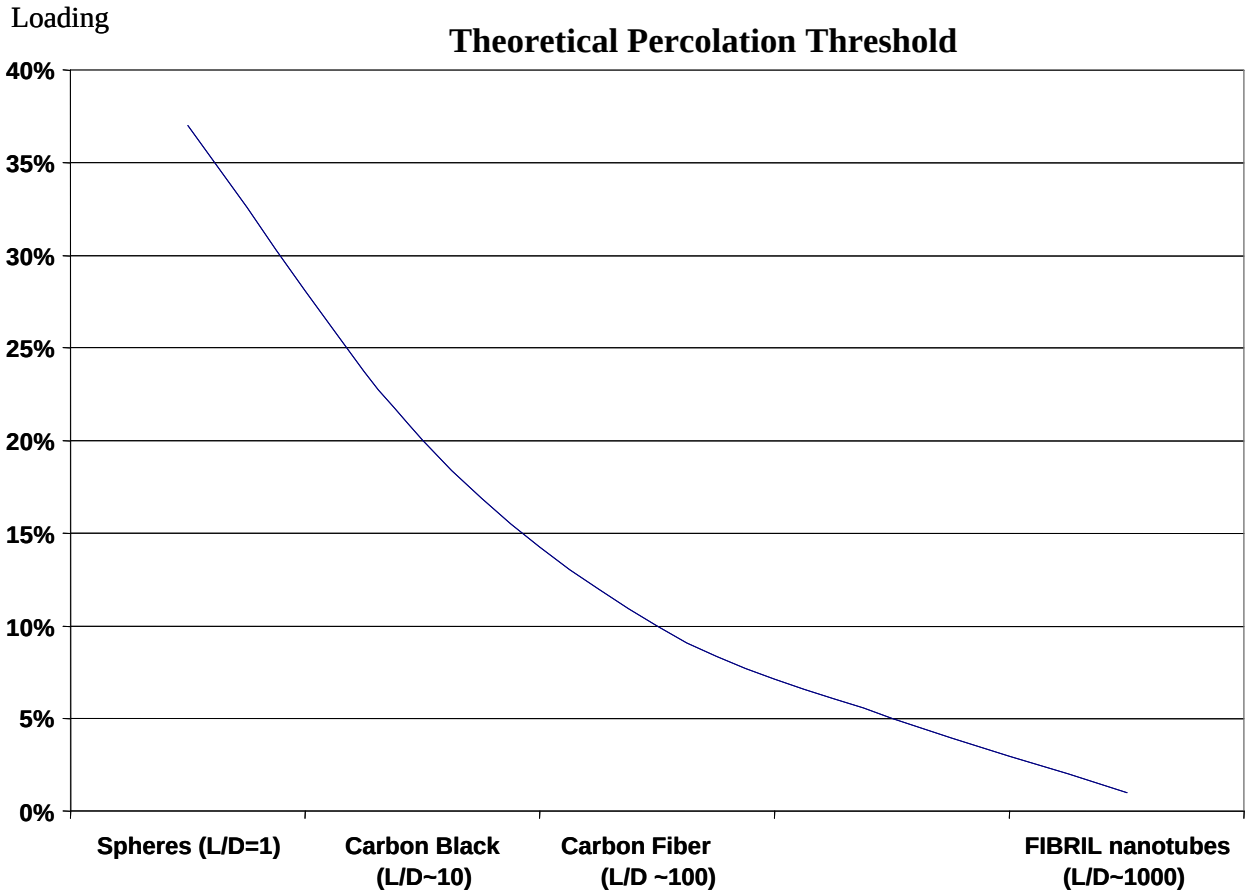
Hyperion Catalysis

Designing for ESD Protection Using FIBRIL™ Nanotubes in Polymer

Effect of Aspect Ratio on Loading

Nanotube's High Aspect Ratio Means A Very Low Loading Will Impart Electrical Conductivity



Static Dissipation

The rate of charge dissipation is not just a function of the material's conductivity. It is governed by the equation:

$$\tau = \rho\varepsilon$$

τ = the time constant for rate of charge dissipation

ρ= resistivity of the material = the ability to conduct a flow of electrical charge when subjected to a given applied voltage

e = permittivity of the material = the ability to store an electrical charge when subjected to a given applied voltage

Static Dissipation

- Lowering a material's permittivity decreases the amount of charge that can be stored.

- Lowering a material's resistivity increases the rate of loss of the stored charge.

THUS

- Decreasing either (or both) decreases the length of time that a given amount of charge is retained in a material.

