Conductive Compounds for MEDICAL APPLICATIONS

Technical Brief

Customized Thermoplastic Solutions

Conductive Thermoplastics can:

- **Allow static to dissipate continuously rather than accumulate and discharge rapidly**
- **Be supplied in a wide variety of colors**
- **Retain transparency, in some cases**
- **Replace metal designs and reduce part weight**
- **Consolidate parts**

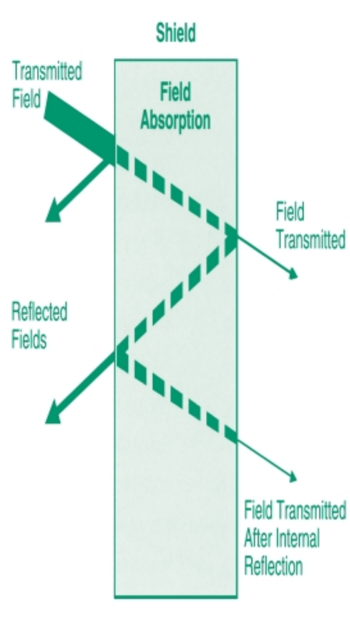

Figure 1. EMI is reflected off the source side of a shield or is rereflected off a second shield surface.

The rapid growth of thermoplastics in medical markets reflects the suitability of these materials to meet the demands of today's healthcare industry. While many medical products are still produced in "off-the-shelf" plastics, designers are expanding their knowledge of new thermoplastic technologies.

Among these technologies are electrically conductive modifiers that, when compounded with thermoplastics, can provide protection against static accumulation, electrostatic discharge (ESD), and electromagnetic interference (EMI). Selecting the proper material technology will include addressing the important concerns of the healthcare industry including 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 $>10^{15}$ ohms).

Conductive modifiers with low resistance can be blended with plastics – in a process called extrusion compounding – to alter 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. Speed of electron movement depends on the separation between the modifier particles. Increasing modifier content reduces inter-particle 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 events in flammable environments. Accumulated static charges can halt mechanical processes by clogging or reducing the flow of materials.

Conductive thermoplastic compounds prevent static accumulation from reaching dangerous levels by reducing a material's electrical resistance. This 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), electric motors, and many other sources. They become undesirable when they interfere with the operation of 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. These compounds also reflect electromagnetic energy from the source side of the shield and also by re-reflecting it from the second surface of the shield (Figure 1).

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-polymerics (ICP and IDP). Varying the percentage or type of conductive additive used in the compound controls the degree of electrical resistivity (Figure 2).

Conductive Compounds for MEDICAL APPLICATIONS

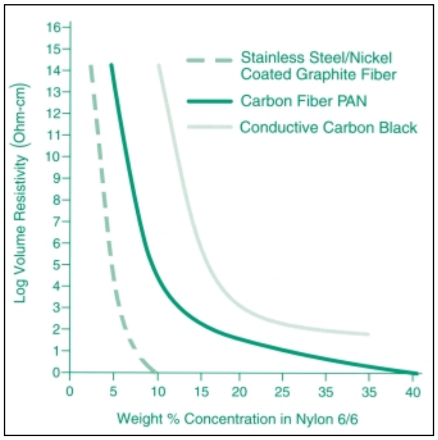

Figure 2 - Additive concentration effect on conductivity in a typical thermoplastic

Intrinsically conductive polymers (ICPs) and inherently dissipative polymers (IDPs) offer an all-polymeric solution. ICP compounds have been developed based in polyethylene, polypropylene, and polystyrene. The key advantages of these materials are optimal ESD control with tuning capability (surface resistance 10^6 – 10^9 ohms), mechanical properties similar to the matrix resin, color options, and processing ease.

RTP Company maintains a number of conductive thermoplastic compounds in Drug Master Files

RTP Company's all-polymeric IDP (also called PermaStat®) compounds provide anti-static properties (surface resistance 10^{10} – 10^{11} ohms) for applications requiring dust-free and static-free environments. PermaStat® products are non-sloughing, colorable, available in a wide array of polymers, and have excellent static decay properties. PermaStat® static dissipative properties are inherent in the molded material, eliminating secondary coating operations and solving problems where anti-static coatings are removed by movement, cleaning agents, or evaporation.

By employing advanced compounding techniques, RTP Company offers PermaStat® Plus materials to boost mechanical or electrical properties in applications that require protection from static build up. PermaStat® Plus compounds are available in "E-Series" (improved Electrical dissipative performance) and "M-Series" (improved Mechanical property performance). PermaStat® Plus compounds are available in Acrylic, ABS, PC/ABS, Acetal, Polycarbonate, and other resins.

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). Design benefits include parts consolidation and more design freedom. Finished parts are lighter in weight, easier to fabricate, and less expensive to process.

