

Electromagnetic Shielding for Thermoplastic Composites An Evaluation of Standardized Electrical Resistance Tests

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Unlike traditional EMI shielding materials made of metal, thermoplastics offer the advantages of design flexibility, lighter weight and lower density.

Selective plated and painted thermoplastic parts are also used as EMI shields. Plating and painting are done as secondary operations. This lengthens the supply chain and adds cost. A more direct solution is to use a thermoplastic material that has been compounded with conductive filler. This allows for advantages of injection molding without costly secondary operations.

In these experiments, several commercially available electromagnetic interference (EMI) shielding thermoplastic materials were evaluated for electrical resistance and EMI shielding. International Electrical and Electronics Engineers (IEEE) test method 299 and ASTM D4395 shielding tests were performed as far field shielding tests. A ladder box configuration was used to evaluate near field shielding. Electrical resistance was measured along the surface and through the parts.

Need for EMI Shielding

Electromagnetic interference (EMI) is radiated or conducted energy that negatively changes an electric circuit's performance. The EMI wave consists of both an electrical field and magnetic field oscillating at right angles to each other (See Figure 1)

When this wave contacts a surface it is either reflected, absorbed, or some combination of all three. This is expressed as: $SE = R + A + B$ ⁽¹⁾

Where SE is shielding effectiveness, R is the reflection factor, A is the absorption factor and B is correction factor for far boundary reflections.

Most EMI shielding materials work by reflecting the EMI wave. This occurs when there is a large impedance mismatch between the shielding material and the wave. This occurs for materials with high electrical conductivity.⁽¹⁾

The necessity of EMI shielding for electronic devices is increasing rapidly. This is driven by advances in wireless devices and a proliferation of electronic devices in the home and in transportation. These devices need to be shielded to ensure their correct operation. Additionally, safety standards are being enacted to limit human exposure to this radiation.

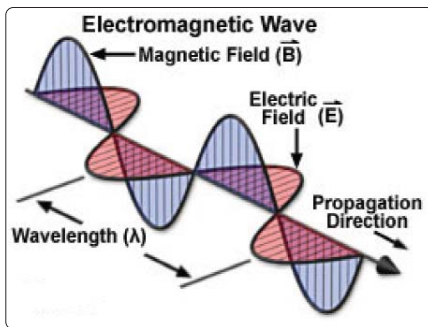


Figure 1

Standard EMI Tests

Standard shielding effectiveness tests of these composites is necessary to compare them to metal or plated plastic solutions. Tests can be performed in the far field or near field and over a wide range of frequencies depending on the desired application. These tests are very effective for the electronic device designer to compare various EMI shield materials to one another.

The issue for the injection molder of thermoplastic shields is to assure parts with consistent electrical performance are delivered to the customer. The need exists to conduct quality tests to ensure that all parts are shielded. Shielding tests require adequate equipment, time and expertise to ensure repeatable and accurate results. This is not a readily available option for most injection molders.

Measuring resistance is much easier in all cases. There are several different techniques for measuring electrical resistance.⁽²⁾ Ideally, they would correlate with EMI shielding. This article examines how well several standard EMI shielding tests correlate with electrical resistance tests.

Testing Methods

High electrical conductivity thermoplastics can be made by compounding conductive filler into thermoplastic. Fillers for these materials include carbon fiber, metal fibers, metal plated fibers and metal particles.^(8,9)

Three commercially available EMI shielding grades of PC/ABS plastic were evaluated. The three different grades contained 10, 20 and 30 wt% nickel plated carbon fiber (NiCF). The NiCF was treated with a proprietary sizing chemistry to ensure thorough dispersion of the fibers in the end part. See Figure 2.

All test parts were molded on a 60-ton Engel injection molding machine with a general purpose screw. The individual part dimensions are explained in the individual test descriptions below.

Electrical resistance was measured by methods of through resistance and surface resistivity.

Through resistance was measured on a 6.35 cm diameter by 3 mm thick disc. The disc is placed between two 51 mm gold plated probes that are attached to an ohmmeter. 358 kPa was applied to the sample. The resistance after 15 seconds under load is recorded. See Figure 3.

Surface resistivity was measured using the probe described in MIL-DTL-83528C. [7] The same 6.35 cm diameter by 3mm thick disc from the through resistance measurement was used. The probe was attached to an ohmmeter. A load of 145 kPa was applied to the probe to ensure good contact with the specimen. Resistance was measured after 15 seconds under load.

