CONDUCTIVE COMPOUNDS FOR MEDICAL APPLICATIONS

CONDUCTIVE TECHNICAL BRIEF

FEATURES

- Continuous charge dissipation to eliminate static events
- Allows for part consolidation
- Can be used in injection molding processes

BENEFITS

- Available in a wide variety of colors
- Retain transparency in some resin systems
- Reduce weight when replacing metal parts/designs

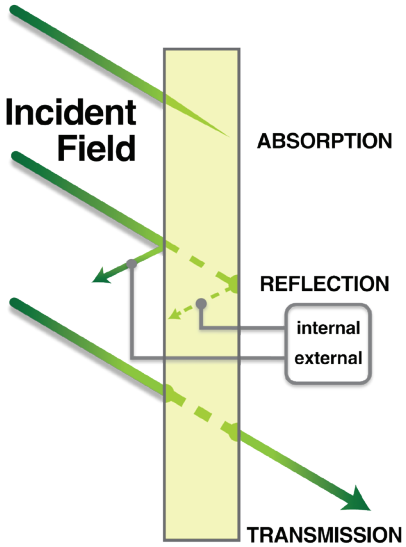

Figure 1. EMI is reflected by shield surfaces and also absorbed within the material

CUSTOMIZED THERMOPLASTIC SOLUTIONS

Often, designers need more than standard, "off-the-shelf" plastics when designing medical applications. RTP Company offers custom thermoplastic solutions to fit the unique requirement of medical devices, parts, and components.

Among these technologies are electrically conductive modifiers that, when combined with plastics resins, can provide protection against static accumulation, electrostatic discharge (ESD), and electromagnetic interference (EMI). Material selection for the healthcare industry must take into consideration additional, important facets such as biocompatibility, chemical resistance, sterilization compatibility, and processability.

MECHANICS OF CONDUCTIVITY

The mechanism of conductivity in plastics is similar to that of most other materials. Electrons travel from point-to-point, following the path of least resistance. Most plastic materials are insulative; that is, their resistance to electron passage is extremely high (generally $>10^{15}$ ohm).

Conductive modifiers with low resistance can be blended with plastics – in a process called compounding – which alters the polymer's inherent resistance. At a threshold concentration unique to each conductive modifier and resin combination, the resistance through the plastic mass is lowered enough to allow electron movement. The speed of electron movement depends on the separation between the modifier particles. Increasing modifier content reduces interparticle separation distance, and at a critical distance known as the percolation point, resistance decreases dramatically and electrons move rapidly.

MATERIAL SOLUTIONS FOR STATIC PROBLEMS

Static may create hazards that can be controlled or eliminated by adjusting electrical characteristics of at-risk materials or their immediate environment. ESD can damage or destroy sensitive electronics and initiate explosive events in flammable environments. Accumulated static charges can attract and hold particulate matter on surfaces or clog and reduce the flow of material through a pathway.

Conductive thermoplastic compounds with low electrical resistance prevent static accumulation from reaching dangerous levels. This lower resistance allows static to dissipate slowly and continuously rather than accumulate and discharge rapidly, perhaps as a spark.

MATERIAL SOLUTIONS FOR EMI

Electromagnetic waves radiate from computer circuits, radio transmitters (including cellular phones), and electric motors, among other sources. They become undesirable when they interfere with the operation of other electronic devices. Shielding reduces electromagnetic interference, ensuring electromagnetic compliance (EMC) with industry standards.

Conductive thermoplastic compounds provide this shielding by absorbing electromagnetic energy and converting it to electrical or thermal energy. There is also some reflection of electromagnetic energy from the surfaces of EMI shielding grade compounds ***(Figure 1)***.

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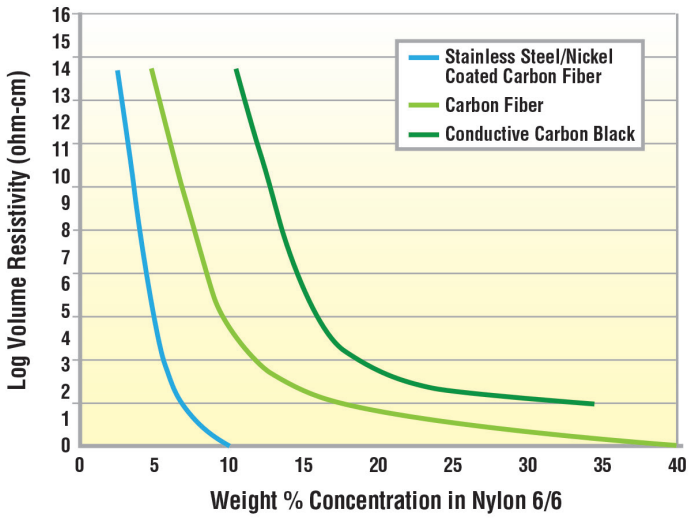

