Application-based Selection of Conductive Thermoplastic Materials

Like most technological endeavors, the development of conductive thermoplastic materials follows a logical sequence.

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INTRODUCTION

EMI, RFI and ESD are present along virtually the entire electromagnetic spectrum (Figure 1). Specially formulated and compounded conductive thermoplastics provide EMI/RFI shielding, static dissipation, and high conductivity to the electronics industry while maintaining thermoplastic's inherent design freedom and economics.

There are a number of factors that go into the selection of conductive thermoplastic materials for electronic devices and tools. In addition to conductivity needs, these include end-use requirements such as physical strength and toughness, flammability rating, anticipated temperature extremes, chemical environment, dimensional tolerances, and color. Defining the application's specific requirements and then applying these to the material is critical for the selection process. Knowing these other requirements at the outset allows a more efficient material development process for any conductive plastic application.

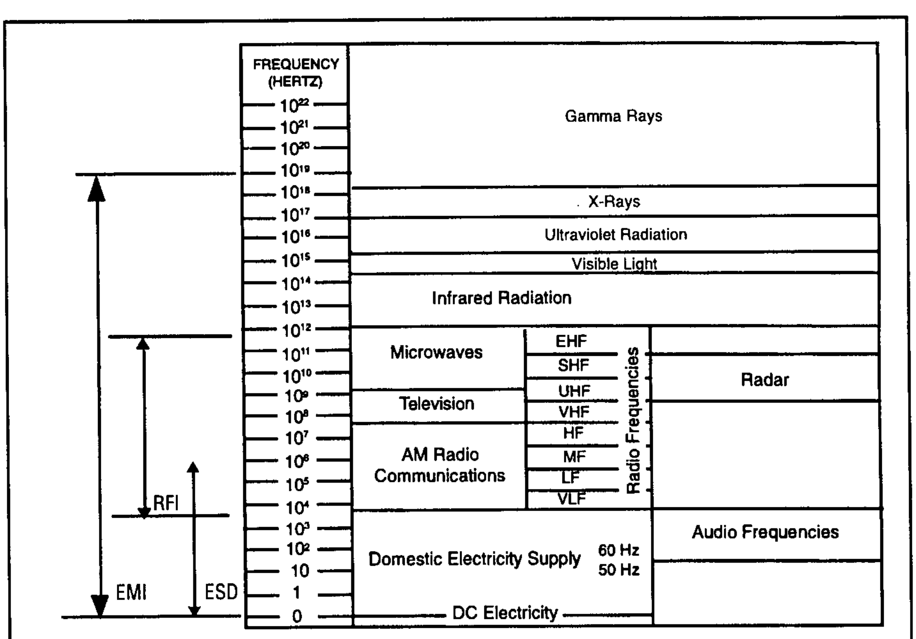

Figure 1. *The Electromagnetic Spectrum.*

Electrically conductive thermoplastics combine a matrix resin and a conductive modifier system. The matrix resin includes a thermoplastic resin with reinforcement, modifiers, or additives to impart physical properties in addition to electrical conductivity. The conductive modifier system may consist of a single conductive additive, a combination of conductive additives, or a specially manufactured conductive additive. The conductive modifier system is designed to achieve specific electrical properties and compatibility with the matrix resin with minimal impact on the material's other properties.

MATERIAL SUMMARY: CONDUCTIVE MODIFIERS

While many conductive modifiers have been available for years, it is only recently that their use in EMI/RFI shielding and static dissipation applications has shown rapid growth. Advancements in compounding techniques and improvements in the quality of conductive modifiers have provided the means to enhance the performance and reliability of conductive thermoplastics.

Metallic, carbon-based, and polymeric modifiers are used to meet the electrical needs of the application. Metal and metallized modifiers are generally used for EMI/RFI shielding, conductive, and dissipative applications. Polymeric derivatives are most often used for static dissipation.

