CONDUCTIVE PARTICLES AND THEIR USE IN THE EMI MARKET

INTRODUCTION

A number of articles have recently been written on the various electronic packaging methods available. Attention has been directed toward optimum shielding design through selection of the appropriate enclosures, materials, and components. The ideal method should create a continuously sealed, conductive envelope preventing outside fields from penetrating the equipment and internally generated noises from escaping the enclosure.

Unfortunately, the concept is difficult to achieve because of ventilation and cable openings, maintenance panels, doors, seams, and connectors. It is, therefore normal to use several components to shield one unit. To ensure that complete and proper EMI protection is achieved, conductive coatings composites, gaskets, greases, and adhesives are used.

The most commonly used conductive particles for shielding applications are identified in Table 1. The majority of the "high shielding effectiveness situations" use pure silver, silver coated glass spheres, and silver coated copper granules. See Table 2. The remainder of this article will discuss these products. The final choice is determined by the design and performance criteria of the operating unit.

RESISTANCE (ohm-cm)	PRODUCT
10^{-1}	Carbon Fibrous carbon
10^{-2}	Silver coated glass spheres Metal coated particles Nickel
10^{-3}	Silver coated glass spheres Copper Silver coated copper Pure silver powder Silver coated flakes
10^{-4}	Pure silver flake or powder Gold Silver coated flakes
10^{-5}	Pure silver flake

Table 1. Typical Conductive Particle Fillers

CONDUCTIVE FILLER COMPARISONS

Pure Silver

Pure silver powders and flakes are highly desirable conductive particles for use in EMI shielding gaskets, compounds, coatings, and adhesives. The metal's relatively high density and constantly fluctuating cost however, often prohibit its use. In addition, the possibility of galvanic corrosion exists when dissimilar metals (e.g., silver and aluminum) come in contact for extended periods. (See Table 3.)

To overcome these problems, the EMI industry has developed hybrid particles that offer the conductive and shielding properties of silver, yet minimize or negate some of the precious metal's drawbacks.

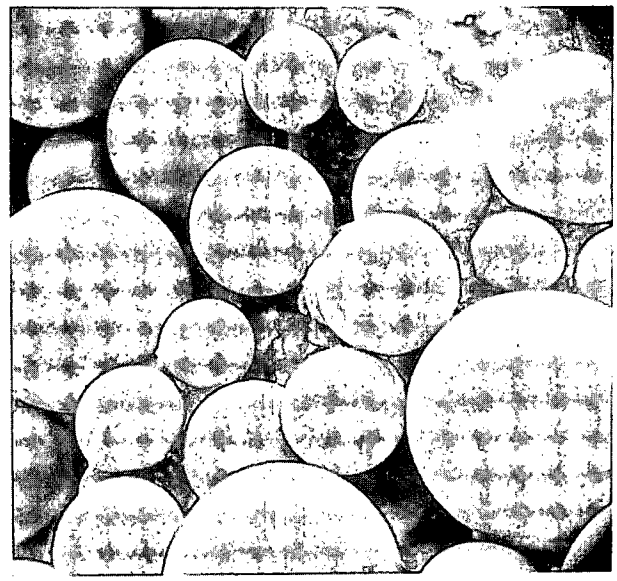

Figure 1. Silver Coated Glass Spheres.

Silver Coated Glass Spheres

Silver coated solid glass spheres have established themselves as proven alternatives in providing acceptable shielding effectiveness. Silver coated glass spheres are available in varying sizes and silver concentrations. They have a density of 2.6 g/cc and the lowest Surface to Volume Ratio, and offer excellent shielding effectiveness at a minimum of weight and cost. (See Figure 1.)

Silver coated solid glass spheres combine the physical and electrical properties of pure silver with the virtual chemical inertness and physical processing characteristics of a round glass particle. This latter feature gives glass spheres the lowest surface area for any given particle, minimizing the amount of precious metal coating required for complete uniform coverage. (See Figure 2.) The product is available in carefully controlled particle size distributions, offering optimum

PARTICLE	DENSITY (g/cc)	CONFIGURATION
Pure Silver	10.5	Powder, Flake
Silver Coated Copper	9.0	Granular, Flake*
Silver Coated Glass Sphere	2.6	Spherical

Table 2. Conductive Particle Comparison

and predictable packing characteristics. They are available with different silver thicknesses, further minimizing use and cost of the precious metal, as shielding effectiveness is achieved through the surface layer of the silver. The unused particle core is an inexpensive glass substrate that will not cause detrimental oxides to the system if the silver is abraded during processing of the final part. (See Table 4.)

- Ability to be easily fabricated into a variety of shapes and sizes
- Ability to maintain conductivity and relative chemical stability when subjected to adverse atmospheric conditions
- Maintains benefits when subject to high compression
- Unique viscosity and processing properties

PURE SILVER

PRODUCT FEATURES	ADVANTAGE	DISADVANTAGE
Available in two shapes: Flake, Powder	Application Flexibility	Relatively highest unstable priced material
Pure solid silver composition	Conductivity continues if oxidized	Galvanic reaction when exposed to surrounding enclosures
	Relatively highest performance at elevated temperature	

Table 3. Advantages and Disadvantages of Pure Silver as a Conductive Filler.

