Electroless Plating for EMI Control

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Electroless plating processes offer significant advantages in their ability to meet the requirements of effective EMI coatings.

BACKGROUND

In the selection of an EMI coating method, there are several very important considerations. They include durability, inherent surface conductivity, capabilities, the uniformity and dimensional tolerance control which can be achieved, adhesion of the coating to the plastic part, the ability of the part to be recycled, and the impact of environmental exposure to the integrity and electrical properties of the coating. Additionally, it is essential that the selected coating process provides reliability over an extended period of time. Electroless plating processes offer significant advantages in their ability to meet all of these criteria, and provide greater flexibility to designers in their ability to incorporate more features in a molded part design (Table 1).

Electroless shielding is based on an autocatalytic chemical plating process that produces a pure, continuous and uniform coating of metal to achieve EMI shielding of plastic electronic enclosures. These coatings are duplex coatings consisting of a layer of electrolessly deposited pure copper with an overcoat of electrolessly deposited nickel-phosphorus alloy (4–10%P).

Each layer provides specific performance benefits and contributes in a synergistic manner to the overall effectiveness of the shield. The thin, highly-conductive layer of copper provides excellent conductivity for E-field and plane wave shielding effectiveness. The primary function of the special electroless nickel-phosphorus topcoat is to protect the copper sublayer from oxidation and corrosion. Additionally, the nickel topcoat provides abrasion and wear resistance due to its high as-plated hardness. Furthermore, the electroless nickel coating functions as an excellent paint base, when required, in post-finishing operations.

Electroless shielding processes can be applied over the entire part, to achieve complete metallization of an enclosure, or applied selectively, to metallize only specified areas. For the selective process, a special conductive organic coating is applied to those areas of the plastic part where plating is desired. The balance of the part is masked to ensure precise definition between those surfaces to be plated and those which are not. Selective plating then proceeds in the same manner as the conventional, double-sided process, but plating only takes place on those areas where the base coat has been applied (Figure 1).

The shielding effectiveness and inherent conductivity of the part, whether it is processed selectively or by conventional means, is primarily a function of the thickness of the copper. Surface resistivity, point-to-point, is also influenced by the smoothness of the surface for a given copper thickness. For most applications, the copper and nickel thicknesses necessary to meet normal EMI performance requirements are in the range shown (Figure 2).

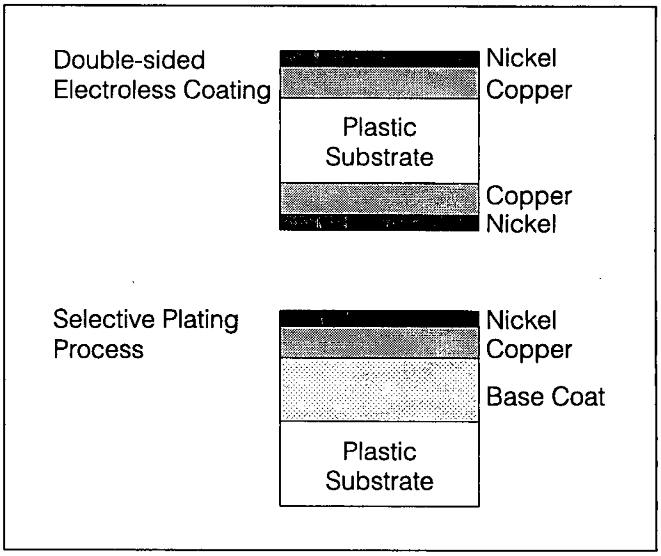

Figure 1. *Electroless Plating.*

	Copper	Nickel
Double-sided Process	40-80 µin 1-2 µm	10-25 µin 0.25-0.6 µm
Selective Plating	80-100 µin 2-2.5 µm	10-25 µin 0.25-0.6 µm

Figure 2. *Required Thicknesses to Meet EMI Applications.*

Increased shielding performance, in both E-field and plane wave, can be achieved by incorporating additional copper thicknesses. Electroless copper can be applied commercially and economically up to ~200 µin (5 µm). Beyond this range, electroplated copper can be used to supplement the process and achieve added film build if required. At the same time, electroless plating is not capable of providing significant levels of H-field shielding. Even with increased thicknesses of nickel, it has limited absorption and permeability capabilities.

