The New Generation of Conductive Elastomers

Conductive elastomers must provide good EMI shielding, EMP survivability, corrosion resistance and good thermal aging characteristics.

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INTRODUCTION

Electrically conductive elastomers based on silver or silver-plated particles have been used for shielding against electromagnetic interference (EMI) and protection against electromagnetic pulse (EMP) for the last thirty years. Silver-based elastomers have been in use since the early 1960s, but have only been widely accepted since the 1980s. When used as a seal or gasket between aluminum flanges, silver-based elastomers show varying degrees of galvanic incompatibility in salt spray environments, and it is for this reason they have not been accepted as universal shielding materials. This article describes a new conductive elastomer which is based on a silicone polymer filled with nickel-coated graphite and which performs very well in EMI, EMP, vibration and salt fog environments.

As shielding applications have changed, so have the performance expectations of conductive elastomers. Conductive elastomers must be electrically conductive, mechanically resilient, and able to conform to the irregularities of mating surfaces in order to provide low interface resistance between mating surfaces, while simultaneously providing moisture, pressure or environmental sealing.

Conductive elastomers which have been formerly available, or are available today, are based on silver, silver-plated particles, or carbon-filled silicones. Silver and silver-plated filler-based elastomers offer high shielding performance. On the other hand, the low electrical conductivity of carbon-filled silicone (2 to 5 ohm-cm) makes it a marginal material for shielding applications. Nickel-filled silicone elastomers have been available for the last few years but with the exception of a few, most have very poor electrical stability. As already stated, silver or silver-plated materials are incompatible with aluminum flanges in salt spray environments. However, the stability of silver surfaces has made them a very viable material for high reliability applications.

The new non-silver based material is a general purpose conductive elastomer which, while not as conductive as military specification materials, offers a compromise for shielding and environmental sealing. This material is low durometer, low compression set, and light weight. Galvanic compatibility with aluminum structures makes it very attractive for aerospace and shipboard applications. This new material can be supplied as molded shapes or extruded parts, and presents an additional dimension for the design engineer who deals with multi-functional (shielding and environmental) seal designs.

MATERIALS & PROPERTIES

This new conductive elastomer is based on nickel-coated graphite particulates dispersed in a silicone matrix. The shape of the particles and filler level have been selected in such a way that the elastomer provides optimum electrical conductivity, tensile strength, resilience and compression set to maintain the physical integrity of the seal. Typical physical and electrical characteristics of the new elastomer and a comparison against two MIL-G-83528 materials are shown in Table 1.

PROPERTY	NICKEL-COATED GRAPHITE GASKET	MIL-G-83528 TYPE A	MIL-G-83528 TYPE B
Polymer	Silicone	Silicone	Silicone
Filler	Nickel/Graphite	Silver/Copper	Silver/Aluminum
Specific Gravity	1.90	3.6	2.0
Hardness (Shore A)	55	65	65
Tensile Strength (psi)	160	200	180
Elongation (%)	200-400	100/300	100/300
Tear Resistance (PPI)	50	25	30
Compression Set (%) (per ASTM 395)	20	32	32
Compression/Deflection (%) (flat sheet @ room temperature)	8	3.5	3.5
Volume Resistivity (ohm-cm) As received	0.05	0.004	0.008
After Heat Aging (@365°F for 40 hours)	0.20	0.010	0.010
During Vibration	0.04	0.006	0.012
After Vibration	0.04	0.004	0.008
After Tensile Break	0.10	0.008	0.015
After Exposure to EMP (9 kA/linear inch of perimeter)	0.05	0.010	0.010

TABLE 1. *Physical and Electrical Characteristics of Selected Gaskets.*

SHIELDING PERFORMANCE

Direct current (dc) resistance across the joints is a good measure for estimating shielding performance of conductive material. However, as the joint resistance drops below 0.0001 ohms, the relationship of volume resistivity to shielding performance becomes insignificant.

The new elastomer has a typical joint resistance of 0.002 to 0.005 ohms when tested as a flat gasket between two metal plates under 100 psi. The values are much higher than the best performing material, including silver-plated copper, or pure silver, and a substantial difference (30 to 35 dB) in EMI performance was expected. However, test results did not support that type of difference in shielding performance. Table 2 shows the plane wave shielding performance of the new material from 20 MHz to 10 GHz tested [2] per MIL-STD-285.

