EFFECTS OF CORROSION ON THE ELECTRICAL PROPERTIES OF CONDUCTED FINISHES FOR EMI SHIELDING

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Abstract

The shielding effectiveness of an EMI enclosure is dependent on the integrity of all the pieces of the shielding system. A wide variety of material finishes (both for the base material and the fingerstock) are available and commonly used to create shielded enclosures for EMI control. This paper examines the results of testing a variety of combinations of fingerstock materials both before and after exposure to an accelerated atmospheric corrosion environment. The transfer impedance of the joint was used to measure the electricl performance and then the corrosion resistance of the conductive finishes.

Introduction

The use of EMI gasket and fingerstock has become widespread throughout the industry as a tool to help suppress EMI. Many metal doors and user removable panels are equipped with EMI fingerstock to insure better metal-to-metal contact between the door and its frame, thereby reducing the slots which could allow EMI to escape.

The weak link in the EMI shielding performance of a shielded computer cabinet (or other enclosure) is often the EMI fingerstock. Although careful engineering insure proper contact between the EMI fingerstock and the door (or other surface), contact is not enough to insure the desired performance. The quality of the contact must be good enough (across the frequency range of interest) to insure the desired shielding effectiveness for the life of the product. This quality of contact is dependent on the amount of surface area in contact, the electrical properties of the materials, and the electrical properties of the interface where the contact is established. The metal finishes will control how the surface conductivity of the materials will change with normal environmental aging. The presence of (relatively) non-conductive corrosion products can have a tremendous impact on the effectiveness of the electrical contact. It is critical that this surface conductivity does not increase significantly with time, thus insuring that the shielding effectiveness of the enclosure remain high throughout the life of the product. Obviously, gaskets can only maintain adequate shielding if they maintain low contact impedance.

Most EMI enclosures are made from steel or aluminum. Although the bare metal provides a good, low impedance surface, if left un-coated, the surface would quickly corrode, greatly increasing the surface impedance. Unfortunately, the coatings that provide the best corrosion resistance often have unacceptably high surface impedance.

Protective finishes for metals are usually evaluated for their effectiveness in protecting the underlying base material from corrosion. This study investigated the electrical contact impedance of these coatings during a simulated lifetime.

Performance Measurement

The shielding effectiveness of EMI fingerstock or gasket is a difficult parameter to measure accurately. Since EMI fingerstock is often used to suppress radiated emissions, a radiated technique is often used to measure its shielding effectiveness. Regardless of whether a large shielded enclosure, or a small test fixture is used, the test results are not always a true indication of the EMI fingerstock performance.

A better indication of EMI fingerstock performance is the fingerstock's transfer impedance [1]. Transfer impedance is a measure of the voltage created across the "far" side of a gasket when a current is induced across the "near" side. This direct measurement eliminates the variables described above, by directly coupling across the gasketed boundary. Transfer impedance is proportional to the inverse of shielding effectiveness, that is, as transfer impedance is lowered, the shielding effectiveness improves.

A special transfer impedance fixture (shown in Figure 1) was built to measure the relative performance of a variety of combinations of fingerstock materials and mating surface materials. This fixture allowed the fingerstock to be placed between two flat metal samples, a disk and a ring-shaped plate, while maintaining coaxial symmetry. This fixture also allowed mated combinations of fingerstock and metal plates (samples are mated using non-conductive screws) to be removed intact, placed in a chamber to

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accelerate the environmental aging process (intact), and then returned to the transfer impedance tester for retesting, without ever disassembling the parts.

The transfer impedance fixture is a high quality shielded enclosure which permits the test signal to be applied to the top side of the metal sample disk. The signal path requires the current to flow across the fingerstock/gasket boundary. Any appreciable impedance will create a voltage drop across the fingerstock/gasket, which is measured by the spectrum analyzer connected to the underside of the metal sample disk. The transfer impedance was measured across the frequency range of 1 MHz to 1 GHz using a spectrum analyzer, tracking generator, and amplifier.