In the case of electroless nickel, 10–25 µin (0.25–0.6 µm) is normally sufficient to provide protection to the underlying copper film and also provide adequate durability. Increased thicknesses of electroless nickel can be achieved readily through longer immersion times. In some cases, greater thicknesses of nickel are desired to accommodate certain attachment procedures, like soldering, or to further improve corrosion and wear resistance.

ELECTROLESS PLATING FOR EMI SHIELDING

ELECTRICAL CONTINUITY

Plastic electronic enclosures involve a series of subassemblies that comprise the final part. These subassemblies may consist of a base, a top and perhaps a bezel. Features included in the molded design include vents, apertures, snap fits, grounds, stand-offs, ribs, bosses, card guides, etc. EMI shielding effectiveness is principally determined by the leakage that can occur at seams and other apertures after assembly in conjunction with the actual electrical properties of the shield itself.

Electroless plating produces a uniform, highly conductive copper film over all subassembly component parts. This allows the assembled part to act and operate electrically as one unit (like a Faraday Cage). In effect, electroless plating provides to the designer the feature of a common ground. Electroless plating is also an important aid in facilitating full-function design utilizing the benefits of injection molded plastics to reduce costly secondary operations.

SHIELDING EFFECTIVENESS

In today's electronic products, the drive to increase fundamental frequencies, allowing digital electronics to operate at faster and faster clock speeds, significantly increases the demand for more effective shielding methods. In addition, the increasing miniaturization of electronics and growth in the use of handheld devices has increased the potential problems from crosstalk due to proximity problems within the enclosure. Furthermore, with the increases in operational frequency, the effect of harmonics has become an increasing concern to product designers (Figure 3).

In general, when E-field or plane wave radiation is involved, each of these issues requires that the shielding method selected imparts excellent conductivity as well as minimizes disruptions in current flows across the surface of the part. This objective is most effectively accomplished with a very uniform, highly conductive pure metal film, such as copper.

Coatings that typically vary in conductivity due to differences in the film thickness of the conductor or variability in the amount of conductive fillers at or near the surface of the part (e.g., conductive paint) can create localized resistance. These disruptions in conductivity can set up ground loops that

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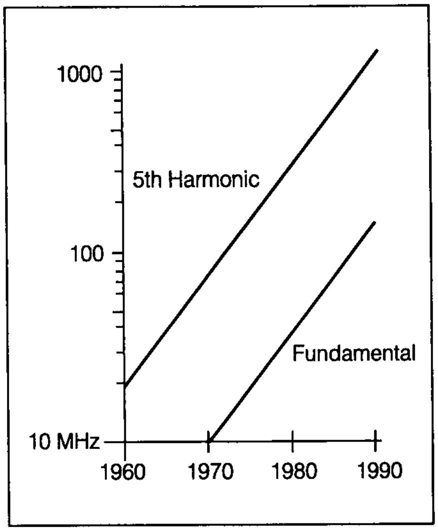

Figure 3. *Trends in Fundamental Frequencies and Harmonic Effects.*

Electroless Copper	Electroless Nickel	Multilayer Electroless Coatings
High conductivity (0.05Ω/sq.)	Low impedance contact	Superior shielding effectiveness
>99.9% pure copper	Excellent environmental corrosion resistance	Excellent environmental resistance
Thin, highly uniform film (40–100µin)	Abrasion, wear resistance	Superior point-to-point resistivity
Low stress deposit	Paint film adhesion	Dimensional control, even with close tolerances
		Flexibility to accommodate complex geometries
		Durability

Table 1. *Benefits of Electroless Technology.*

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radiate. This circumstance becomes more likely when additional features are incorporated into the molded design.

