CONDUCTIVE COATING BY VACUUM METALIZATION

Basic problems in shielding

The growth of the electronic equipment market in both industry and the domestic sphere is bringing unusual prominence to the problem of electromagnetic shielding. Not only are computers and other electronic devices and components being introduced at a rapid rate, but also miniaturization results in positioning these individual units in ever-closer proximity.

Increasing numbers of components and, hence, more potential sources of interference, are being incorporated in each individual device. The safety hazard presented by this adverse influence becomes ever more serious.

With this in mind, we can formulate two basic requirements:

1. No electronic device should emit electrical interference signals to its environment which exceed a given limiting value (active interference emissions).
2. Every electronic unit should operate reliably, despite the presence of difficult-to-suppress fault signals. In other words, the unit must be resistant to interference.

With the aim of keeping emissions within limits, the German authorities set maximum limits for radiated interference signals. These are found in German VDE, the analogous German Industrial Standards (DIN) and FTZ regulations. Particular importance has been attached to the security of communications signals. For this reason, as of July 1, 1982, VDE regulation 0871 was applied to audio and TV equipment.

The Federal Republic of Germany occupies a leading position in regard to shielding regulations. Work is currently progressing on unifying the various European regulations. The FCC regulations, which become compulsory in October 1983, correspond in most respects with the German VDE standard. More stringent shielding regulations will be introduced in the future.

As a consequence, shielding has become an important factor in equipment design and development throughout the world. Proper shielding constitutes a quality parameter in the manufacture of all items of electronic equipment.

Metal or plastic housings

Metal housings offer the best shielding results, but are the most expensive approach. Since manufacturers' hardware is regarded as too costly, the electronics industry has turned increasingly to the advantages offered by modern plastics technology. This technology permits the production of housings of the most complex configuration much more cheaply than if they were fabricated from metal. As a result, more scope is provided to designers and constructors. For example, fastenings can be injection-molded into housings, so that individual components can be attached efficiently at low cost. To an increasing extent, plastic housings are being produced with their final finish already applied, so that external painting, which has been a cost factor and sometimes the source of rejects, is eliminated.

One drawback of plastics is the fact that they are electrical non-conductors. As a result, electrical radiation is neither absorbed nor reflected, and no resistance is afforded to its penetrating the housing.

Various techniques have been developed to render the housings electrically conductive and to achieve the necessary shielding effect. These can be grouped into two categories:

1. Processes by which metals or conductive particles are applied to the surface of the plastic material after it has been molded. These include metal spraying, galvanizing, painting with conductive coatings of various kinds (graphite, copper, nickel or silver) and conventional vaporizing processes.
2. Processes which incorporate metal powder or other conductive materials in the plastic prior to molding.

All the processes which fall under heading 1 offer definite advantages in specific areas of application. However, none can be regarded as the last word, since all have considerable technical shortcomings or are too expensive.

The processes in category 2 are not being used on a significant scale or are still in a developmental stage.

Advantages of a Vacuum Metalizing Process

The primary objective in developing a vacuum metalizing process was to achieve the optimum shielding effect, while at the same time, keeping costs to a minimum. Effective shielding and the process and material costs must always bear a sensible relationship to each other. Both these requirements could best be met by a special vaporizing process.

The Vacuum Metalizing Principle

Batches of plastic components are placed in a high-vacuum chamber and arranged in such a way as to utilize available capacity to the fullest. They are mounted on fixtures which can also serve to mask areas that will not be coated. Although in the past it was possible via the high-vacuum principle to deposit very thin metal coatings which exhibit relatively poor adhesive properties, the new process can produce adhesive layers of up to 240 microinches (= 0.24 mil) in thickness. Futhermore, in contrast to conventional metal spraying and conductive paint coating methods, these coatings are free of porosity and inclusions. The resulting metal coatings are highly conductive, dense and ductile. They adhere tenaciously to the plastic surface.

