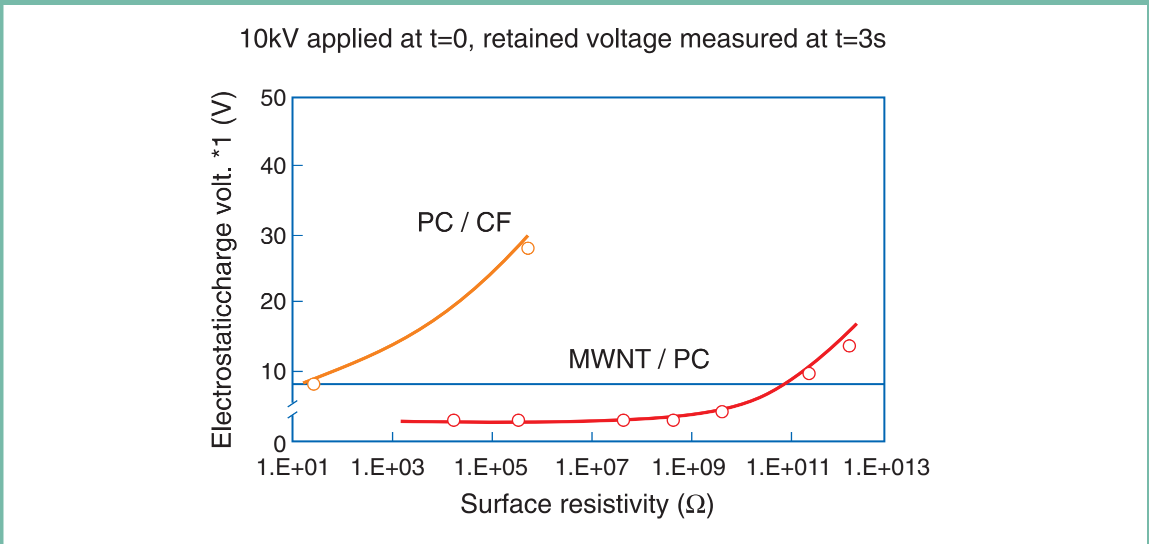

Figure 4

"Due to the fact that nanotubes are so small, there are many more gaps in the compound than when other conductive additives are used," says John Hagerstrom. "Therefore, the quantum mechanism of conductivity is predominant and there is a non-linear current/voltage behaviour."

Figure 3 shows the current/voltage characteristics for polybutylene terephthalate (PBT) with a 3.5% loading of carbon nanotubes.

The company claims that the reasons that only low loadings of Fibril nanotubes are necessary for ESD protection include the ease of formation of a conductive network at low loadings. Other factors include the low permittivity of the conductive network and the non-linearity of the conductive network.

According to the company, in order to achieve a rapid dissipation of a static charge, polycarbonate (PC) filled with carbon fibre (CF) has to be more conductive (higher loading) than a similar sample filled with Fibril nanotubes (MWNT) - see Figure 4. Hyperion Catalysis adds that the effective nanotube loading can be so low that the surface resistivity of the nanotube-filled PC, which is measured at 1 volt, seems to indicate that it would be ineffective.

painting of automotive parts is preferred for a number of reasons. These include more efficient use of the paint and reduced plant emissions. In addition, the electrostatic process lends itself well to painting parts with complex shapes. However, the part to be painted must be conductive enough to be electrically grounded. This can be a problem as plastics continue to replace metals for automotive parts, because plastics are typically highly electrically resistive, says Hyperion Catalysis.

The company adds that imparting conductivity using traditional conductive additives can result in unacceptable degradation of both the polymer's physical properties and the surface quality of the final part. A partial solution has been to apply a conductive primer coat to the part using conventional spray painting techniques.

Hyperion Catalysis says that by adding nanotubes to the plastics compound, conductivity adequate to ground the part is achieved at very low nanotube concentrations. Consequently, the physical properties of the part are preserved at levels that meet specifications and the surface of the part is of sufficient quality to be painted directly, with no secondary finishing operations.

According to the company, by converting from conventional spray painting the efficiency of paint use can be increased by 2-3 times. Overall paint usage is reduced, as well as plant emissions. This can allow the capacity of a plant to be expanded, if operations are being restricted by emissions regulations.

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