Secondary Electromagnetic Shielding Technologies

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INTRODUCTION

Today's faster clock speeds, smaller electronics packages, and stricter regulations necessitate higher levels of shielding and coating performance. As a result, secondary coating technologies are being pushed to their maximum potentials. To maintain high performance levels, quality control is essential, particularly for products designed to meet the requirements of the FCC, the International Standards Organization (ISO), and other regulatory agencies.

This article presents quality control guidelines for two EMI shielding techniques: conductive paint and electroless copper/nickel plating.

Quality can be defined as the acceptable and reproducible performance of a product in its intended use. The quality of a product is an arbitrary standard set by the customer, and comprises many factors, including appearance, functionality, regulatory compliance, durability, and product life.

Manufacturers of secondary coating technologies rely on the industry's latest equipment and trends to monitor and deliver a product that is consistent from batch to batch, order to order. Reproducibility of performance is of utmost importance to the OEM. The biggest burden in obtaining consistency of quality falls on the EMI coating applicator. Here the number of variables that affect the final product quality increases significantly with the use of a secondary coating. Questions for consideration are:

1. Will it peel or flake off into the electrical circuitry?
2. Will the shielding attenuation be consistent from part to part?
3. Will the coating maintain its attenuation over the life of the product?

Conductive coatings can be evaluated in terms of thickness, adhesion, electrical integrity and appearance.

Several variables should be monitored and controlled in an effort to meet the customer's quality requirements. These include coating thickness, adhesion, electrical integrity, and appearance.

THICKNESS MEASUREMENT

Coating performance is dependent upon obtaining a minimum thickness level for the given technology. In most cases, thickness requirements for conductive metal-filled coatings and electroless nickel over electroless copper plating are minimums of 0.0015" and 0.0001", respectively. The 0.00010" for electroless coating is further defined as minimums of 0.00004" copper followed by 0.00001" nickel per side for double-sided plating technology or minimums of 0.00008" copper and 0.00001" nickel.

Electroless plating thickness can be measured with x-ray fluorescence, beta backscatter, kocur, eddy current tests and/or microscopical examination. Industry accepted methods for routine nondestructive testing have predominately focussed on beta backscatter. Beta backscatter is limited however, in that it gives readings of metal thickness in total metal, copper and nickel. Specific measurements must be taken of the individual metal layers after copper plating a production part or sample plaque. Nickel thickness is calculated as the difference between the final tested part and the copper only measurement.

Applicable documents for thickness measurements of electroless plating include:

ASTM B 554-87 — Measurement of Coating Thickness by Beta Backscatter Method
ASTM B 567-84 — Measurement of Coating Thickness by Beta Backscatter Method
ASTM B 568-55 — Coating Thickness by X-Ray Spectrometry
ASTM B 487-85 — Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of a Cross-Hatch

For conductive metal-filled paints, the thickness of the coating application is usually monitored by a wet film gauge. Dry film thickness using nondestructive technologies are difficult because of the nonmetallic base. For quality control checks, a "tooke" gauge is used to cut through the coating into the base plastic. Measurement is calculated in relation to the radial section cut through the paint.

Related standards include:
ASTM D 1005-84 —Test Methods for Measurements of Dry Film Thickness of Organic Coating Using Micrometers
ASTM D 1212-85 — Methods for Measurement of Wet Film Thickness of Organic Coatings
ASTM D 4138-82 — Method of Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means
ASTM D 4414-84 — Practice for Measurement of Wet Film Thickness by Notch Gauges

ADHESION

Adhesion of both conductive coatings and electroless plating rely on the mechanical bonding of the coating with the subsequent base thermoplastics. In the case of conductive coatings - either water-based or solvent-based formulations - and the recent selective electroless plating technology, adhesion is related to the chemical attachment of the solvents within the formulation which "bite into" the surface of the thermoplastic. Mixtures and concentrations of solvents are dependent upon the type of thermoplastic (i.e., polycarbonate, ABS, polycarbonate/ABS blends, etc.) and, in some cases, upon resin additives (i.e., flame retardants, release agents, etc.)

With double-sided electroless plating, the mechanical bonding is achieved through the chemical attachment of the thermoplastic to produce a microscopically roughened surface. The type of resin and molding process (solid wall or structural foam) will dictate the chemical etching process and associated process parameters, including temperature, immersion time, concentration, and process chemistry. Through extensive research and development in both laboratory and monitored field production process cycles, windows have been developed by specialty chemical suppliers of electroless technology.

Much of this process development is within tightly monitored molding conditions. A greater degree of uncertainty with regard to adhesion is noted as molding conditions vary from the optimum parameter range. For example, structural foamed plastics consist of outer skins and a cellular interstructure. As molding conditions such as mold temperature, melt temperature, and peak injection pressure vary, the outer skin thickness can be affected. Should a thinner skin be present, the pre-etching and etching solutions of the chemical plating process could expose the inner cellular core, thus entrapping process solutions. Once entered into the cellular core, solutions can "bleed-out," creating adhesion failures. Also, it should be noted that successful application of double-sided electroless plating technology depends upon the custom injection molder's ability and knowledge specific to molding for plating.

Adhesion of secondary EMI coatings should be measured in the as-applied condition and after exposure to some form of stress. Stress can be in the form of thermal cycling, in which the coated plastic is exposed to low and elevated temperatures, temperature/humidity cycling or even mechanical stresses such as impact or deflection. Adhesion is usually checked by a tape test (nondestructive) or a cross-hatch with tape (destructive).

Acceptance criteria is mutually agreed upon by the OEM/contracting company and the applicator/plater. Typically, the removal of any coating as an immediate result of application constitutes test failure. During and at completion of thermal cycling and/or temperature/humidity testing, small flakes at the edges and intersections of cross-hatch lattice should not exceed 15 percent total coating removal. This is in accordance with ASTM D 3359-90.