The Use of Aluminum

Apart from silver and copper, aluminum is one of the elements having the highest conductivity. Silver often is not chosen due to its high price. In the case of copper, oxidation can take place, possibly resulting in considerable corrosion problems. After vaporization, aluminum in contact with the oxygen in the air forms a stable oxide layer on its surface which is less that 200 ANGSTROM thick. This layer, which does not interfere with proper electrical contact, affords a good protection against corrosion. No changes in electrical resistance have been recorded after a 120-hour alternating-cycle humidity test (5 cycles) in accordance with DIN 50017.

Structure of the Coating

A significant advantage of this vacuum metalizing process resides in the crystalline structure of the coating, which is created by the build-up of columnar crystals. (See Figure 1)

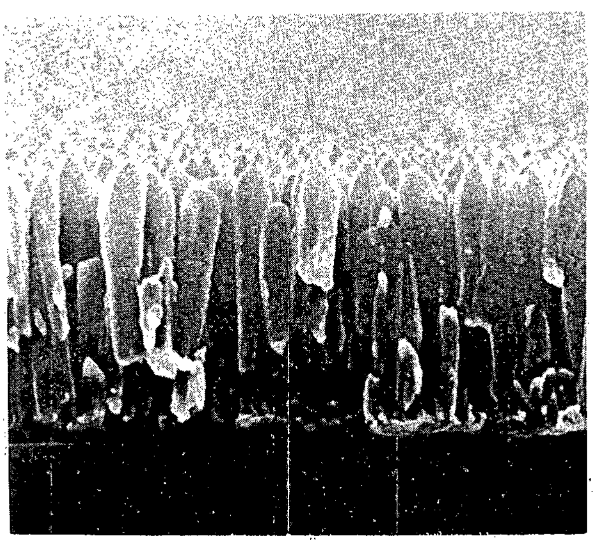

Figure 1. Columnar crystals in a 3.4 μm thick aluminum coating on a glass surface as seen through a scanning microscope.

The columnar crystals, having a diameter of less than 0.5 μm, form a flexible metal coating. Because of its structure, the aluminum coating is not stressed and, therefore, exerts no great influence on the mechanical properties of the substrate. Hence, the plastic material does not become brittle.

The scanning microscope image presented in Figure 2 reveals uniform configuration of the columnar crystal aluminum coating. For the purpose of comparison, Figure 3 shows the surface structure of a zinc spray coating. This technique necessitates building up the coating by bombarding the surface with liquid droplets of metal which rapidly cool in contact with the substrate. The droplets coalesce only partially, so that the resulting coating is flaky and pitted. Metal-sprayed coatings are normally subjected to a finishing process to reduce the tendency of loose metal particles to flake off.

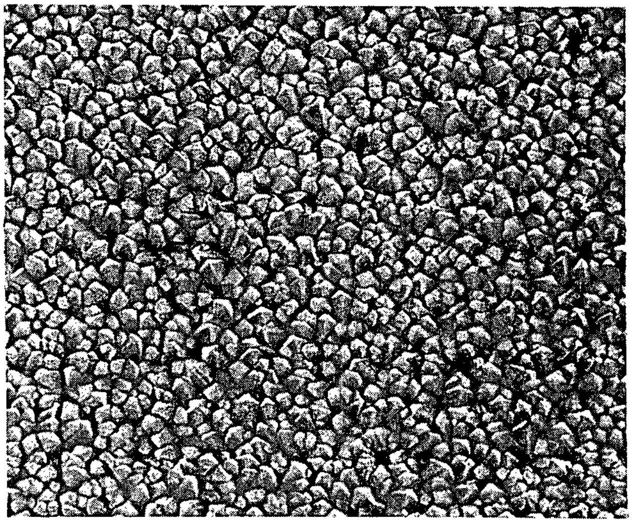

Figure 2. Top view of the coating. Scale 10,000 to 1

Figure 3. A sprayed-on metal coating. Scale 1000 to 1

Bonding

In most high-vacuum processes, adequate adhesion to the substrate is normally obtained only by first applying a primer lacquer. With this process, however, special surface treatment ensures good adhesion to the plastic material.

