Selecting materials for injection-molded EMI shielding applications

Selection criteria for shielding materials include composition, minimum wall thickness, and target attenuation levels.

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Thermoplastic materials have been used in applications as EMI-shielded electronic enclosures for many years. Thermoplastics offer weight and cost reduction advantages over solid metal housings. In order to make plastics use feasible for EMI-shielded housings, they must be made conductive by some means. Often this is accomplished through metal plating of an unfilled injection molded plastic housing. These housings are made out of a thermoplastic such as ABS (acrylonitrile, butadiene, styrene), which has been optimized to accept metal plating. This requires fabrication of a steel-injection mold for producing the housing and injection molding of plastic. Additionally, the part is plated/sprayed with a metal coating generally containing copper-nickel to provide EMI attenuation.

Another method of achieving a shielded housing is through the use of filled thermoplastics. Here the thermoplastic is combined with highly conductive additives such as stainless steel fiber or nickel-coated carbon fibers prior to injection molding of the thermoplastic. During the molding operation, the shear of the injection molding screw disperses the conductive additives throughout the thermoplastic resin. The result is an injection-molded part which has the conductive matrix of metallized fibers to provide EMI attenuation. This technique does not require the additional secondary operations to apply conductive coatings or plating to achieve EMI attenuation.

The suppliers of such injection-moldable EMI shielding composites possess advanced knowledge of injection molding these composites and the electrical capabilities of their products. For EMI attenuation using thermoplastics, whether it is conductive fabrics, plating electrically insulating plastics, or injection molding of EMI shielding composites, compliance testing of the assembled device is the final measure of acceptability. Few suppliers of conductive fabrics, metal plating, or moldable EMI composites are equipped to provide pre-compliance or compliance testing of assembled electronic devices. Outside testing facilities are usually sought to provide this level of verification.

TEST RESULTS

Suppliers of an injection-moldable EMI shielding material should have some ability to qualify their materials for EMI shielding capabilities. This improves the probability that an assembled device will pass compliance testing. For thermoplastics filled with conductive additives, this is most often done through ASTM D 4935-89. Entitled "Measuring the Electromagnetic Shielding Effectiveness of Planar Materials," this test method allows material measurement over the frequency range from 30 MHz to 1.5 GHz. This requires a ASTM D 4935-89 testing fixture, a tracking generator, and a spectrum analyzer. The test specimens are injection-molded disc-shaped specimens which are a minimum of 5 inches in diameter. A typical output is shown in Figure 1, which indicates the generated signal (top line), the test specimen and the noise floor. The differential between the generated signal and the noise floor is the total measurable shielding range (55-60 dB).

The test specimen in Figure 1 shows an attenuation of approximately 48-50 dB below 500 MHz and approximately 60 dB above 500 MHz. This measurement technique gives some idea of the maximum shielding capabilities of the material across the 30 MHz to 1.5 GHz frequency range. From this, materials can be selected which have the potential to pass compliance testing by qualifying that the minimum level of shielding is achievable at frequencies of concern. Also, this qualification can help reduce conductive filler content (and cost) to some degree by not exceeding the level of fillers needed for adequate shielding. This test is particularly useful in the early phases to reduce the number of materials for pre-compliance or compliance testing.

An additional test that is useful for producers of injection-moldable EMI shielding grades is a relative shielding test. The test uses two close field probes, a tracking generator, and a spectrum analyzer. The testing can be performed from 30 MHz to 1 GHz (the effective range of the probes). This method makes it possible to test over a considerably smaller area than the ASTM procedure. It is useful in qualifying a moldable shielding composite for evaluation in an application that is presently being plated. A plated housing, or sections of one, can be put between the emitting and receiving probes and a plot can be generated from 30 MHz to 1 GHz. This can be compared on the same plot to a section/plaque of an injection-moldable EMI shielding grade of the same wall thickness.

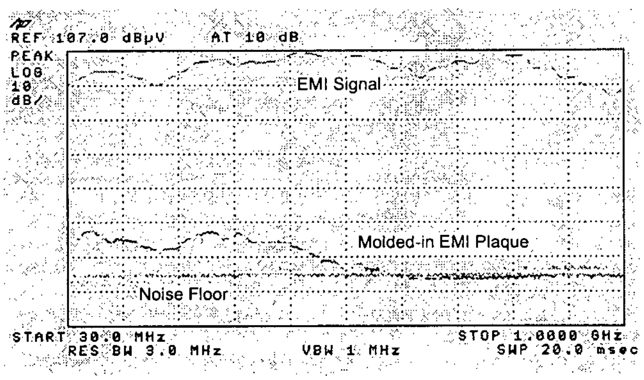

Figure 1. ASTM D 4935-89.