FREQUENCY (MHz)	SHIELDING EFFECTIVENESS (dB)
20	123
40	127
60	139
80	132
100	124
200	130
400	150
600	137
800	135
1000	132
2000	105
4000	124
6000	112
8000	109
10000	102

TABLE 2. *Shielding Performance.*

EMP SURVIVABILITY

The EMP survivability of shielding material when used as a gasket in electronic enclosures is always a big concern for design engineers. The gasketing material should not show physical damage or any significant

INITIAL RESISTIVITY (ohm-cm)	FINAL RESISTIVITY (ohm-cm)
0.061	0.035

TABLE 3. *Resistance after Exposure to EMP.*

NO.	FREQUENCY (Hz)	FORCE (G)	RESISTIVITY (ohm-cm) BEFORE	DURING	AFTER
1	405	10.1	0.034	0.0406	0.0370
2	405	10.0	0.036	0.0421	0.0385

TABLE 4. *Electrical Stability.*

MATERIAL	PLATE SURFACE FINISH	PLATE CONDITION RATING	CONDITION OF GASKET
Silver/Copper (Type A)	Bare Chem. Finish Nickel-plated	Very Slight Very Slight Very Heavy	Poor Fair
Silver/Aluminum (Type B)	Bare Chem. Finish Nickel-plated	Very Slight Very Slight Heavy	Excellent Good Good
Nickel Graphite	Bare Chem. Finish Nickel-plated	Very Slight Very Slight Heavy	Excellent Excellent Excellent

RATING:
Very Slight: Negligible pits, pit depth less than 0.05 mm.
Slight: Less than 10 pits, pit depth less than 1.0 mm.
Moderate: Greater than 10 pits, pit depth less than 1.0 mm.
Very Heavy: Pit depth greater than 2.0 mm.

TABLE 5. *Galvanic Rating.*

change in joint resistance when subjected to an electromagnetic pulse. Accordingly, the nickel-coated graphite elastomer was tested per MIL-G-83528 Specification, paragraph 4.6.16.[3] Test results indicate that the resistance actually *decreased* after exposure to a 9 kA peak-to-peak sinusoidal current pulse. This indicates that the material does survive EMP conditions. The test results are shown in Table 3.

ELECTRICAL STABILITY DURING VIBRATION

The shape of the filler particles have a major effect on the stability of the conductive elastomer under vibrations. The new elastomer is based on an irregularly shaped conductive powder dispersed in a silicone matrix and survive under vibratory conditions. This material has been tested to MIL-G-83528 Paragraph 4.6.13. Test data has shown the material to have very good electrical stability during vibration.[4] The results are shown in Table 4.

THERMAL AGING

Thermal aging provides useful information about the shelf life of gaskets. Accelerated heat aging shows the change in electrical conductivity and modulus, the two most critical characteristics required for good sealing practices. A sample of the new gasket was placed (unflanged) in an oven at 365°F for 72 hours and evaluated for change in volume resistivity and hardness. The volume resistivity had changed from 0.05 to 0.15 ohm-cm, whereas no significant change was observed in hardness. The results prove that this material will maintain its electrical properties over time.

GALVANIC CORROSION

EMI gasket materials based on silver and silver-plated particles are incompatible with aluminum flanges when exposed to salt fog environments. This new material is a non-silver based material with excellent corrosion resistance over the traditional conductive material. This material has been tested against silver-plated copper (MIL-G-83528 Type A) and silver-plated aluminum (MIL-G-83528 Type B) for the 1,500-hour salt fog test per ASTM B117-73. Results are shown in Table 5, which compares the new materials with both a silver-plated copper and silver-coated aluminum filled silicone material after being exposed to 1500 hours of salt fog spray per ASTM B117-73.[5]

CONCLUSION

This article describes a new generation of conductive elastomers which provide good shielding, EMP survivability, performance under vibration and good thermal aging characteristics. The material is lightweight, compatible with aluminum flanges and offers an excellent choice for design engineers who deal with aircraft and shipboard applications. This material has a low compression set (16%), is cost-effective, and an attractive alternative for multi-purpose sealing/shielding applications.

REFERENCES

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