Figure 4 shows a portion of the coating on an ABS specimen at the point of fracture. The manner in which the metal layer interlocks with the substrate is mechanically stable. The line of fracture does not extend along the interface between plastic and metal, but instead passes through and destroys the substrate itself. The same behavior is exhibited by all of the plastics which are normally used in the manufacture of such housings.

Adhesion testing of these coatings according to DIN 53151 gives adhesion values of GT 0-1. Adhesion is unaffected by temperature changes or shock temperature loads in the critical range between -40 and +100° C.

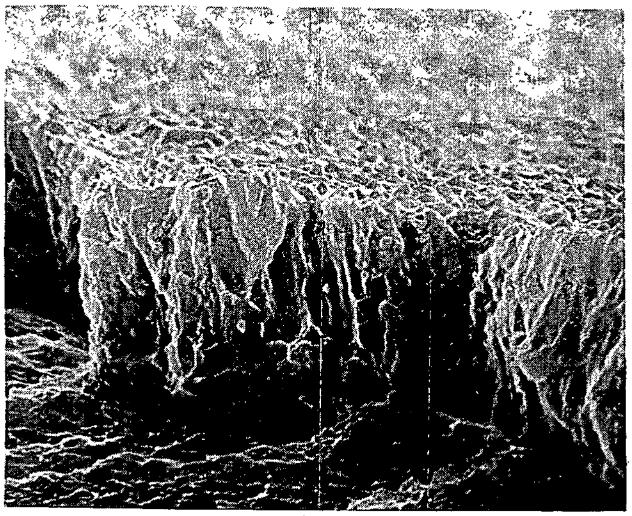

Figure 4. Scanning microscope image of a 4 μm thick aluminum coating on a plastic surface, after fracture test.

Plastics Which Can Be Coated

The plastics used in industry for the manufacture of housings, and similar items which require shielding, exhibit different properties which affect the adhesion of the coatings. The table which follows summarizes these plastics and their preferred applications.

Type of plastic	Method of processing	Areas of application
ABS Noryl Polycarbonate Polystyrene Polysulfon Thermoplastic polyester Polyamide	Injection molding	High volume articles with finished surfaces
Noryl Polystyrene ABS Polyurethane	Structured foam	High-strength items, medium and high volume
Fiber-reinforced polycarbonates and polyamides Thermoplastic polyester	Fiber-reinforced injection molding	Items subject to high mechanical loads, with thick walls, produced at high volume
Fiber-reinforced polyesters and epoxy resins	Fiber-reinforced laminate	High-strength articles, low volume
Phenol-formaldehyde Melamine resins Urea resins	Compression molding	Small housing and in large quantities
ABS PVC Polystyrene Polycarbonate	Thermoforming	Simpler housings, small to medium volume

Figure 5. Plastics Tested for Vacuum Metalizing Process

Coating Thickness

As mentioned above, this process is capable of producing coatings up to 240 microinches (= 0.24 mils) thick. Of course, this coating thickness does not adversely affect the fitting tolerances of sections of the housing or molded mountings. Accordingly, inserts or similar bushings can be coated and used as contacts. This special process produces layers of reproducible thickness, so that the desired high standard of quality can be consistently maintained.

Cost Effectiveness

When comparing the various surface-coating processes, both the cost and the quality of the coating must be considered. Material and processing costs are not the only factors involved in a shielding process. The reliability of the process, as expressed in the reject rate, and the cost of pretreating and finishing the coated articles, are equally important factors.

The cost of the aluminum used in this process is negligible. Calculations must be based on the number of components which can be accommodated in the chamber in a single processing batch. Since this process is automatically controlled, consistently high quality is always achieved. Scrap is equivalent to zero.

Masks are integrated in the component mountings and constitute a once-only cost item. Coating can be limited to precise contours of the components, so that no subsequent finishing work is needed. Housings having a final surface finish can be coated without difficulty. In contrast to many other industrial methods, the vaporizing process is environmentally acceptable. Metalizing takes place in a closed chamber so that, unlike the application of conductive lacquers or metal spraying, no special environmental protection measures are required.