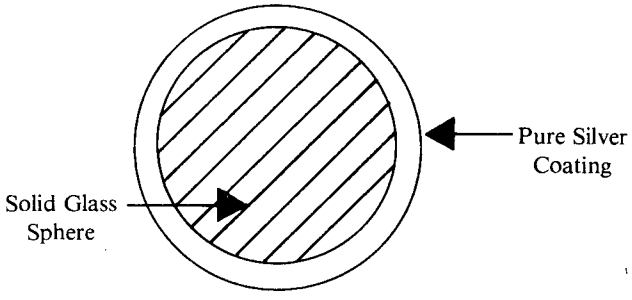

Figure 2. Cross Section of Silver Coated Solid Glass Sphere.

General Benefits of Silver Coated Glass Sphere Filled Elastomers

- Acceptable shielding effectiveness of pure silver at a fraction of the cost of precious metal.
- Low density of spheres allows:
  —high loading with overall weight reduction of final part
  —minimal amount of silver in system when compared to other silver fillers

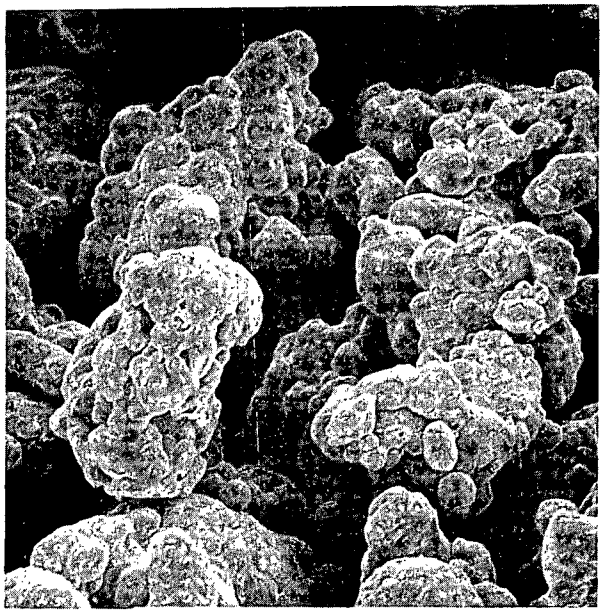

Figure 3. Silver Coated Copper Particles.

SILVER COATED GLASS SPHERES

PRODUCT FEATURES	ADVANTAGE		DISADVANTAGE
Pure silver coating	Conductivity in the 10^{-3}–10^{-2} ohm-cm range Conductivity continues even if oxidized Maintains same degree of chemical inertness as pure silver	Level thickness is adjustable to meet application's need No residual processing contaminants	Possibile galvanic reaction with surrounding metal enclosures Relatively high unstable price
Glass substrate	Relatively high temperature operating range (589°C) Virtually chemically inert Relatively low particle density	Exposure of glass through abrasion in silver will not cause detrimental oxides	Non-conductive
Spherical Shape	Minimum surface area minimizing silver used Enhanced dispersion & rheology of resin matrix Low uniform shrinkage of final part	Optimum & predictable packing characteristics Allows flexibility of final part with low uniform shrinkage Favorably influences compressive and flexural moduli	"Ball Bearing" effect may not be desired in certain processing methods
Closely controlled particle size distribution	Uniform packing produces multiple contact points Predictable void volume	Reproducible loading characteristics	
Large selection of standard sizes and coating levels	Ensure lowest user cost by balancing physical and electrical properties		
Custom gradations and coating levels available	Wide application flexibility		

Table 4. Advantages and Disadvantages of Silver Coated Glass Spheres as a Conductive Filler.

SILVER COATED COPPER

PRODUCT FEATURES	ADVANTAGE	DISADVANTAGE
Irregular particle shape	May adhere to resin in vibratory environment Ready availability of substrate	Increased surface area over spheres—requires additional silver comparable thickness in coverage vs spherical fire polished surfaces
Pure silver coating	Conductivity in 10^{-3} ohm-cm range Conductivity continues even if oxidized	Possible galvanic reaction with surrounding metal enclosures
Copper substrate	Conductive material	Relatively high density Oxidizes over time, in elevated temperatures and humid environment Oxidation negates conductivity Particle must be completely coated with silver to prevent above

Table 5. Advantages and Disadvantages of Silver Coated Copper as a Conductive Filler.

Silver Coated Copper Granules

Silver coated copper particles are also commercially available. (See Figure 3.) Silver coated copper granules, if plated properly, offer the shielding benefits of silver and copper. This allows use in relatively high shielding applications. Particle configurations resemble grains of sand or agglomerated grapes. Copper by itself is conductive, copper oxide is not. Therefore, extreme care must be used in plating to assure complete and uniform silver coverage. Copper oxide may develop and envelope the silver coating during gasket curing or exposure to high temperature/humidity environments. Resistivity achieved is in the 10^{-3} ohm-cm range. (See Table 5.)

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