Filler Loading Effects Permittivity

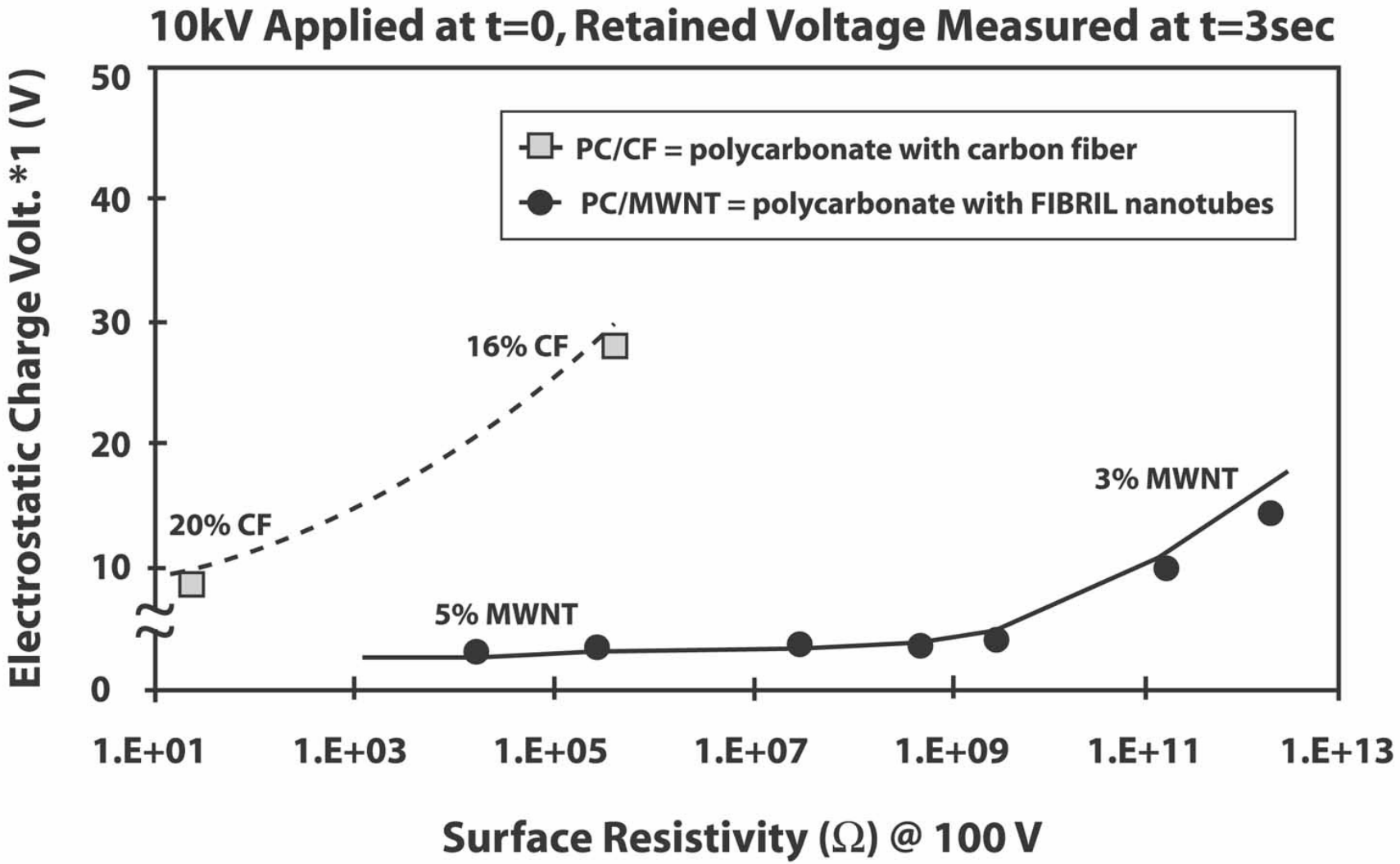
- Unfilled polymers have $\varepsilon \approx 3$
- Perfect conductors have $\varepsilon \approx \infty$
- Conductive additives have $\varepsilon \approx$ very large
- Thus, filled polymer's ε increases with filler loading

Conduction Mechanism in Plastics

- FIBRIL nanotube's high aspect ratio means that a conductive network is established at very low loading compared to other fillers
  - The resistivity ρ drops
  - The permittivity ε does not rise

- Thus FIBRIL nanotubes give a very low time constant (fast rate of discharge) due the combination of the two effects.

Static Decay Performance



FIBRIL Nanotubes For ESD

- FIBRIL nanotubes give rapid rate of static discharge even at higher measured resistivity.
- Higher allowable resistivity means lower loading of FIBRIL nanotubes.
- Low nanotube loading means good retention of physical properties and excellent surface quality.

Design Tips For ESD Applications

- Design for the anticipated voltage that will be seen in-use and the required rate of charge dissipation.
  - Do not design using a material conductivity measured by a voltmeter at 1 volt; conductivity will increase with increasing voltage.
  - Do not measure conductivity using a surface conductivity measurement, injection molded plastic parts can have a non-conductive skin, but this effect is lower in extruded sheet.
- Test prototypes under conditions of use before finalizing any material specification.
- Be aware of detrimental effects of high loading of conductive additives.