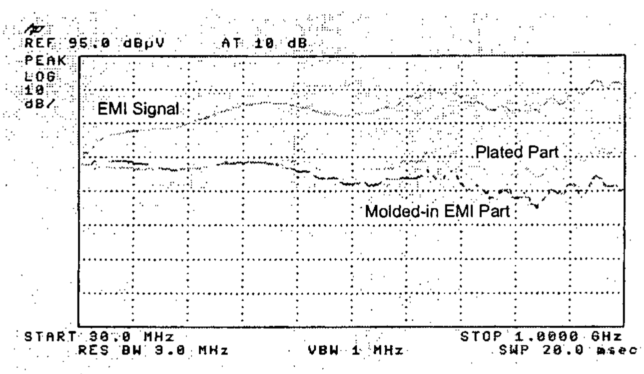

Figure 2. Field probe EMI test.

The ability to select a material which appears to have at least the same or better shielding than the plated housing can be achieved by this method. A typical plot is shown in Figure 2; the generated signal, a plated ABS housing and the injection-moldable EMI composite are shown. This curve shows that the injection-molded EMI composite attenuates more of the EMI signal than the metal-plated housing. The high loss in the field probes does not allow for specific dB measurements as in the ASTM D 4935-89 method.

Some correlation between these tests can be inferred by testing a specimen by both the field probe and ASTM method to get an idea of shielding potential in dB. A relative comparison of shielding effectiveness between an injection-moldable EMI shielding grade can be made to electrically insulating thermoplastics (for demonstration of shielding) or to plated or conductive fabric shielded enclosures. Having the ability to test small areas gives some idea of the variability in shielding effectiveness across a surface or as a function of features (apertures, wall thickness changes, etc.) in a molded part.

In qualifying a material for an injection-molded EMI shielding composite, several application specifics must be determined to select a suitable material. A thermoplastic resin replacing a metal housing must be able to function over this same range. Injection-moldable EMI shielding materials can be made from resins which, once molded, can withstand up to 600° F. More important are the specifics of the shielding requirements and the basic part design. Features of the part, such as apertures and variations in wall thickness, can have an effect on the EMI shielding of an enclosure. In order to achieve adequate shielding in an enclosure, a balance exists between the level of stainless steel fiber or nickel-coated carbon fibers needed at a given thickness to achieve the minimum level of shielding effectiveness. So a number of key application parameters must be defined to best select a grade.

Information from the device manufacturer can help define the shielding requirements, base resin, conductive filler, and filler level needed to provide shielding for an application. Often customers select 40 dB or above as their shielding requirement. This decision is typically based on the FCC standard. There are cases where the application does not require this degree of shielding due to low EMI emission, due to careful circuitry design/limited frequency generation. A deeper understanding of the application requirements will result in a composite that is both functional and cost-effective.

The radiated frequency, if known, is a vital piece of information when selecting an appropriate shielding composite. This information will help define the amount of conductive filler needed to provide shielding at specific frequencies or across a broad range. Average wall thickness is another variable that will determine the amount of filler needed to meet the shielding requirements. A composite with a given filler level will not shield as effectively in thinner wall sections as it will in thicker sections. Adjustments to filler levels will need to be made if an application calls for thinner walls. Other considerations when selecting a composite include whether part consolidation can be applied to the part currently produced in metal. Structural and chemical requirements, along with minimum thickness requirements, need to be considered.

These variables and questions help a material supplier or compounder select the EMI/RFI shielding composite that will best fulfill the requirements of an application. Some, but not all, of these variables need to be known to help define the composite. Each additional piece of information allows for a more defined material selection. Examples of how these variables can be used to define what composite is best suited for an application will be discussed using the data included in the figures which follow.

The data was accumulated by using the ASTM D 4935-89 test method at frequency ranges between 30 MHz and 1 GHz. The base resins used in the examples are ABS, a polycarbonate/ABS blend (PC/ABS), and polycarbonate (PC). The two conductive fillers used to provide shielding were stainless steel (SS) and nickel-coated carbon fiber (NiCF). The base resins and conductive fillers were combined to provide different performance shielding composites. The loading levels of the conductive fillers were varied between 5 percent and 25 percent in 5-percent increments. Samples were injection-molded into 6" x 8" plaques. The thicknesses of the samples were 0.040", 0.060", 0.080", and 0.100". Each combination was used on all three base resins.

