A NOVEL APPROACH TO THERMAL MANAGEMENT AND EMI SHIELDING VIA A METALLIC CONFORMAL COATING ON A PLASTIC HOUSING

John Hannafin
Chomerics Division
Parker Hannifin Corp.
Woburn, MA
jhannafin@parker.com

ABSTRACT

With the evolution of 3G wireless communications, the once benign thermal management requirements of portable handset design are quickly gaining potential for becoming long-term performance and safety roadblocks.

The need for EMI shielding of plastic-housed handsets, particularly wireless devices, has long been known and met through a variety of methods. The most common approach to shielding at the plastic enclosure level is to apply a conductive coating on the housing's interior surface. Methods for applying this conductive layer include; sprayed conductive paint, vacuum deposited metallization and electroless plating. However, none of these existing techniques address the designer's thermal management challenges.

A new method developed for applying a metallic conformal coating to plastic enclosures combines traditional EMI shielding performance with a heat-spreading material layer that provides an effective thermal management solution. Thermal performance data has been gathered for a typical power semiconductor component mounted to a plastic housing in a closed environment. The metallic conformal coating layer has been shown to lower both the junction temperature and the plastic enclosure temperature by as much as 30°C.

Key words: thermal management, EMI shielding, conductive coating, adhesion, heat spreaders

BACKGROUND

Engineers designing portable electronic systems often face performance problems, as well as government and industrial regulations, concerning electromagnetic interference (EMI). As plastic-housed electronics shrink in size and run at higher clock speeds, the chances for EMI problems increase. RF and digital components, current carrying traces, wires, and other conductors are the typical sources of most EMI emissions. In some cases, noisy components can be moved away from sensitive areas. But smaller devices and tightly packed boards minimize that opportunity in a great many systems.

Most high-frequency systems require some form of EMI shielding at the enclosure level. While a conductive metal housing is inherently an effective EMI barrier, plastic enclosure parts must be made conductive. This has typically been achieved using a metallized paint, vacuum deposition or plating process. While each method offers advantages to the designer, there is almost always a cost-performance tradeoff necessary in the selection. The best of these systems accommodate the deepest recesses in a plastic housing part, where the smallest discontinuity provides a pathway for spurious emissions. [1][2]

Managing heat can be crucial to maintaining the reliability and extending the life of portable electronics. A broad choice of cooling solutions is available for shunting away excess component heat, including heat sinks, heat pipes and flexible metal or ceramic heat spreaders. These typically require a thermally conductive interface material between the hot component and the heat-sinking device. Much of this hardware can potentially be replaced by conveying thermal energy through a transfer material and into the new conductive conformal coating. The all-metal coating is an effective heat conductor. The coating layer can spread and dissipate thermal energy along the housing surface. [3]

METALLIC CONFORMAL COATING PROCESS

A new metallic conformal coating process is both an automated application and material solution for metallizing plastic electronic enclosures. This robotic technology produces a high performance conformal coating without several limitations of traditional coating technologies. The 100% metal coating eliminates runs, edge pulls, corner puddles, and voids. Free of solvents and corrosives, the low temperature process is environmentally safe.

While this new process for applying a metallic conformal coating lends itself to use with many metals or alloys, a high-purity tin/zinc alloy has been found suitable for the full range of today's higher performance electronic applications. The alloy is a pure metal wire with a metallurgical composition free of defects or contaminants. When applied using the robotic process, the alloy conforms to the substrate much like paint, but with the higher EMI shielding performance of solid metal such as a plating.

In a single pass, the low-melting point alloy is atomized and sprayed under tightly controlled particle size, temperature and velocity. The molten metal flows, flattens and cools

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almost instantly, without sufficient thermal mass to deform thin-walled plastic substrates. The resultant laminar film has low porosity and oxidation, and requires no curing or further processing. The automated system produces a uniform conductive film build of precise thickness. A typical film build for the alloy coating is 25 µm (0.001 inch), but significantly thicker layers, or thinner layers down to 12.5 µm (0.0005 inch) are readily achievable, on horizontal surfaces or vertical walls.

ADHESION

The primary adhesion method for the conformal conductive film is via mechanical interlocking or keying. Adhesion is enhanced using a gritblast treatment to modify the surface morphology of the substrate. The treatment creates an extremely uneven plane with a high number of peaks and valleys and ridges.

When the molten metal droplets strike this surface, they flatten and fill in these areas to form the interlocking pieces much like a puzzle. As more molten drops land on each other, there is a mechanical interlocking effect. In addition, some metallurgical and diffusion bonding results as molten droplets re-melt the surfaces of cooled droplets.