METALLIC MODIFIERS

Metallic modifiers include metal fibers and powders and metal-coated substrates. Some metal-coated substrates include glass and carbon fiber, glass beads, and minerals like mica and titanium dioxide. Examples are stainless steel and copper fibers; stainless steel and nickel powders; silver- and nickel-coated minerals or glass beads; and nickel-coated graphite fibers.

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CARBON-BASED MODIFIERS

Carbon-based modifiers include carbon black powder and carbon fiber (also known as graphite fiber). Conductive properties imparted by carbon-based modifiers are dependent upon the physical and chemical characteristics of the substance. Included are particle size and structure, surface purity, and degree of carbonization. Maximizing these characteristics allows superior performance in the compounded material.

Carbon blacks are designated by the structure and size of their unit component, called a primary aggregate. This primary aggregate is made up of carbon black particles attracted to one another by strong physical forces. The larger the primary aggregate, the lower the volume percent required to give electrical conductivity in thermoplastic compounds. Thus, larger aggregate size will improve material performance.

Carbon (graphite) fibers are differentiated by the precursor utilized in manufacturing, the degree of carbonization (graphitization), the fiber diameter, and the level of surface contamination. Standard precursors are polyacrylonitrile (PAN) and various carbon-pitch sources. Higher carbonization and smaller fiber diameter generally yield higher strength, higher purity, and greater electrical conductivity in thermoplastic compounds. Carbon fibers are available to the plastics compounder in continuous tow, chopped, and milled forms.

POLYMERIC MODIFIERS

Polymeric modifiers, also called inherently dissipative polymers or IDPs, allow for colorable, non-sloughing (non-marking), and permanently dissipative properties when blended with thermoplastic resins. IDPs are generally used in antistatic and static dissipating applications.

CONDUCTIVE THERMOPLASTICS: TESTING AND MEASUREMENT

Knowing the application's technical specifications for conductivity is essential when evaluating the performance of conductive thermoplastic material. In addition, the proper use of recognized test procedures ensures accuracy and validity. Electrical properties are evaluated through a material's volume and surface resistivity, electrical resistance, static decay rate, and EMI/RFI attenuation.

Several test methods follow with a brief description of each.

VOLUME AND SURFACE RESISTIVITY

The most common test method for conductivity of plastics is ASTM D257, measuring both volume and surface resistivity. Because this method is intended to evaluate insulating materials, not conductive materials, alternate methods have been proposed but have not found industry-wide acceptance. Electrostatic charge is generally a surface phenomenon. As a result, surface resistivity tends to be the more meaningful of the two tested properties.

RESISTANCE

In some situations, a low level of conductance (the inverse of resistance) through a part is sufficient to provide static discharge protection. EOS/ESD Association Standard 11.11 provides a common test method for resistance (the inverse of conductance). An application-specific test method can often be designed based on the specific part to be evaluated. Conductance/resistance limits are established and in-process evaluation of molded parts is performed with either an ohmmeter or a megohmmeter.

STATIC DECAY RATE

Volume and surface resistivity and resistance measurements indicate a material's conductivity.

However, these measurements may not necessarily indicate the actual electrostatic performance of the part. In a simulation of real static events, Federal Test Method 101, Method 4046 for static decay measures how quickly a static charge dissipates. MIL B81705-C specifies this static decay test for packaging materials. It requires that a 5,000-volt charge be dissipated from the material in two seconds or less at 12% relative humidity.

EMI/RFI SHIELDING AND ATTENUATION

Determining the effectiveness of a conductive thermoplastic material in an EMI/RFI shielding application is not as simple as a measurement of electrical characteristics. Attempts are often made to relate surface resistivity to attenuation. Surface resistivity, however, only gives an average of system conductivity. Since it measures conductive pathways on the part surface, it fails to identify nonconductive areas within a part that would allow EMI/RFI leaks. Also, the shielding additive in conductive thermoplastic systems is mostly within the walls of the part and not on the surface. Therefore, surface resistivity by itself cannot correlate directly to shielding effectiveness.

Determining shielding effectiveness requires actual testing of the finished part. This necessitates making a housing of the proposed material and testing the assembled and operating device for susceptibility to interference in a real-life environment. Radiated noise levels should also be tested; this is generally performed under agency-specified methods.