Figure 3 shows the effect part thickness has on the shielding capabilities of a shielding composite and how it can be used to help identify an appropriate material. In this case, a 10-percent NiCF-filled PC is represented and measured at an operating frequency of 500 MHz. Notice that thickness is directly proportional to shielding effectiveness. This trend holds true for each of the base resins in the study. Many handheld devices are progressing toward thinner walls. These applications often require protection from susceptibility, as well as compliance to FCC standards. Knowledge of the wall thickness will help determine if an increase in filler level is needed to counteract the reduction in shielding that is associated with injection molding thin wall, shielded parts.

Figure 4 shows an example of the effect filler level has on shielding. As expected, increasing the filler level increases a composite's shielding capability. The sample represented is a SS PC/ABS, injection molded at a 0.060" wall thickness. The data is collected at 500 MHz. There is a noticeable increase in shielding as the filler level increases to 15 percent. The slope decreases after this point and a less dramatic shielding increase is seen. The 25-percent filler level data however, may provide more shielding than what is listed in Figure 4. Because the data was taken close to the noise floor, it is difficult to determine exactly how much shielding could have been provided.

By better understanding how much shielding is required, a compounder can tailor a composite's filler level to meet the application requirements. This is important in two ways. There are advantages and disadvantages to all conductive fillers. Depending on the application, increasing or decreasing the filler level cannot only affect shielding, but can affect material properties, and their ability to be processed. Secondly, if a product does not need to shield above 50 dB, for example, then a lower filler level can be substituted, resulting in a lower cost composite.

Figures 5 and 6 show what effect the three base resins have on shielding. Figure 5 represents a 15-percent

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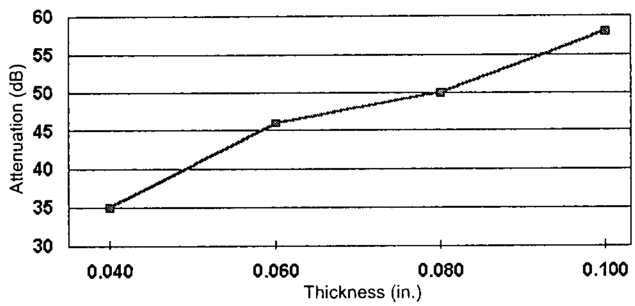

Figure 3. Effect of thickness on shielding at 500 MHz.

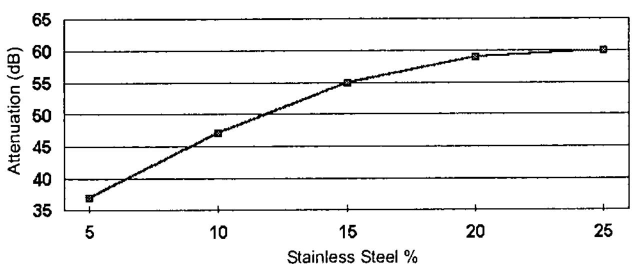

Figure 4. Effect of filler level on shielding for SS PC/ABS, 0.060 in. thick at 500 MHz.

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SS at 0.040" at 500 MHz. Figure 6 is an NiCF-filled composite at the same loading level, thickness, and frequency. Figure 5 shows that PC exhibits slightly lower shielding capabilities when combined with stainless steel fiber. The ABS and PC/ABS composites show no major differences when combined with this filler system. Figure 6 shows that the shielding performance of the three base resins is not dramatically different when combined with NiCF.

Figure 7 further defines some of the differences between stainless steel and NiCF. Shown is an ABS sample, injection-molded at a thickness of 0.060". The data was taken at 500 MHz. The data shows that until the NiCF filler reaches 10 percent, it does not provide sufficient shielding for most applications. Stainless steel provides better shielding at the 5-percent level but still may be too low to be truly functional. When used above 10 percent, both fillers provide very similar and effective shielding capabilities at this frequency.

Again, it is difficult to determine the actual shielding of the composites when tested at the higher filler levels. This is due in part to the readings being so close to the noise floor. Advanced measuring techniques may provide more defined readings at the higher loading levels. That type of testing could reveal a performance advantage for one of the fillers.