Electroless plating, with its use of a uniform, highly conductive film of copper, minimizes the potential impact of these issues for the product designer. Importantly, as frequencies increase, current flows within a pure copper layer are contained within the first three or four skin depths of conductive film. This would not be the case for a less conductive film.

IMMUNITY

In many areas, immunity has traditionally been an unregulated responsibility of the manufacturer. Voluntary standards and individual OEM standards have been the primary means for ensuring reliability. In applications where safety and health issues are involved (such as medical, automotive, aerospace and military), immunity is actively addressed. For other digital electronic devices, such as computers, cellular phones, etc., the EC EMC Directive, which became effective in 1996, formalized regulations and established the need to address future product designs with both immunity and radiated emissions in mind. Globally, this affects all major manufacturers of regulated electronic equipment.

In this regard, assurance of electrical continuity throughout the entire enclosure becomes essential when selecting a shielding method. Furthermore, along vent areas and other types of apertures, electrical continuity through the internal depth of the waveguide is also important to ensure effective EMI protection. Electroless plating offers excellent uniformity to meet this need. In addition, in some cases, the use of double-sided plating may be elected since this application method provides a conductive coating on both sides of the plastic surface and results in "an insurance policy" with regard to shielding effectiveness (Figure 4).

DESIGN CONSIDERATIONS

Enclosure design, which incorporates tightly mated parts, is an important consideration in assuring consistent EMC performance in production (Figure 5). The integrity of the fastening techniques is an increasingly important issue as a result of the focus on product disassembly for recycling and the importance of electrical continuity between mated parts over time. Snap-fit construction is the principal technique used to meet these needs. It provides flexibility for full-function product design where multiple exit and entry is anticipated. Snap fits also maintain a minimum contact pressure, part-to-part, to insure electrical continuity (Figure 6).

One of the most important aspects of part design is the method used to achieve conductivity at overlapping walls and various mated surfaces. EMI leakage between mating surfaces at joints and seams is a primary concern. If a continuous conductive path does not exist between the mating surfaces, slot antennas can develop. Where electrical conductivity is constricted between two mated surfaces, the resulting resistance can produce radiated emissions due to the interruption of current flows in that area (Figure 7). Electroless plating offers extremely tight tolerance control on metal film thickness. This adds flexibility in specifying tighter dimensional control without concern for slot antennas or coverage in recessed areas.

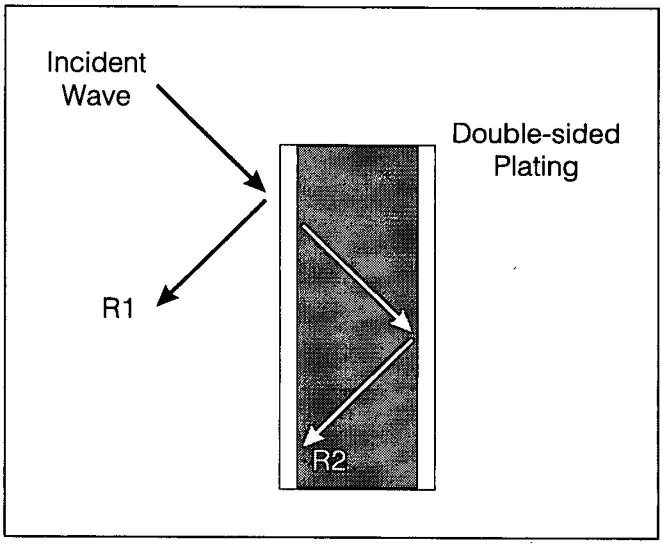

Figure 4. *Double-sided Plating Offers Two Opportunities for Reflection of the Radiated Wave.*