Shielding effectiveness was measured per ASTM D4935, a modified IEEE 299 standard, and the Ladder Box method.

ASTM D4935 is a standard method for testing far field shielding effectiveness⁽⁶⁾. A 13.3 cm diameter by 1.5 mm thick disc of NiCF filled polymer is put in an enlarged coaxial transmission line. This is placed between a signal generator and a receiver. Shielding effectiveness is found from the change in received power of the sample. A frequency range of 100 to 1,000 MHz was examined.

The Ladder Box (Figure 4) was developed as a method to test near field shielding to mold small handheld devices. The test method uses a molded part consisting of three five-sided cavities that are a square with a length of 3.8 cm. An electrical conductive gasket is applied to the top of each rib wall. This is then mated against a printed circuit board with an antenna for each cavity. A network analyzer is used to measure shielding effectiveness from one cavity to the other.⁽¹³⁾

IEEE test method 299 describes a test method for testing the EMI shielding of complete electronic devices.⁽⁵⁾ This test method was modified to test flat plaque. A 13.3 cm diameter by 1.5 mm thick disc of sample material is mounted to a test fixture to cover a circular opening. An arrangement of four blind hole nuts and bolts is used to attach the disc. See Figure 5. A receiving and transmitting antenna are placed one meter from the test fixture. A power measurement of the transmitted signal is measured for several frequencies. This measurement is subtracted from the power measurement of the open reference to obtain shielding effectiveness at each frequency. Three samples were measured for material.



Figure 2: Conductive Thermoplastic Pellets

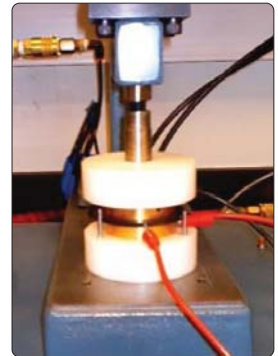


Figure 3: Through Resistance Test Fixture

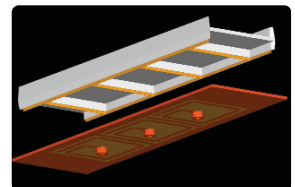


Figure 4: Ladder Box Shielding Method



Figure 5: IEEE 299 Far Field Shielding Evaluation Test

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Results

Generally, it was found that through resistance provides a better correlation than surface resistance for all shielding tests. Type and fit of the correlation between shielding effectiveness and electrical resistance varied across the frequency sweep. This may be due to the increased within test variability of surface resistance compared to through resistance.

Results of shielding and resistance data are shown in Tables 1 and 2, respectively. As expected, electric resistance decreases and EMI shielding effectiveness increases as the filler level increases.

Surface resistance data has more within test variation than through resistance. The coefficient of variation, which is standard deviation normalized by average, for the surface resistance measurements is more than 2X that of through resistance. Additionally, test variation is lowest for all tests at the 30 wt percent NiCF material. There is a weak positive trend with coefficient of variation and NiCF wt percent.

Figure 6 is the plot of shielding effectiveness versus through resistance for the three polymer grades. The curves for ladder box method and ASTM 4359 both have significant negative correlation between shielding effectiveness and electrical resistance. Data from IEEE 299 gives a curve with very little slope. These trends are also true for surface resistivity.

Shielding effectiveness is a function of frequency applied. This is evident from looking at the data in Table 1 and the plot of the data in Figures 7 and 8. Examining single point shielding effectiveness or an average shielding effectiveness across a frequency sweep can be misleading. For example, 30wt percent NiCF and 10wt percent NiCF have very similar average IEEE 299 shielding results, 62.6 dB and 62.2 dB. Examining the entire curve shows very different behavior across the frequency range. 10wt% NiCF yields lower shielding effectiveness values than 30wt percent NiCF at frequency lower than 4,000 MHz but higher shielding effectiveness at frequencies greater than 8,000 MHz.