Figure 2. Additive concentration effect on conductivity in a typical thermoplastic

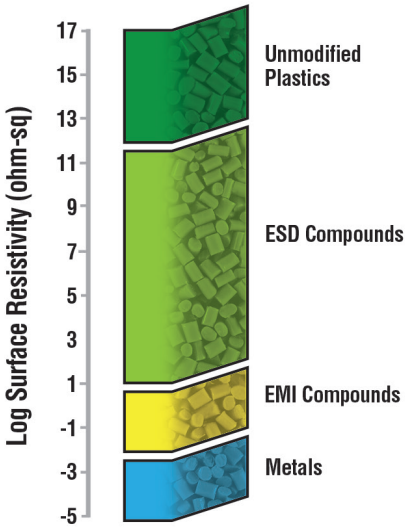

Figure 3. Conductivity values of thermoplastic compounds fall between those of unmodified plastics and metals

STRUCTURE OF CONDUCTIVE COMPOUNDS

An electrically conductive thermoplastic compound is a resin that has been modified with conductive additives, including carbon-based (powder and fibers), metal-based (solids and coatings), and all-polymeric alloys. Varying the percentage or type of conductive additive used in the compound controls the degree of electrical resistivity ***(Figure 2)***.

RTP Company's PermaStat® all-polymeric compounds provide anti-static properties (surface resistivity 10^{10}–10^{12} ohm/sq) for applications requiring dust-free and static-free environments. PermaStat® products are non-sloughing, fully colorable (transparent in some resins), available in a wide array of polymers, and have excellent static decay properties. PermaStat® static dissipative properties are inherent in molded articles; they eliminate secondary coating operations and solve problems where anti-static coatings are removed by abrasion, cleaning agents, or are humidity-dependent to function.

PermaStat PLUS™ compounds can dissipate 5,000 volts in under ½ second.

When more advanced materials are needed, RTP Company offers PermaStat PLUS™ compounds, which boost electrical properties in applications that require additional protection from static build-up. PermaStat PLUS™ compounds have a surface resistivity of 10^{8}–10^{10} ohm/sq, providing optimal static dissipative properties in an all-polymeric material. PermaStat PLUS™ compounds are available in acrylic, ABS, PC/ABS, acetal, polycarbonate, polyolefins (PP & PE), and other resin systems.

FEATURES OF CONDUCTIVE COMPOUNDS

Conductive thermoplastics offer a number of advantages compared with other materials, such as metals, for ESD protection or EMI shielding ***(Figure 3)***. Benefits of plastic include part consolidation and increased design freedom. Finished parts are typically lighter in weight, quicker to fabricate, and less expensive to produce than comparable metal designs.

A common misconception is that conductive plastics are always black in color; this is not always the case. As color is important for aesthetics or brand recognition, RTP Company offers conductive thermoplastics in a wide variety of colors. With a precolored conductive thermoplastic, the color is inherent in the material rather than added in a secondary surfacing operation.

Opaque is also not the only option, as a number of conductive thermoplastic compounds retain transparency while exhibiting static control properties. Clear or translucent grades are achievable in ABS, acrylic, and polypropylene resin systems.

Conductive compounds are engineered to meet the demands of your specific application and may offer additional value-added properties such as color, flame retardance, wear resistance, or structural reinforcement in a single material.

TESTING FOR CONDUCTIVITY

Three major characteristics used to evaluate the electrostatic properties of ESD compounds are resistivity, both volume and surface; electrical resistance; and static decay rate. EMI shielding materials are additionally evaluated by shielding effectiveness testing.

The most common test method to determine the conductivity of plastics is ASTM D257, which measures both volume and surface resistivity. Since electrostatic charge is a surface phenomenon, surface resistivity tends to be the more meaningful of the two. Surface resistivity is the measured resistance between two electrodes forming opposite sides of a square, and is reported as ohm/square. Volume resistivity (also referred to as bulk resistivity) is measured resistance through the sample mass. It is an indicator of how well a conductive additive is dispersed, and is expressed as ohm-centimeter.

Electrical surface resistance is defined as opposition to the flow of electricity. The EOS/ESD Association STM11.11 standard measures surface resistance as opposed to surface resistivity.

Static decay is measured with Federal Test Method S101C, Method 4046.1. This test measures how quickly a charge is dissipated from a material under controlled conditions, which is one parameter of actual electrostatic performance.