The previous figures have represented data and information at a given frequency. Figures 8 and 9 show typical outputs from the ASTM test. This output covers a frequency range from 30 MHz to 1 GHz, and at each of the five filler loading levels. Figure 8 is based on SS PC,

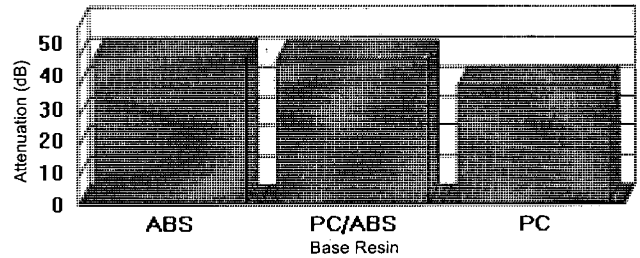

Figure 5. Base resin effect on shielding using 15% SS, 0.040 in. thick at 500 MHz.

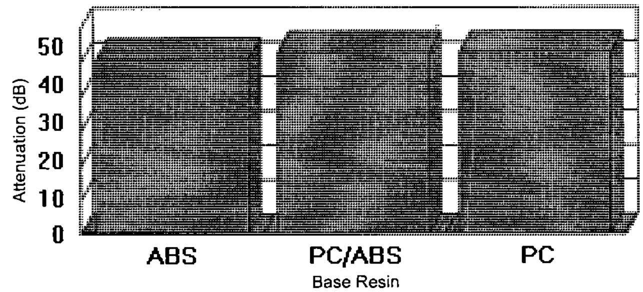

Figure 6. Base resin effect on shielding using 15% NiCF, 0.040 in. thick at 500 MHz.

and Figure 9 is based on NiCF PC. The sample thickness for both figures is 0.080".

A noteworthy point is the increase in shielding below 600 MHz, as the filler loading level increases. As shielding increases at the lower frequencies, a relatively flat curve forms and a consistent performing part, at all frequency ranges, is established. The steps between the filler levels tend to be more incremental with the SS filler than with the NiCF filler, which is more sudden after 15 percent. Figure 9 reinforces the point made earlier that actual shielding does not occur until a 10-percent NiCF filler level has been reached. Once the filler level goes above 15-percent NiCF, the shielding curve is quite flat and consistent across the entire frequency range. This type of output can help establish an appropriate filler level based on the operation frequency and shielding requirements of the application.

CONCLUSION

Qualifying injection-moldable EMI shielding grades for an application can be accomplished with specific information from the end-user. Understanding criteria such as minimum wall thickness, and target attenuation levels will simplify the selection of these composites. Involvement with the end-user at the early stages of development can help reduce the amount of pre-compliance testing, as well as the associated costs. Success in

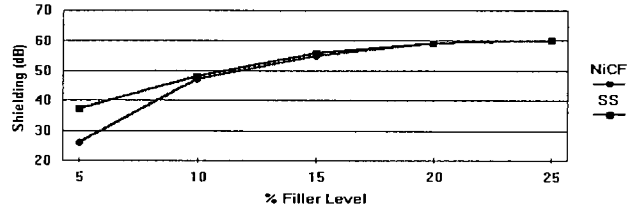

Figure 7. Shielding vs. filler type of ABS, 0.060 in. at 500 MHz.

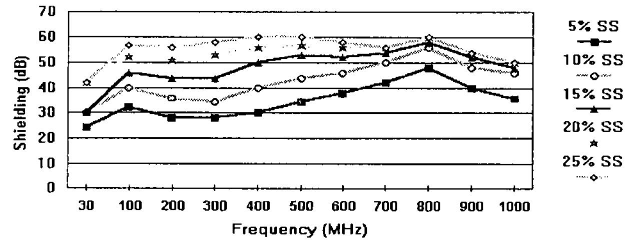

Figure 8. Shielding effectiveness of stainless steel PC, at 0.080 in. thickness.

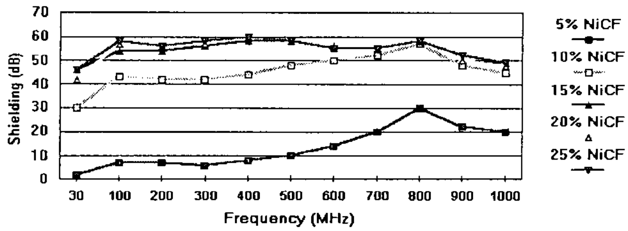

Figure 9. Shielding effectiveness of NiCF PC, 0.080 in. thickness.

developing applications for injection-moldable EMI shielding grades is best achieved when suppliers of these grades possess the ability to qualify their materials for EMI shielding potential.

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