CHOOSING AN ESD CONTAINER: MATERIALS AND MECHANICS

Both high and long-term costs are at stake in the choice of a container that balances the need for ESD protection against the many other demands of the manufacturing process.

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ESD protection has challenged the electronics industry ever since it emerged as an issue in the early 1970s. That challenge has carried over to manufacturers of plastic containers used to store and transport ESD-sensitive components. In response, container manufacturers have evolved new materials to keep up with electronics companies' rapidly growing and changing needs. Today, material-handling containers are becoming available in a wide variety of ESD-protective materials, sizes, and styles.

Still, electronics manufacturers face the same old challenge: choosing from among the many new materials and designs available, the ESD container that suits the needs of the storage and handling system in the most cost-effective manner.

Both high and long-term costs are at stake in the choice of a container that balances the need for ESD protection against the many other demands of the manufacturing process. There is little argument that container material deserves first consideration. By some estimates, ESD damage costs the industry up to ten billion dollars a year. The potential for loss is increasing with the trend toward smaller and even more sensitive circuitry. Furthermore, new issues are emerging:

- Electromagnetic interference (EMI) shielding;
- General corrosion of devices and leads caused by sulfur and other chemicals inherent in totes;
- Macro- and micro-contamination, such as sloughing in sensitive work areas and clean room environments; and
- Permanence of electrical characteristics.

When these considerations are added to the list of ESD characteristics normally desired, even more demands are imposed on container materials. At the same time, concerns about ESD should not overshadow all the many other selection criteria. A container that meets ESD requirements, but fails to fit the basic needs of the manufacturing system, can still cause severe losses — in reduced efficiency, wasted space and product damage.

So, after deciding upon a container's ESD requirements, the user must also consider dimensions, structural strength, and numerous design features. How large and how heavy are the unit loads? Should the containers stack? How will the loads be transported? Must the container interact with automated equipment such as bar code scanners or robots? Without answers to these and many other questions, it is almost impossible to choose the optimum container. It is the complexity of balancing ESD protection with all the other needs that has made the development of protective totes so challenging.

Most ESD plastics derive their electrical properties from materials added to the base resin. The difficulty has rested in finding additives that deliver the desired electrical properties without compromising the structural or other electrical properties. For example, past ESD-protective totes often came with trade-offs in the form of decreased rigidity, decreased load-bearing capacity, and a tendency to soften or crack after contact with cleaners and solvents.

In developing ESD plastics, manufacturers have focused their research on materials compatible with existing container tools; this focus allows them to offer new materials in proven container designs. This strategy is important because materials that require re-tooling or a special manufacturing process threaten to make containers cost-prohibitive.

Advances in container technology have tended to come in quantum leaps, each new generation of materials bringing major advances in strength and electrical properties (Table 1). Not surprisingly, each advance has also brought an increase in price.

The new materials have expanded the capability range of ESD totes and have provided more options for the user. But earlier materials are still well-suited to numerous applications. Even while new generations of materials are being developed, earlier generations are being refined to suit specific needs.

ESD materials are generally classified by surface resistivity, which is measured in ohms/square. Currently, materials are divided into three categories:

- Conductive (surface resistivity of less than 10^5 ohms/square);
- Static dissipative (10^5 to 10^{10} ohms/square); and
- Anti-static (greater than 10^{10} ohms/square).

At present, the electronics industry uses mainly conductive and anti-static materials. However, there is increasing demand for new materials that will perform even better.

FIRST GENERATION: PINK POLY

Linear low-density polyethylene, *pink poly* was the container industry's first ESD material. Developed in the early 1970s for use in protective bags and films, it was later adapted to the manufacture of tote boxes. *Pink poly* is an anti-static material (surface resistivity between 10^9 and 10^{12} ohms/square) that provides limited ESD protection. But it has significant drawbacks as a container material.

- It exhibits low stiffness and poor

Property	1st generation Linear polyethylene	2nd generation Anti-static polypropylenes	3rd generation Conductive polypropylenes	Reinforced conductive polyester	4th generation Fiber-impregnated polypropylene	Fiber-impregnated polyphenylene oxide
Surface Resistivity (ohms/square)	10^{9}-10^{12}	10^{9}-10^{12}	less than 10^{5}	less than 10^{5}	10^{5}-10^{9}	less than 10^{5}
Non-sloughing	yes	yes	no	no	yes	yes
Faraday cage protection	no	no	yes	yes	yes	yes
Triboelectric charge generation	low	low	higher	medium	low	medium
Decay rate MIL-B-B1705B FTM 4046	pass	pass	pass	pass	pass	pass
Sulfur (total)		non-carbon black	less than .20%	.025%	less than .01%	less than .05%
Humidity independent	yes	no	yes	yes	yes	yes
Colorable	no	yes	no	no	limited	limited
Temperature applications	low	low	low	high	low	high
Rigidity	very low	low	low-med	very high	medium	high
Dimensional stability	very poor	poor	good	excellent	good	excellent

Table 1. ESD Material Properties.

dimensional stability.
- It is easily damaged by solvents.
- Its electrical properties are relatively short-lived.
- It provides no EMI shielding.

SECOND GENERATION: ANTI-STATIC POLYPROPYLENES

Anti-static polypropylenes are ESD materials that owe their electrical properties to additives. Typically, a hygroscopic additive draws moisture from the air to form a conductive layer on the container surface that dissipates static charge when the container is properly grounded.