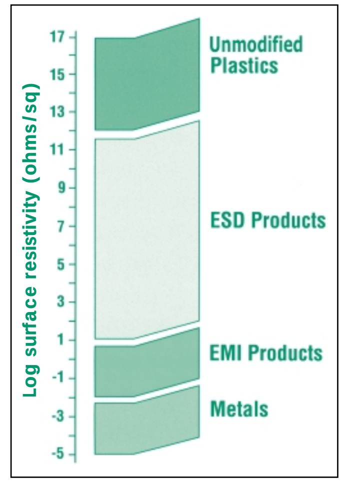

Figure 3 - Conductivity values of thermoplastic compounds fall between those of unmodified plastics and metals

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

Neither is opacity the only option, as a number of conductive thermoplastic compounds retain *transparency* while exhibiting static control properties. Particular static control additives can match refractive indices of some thermoplastic polymers, rendering clear parts.

A conductive compound will be engineered to meet the demands of your specific application and may offer value-added properties such as color, flame retardance, wear resistance, or structural reinforcement.

Testing for Conductivity

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

Conductive Compounds for
MEDICAL APPLICATIONS

The most common test method to determine the conductivity of plastics has been ASTM D-257, 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 resistance* is defined as opposition to the flow of electricity. The EOS/ESD Association S11.11 measures surface resistance as opposed to surface resistivity.

Static decay is measured with Federal Test Method 101, Method 4046. 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 is evaluated under ASTM D-4935, in which coaxial transmission line methodology analyzes planar specimens under far-field conditions over a frequency range from 30 MHz to 1.5 GHz. Shielding effectiveness is represented as the ratio of power received with and without a candidate material present, and is expressed in decibels of attenuation.

Formulating for Medical Applications

Where medical products are concerned, the whole field of polymers and additives comes under scrutiny. A thermoplastic formula may start with ingredients that have undergone extraction testing according to Title 21 of the Code of Federal Regulations (21 CFR) promulgated by the U.S. Food and Drug Administration (FDA). Where bodily contact is involved, the healthcare industry tends to use materials that are compliant to either USP Class VI or ISO 10993-1 test criteria to address both biological and legal risks.

Thermoplastics 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 plus optical clarity. Both rigid and tough and has a high gloss surface appearance. Applications include luers, fittings, packaging trays, catheter accessories, inhaler bodies, and IV components.

Fluoroplastics (PTFE, PVDF, PFA) - Nonflammable and have excellent chemical and solvent resistance. Wide thermal service range and, with a very low coefficient of friction, find many uses in valve assemblies, bearing surfaces, catheters, and tubing.

Polycarbonate (PC) and PC Blends - Sterilizable by all common methods, it has especially good toughness and impact resistance. Equipment housings and surgical tool handles are typical applications.

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

Polyolefins (Polypropylene, Polyethylene, Polymethylpentene) - Light-weight, 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) - Possessing excellent thermal stability and toughness, they are resistant to a variety of chemicals and can be supplied in transparent grades. Sterilizable using autoclave, EtO, or radiation. Applications include instrument handles, fluid handling components, food service trays, and surgical instrument trays/containers.

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

Styrenics (Polystyrene, ABS) - Rigid and good impact resistance places these materials into applications where chemical and heat resistance is of lesser importance. Applications include inhaler bodies, surgical tool handles, and housings.

Conductive Compounds for

MEDICAL APPLICATIONS

Medical Applications

Applications (commercialized or under evaluation) 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 suddenly releases) being administered.
- **Breathing tubes and structures** - gas flow creates triboelectric charges, which must discharge or decay. Buildup of charges could initiate 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
- **Thermally conductive sterilization case** - (see story below)

Thermal Conductivity

Thermally conductive modifiers reduce "hot spots" by absorbing and redistributing heat more evenly than unfilled resin. While metals have higher thermal conductivity values than plastics, much of their effectiveness can be lost. Air movement (or convection) actually determines how quickly heat is removed from a system. Designs with minimal or insufficient convection may not fully utilize the thermal conductivity of metals. In these cases, thermoplastic *thermally conductive* compounds may offer a better balance of cost, performance, and processing ease. They have good chemical resistance, offering an excellent alternative to parts that have failed due to corrosion.

Linvatec's PowerPro® SureCharge™ battery charging cases go through repeated sterilizations via steam autoclaving. When the decision was made to replace their all-aluminum cases, Linvatec selected a **RTP 1400 Series compound**, which incorporates an additive to improve the thermally conductive properties, while maintaining the electrical insulating properties. Enhancing the heat deflection temperature to more than 400 degrees F @ 264 psi (204 degrees C @ 1.82 MPa), the compound easily holds dimensions and reduces moisture buildup during repeated sterilization cycles. Tests indicate the new compound more than doubles the through-plane thermal conductivity values of the PPSU base resin.

Full Story: www.rtpcompany.com/info/apps

▶ *Visit www.rtpcompany.com for our latest applications, technical papers, and product information.*

RTP Co. Imagineering Plastics®

RTP Company
P.O. Box 5439
580 East Front Street
Winona, MN 55987

Tel: 1 (800) 433-4787
1 (507) 454-6900

Fax: 1 (507) 454-4629

Website: www.rtpcompany.com
E-mail: rtp@rtpcompany.com

Manufacturing Facilities: Winona, MN • South Boston, VA • Beaune, France
Fort Worth, TX • Indianapolis, IN • Singapore

ISO 9001/QS-9000 Registered Facilities ISO 9001 REGISTERED FACILITIES