Thermoformed Vacuum-Metallized Inserts for EMI Shielding

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INTRODUCTION

Electronic devices are both sources and receptors of EMI. Since electromagnetic radiation penetrating the device may cause electronic failure, manufacturers need to protect the operational integrity of their products. Also, manufacturers must comply with regulations aimed at reducing electromagnetic radiation from electronic products. Proper design is necessary to prevent disruption of the device's function by emissions from external sources, and to minimize system emissions.

Today, plastics are replacing metals as the material of choice for electronic enclosures because plastics offer increased design flexibility, improved productivity and lower cost. The switch from metal to plastics as a housing material for electronic equipment has contributed to problems with EMI shielding. Plastics are insulators, so EMI waves pass freely through unshielded plastic without substantial impedance or resistance. Additionally, ever-increasing device miniaturization and increased clock speeds of microprocessors make it more difficult to handle the EMI pollution. As a result, a variety of technologies using metal/polymer combinations are being used to achieve effective EMI shielding.

Current methods of EMI shielding include the use of metal housings, metal-filled polymer housings, metal liners for housings, and conductive coatings for the interior of rigid polymer or composite housings. Metal coatings on rigid plastic housings are applied with conductive paints or metal plates, and adhere through chemical plating (electroless plating), electroplating, or vacuum metallization techniques. Metal foils with adhesive backings can be applied to the inside of plastic cases to enable electronic instruments to meet shielding requirements. Zinc arc spray techniques are also available to apply a metal coating to a plastic housing.

Thermoforming has become a viable alternative to injection molding for electronic equipment designs.

Each of the current shielding methods has shortcomings. The major disadvantages of plating are its high cost, complex process cycles, and an application that is limited to certain polymer resins. Metal-filled resins for injection molding suffer from poor conductivity compared to metals. The conductive polymer resin is very expensive, and complex shape molding is difficult from flow and uniformity perspectives.

Three types of conductive metal-bearing paints are in general use. Silver paints have the best electrical properties but they are extremely expensive. Nickel paints are used for relatively low attenuation applications and are limited by high resistance and poor stability. Passivated copper paints have moderate cost and low resistivity, but also lack stability. All application processes have difficulties with coating uniformity, blow-back in tight areas and recesses depending on part complexity, and exhibit application problems which can lead to flaking.

The use of metal cases for EMI shielding of personal computers or other electronic devices may not always be desired because of concerns about weight and aesthetics, weight being a particular concern for laptop computers or portable and/or handheld devices of any type. The use of a metal shroud to line a plastic case is an improvement over a purely metal case in terms of aesthetics and design, but results in an additional assembly step and little weight minimization. Metal also lacks the stability to be formed into complex shapes; it often takes up unnecessary room adjacent to the circuitry and assembled electrical components.

Coated plastic may not provide a suitable solution when one considers that personal computers currently can operate at clock speeds of 100 MHz, which gives rise to EMI not previously confronted. Furthermore, the ever-increasing clock

*See Advertisement on Page 274.

speeds of today's personal computers make effective shielding more and more challenging since any breach in the shield which has one dimension in excess of 0.23-inch may allow substantial EMI leakage, causing the unit to fail U.S. Federal Communication Commission regulations.

The use of metallic coatings on plastic housings presents certain manufacturing and service concerns. A slipped tool used during assembly or repair can cause a scratch in the metal coating of sufficient size to create a slot antenna, thereby making the case totally useless and leading to a costly item being discarded. In fact, any seams of metal-plated plastic housing will act like slot antennas unless the housing sections are conductively joined by the use of overlapping joints, conductive gaskets or conductive tape.

THERMOFORMS FOR EMI

Improvements in thermoforming techniques have made this process a viable alternative to injection molding for electronic equipment designs. Both heavy-gauge and light-gauge plastic are being used. Shielding methods for heavy-gauge thermoforms are the same as injection-molded components. Also, new methods are being developed to create EMI-shielded thermoforms which involve laminating woven and non-woven layers of mesh or metal fibers into components as they are being formed.