ASTM D4935-89 provides a method to determine the shielding characteristics of planar materials in the far field. The values are expressed in decibels (dB) of attenuation. This method requires a standard planar test specimen which can sometimes be cut from molded parts but generally must be molded especially for the test.

In many instances, application-specific test methods can be devised which utilize either the actual molded part or a test specimen. These methods can provide correlation of candidate materials to an established standard. Laboratory testing of molded samples, instead of operating units, can provide an indication of shielding effectiveness, but the best method is testing the completed product in open-field testing.

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OTHER REQUIREMENTS: CASE STUDIES

As previously mentioned, knowing the other requirements which must be met by a conductive thermoplastic material allows an efficient material development process. Once the conductive specifications and testing techniques are established, the application can be evaluated for its other property requirements. Since these nonconductive properties can be numerous and varied, case studies of applications are offered depicting several material development sequences.

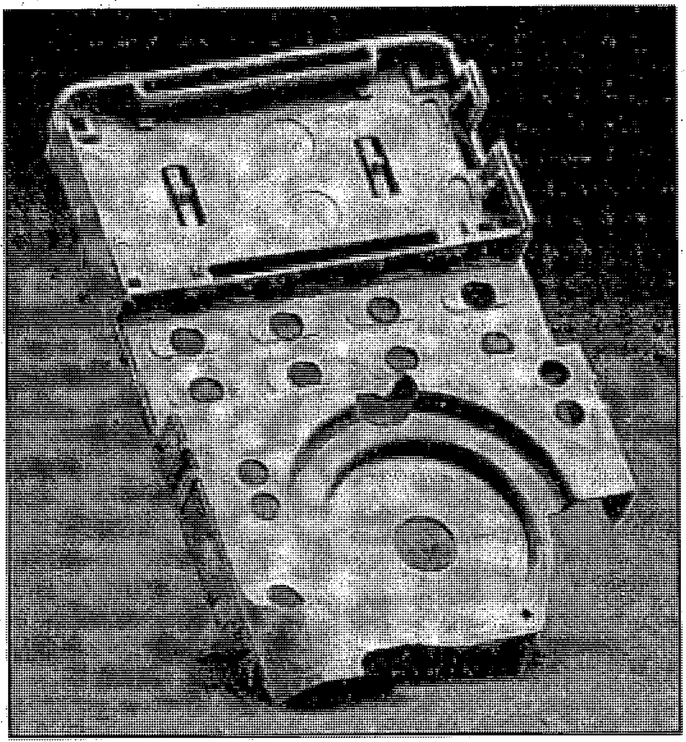

Figure 2. *Multimeter Chassis.*

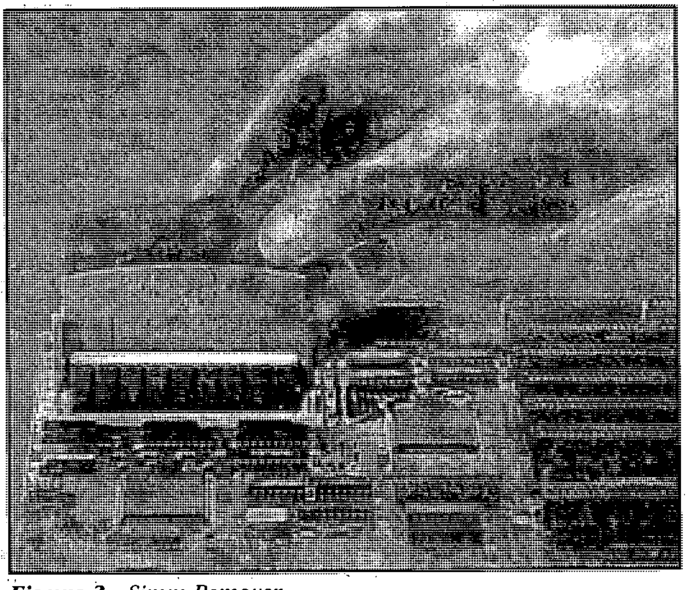

Figure 3. *Simm Remover.*

MULTIMETER CHASSIS

An internal component of a hand-held digital multimeter, the chassis supports the electronics and associated displays and function keys (Figure 2). The chassis is needed to function as an electrical ground and also as a shield against internal EMI/RFI crosstalk. Injection- molded thermoplastic was specified to meet the geometric configuration for the compact design. Physical requirements included dimensional stability for accurate positioning of locator points and snap-fit assemblies, and toughness to withstand breakage during a drop to hard surfaces. Existing tooling required a material with specific mold shrinkage. A UL 94 V-0 flame rating completed the list of specifications.

A polycarbonate resin was chosen for its dimensional stability and inherent toughness with high physical strength and stiffness. Stainless steel fiber provided EMI/RFI shielding and a strong electrical ground plane. Glass fiber reinforcement increased strength and stiffness and allowed a match to existing tooling. Finally, a UL 94 V-0 flame rating on the material was achieved with the addition of flame retardant additives.

