ELECTROLESS COPPER/NICKEL SHIELDING: DESIGNING TO ITS FULLEST ADVANTAGE

While the shielding effectiveness of electroless copper/nickel duplex coatings has been well-documented in technical articles and field performance, it is only one of the features necessary to meet industrial, consumer and military requirements for field use. Other factors for EMI shielding coatings include adhesion, environmental stability, ground plane ability and adaptability to various assembly methods.

Barry R. Chuba, Chromium Corporation, Dallas, TX and Richard Brander, Enthone, Inc., West Haven, CT

INTRODUCTION

Electroless shielding is based on an autocatalytic chemical plating process which produces a pure, continuous, uniform coating of metal to achieve EMI/RFI shielding of electronic enclosures. Normally, electroless copper is first deposited on a properly activated non-conductive substrate. Electroless nickel follows as a protective layer ensuring environmental stability and wear/abrasion resistance of the copper underlayer. Based on the activation method chosen, electroless copper/nickel plating can be applied to the entire component surface, the inside only, or selectively in critical areas.

Typically, 80 to 100 microinches of copper and 10 to 20 microinches of nickel are deposited on plastic enclosures to provide shielding attenuation of more than 80 dB. Near-field dual chamber testing results for shielding attenuation are given in Table 1.

The shielding performance of electroless multilayer coatings is well-documented in both laboratory testing (dual chamber and transmission line test methods) and field use. However, high shielding effectiveness is only one attribute of the electroless shielding process that can be engineered into the enclosure design. Additional advantages will be discussed.

METAL TO PLASTIC

For various reasons, including cost considerations forced by global competitors and higher quality standards, engineered plastics have become a dominant factor in today's aggressive world markets. Replacing metal castings and metal boxes with engineered plastics allows manufacturers to capitalize on those advantages. Plastics allow greater productivity, with more parts processed per tool, and greater design flexibility to produce more complex configurations. As the complexity of plastic enclosures increases, more attention must be given to part designs, molding process conditions and the shielding systems selected. As a general rule, more complex configurations require narrower process conditions for the molder, as well as the electroless copper/nickel applicator. In producing electroless shielded components, ranging from simple to the most complex, quality begins with a properly designed part and proper molding conditions.

Parts should be designed for racking at non-critical points during suspension in the electroless process. Although most plating fixtures provide for complete coverage using a floating part design in the racking fixture, some complex parts may nest, which prevents solutions from reaching the plastic and prevents

Plastic Substrate	Total Metal Thickness per Side Cu/Ni (microinches)	Shield Efficiency (dB) 30 MHz DR = 105dB	100 MHz DR = 102dB	300 MHz DR = 106dB	1000 MHz DR = 112dB
Polycarbonate	40/15	>105	>102	>106	88
Polycarbonate	65/15	>105	>102	>106	95
Foamed PPO	65/15	>105	>102	>106	92
ABS	65/15	>105	>102	>106	88
ABS	100/10*	>105	>102	>105	72
ABS	80/10*	>105	>102	>104	68

*One Side Application Only

Table 1. Shielding Effectiveness of Electroless Copper/Nickel Coatings, Dual Chamber Method (ASTM ES 7-83).

proper deposition of metal layers. These applications require a secure hold to keep parts separated in bulk processing.

Molded-in stress narrows the window for processing by the electroless shielder. At higher levels, stress of the copper/nickel plating may show signs of cracking, breakage and/or loss of impact/flexibility properties in the base plastic. Lowering potential stress problems must begin with the initial part conception and tool manufacturing. Proper design considerations should be adopted such as eliminating sharp corners with recommended radii, placement of localized heating/cooling zones to ensure recommended resin processing conditions and gate/injection pin placement.

In conjunction with recommended tooling and part design, injection molders must also work within the resin processing windows. The most frequently encountered problems associated with higher stress levels are the improper drying of resins prior to injection, especially polycarbonate and polycarbonate blends where moisture lowers impact resistance of plastic, and extremes in resin injection temperatures.

Homogeneity of molded plastic as well as molded-in stress affects the performance of the subsequent electroless coating. The skin depth should be as uniform as possible so that the controlled attack of the surface used to gain adhesion does not become too aggressive (or not aggressive enough). If the bulk plastic is opened up in the pretreatment process, adhesion is often very poor. Furthermore, thermal cycle adhesion is typically unacceptable. Knit lines and gate areas must be controlled to avoid soft areas that will not adhere equally to other surfaces of the electroless coating.