Shielding effectiveness can be evaluated using several different test methods. Typically, shielding properties are represented as a ratio of power received through a test apparatus with and without a candidate material present, and is expressed in decibels of attenuation.

FORMULATING FOR MEDICAL APPLICATIONS

When utilized for medical devices, the whole field of polymers and additives comes under scrutiny. Formulation of thermoplastic compounds for medical applications typically starts with selecting ingredients that have undergone extraction testing, been used in similar medical devices, or are compliant to either USP Class VI or ISO 10993-1 test criteria to address biocompatibility.

Base Polymers used in Conductive Compounds

Nearly every type of polymer can be compounded with conductive fillers. Some of the more common polymers used in medical applications that can be rendered electrically conductive are:

Acetal (POM) - Combines toughness, resistance to water (liquid and vapor) permeation, high strength and rigidity, and low coefficient of friction. At room temperature, resistant to most chemicals and organic solvents. Used in fluid handling components, conveyor systems, and gears.

Acrylic (PMMA) - Compatible with human tissue contact. Rigid material with a high gloss surface appearance and optical clarity. Applications include luers, fittings, packaging trays, catheter accessories, inhaler bodies, and IV components.

Fluoropolymers (PTFE, PVDF, PFA) - Non-flammable and have excellent chemical and solvent resistance. Wide thermal performance range and with a very low coefficient of friction makes them useful in valve assemblies, bearing surfaces, catheters, and tubing.

Polycarbonate (PC) and PC Alloys - Sterilizable by most common methods, with especially good toughness and impact resistance. Equipment housings and surgical tool handles are typical applications.

Polyetheretherketone (PEEK) - Withstands all standard sterilization techniques and offers good chemical resistance. Common uses include extruded tubing and surgical devices.

Polyolefins (PP, PE, PMP) - Lightweight, chemical and moisture resistant, and easy to process. Ideal for packaging, syringes, introducer and catheter components, pMDI spacers, and closures/caps (good hinge properties).

Polysulfone, Polyethersulfone (PSU, PES) - Excellent thermal stability and toughness; resistant to a variety of chemicals; available in transparent. Sterilizable using autoclave, EtO, or radiation. Applications include instrument handles, fluid handling components, food service trays, and surgical instrument trays/containers.

Thermoplastic Polyurethane Elastomer (TPUR) - Available in a wide range of hardnesses; high clarity; can be sterilized using dry heat, EtO, or radiation. Applications include tubing, catheters, shunts, connectors and fittings, and transdermal drug delivery patches.

Styrenics (PS, ABS) - Rigid, with good impact resistance; ideal for applications where chemical and heat resistance are less important. Applications include inhaler bodies, surgical tool handles, and housings.

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CONDUCTIVE TECHNICAL BRIEF

Medical Applications

Applications incorporating conductive thermoplastics include:

- **Pharmaceutical delivery systems, such as pMDI or DPI inhalation devices -** facilitate accurate drug dosages for powders/aerosols. Without conductive plastics, inaccurate dosages could result from either too little medicine (micro-particles attracted to the walls) or too much medicine (medication builds up and and suddenly releases) being administered.
- **Breathing tubes and structures -** gas flow creates triboelectric charges, which must discharge or decay. Buildup of charges could initiate explosive events in flammable environments.
- **EMI housings -** provide Faraday cage protection for electronic components inside diagnostic equipment.
- **Pipette tips -** conductivity allows capacitance-based liquid-level detection for automated pipetting systems.
- **Pickup electrodes -** monitor bioelectricity in EKG leads and provide conductive pathway for muscle stimulation.
- **Heat Transfer -** thermally conductive modifiers reduce “hot spots” by absorbing and redistributing heat more evenly than unfilled resin.

RTP Company White Papers

Effects of Static on Plastics Used in Drug Delivery Devices

Growing interest in the delivery of aerosol or dry powder pharmaceuticals via inhalation brings with it concern of static attraction in the drug delivery pathway of medical devices.

Our conductive and medical materials experts have devised a simple experiment that illustrates this problem and discusses material solutions that minimize problems associated in inconsistent dosages in our white paper “Effects of Static on Plastics Used in Drug Delivery Devices”.

http://web.rtpcompany.com/info/papers/index.htm

Selection of Materials for Medical Applications

Although plastics have been used in the healthcare field for some time, specialty compounds that provide anti-static, wear resistant, or elastomeric properties are beginning to offer solutions to evermore complex medical applications.

Although the material selection process can be intimidating, Karl Hoppe, Senior Product Development Engineer for RTP Company, discusses how proper communication between designers and suppliers about application requirements and material capabilities is paramount to selecting an appropriate plastic for a medical device.

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