Modified IEEE 299												
Frequency (MHz)	800	1000	2000	4000	6000	8000	10000	12000	14000	16000	18000	Ave. SE (dB)
Material	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)
30% NiCF	68	61	61	50	57	60	64	55	67	66	63	63
20% NiCF	44	52	76	54	58	63	63	61	65	66	74	62
10% NiCF	39	41	50	55	64	73	73	71	79	75	63	62

ASTM 4935												
Frequency (MHz)	20	40	60	80	100	200	400	600	800	1000	Ave. SE (dB)	
Material	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	
30% NiCF	65	66	67	71	74	88	87	86	93	94	79	
20% NiCF	57	57	59	62	64	67	75	79	84	87	69	
10% NiCF	57	59	57	63	68	70	68	67	71	73	65	

Ladder Box												
Frequency (MHz)	850	1000	1800	1920	2400	5200	Ave. SE (dB)					
Material	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)	SE (dB)					
30% NiCF	35	42	52	54	53	49	48					
20% NiCF	19	21	42	52	44	50	38					
10% NiCF	1	1	29	36	29	39	22					

Table 1: Shielding Effectiveness Data

WT% NiCF	30	20	10
Average Through Resistance (mOhms)	18	48	227
Through Resistance Standard Deviation	3.3	17.8	43.7
Average Surface Resistance (mOhm/square)	162	551	2187
Surface Resistance Standard Deviation	31.6	373.2	1597.4

Table 2: Electrical Resistance Data

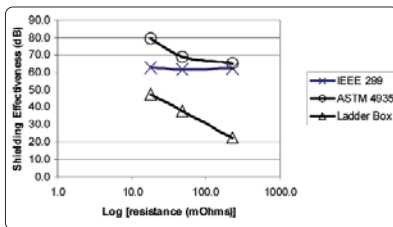


Figure 6: Through Resistance vs. Shielding Effectiveness

positive to negative over the frequency range. At some frequencies there is no trend as the 20 percent NiCF gives the highest shielding effectiveness.

This behavior is not as pronounced for the ASTM 4935 and Ladder Box shielding effectiveness tests. For these tests, shielding effectiveness vs. resistance shows a negative trend across the entire frequency. This may be a function of test frequency, the ASTM test has little overlap with the IEEE 299 test, or it may be a function of test setup. The tests do give different results from each other in terms of the magnitude of the shielding effectiveness values. ASTM D4935 yields the highest values for all three materials and Ladder Box yields the lowest.

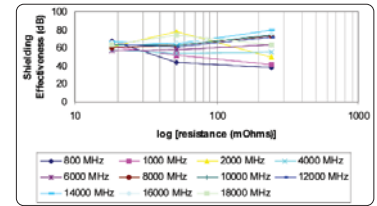


Figure 9: Log Resistance vs. Shielding Effectiveness

Conclusions

The data presented show that it is difficult to predict shielding effectiveness with resistance measurements alone. Shielding effectiveness is not a single point but a curve over a frequency range. The frequencies of interest must be understood and defined to ensure the behavior at those frequencies.

ASTM 4935 and Ladder Box shielding effectiveness test show greater demarcation between the materials tested than IEEE 299. Surface resistivity has more within test variation than through resistance. Additionally, the magnitude of results is very different from the different EMI shielding tests even at the same frequency.

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Acknowledgments

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Author Biography

Chris Severance is a Technology Team Leader for Chomerics Division of the Parker Hannifin Corp. He has a MS in Plastics Engineering from University of Massachusetts-Lowell and a BS in Chemical Engineering from the University of New Hampshire. He has worked on processing and developing conductive polymer composites for the last eight years. He may be reached at 781-939-4346 or cseverance@parker.com.

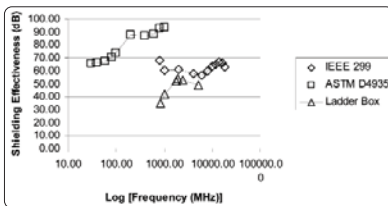


Figure 7: Frequency vs. Shielding Effectiveness for 30 percent NiCF

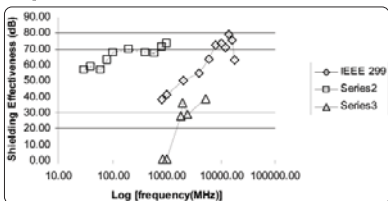


Figure 8: Frequency vs. Shielding Effectiveness for 10 Percent NiCF

This behavior changes the correlation between electrical resistance and shielding effectiveness. Figure 9 shows electrical resistance plot against shielding effectiveness for each individual frequency tested. The slope of the plot shifts from

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