Excessive molded-in stress from improper design or processing becomes apparent in electroless copper/nickel plating. Dependent on resin and stress levels, some stress can be overcome by the electroless shielder. Methods used include part annealing and chemical process optimization to specific molding conditions. Open communications and working relationships between the injection molder and the electroless shielder usually provide for higher quality electroless shielded components, as well as an expedient solution to the occasional problem.

MOLDED ENCLOSURE DESIGN/IN-COLOR MOLDED ENCLOSURE

A number of issues guide the design of molded enclosures, and almost all of these affect the method selected for shielding. A starting point is the choice of an in-color molded plastic or the use of a painted exterior. In the former case, the shielding method is restricted to the inside surfaces. This has favored the use of nickel and copper paints, or a proprietary basecoat followed by selective plating of copper and then nickel for EMI protection. Vacuum metallizing is also a possibility assuming that the parts are small and not too complex. Bulk processing, using conventional electroless plating, has not been practical or economical for in-color molded plastics until recently. New developmental process schemes, however, may allow this method so it can be considered as an approach for the design engineer.

When the exterior of the enclosure is to be painted or fog coated for color control, the use of electroless plating on both sides of the part is normally recommended. The two-sided copper/nickel coating provides an excellent paint base and also superior EMI protection.

As with any metal surface, an electroless nickel top coat will fingerprint. These fingerprints are easily removed with a solvent wipe. Fingerprinting can be minimized by texturing the plastic surface.

ENCLOSURE MATING SURFACES AND IMPEDANCE

Conductivity from point-to-point is also an important aspect of shielding plastic enclosures, especially those with more complex geometries. With high frequency circuitry being used in today's electronics, the problems associated with impedance, development, and the potential for development of conducted EMI are a real concern. Radiation resulting from such impedance can be as big a concern to the EMC engineer as dealing with the basic EMI problem. Some conductive filled plastics have been flawed in their ability to provide consistent conductivity unless fill ratios are extremely high. Such high fill ratios, however, can jeopardize many of the beneficial properties of the plastic. In addition, conductive fillers have difficulty retaining adequate and consistent conductivity at corners and curves. This can result in impedance or even a radiating antenna. Nickel or copper paint can have some thickness variation, particularly at corners, edges, and areas where line-of-sight application of the paint is not possible. This can produce areas of impedance that result in the potential for conducted EMI. Vacuum metallizing also exhibits some limitations as part sizes increase and as the geometry of the components become more complex. Electroless multilayer copper and nickel plating has an advantage in this case.

ASSEMBLY METHODS

Snap fits are a popular option elected by many design engineers. In general, they allow multiple site production of various parts of the equipment and easy, low-cost and centralized assembly. Snap fits may also be used in many situations when exit and entry to the internal electronics occurs with some frequency. The same is true of hinged areas where periodic opening and closing of a panel are anticipated over the life of the equipment. The importance of retaining a conductive path at the contact surface to avoid attenuation loss and slot antenna effects is clear. Thus, the shielding media selected by the design engineer has to be durable enough to handle this type of usage. Nickel and copper paints can have problems in durability when multiple insertions of openings are involved. This is particularly true when the thickness of the paint is excessive on corner areas, making the coating more prone to chipping or abrasion. Vacuum metallizing also has some limitations in durability and is prone to abrasions or wear in service. Electroless plating using electroless copper followed by electroless nickel has several advantages in this regard. First, the coating thickness is thin (typically <100 μin, total) and very uniform. Second, the electroless nickel outer coating is very hard and abrasion resistant. Recently the introduction of low phosphorus electroless nickel technology added significantly to the abrasion resistance of this outer layer.

GROUNDING

Adequate grounding has become an increasing concern of electronic equipment designers. This is directly related to the increased clock speeds associated with modern digital electronics. With the increased clock speeds, electrical fields build and fade, setting up current flows and the potential for electromagnetic interference. In the past, enclosures were larger and the distance from the enclosure to the internal electronics was greater, thus reducing potential EMI problems. With smaller enclosures and more populous electronics, field interactions are a necessary concern, and grounding is required to avoid conducted EMI. In addition, higher frequencies associated with many of today's advanced circuitry, particularly microwave circuits, create signal noise due to the building and fading of this field at a fast rate. This was not a problem with low frequency circuitry, and grounds were easier to incorporate into the design of electronic equipment than they are today. In addition, the shift toward higher density circuits using surface mount components and advanced packaging concepts places a signficantly increased level of functionality on a single board layer. Circuit lines are much closer together in this case and field interactions are a very significant issue for the design engineer. These were not concerns when large multilayer boards with single function passive components and leaded metal packages (i.e., dip) were used. Adequate grounding is an essential element in dealing with these EMI sources as well.

