Solutions

INNOVATION

Hyperion Catalysis

THE LEADER IN NANOTUBE TECHNOLOGY

Cleanliness for Clean-Room Environments

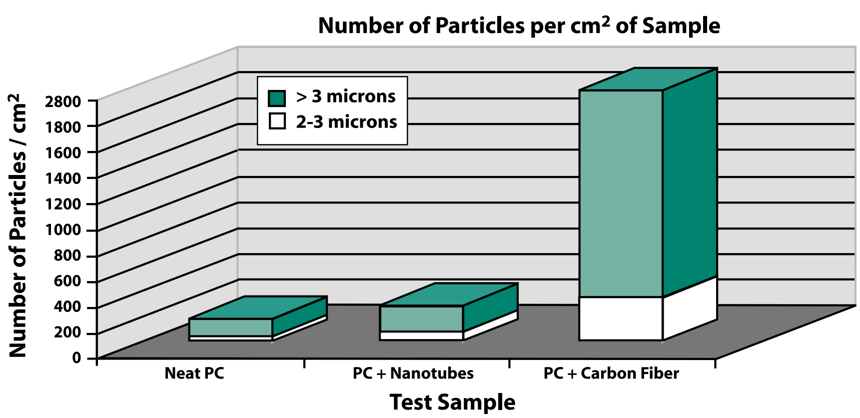
Cleanliness of conductive-plastic components is a vital consideration in clean-room manufacturing. Sloughing of particles as components slide against each other can cause contamination. In addition, volatilization of organic compounds, such as sizing or coupling agents, can be a source of contamination. Fortunately, conductive compounds based on FIBRIL™ nanotubes from Hyperion are characterized by low sloughing and chemical cleanliness.

Historically, carbon fiber has been used as a low-sloughing conductive additive in polycarbonate (PC), which is itself considered to be a clean, low- sloughing resin. To evaluate the relative cleanliness of compounds made with FIBRIL™ nanotubes, liquid particle count, abrasion resistance, and outgasing tests were conducted on commercially available grades of polycarbonate containing both carbon fiber and carbon nanotubes. The details of the studies follow.

LIQUID-PARTICLE COUNT

One method for measuring surface cleanliness or resistance to sloughing is the Liquid Particle Count (LPC) test. Three different injection molded test plaques made from commercially available grades of polycarbonate – one neat, one containing 3% FIBRIL™ nanotubes, and one containing 10% carbon fiber – were tested (the loading differences reflect the concentration of nanotube and carbon fiber additives required to reach equivalent levels of conductivity).

In this test, a 50 x 90 x 3 mm plaque was immersed in 50 ml of deionized water and then subjected to ultrasonic energy for 1 min at 45 kHz. In order to eliminate any differences in processing, handling, and exposure history, this first bath of water was exchanged for fresh deionized water and the plaque was again subjected to a cycle of ultrasonic energy at the same frequency for 1 min. Subsequently, 10 ml of the water were aspirated into a liquid particle counter. Three samples of the aspirated water were tested to reach an average particle count/cm^2 of part surface area. Results are presented in the table and graph here.



Sample Plaque	Filler Loading (Wt-%)	Volume Resistivity (Ω-cm)	Number of Particles (particles/cm^2) Particle Size	
			2-3 µm	> 3 µm
Neat PC (control)	0	1×10^{14}	29.0	138.3
PC with nanotubes	3	3×10^{6}	51.8	225.5
PC with carbon fiber	10	1×10^{7}	324.9	1606.3

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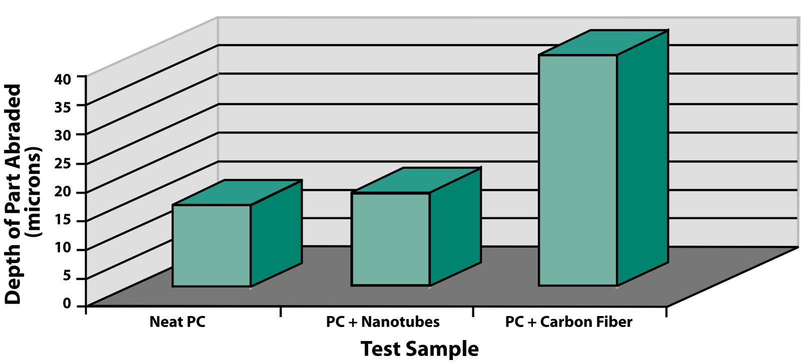
IMPROVED ABRASION RESISTANCE

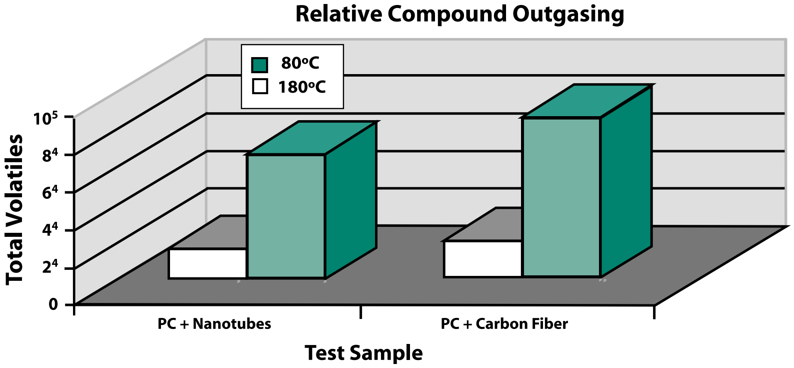
Another test to determine suitability for use in a clean-room environment is abrasion resistance. Abrasion caused by two surfaces sliding together may lead to sloughing of particles that can contaminate clean-room components. Three commercial polycarbonate grades - neat PC; PC with 3% carbon nanotubes, and PC with 10% carbon fiber - were evaluated in a reciprocating-motion wear test. A 1 x 50 mm glass plate under a 718 g load was moved across a molded plastic plate at a speed of 300 mm / sec for a total of 5,000 cycles. At the end of the test, the depth of the abrasion on the plastic part was measured and the results are presented in the table and graph below.

Sample Plaque	Filler Loading (Wt-%)	Volume Resistivity (Ω-cm)	Depth of Surface Scraped (μm)
Neat PC	0	$1x10^{14}$	14
PC + nanotubes	3	$3x10^{6}$	16
PC + carbon fiber	10	$1x10^{7}$	40

Suceptibility to Abrasion



Relative Compound Outgasing



Data from this test indicate that the depth of abrasion is significantly less from samples containing FIBRIL™ nanotubes than with carbon fiber. This means that there is a lower likelihood of sloughing in a sliding wear environment.

LESS OUTGASING OF VOLATILES

Since electronic components can experience thermal cycling during various production steps or in use, it is important to understand if any volatiles are likely to outgas during such operations, as they can damage delicate microelectronics.

Two commercial compounds - polycarbonate with 3% FIBRIL™ nanotubes, and polycarbonate with 10% carbon fiber - were exposed to temperatures of 80ºC and 180ºC. Volatiles outgased were taken to be the total area under the gas chromatography peaks. Results are shown below. Note: in this test, no control (neat polycarbonate) sample was tested because neat PC would have had fewer compounding steps (heat histories) than the compounds with conductive additives. Thus the baseline of volatiles would not be the same.

The compounds with FIBRIL™ nanotubes showed substantially less outgasing than those with carbon fiber. This means that compounds made with FIBRIL™ nanotubes will have a lower risk of contaminating delicate electronics during heat cycling, either during part manufacture or in-use.

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