SIMM REMOVER

The SIMM remover is a tool for extracting SIMMs (Single Inline Memory Modules) from sockets on personal computer motherboards and memory boards (Figure 3). This hand-held tool slides over the edges of the SIMM to disengage delicate socket latches and cannot stress the socket or its connections. It must prevent both an accumulation of static charge and also a direct transmittal of any charge into the SIMM or circuit boards.

Acrylonitrile butadiene styrene (ABS) resin was chosen for its dimensional stability and inherent toughness with high strength. An inherently dissipative polymer (IDP) additive provided the permanent antistatic behavior and high surface resistivity needed to prevent both static accumulation and direct transmittal of charge into the SIMM. The material can be colored for identification purposes and is cost-effective.

TAPE DRIVE DISPLAY COVER

This item is a front cover of a computer peripheral (Figure 4). The cover required impact resistance and a surface suitable for long life in an office environment, a UL94 V-0 flame rating, and suppression of both radiated and conducted EMI/RFI. Other requirements were the ability to be recycled and colored to coordinate with adjoining components.

Polycarbonate/ABS alloy was selected for its impact properties, recyclability, and processing ease with flame retardant additives. Nickel-coated graphite (NCG) fiber provided EMI/RFI shielding, increased physical strength, and maintained colorability and surface appearance.

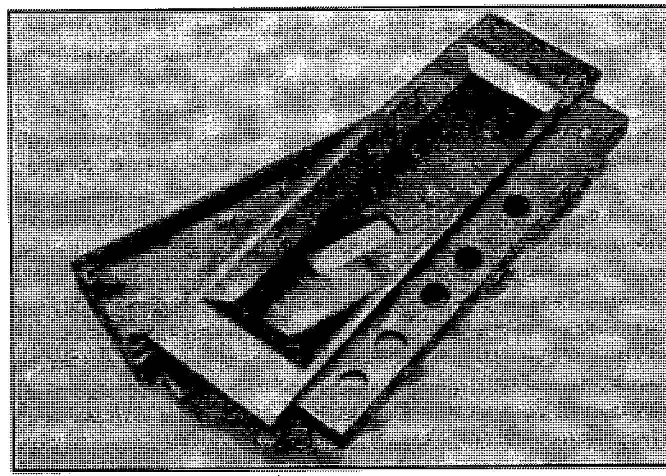

Figure 4. *Tape Drive Display Cover.*

CONCLUSION

Like most technological endeavors, the development of conductive thermoplastic materials can follow a logical sequence. Selection of materials for EMI/RFI, ESD, and highly conductive applications must begin with the identification of not only specific conductive requirements, but also other equally important needs. Conductive modifiers may cause changes in plastic material properties such as shrink rate and dimensional stability, temperature and chemical resistance, strength and toughness, and color. Reinforcements, fillers, and other additives may affect these same properties and also affect conductive performance. Knowing all the application requirements and how conductive and other modifiers may affect properties allows product development to proceed quickly. When a logical process is followed, success rates are high and customers are pleased.

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