In the mated condition, the sample packages were exposed to a flowing mixed gas environmental chamber for 14 days. The chamber maintained approximately 10 ppb chlorine, 200 ppb nitric oxide, and 10 ppb hydrogen sulfide, along with controlled temperature and humidity. This exposure was selected to simulate roughly five to eight years of exposure to a somewhat corrosive commercial computer product environment. The transfer impedance of the mated package was measured before and after the corrosion exposure to determine the effect of corrosion on the electrical conductivity of the surfaces.

The following materials/Finishes were tested during this study:

- 304 Stainless Steel, passivated, MIL STD QQ-P-35B

- 1010 Steel, electroplated bright tin, 0.0003 inch nominal coating thickness, ASTM B545

- 1010 Steel, electroplated nickel, 0.0005 inch nominal coating thickness, ASTMB689

- 1010 Steel, electroless nickel, 0.0005 inch coating thickness

- 1010 Steel, zinc plated, 0.0005 inch plating thickness, with yellow chromate conversion coating

- 1010 Steel, zinc plated, 0.0002 minimum zinc thickness, with blue bringt chromate conversion coating

- Electrogalvinized steel, 0.0007 inch zinc thickness, with yellow chromate conversion coating

- Steel with hot-dipped aluminum-zinc (55:45) coating, 0.0008 inch coating thickness

- 5052 aluminum, with yellow chromate conversion coating

- 5052 aluminum, with clear chromate conversion coating, ASTM B449, class 3

The metal panels were mated with beryllium copper fingerstock to make the joints typical of computer enclosure doors and panels. The finishes on the beryllium copper were:

- Electroplated bright tin

- Electroplated bright nickel

- Electroplated tin-lead (60:40)

- Bright dip (thin chromated conversion coating

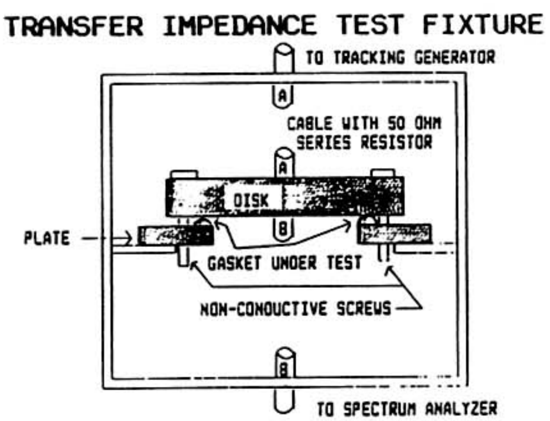

Figure 1

Test Results

Although each combination of sample plate material and fingerstock material was measured over the entire frequency range of 1MHz to 1GHz, it was found that the spectral shape of the test results varied little from material combination to combination. The level of the test results varied greatly, as was expected, but no extra information was gained from the frequency response. It is likely that the spectral shape is due to the test fixture itself, more than any change in impedance of the fingerstock joint due to frequency. The test results could therefore be summarized by listing the worst-case impedance for that combination of metal plates and fingerstock. A typical test result (as a function of frequency) is shown in Figure 2.

Nearly all the clean new metal samples gave low transfer impedance readings. However, as expected, the yellow chromated samples gave higher transfer impedance measurements than the samples with thinner chromate coatings, or none at all. The results repeatedly show higher transfer impedance when there is a chromate conversion coating, whether this coating is used on the metal plate surface or the fingerstock surface. These new metal sample results are shown in Table 1.