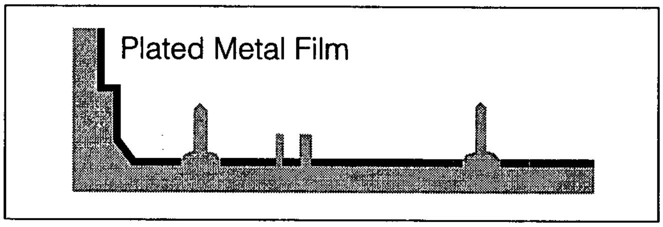

Figure 5. *Characterization of the Uniformity for Plated and Painted Coatings.*

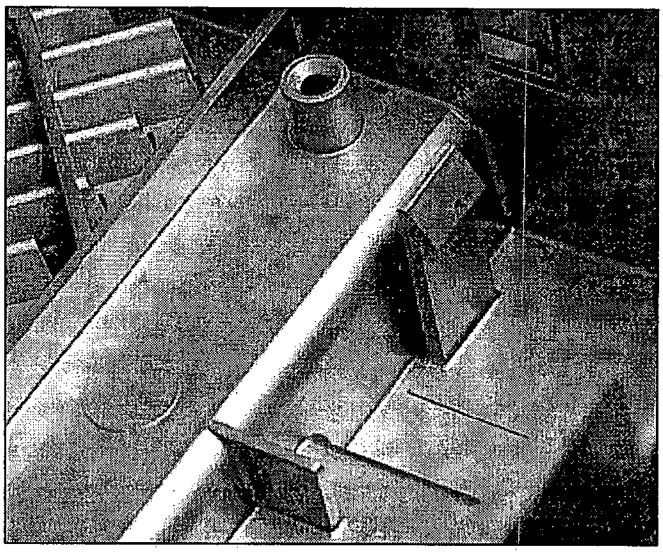

Figure 6. *Snap Fit Construction.*

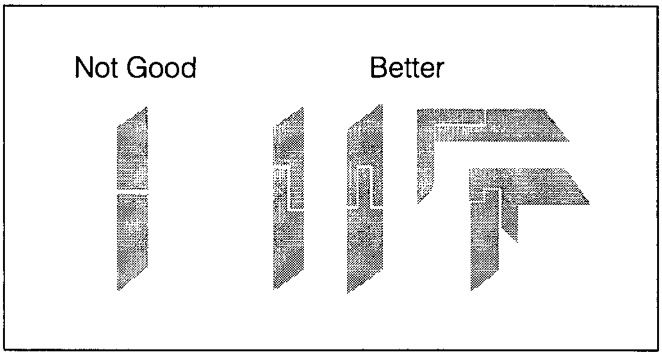

Figure 7. *Resistance Due to Interrupted Current Flows at Mating Surfaces.*

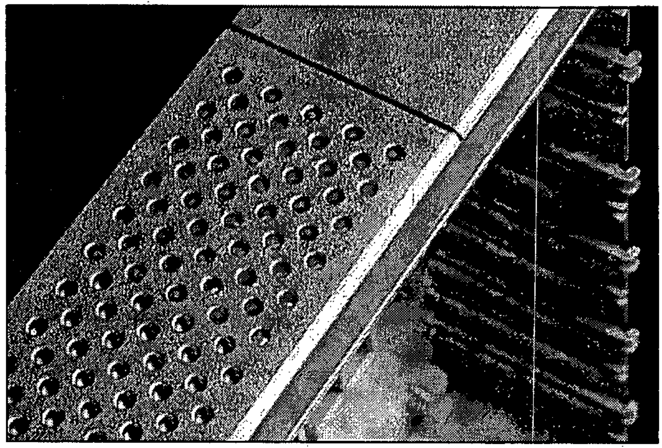

Figure 8. *Cooling Vents.*

Improperly designed mating surfaces (or poor molding conditions) can result in bowing or waviness. Such dimensional discontinuities along contact surfaces will result in EMI leakage when the length of the slit approaches one-half of the shortest wavelength (highest frequency) of the fundamental operating frequency of the system or that of the highest harmonic. Part designers should consider this effect up to the seventh harmonic.