Even more recent developments are being applied to light- or thin-gauge materials. Light-gauge material can be used within the enclosure to replace metal cans and boxes which cover integrated circuits and power supplies, to encapsulate the entire board assembly in a "clamshell," and to act as a liner or skin inside the enclosure itself. The laminated mesh and fibers work quite well with light-gauge material as compared to heavy-gauge. However, some of the more traditional methods of EMI shielding do not work very well on thin-gauge material. Rigid coatings on thin flexible film can crack and eventually flake when stressed. Several research efforts centering on paints, electroless plating techniques, and vacuum deposition processes are currently underway to resolve these problems.

VACUUM-METALLIZED THERMOFORMS

Several vacuum deposition techniques have been developed in recent years to apply relatively thick thin films (from 1 micron to over 10 microns) to the inside of plastic injection-molded housings to achieve electromagnetic compatibility, and these techniques can be applied to thermoforms. Market estimates from a 1993 survey conducted by Business Communications Company provide the data given in Table 1.[1] The fastest growing technique is projected to be vacuum metallizing, growing annually at a rate of more than 20%. The increase is expected to be primarily in the area of injection-molded components, including portable electronics, cellular phones, notebook computers, and so on. Vacuum-metallized thermoforms offer the following features:

- Parts are lighter and nest for more compact handling and shipping.
- Rejected material which has been scratched, marred, or damaged during handling can be replaced at less expense.
- Use of thermoforms at the board level to replace metal-stamped cans (dog houses) and boxes can result in further miniaturization of the outside case or enclosure because the form can conform more closely to the component, leaving additional room to squeeze components closer together.
- Parts can be partially slit and remain in the web sheet for metallizing. Parts can also be ganged for processing. This not only results in labor savings but also eliminates contamination by handling. The gangs of parts may be shipped and then snapped out when ready for assembly.
- Standardizing films by thermal property categories increases efficiency and reduces costs. Quantity buying, inventory management stocking procedures and agency approval are simplified.
- Double-sided metallizing not only offers from 10 to 20 dB more shielding effectiveness but gives additional insurance against scratches in the coating caused by servicing or repair. Sealed units can also be used in very corrosive environments.
- Small and economical ultrasonic clamshell welders allow the sealing task to be

	1993		1998	
	Square Footage	$$ in Millions	Square Footage	$$ in Millions
Electroless Plating	30	60	36	80
Vacuum Metallizing	14	25	40	60
Conductive Paints	22	30	22	30
Laminates and Tape	4	10	5	13
Other (Zinc Arc)	1.4	6	1.8	7.5
Totals	71	131	105	191

Table 1. *Surface Shielding Methods in U.S.*

done within the product assembly process. Other sealing methods such as conductive adhesives, laser welding, conductive tape and snap-fit seams are easy to do and eliminate costly conductive gaskets.

There are often coating problems associated with injection-molded parts. Molders often need mold release to process parts. Even if steps are taken to avoid mold releases, slide and ejector pin lubricants can contaminate parts. This necessitates cleaning to insure adhesion of any EMI coating. Thermoforms can be formed without the assistance of these compounds. Eliminating surface contaminants makes the cleaning step of the coating process unnecessary.

Portable electronic cases are subject to tough impact or drop-test requirements because they are normally hand-held. As a result, a majority of portable products are being molded from polycarbonate (PC) and PC blends, which are difficult to coat and achieve adequate adherence. Polycarbonates always require a surface modification technique such as chemical etching, plasma treating, or mechanical roughing prior to coating. Metallized inserts eliminate adhesion problems of the coating on the injection-molded case.