This material (surface resistivity 10^9 to 10^{12} ohms/square) offers low triboelectric charge generation and electrical properties that last longer than those of *pink poly* — generally about 5 years. It also provides:

- Better stiffness and dimensional stability, allowing it to be used in some automated handling systems;
- Resistance to sloughing; and
- Limited colorability for color-coding or aesthetics.

However, anti-static polypropylenes lack the strength for many heavy-duty applications and are affected by chemicals and solvents. The hygroscopic action gives the containers an oily feel and, in many cases, prevents their use in clean rooms. Also the material should not be used in prolonged dry environments because its electrical properties depend on humidity.

Nevertheless, anti-static polypropylene tote boxes are still widely used. In fact, the past year has seen the development of a translucent grade of polypropylene that can be used to manufacture container lids and some kinds of totes. Also new to the market is a high-grade, clear, anti-static styrene used to make container lids. Both allow users to see inside closed containers.

THIRD GENERATION: CONDUCTIVE POLYPROPYLENES

Conductive polypropylenes offer ESD-protection due to carbon black added to the base resin. These materials (with surface resistivity of less than 10^5 ohms/square) represent a major improvement in both structural and electrical properties. They offer:

- Permanent, humidity-independent ESD protection;
- Fast static decay;
- Some static shielding;
- Higher rigidity and dimensional stability; and
- Resistance to most chemicals.

These advantages come with a few trade-offs. Some conductive polypropylene forms can be relatively high in sulfur. Because of its carbon black additive, no coloring is possible. Also it is not recommended for use in clean rooms because it sloughs conductive carbon particles.

Nevertheless, conductive polypropylene containers — both off-the-shelf models and custom designs — suit a wide variety of applications. They have been used successfully in some of the most advanced automated and manual handling systems in the electronics industry.

A more recent development within this generation is a conductive material made by adding carbon black to a fiberglass-reinforced polyester. This material, which is compression-molded rather than injection-molded, exhibits even higher strength and load-bearing capacity.

The fiberglass reinforcement imposes some design limitations. However, the material is ideally suited for heavy-duty storage and for carrying components through high temperature processes, such as baking.

FOURTH GENERATION: FIBER-IMPREGNATED MATERIALS

The most recently developed materials come closest to providing ESD protection without compromises. These materials are impregnated with a random network of fibers that provide structural reinforcement as well as static charge dissipation.

The earliest of these materials, a conductive grade, is made from a polyphenylene oxide base resin containing graphite fibers. These materials are extremely rigid, durable and heat-resistant. However, this specialty base resin imposes severe design limitations and is difficult to use in container tools designed for polyolefin-based resins.

These materials include a conductive grade made from a polyphenylene oxide base resin. The materials are extremely rigid, durable and heat-resistant. In addition, they offer:

- Low triboelectric charge generation;
- Permanent, humidity-independent ESD protection;
- Extremely low sulfur content;
- Colorability;
- Very high load-bearing capacity and tensile strength;
- Resistance to moisture, oils and most chemicals; and
- High resistance to sloughing.

The materials also exhibit high dimensional stability, which means they can be manufactured to the tight tolerances required in robotic and other highly automated applications.

Also under development are polypropylene-based plastics that use fiber technology. These materials generally fall into the conductive and static-dissipative ranges (10^3 to 10^{10} ohms/square) and exhibit promising static decay performance.

MEETING TODAY'S NEEDS

As advanced as the new materials may be, they are not the final answer. They are only the latest step in evolution. New materials will continue to evolve as the electronics industry refines and quantifies its needs.

For the time being, users face the challenge of meeting today's needs with the materials currently available. The selection process can be arduous; and because each application is different, there is no set procedure to follow. Presented here are some good general guidelines.

Establish Material Requirements. Define requirements for all forms of protection — ESD, EMI, sulfur corrosion, contamination. Assign safety factors to each requirement; if an occasional failure is not too costly, keep safety factors low. To the extent possible, strike a balance between electrical and structural properties. Over-specifying on either side drives up costs needlessly.

Evaluate the System's Needs. Consider carefully how the container must interact with all parts of the material-handling process, both manual and automated. If even one factor is ignored, the container will not meet the needs of the system; and inefficiencies will result. In particular, consider component sizes and weights; note the types of racking, shelving, carts, conveyors and chutes; determine the accessories needed — collars, covers, partitions, circuit board holders, paperwork pouches.

Assign Priorities. No container will meet all of the system's requirements. Therefore, list all needs in order of importance. Then, consider carefully which needs can be compromised and which cannot.

Find Out What Is Available. Survey different suppliers to see what materials and container designs they offer. Check how different models match the system's top priorities. Ask for complete electrical and structural specifications, as well as information on how their products are used in various applications.

Test Containers. After choosing the top candidates, ask the manufacturers for samples to test. Check their surface resistivity and other electrical characteristics. Insist on testing finished containers rather than unprocessed material samples. The manufacturing process can affect performance. If electrical properties are suitable, give the containers a *test run* in the actual handling process.

CONCLUSION

If no off-the-shelf container seems acceptable, custom manufacturing can be considered. But this step can be cost-justified only when careful study clearly shows it is the only option.

Assistance in choosing containers is available from container manufacturers and their representatives. Their expertise can be useful at any stage of the selection process. Manufacturers also have information on the latest materials under development and can estimate when these will be commercially available. ■