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In a full function plastic part, ribs, bosses and standoffs serve to reinforce the part. Bosses also function as mounting sites for subassemblies. Thus, their location becomes part of the EMI design strategy.

The complexity associated with design elements such as four-sided standoffs, notched ribs and hollowed bosses present a challenge to the selection of alternative EMI coating materials. In general, the incorporation of line-of-site limitations into part design favors the use of electroless plating technology. Furthermore, the ability to maintain very low resistivity across the surface of the part including the complexity introduced with these added design features is maximized when electroless plating is used.

Vents facilitate cooling of the internal electronics. Apertures provide access for cabling and other electronic connections. Although these openings serve necessary functions, they also represent a potential source of EMI leakage (Figure 8).

The two key considerations in the design of vents and apertures are size and depth in relationship to the frequency of device operation. This relationship defines the basis for an EMI shielding technique known as the waveguide effect. A waveguide is defined not only by the dimensions of the opening but also by the depth of the opening and the relationship between these two parameters and the frequency of operation.

A waveguide has a cutoff frequency f_c below which it becomes an attenuator.

$$f_c \text{ (Hz)} = [3 \times 10 \text{ (M/S)}] \div \text{wavelength}_c \text{ (M)}$$

where
$\text{wavelength}_c = 2 \times$ maximum dimension (of a slot), or
$c = 1.7 \times$ diameter (of a hole)

When the wavelength of the signal is below the cutoff frequency of the waveguide (i.e., the wavelength of the signal is longer than the cutoff wavelength of the waveguide), the theoretical attenuation of the waveguide is:

$$\text{SE (dB)} = 27.3 \text{ d/w (slot)} = 32.0 \text{ d/D (hole)}$$

where
d = depth of the opening
w = width of the opening
D = diameter of the hole

For example, a 0.25-inch diameter hole has a cutoff frequency of 2.8 GHz and a corresponding cutoff wavelength of 1.1 cm (0.43 inch). A 1-inch slot has an f_c of 600 MHz and a wavelength c of 5 cm (2 inches).

Key factors in design for leakage control are the largest dimension of the aperture (d) and the wavelength of the radiating field.

Guidelines to be remembered are that in cases where:
$\lambda <$ 2d, radiation will pass freely
$\lambda =$ 2d, "0" EMI shielding (cut off frequency)
$\lambda >$ 2d, effective shielding

Multiple vent spacing should be at least 1/2 λ away ($\lambda/2 > d$).

GROUNDING

With the continued advancement of clock speeds associated with electronic enclosures, electric fields build and fade at a rapid rate. These transitions can set up current flows which result in electromagnetic interference. Furthermore, the trend toward smaller, more compact electronic products, as well as the increasing population of electronic devices, make field interactions a necessary concern. In addition, the increasing use of high density circuits incor-