Electroless copper/nickel multilayer coatings have several features which aid the design engineer in solving grounding problems. First, the copper layer is both uniform in thickness and consistent in point-to-point conductivity, eliminating any impedance at the ground. Second, plated copper responds differently to fluctuations in conducted or radiated emissions. Eddy currents develop which destroy each other, and electronic energy is converted rapidly to heat energy and dissipated without direction. In essence, the plated copper provides a common RF ground and a measure of safety and assurance to the design engineer.

			Shield Efficiency (dB)			
Plastic Substrate	**Sample Condition**	**Total Metal Thickness per Side Cu/Ni (microinches)**	**30 MHz DR = 105dB**	**100 MHz DR = 102dB**	**300 MHz DR = 106dB**	**1000 MHz DR = 112dB**
Polycarbonate	As Plated	65/ 15	>105	>102	>106	95
Polycarbonate	31 Cycles*	65/ 15	>105	>102	>106	96
Foamed PPO	As Plated	65/ 15	>105	>102	>106	92
Foamed PPO	35 Cycles*	65/ 15	>105	>102	>106	84

*Temperature/humidity alternates from 75°F to 150°F and 45% to 93% relative humidity per 24 hour period (one cycle).

Table 2. Shielding Effectiveness of Electroless Copper/Nickel Coatings with Temperature/Humidity Exposure, Dual Chamber Method (ASTM ES 7-83).

Plastic Substrate	Total Metal Thickness per side Cu/Ni (microinches)	Temperature/Humidity* Exposure (days)	Resistance** (Ohms/sq.)
Polycarbonate	40/ 10	0	0.020
Polycarbonate	40/ 10	20	0.010
Polycarbonate	40/ 10	50	0.014
Polycarbonate/ABS	40/ 10	0	0.012
Polycarbonate/ABS	40/ 10	20	0.010
Polycarbonate/ABS	40/ 10	50	0.013

*Temperature/humidity alternates from 75°F to 150°F and 45% to 93% relative humidity per 24 hour period.
**Resistance readings are the average of several readings in various locations of the component tested.

Table 3. Conductivity of Electroless Copper/Nickel Coating after Temperature/Humidity Exposure.

ENVIRONMENTAL STABILITY

Clearly, from the standpoint of the design engineer, the integrity of the coating must be maintained (including its adhesion to the plastic substrate) over the expectant service life and stated warranty period of the equipment. The electroless shielding process incorporates a nickel-phosphorous top layer to protect the inherently oxidation-prone copper layer. Nickel has excellent stability in humid and brine environments. Table 2 and Table 3 demonstrate the ability of the electroless copper/nickel duplex coating to maintain shielding and conductivity properties in temperature/humidity exposures.

In today's climate of statistical process control, an essential component of process improvement is prevention rather than detection of rejects after they are made. That is, under "normal" quality control methods where testing is performed after the fact, the principles of SPC are violated. Obviously in this case, the exposure to the temperature/humidity test falls far short of providing the kind of timely on-line information necessary to ensure that the process is in control and capable of producing good parts.

More recently, a new accelerated autoclave test method was introduced for evaluating the adhesion and EMI performance of coatings after exposure to temperature and humidity. Although developmental in nature, the method is low in cost, simple to set up and produces rapid results on-line during the manufacturing process. General conclusions about its suitability have yet to be reached since the bulk of the work has been on electroless plated polycarbonate. Correlation to the temperature/humidity exposure test method, however, has been good. It has also proven to be effective in identifying optimum cycles for plating. In addition, EMI shielding tests can be performed before and after, providing an assessment of long-term EMI protection. Electroless plating excels in its ability to retain EMI shielding after exposure to the elements. This, of course, is attributed to the electroless nickel outer layer.

SUMMARY

Challenges to the design engineer will continue to grow as competition and high-speed electronics regulations increase. Not only is the design engineer confronted with meeting today's EMC requirements but is also responsible for providing higher quality at lower costs to meet ever-growing electronic marketplace competition.

Electroless copper/nickel shielding has many advantages that can improve manufacturing assembly methods and lower product cost. However, the performance characteristics and shielding effectiveness of electroless coatings should be considered in the earliest stages of product design in order to use them to their fullest advantage. ■