SHIELDING EFFECTIVENESS

Table 2 compares the shielding effectiveness of several coatings. Nonwoven laminated fibers perform exceptionally well at the lower frequencies. This is because they are relatively thick and absorb the lower magnetically dominant waves. Thickness has minimal effect on the amount of energy reflected. The shielding effectiveness drops at

F(MHz)	#1	#2	#3	#4	#5
30	75	53	46	55	67
60	70	47	41	54	65
100	67	48	42	58	57
200	60	59	50	69	60
450	53	60	56	68	60
600	50	58	53	80	70
800	50	60	59	79	80
1000	48	66	58	73	70

Sample Descriptions

#1 Laminated non-woven alloy fibers, 0.020" thick.[2]

#2 Silver acrylic paint, 2 to 3 mils.[3]

#3 Aluminum, single-sided, over 1 micron.[3,4]

#4 Aluminum, double-sided, over 1 micron/side.[3] Total of over two.

#5 Aluminum, single-sided, over 3 microns.[2]

***Table 2.** Test Data Summary Shielding Effectiveness, dB Electronic Field Test (Abbreviated).*

higher frequencies because nonwoven laminated coatings are not as reflective as other coatings.

Silver paints perform adequately over the full spectrum

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and results are better than with a 1-micron thick aluminum coat. One-micron aluminum on both sides is 10 to 20 dB better than a single-sided application. Both double-sided and 3-micron thick aluminum compare favorably to silver paint. The 3-micron coat is better at lower frequencies, but the 2-sided appears more reflective and more effective at frequencies above 100 MHz.

VACUUM DEPOSITION CYCLE

Thermoforms being processed in vacuum equipment normally go through a pretreatment or surface modification step prior to the deposition cycle to improve adhesion. This is known in the industry as glow discharge or plasma etching. During this cycle the polymer substrate is bombarded by electrons and negative ions of inert or reactive gases.

Inert gases such as argon and nitrogen, along with reactive gases such as oxygen, nitrous oxide, and various fluoride and chlorine compounds and gas mixtures can be used. The gas plasma is subsequently ignited with voltages from 2 to 5 kV and currents from 50 to 500 mA. Different chamber pressures (50 to 300 mTorr) and cycle durations (30 seconds to 10 minutes) all have an impact on surface treatment.

During the metal deposition cycle, heat is generated and the distance from the deposition source to the thin-walled thermoforms becomes a critical factor. In a vacuum there is no conduction or convection of heat but the radiant energy from the evaporative source can warp, stress-relieve and even melt the polymer forms, especially in corners or deep draws where the film is drawn to its thinnest dimension. Thermal properties and wall thickness of the thermoformed film, heat output of the evaporative source, distance from source to substrate, duration of vaporization, and rotation speed of the substrate are all variables which need consideration.

RECYCLABILITY

Recyclability after an electronic device becomes obsolete is a growing concern. Painted and plated housings require chemical or mechanical stripping. These are difficult and expensive processes, and the stripped residue waste becomes an environmental problem.

With thermoform technology, less expensive and simpler processes can be used. Two options for recycling metallized inserts are available. Vacuum-deposited aluminum is easily removed with solutions of potassium and sodium hydroxide. These spent solutions containing aluminum can be diluted or neutralized with acid. Solutions with a pH under 12 which contain no heavy metals can be released to a sanitary sewer system without any treatment. Other deposited metals would require pretreatment depending on their concentrations.

A better alternative is to simply shred and regrind the metallized thermoforms. This material can then be re-extruded into roll or sheet form (as would also be done with the trimmed metallized scrap). The re-extruded material has already been filled with metal. This material is used to form new inserts which would be deposited with metal on their exterior surfaces again. In effect, the material becomes more conductive the more it is recycled; this is the recommended manner of disposing of inserts metallized with metals and alloys other than aluminum.

A recent IBM study concluded that for recycling injected molded/metallized plastics, "the metallization does affect the appearance, ultimate elongation and impact resistance of the recycled materials. Coated materials could only be recycled two to three times (a four-fold maximum with vacuum-deposited aluminum) whereas uncoated virgin material could be reground and recycled up to nine times."[5]

CONCLUSION

Thermoformed vacuum metallized inserts can resolve a variety of complex EMI problems associated with portable electronics. The recycling aspect alone is likely to make this the most effective, efficient and least costly method of shielding.

REFERENCES

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