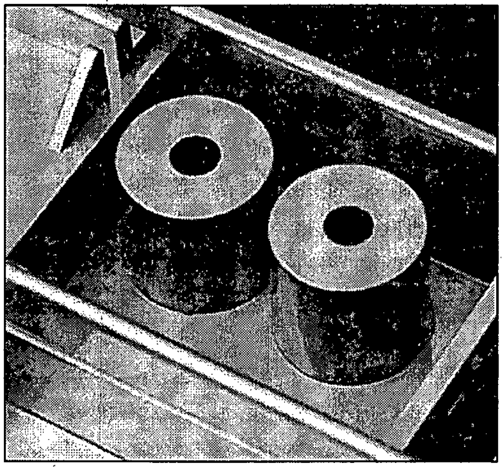

Figure 9. *Design Complexity Necessitates Easy Line-of-sight.*

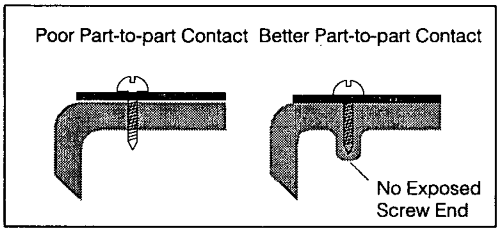

Figure 10. *Gasket Contact.*

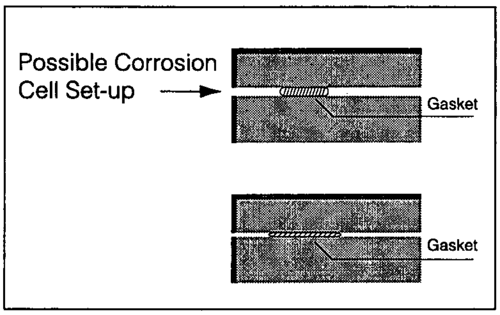

Figure 11. *Corrosion Prevention.*

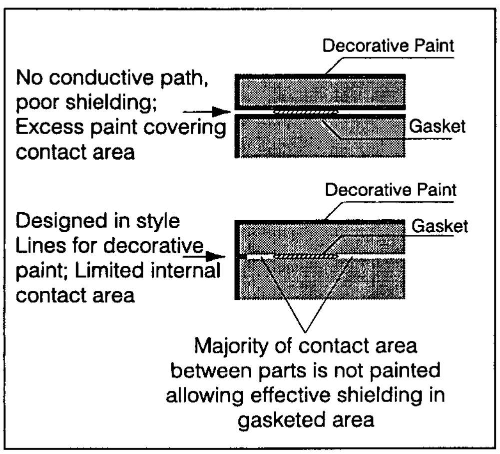

Figure 12. *Paint Application for Maximum Effectiveness.*

porating advanced packaging technology and mixed logic circuits has aggravated the problem of electrical interactions within the enclosure. Grounding is essential to avoid resultant problems with conducted EMI. In many cases properly placed fasteners can become part of a common ground between mated parts.

Coating requirements for grounding are similar to the coating requirements already discussed. In all cases, surface conductivity, including the ability to maintain conductivity after environmental exposure, is a key requirement. If the conductivity of the shielding coating decreases due to oxidation or corrosion effects, the resistance across mated surfaces will increase. This can result in a failure of the grounding systems at some point.

Grounds can be relatively simple or fairly complex in design depending upon the actual enclosure configuration. For relatively simple product designs, line-of-sight issues are not a real concern. In the case of enclosures with increased levels of design complexity, it is essential that the shielding method selected does not have significant line-of-sight problems (Figure 9).

Electroless plating processes provide superior conductivity and uniformity to insure effective grounding. The underlying copper layer dissipates eddy currents created during electrical field fluctuations in the form of heat energy. The use of electroless technology can reduce extensive ground plane strapping, clips, gaskets and bonding straps sometimes incorporated for EMI control.

GASKETS

Gasketing is an important consideration in EMI control, particularly when higher operating frequencies are involved. When gasketing is selected for use in a product design, the manufacturer's recommendations should be followed (Figures 10, 11, and 12).

For effective gasketing, the groove depth ranges from 50–90% of the uncompressed gasket height, depending on the recommended closure pressure for the selected gasket.

When gasketing is incorporated into the design, a decorative paint overlap is recommended to prevent any possible localized corrosive degradation. Excessive space left between two mating, decoratively painted surfaces can be a site of corrosion cell set-up.

CONCLUSION

Electroless shielding is based on an autocatalytic chemical plating process that produces a pure, continuous and uniform coating of metal to achieve EMI shielding of plastic electronic enclosures. Durability, surface conductivity, adhesion and flexibility of applications are a few of the characteristics that enable it to be used as an effective coating method.

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