Other reference documents on procedures for testing adhesion are:
ASTM B 533-85 — Peel Strength of Electroplated Plastic Surfaces
ASTM D 3330-83 — Test Method for Peel Adhesion for Pressure-Sensitive Tape at 180° angle
ASTM D 3359-90 — Cross-Hatch Adhesion Test
UL746C — Polymeric Materials Used in Electric Equipment Evaluations
ASEP TP-201 — Dynamic Test of Plate Adhesion by Thermal Cycling
ASEP TP-202 — Environmental Thermal Cycling of Plated Plastics

ELECTRICAL CONDUCTIVITY

Shielding performance and electromagnetic compatibility afforded by the secondary EMI coating is directly related to the surface conductivity, the ability to carry and dissipate the electromagnetic energy. Surface conductivity is measured by two means: ohms per square and point-to-point resistance measurements. Ohms-per-square readings utilize either two-point or four-point probes to record the surface conductivity as related to an infinite plane. Thus, measurements taken near edges can provide higher readings. Ohms-per-square measurements are typically used to classify various coatings at maximum limitations. Table 1 shows industry accepted ohms per square measurements for selected secondary coatings.

A more meaningful quality control check entails the resistance measurements across the surface of the parts. Readings are taken from the farthest distances of the tested part and on surfaces of significant EMC importance: grounding areas, mating areas, bosses, snap fits, etc. In some cases, resistance measurements are made across mating components to quality check impedances that might occur at these interfaces. Exact maximum limitations at testing locations are typically specified by the EMC compliance department within the OEM.

ENVIRONMENTAL STRESSES

Neither adhesion as tested by the ASTM D-3359-90 crosshatch test, nor the electrical characteristics of the plated or coated product should change significantly with repeated exposure to temperature and/or humidity. Typical test temperatures of 24°C to 60°C with 55 percent to 95 percent relative humidity offer a good range for coated thermoplastic enclosures. The temperature/humidity cycle is given in Figure 1. Quality control checks require 20 cycles without significant failures of electrical integrity or adhesion.

In efforts to shorten the 20 day temperature/humidity cycling, an autoclave test method was introduced for coatings on high temperature thermoplastics such as polycarbonate. Plated and painted samples are put into an autoclave for 30-minute cycles at 11-13 psi steam. Following the 30-minute exposure, the sample is allowed to stabilize to room temperature. Adhesion test results are recorded. This test is repeated, to

COATING	OHMS PER SQUARE (MAXIMUM)
Nickel-filled Conductive Paint	1.0
Copper-filled Conductive Paint	0.5
Double-sided Electroless Plating	0.1
Single-sided Elecroless Plating	0.1

TABLE 1. *Industry Accepted Conductivity Levels.*

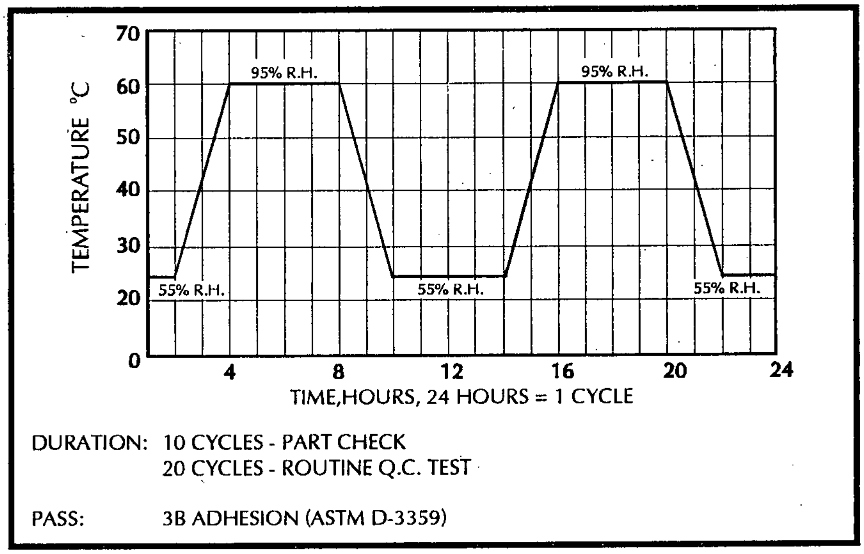

FIGURE 1. *Temperature Humidity Quality Control Test.*

a total of 5 cycles. At no time should any significant changes in electrical properties be observed.

Other testing and related documents include:
ASTM B 117 — Salt Spray Fog
ASTM B 368 — Copper Chloride Modified Acetic Acid Salt Spray Test (CASS)
ASTM B 380 — Corrodkote Test Method

Products meant for harsher environments should be exposed to these environments in initial test phases. For example, process control equipment located in pulp and paper productions are exposed to environments which contain strong alkalies, acids, sulfur and chlorides, and high temperature and humidity levels. More specialized testing procedures should be followed or adopted in conjunction with corrosion testing laboratories (most applicators and OEMs do not have capabilities for such sophisticated testing internally).

APPEARANCE

All coatings should be inspected visually to ensure quality. Coatings should be free of voids, skips, thin spots, blisters, or any imperfections that will impair coating performance. Plated or painted parts should be viewed under well lit conditions at distances of 12 to 18 inches for a minimum of 15 seconds. The actual time needed is dependent upon the complexity of the test and the areas coated by conductive paints and electroless plating.

CONCLUSION

Many different methods can be used to test and certify the quality of the service performed and product produced. The examples provide guidelines for testing conductive paints and electroless plating. The success of secondary coatings as a quality solution to EMI depends on the degree to which the customer's needs are communicated and understood.

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