The Shielding Effectiveness

German VDE regulations 0871 and 0875 govern the operation of electrical equipment in the frequency range from 10 KHz to 18,000 MHz. Equipment manufacturers have constantly tried to remain within the limits set by VDE standard 0871, Class B, so that their products can be operated without the need for individual testing and sold without the need for a special approval number.

It is important to note that emissions in various frequency ranges must be dealt with by shielding measures of different types. In the lower frequency range of up to approximately 1 MHz, magnetic interference predominates. This cannot be adequately suppressed by plastic housings, sometimes not even by housings made of metal.

In the high-frequency range, above about 800 KHz, the magnitude of the interference caused by the electrical field increases. Shielding by electronic means becomes more difficult since interference is not caused by individual components alone, but also by wiring connections and the circuit boards themselves. We are thus faced with what are known as "complex interference sources." These cannot be screened unless a "Faraday cage" is used to surround them. This can be achieved by rendering the plastic housing conductive.

The success of all shielding measures, designed to attenuate the radiation of interference signals, depends on two principal mechanisms: absorption and reflection. In the case of attenuation by reflection, only the conductivity of the material used is important. One of the main advantages of these vacuum metalizing coatings is that they exhibit a high level of conductivity.

With regard to the absorption of interference, the mass of the conductive material is the decisive factor. Nevertheless, above about 100 MHz, the "skin effect" causes an attenuation of the electrical field only on the surface of the shielding material. In this case, the conductivity of the skin again becomes decisive.

Measuring Attenuation on Coated Plastics

The effectivenes of a shielding precaution can be shown by a simple attenuation method. Coated plastic panels are placed in a window of a shielded area and the attenuation they cause is measured over the entire frequency range. The characteristic graph obtained represents the attenuation behavior of the material being investigated.

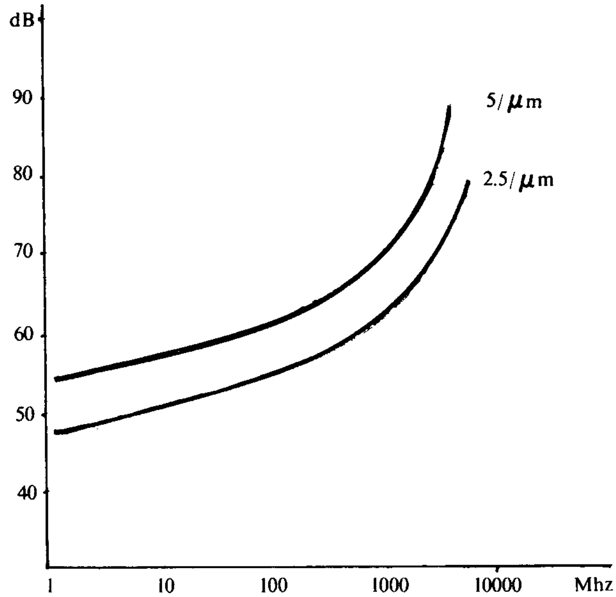

Figure 6. Interference Attenuation of Specimen Panels after Vacuum Metalizing Coating. (Note: 5μm = 200 microinches.)

It should be expressly noted that such measurements are largely of theoretical significance, e.g., demonstration of skin effect, and are not in themselves sufficient to determine the selection of a suitable screening process.

Practical Applications

The most frequently encountered shielding application is for the housings of data and word processing machines. Coatings are applied to CRT terminals, printers, memory stores, keyboard and connector housings. Digital telephones, and measuring and regulating equipment are shielded in a similar manner, as are intercoms and microphones. A new area of application includes apparatus for radiation therapy and ultrasonic equipment used in medical electrotherapy. This process is successfully being used in Europe; plants are in West Germany and Great Britain. Licenses are granted in the U.S.*

As the need for effective interference suppression and shielding continues to grow, this process will undoubtedly be extended to many other areas of electrical engineering and electronics in which techniques are still at an early stage of development.

** For further information contact Dr. W.A. Schaller, Degussa Corp. Rt. 46, Teterboro, NJ 07608, phone: 201-288-6500*

This article was prepared for ITEM by Dr. W.A. Schaller, Technical Manager, Degussa Corporation, Teterboro, NJ.