The impedance readings increased after the mated samples were aged. Table 2 shows the test results from the aged samples. Although there was no visual evidence of

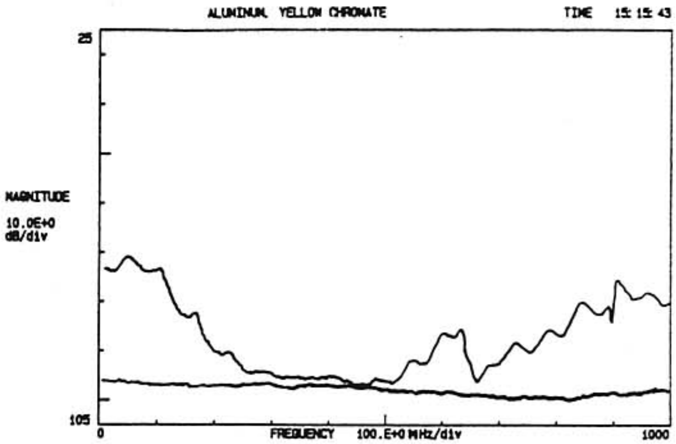

Figure 2

Table 1
TRANSFER IMPEDANCE RANGES OF NEW SAMPLES

BASE MATERIAL	TIN-LEAD	NICKEL	TIN	BRIGHT DIP
Electroless Nickel on steel	2	2	2	3
Electroplated Nickel on steel	1	1	1	3
Tin plate on steel	1	3	1	1
Zinc plated steel w/yellow chromate	2	6	3	5
Electrogalvanized steel w/yellow chromate	1	2	1	3
Zinc plated steel w/ blue-bright chromate	1	3	1	5
Aluminum-zinc coated steel (Al-Zn)	1	2	1	3
Aluminum w/yellow chromate	1	6	4	7
Aluminum w/clear chromate	1	2	2	3
304 Stainless steel	1	2	1	2

SCALE	TRANSFER IMPEDANCE
1	0.5 - 0.8 milliohms
2	0.8 - 1.6
3	1.6 - 2.8
4	2.8 - 5
5	5 - 8.9
6	8.9 - 15.8
7	15.8 - 28.1
8	28.1 - 50
9	50 - 158
10	>158

Table 2
TRANSFER IMPEDANCE RANGES OF AGED SAMPLES

BASE MATERIAL	TIN-LEAD	NICKEL	TIN
Electroless Nickel on steel	3	2	5
Tin plate on steel	1	3	1
Electrogalvanized steel w/yellow chromate	3	2	3
Zinc plated steel w/ blue-bright chromate	4	4	9
Aluminum-zinc coated steel (Al-Zn)	4	3	
Aluminum w/yellow chromate	4	6	10
Aluminum w/clear chromate	4	6	8
304 Stainless steel	4		3

corrosion products, the impedance increased. The samples were aged in the mated position, but this mating was not a gas-tight connection, just as a normal fingerstock mating is not gas tight.

Although the chromate conversion coatings protect their surfaces effectively, the test results showed a significant increase in the impedance of those surfaces after exposure to the corrosive environment. The thicker chromate conversion coatings (yellow chromate) increase impedance more than the thinner coating. In some cases, the impedance increased more than an order of magnitude.

The test results are shown in Figures 3 through 10 for each base material individually. Note that the scale numbers are used, rather than the actual impedances. The scale numbers are the same as the scales used in Tables 1 and 2.

There was little or no increase in impedance when Electroless Nickel (Figure 3) was used with Tin-lead or Nickel fingerstocks. However there was a moderate increase when Tin fingerstock was used.

Tin plated steel (Figure 4) showed the best overall (lowest) impedance after aging. There was no difference between the new and aged samples when tin plating was used.

Electrogalvanized steel (Figure 5) showed moderate or no impedance increase before and after aging, regardless of the fingerstock type used.

Zinc Plated steel (Figure 6) showed a dramatic increase after aging with the tin plated fingerstock. After aging both the tin-lead and nickel fingerstock had high impedances.

The Aluminum-Zinc coated steel (Figure 7) showed a moderate increase in impedance with tin-lead fingerstock, but little increase with the nickel fingerstock after aging. There was no information available on the after aging results with the tin fingerstock.