Also, as with any coating, adhesion is aided by the weak bonding effects of Van der Waals forces. [4]

As a result of the interlocking and bonding of the alloy, strong adhesion of the coating is achieved on standard plastics and metals used in electronic device parts and housings. These include PC, ABS, PC/ABS, polysulfone and other thermoset and thermoplastic injection molded polymers. Crosshatch adhesion testing of the conductive alloy applied to these substrates, conducted per ASTM D3359-78 Method B, yield consistent ratings of 5B.

EMI SHIELDING

Figure 1

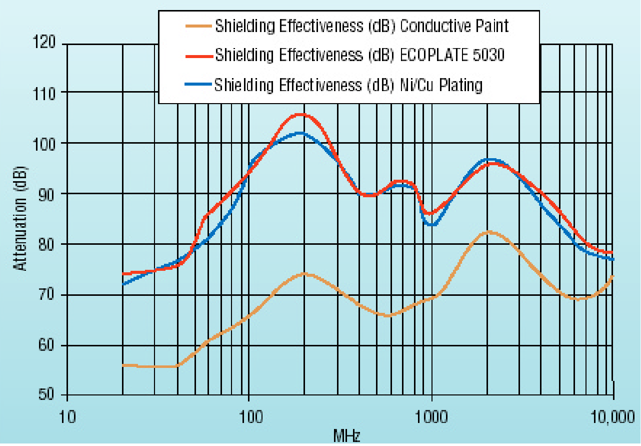


Figure 1 compares the EMI shielding performance [5] of common plastic housing metallization systems (conductive paint and plating) with the new all-metal conformal coating. The coating provides equal or improved shielding performance, over a broad frequency range, to the traditional methods, typically at lower cost, and in a more environmentally friendly system.

THERMAL PERFORMANCE

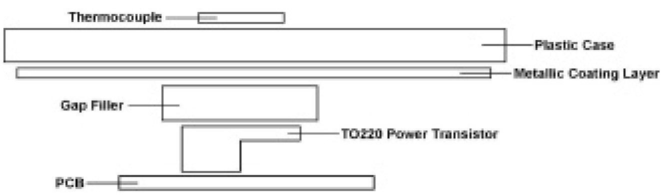
Thermal testing of the alloy, coated at four different thicknesses on an ABS substrate, showed that the metal plating provides effective heat spreading performance. Simulation testing of a semiconductor in a closed environment showed that the metal layer lowers junction temperatures by as much as 30°C. The conformal layer also diminishes or eliminates hot spots typically found on plastic electronics enclosures.

DESCRIPTION OF TEST METHOD

Test vehicles were prepared using the metallic conformal coating process. Individual plaques of 0.125-inch acrylonitrile-butadiene-styrene (ABS) substrate were coated with 1.5, 4.0, 11.0 and 17.3-mil thick alloy layers and cut into 2 x 2-inch test pieces. Additional plaques were left uncoated.

A Type "T" thermocouple was attached with thermally conductive adhesive tape to the ABS surface to measure the skin temperature at the center of the ABS surface. 0.750 x 0.750-inch pieces of 0.070-inch thick thermally conductive silicone pads were applied between the heat source and the test panels. The pads, which included a layer of aluminum foil on one side, were attached to the center of the test panels with the foil surface against the metal alloy coating. The heat source, a TIP31 in a TO220 package, was attached through its base to the other (elastomer) surface of the thermal pad. (There was sufficient surface tack to maintain thermal contact throughout the test.) Figure 2 depicts a schematic of the test configuration. The TIP31 was connected to an Analysis Tech Phase 10 Thermal Analyzer to power the device and perform the temperature measurements. Junction, ambient and plastic case temperatures were recorded when thermal equilibrium was established.

Figure 2



RESULTS

The following results were obtained:

Thick-ness (mils)	**Power** (watts)	$T_{junction}$	T_{ABS}	$T_{ambient}$	$R_{j\text{-}ABS}$	$R_{j\text{-}ambient}$
0	2.02	110.8	74.6	22.2	17.8	43.8
1.5	2.02	103.7	67.3	21.2	18.0	40.7
4.0	2.02	94.5	60.2	21.8	17.0	35.9
11.0	2.02	86.8	54.0	20.9	16.2	32.5
17.3	2.02	81.3	48.0	22.1	16.4	29.2

CONCLUSIONS

These results show that the metallic conformal coating, in layers as thin as 1.5 mil, will spread the heat generated by a semiconductor, and reduce the overall heat load that the plastic case must dissipate into the environment. This thermal spreading performance reduces the junction temperature of the device as well as reducing the hot spot on the plastic case. The 4.0-mil thick coating has a very significant effect in that it reduced the junction temperature by 15ºC and the case temperature reached 60ºC. The case temperature reduction is important because a case over 60ºC can cause burns when touched.

The metallic conformal coating process lends itself for use with a variety of metals and alloys that may have a greater initial thermal conductivity. In light of these encouraging initial results, additional investigation is needed to determine an optimum balance of film build, physical attributes, cost and thermal performance.

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