The Aluminum with yellow chromate (Figure 8) showed very high impedance with the tin fingerstock after aging. All fingerstocks performed poorly with this base material.

The Aluminum with clear chromate (Figure 9) showed a dramatic increase with all fingerstocks after aging. Tin plated fingerstock with the clear chromate was the worst, but still slightly better than the tin plated fingerstock with the yellow chromated aluminum.

The Stainless steel (Figure 10) showed a moderate or little increase with aging when the tin-lead or nickel fingerstocks were used. There was no information on the plated fingerstock with this material.

Overall, the results indicated that chromates (yellow or clear) had significant impedance increase after aging. Tin plated steel showed the best impedances, regardless of the type of fingerstock used, before and after aging.

Conclusions

Atmospheric corrosion for the conductive metal finished used in shielding applications can dramatically increase the electrical contact resistance, thereby decreasing the shielding effectiveness of the enclosure. Some finishes are affected more than others.

Of the impedances tested, the tin plated surface was the only surface that did not increase impedance because of the atmospheric corrosion.

Thin chromate conversion coatings can provide low surface contact impedances when new, but the impedance of chromated surfaces increased significantly during corrosion exposure (aging).

Yellow chromate conversion coatings provide relatively high impedance when new, and this impedance increases further during the aging process.

References

[1] B.R. Archambeault, "EMI Fingerstock When Mated to Various Surfaces", IEEE/EMC Symposium, August 1987.

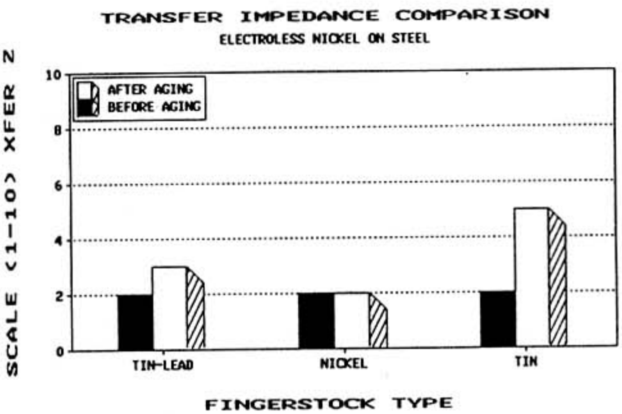

Figure 3

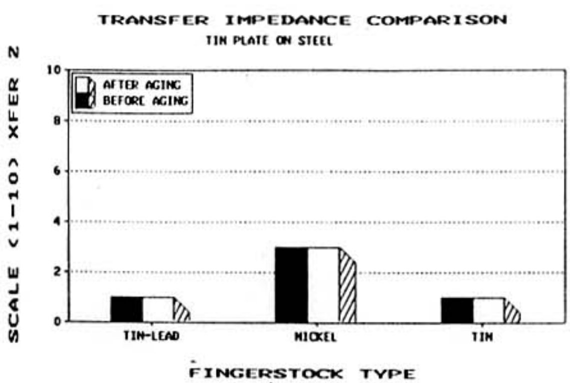

Figure 4

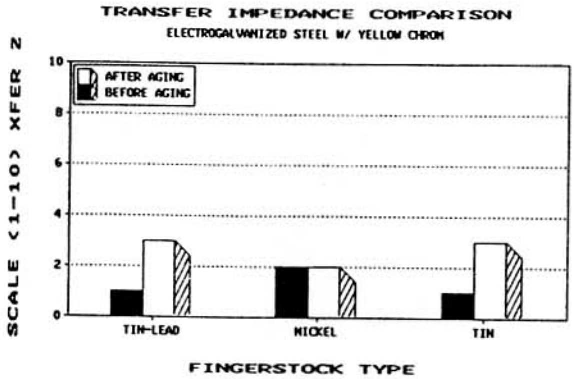

Figure 5

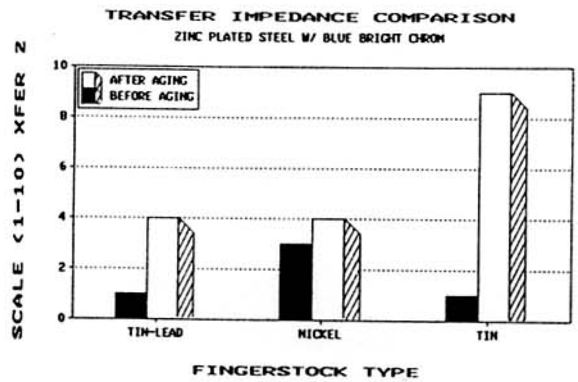

Figure 6

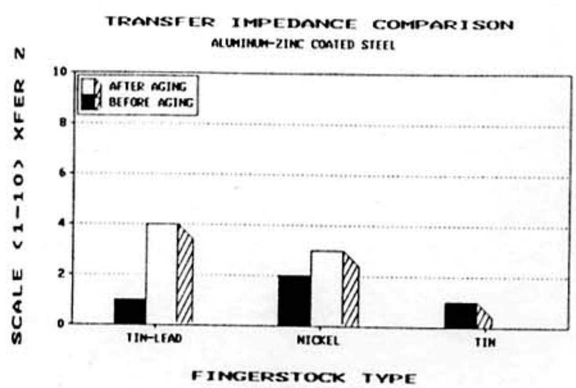

Figure 7

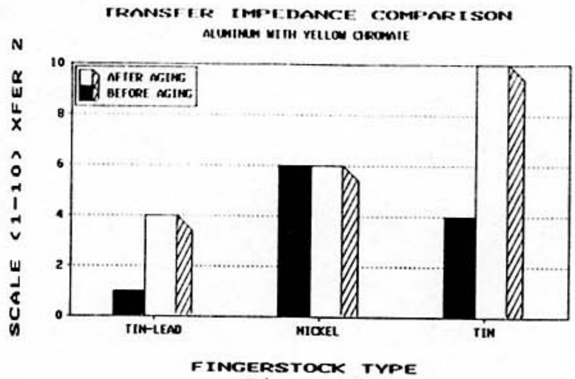

Figure 8

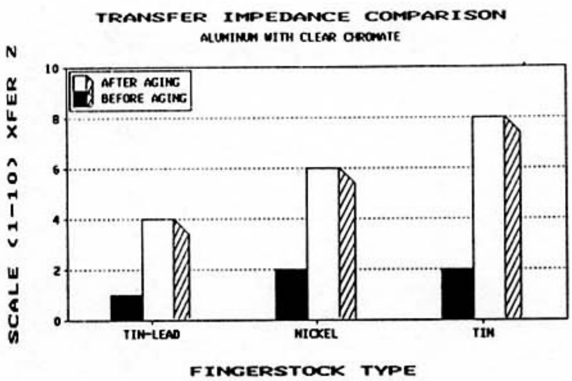

Figure 9

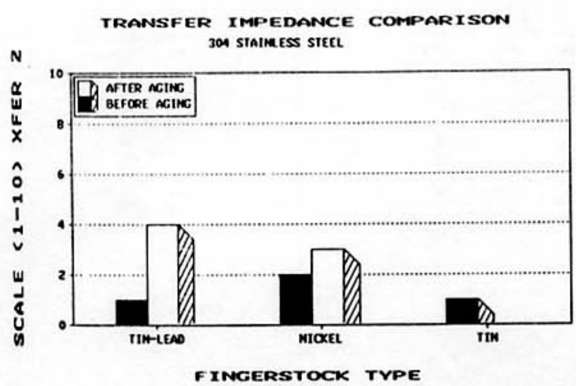

Figure 10