ESD BAGS: TO SHIELD OR NOT TO SHIELD:

What type of bag should you use?

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INTRODUCTION

Populated printed circuit boards (PCBs) are typically protected from ESD when in storage or transportation by a sealed ESD-protective bag. "95% of ESD control programs use shielding bags", said Jim McKeon of Desco/Charleswater, "because it increases the programs confidence and makes a program more foolproof". There are several types of ESD bags on the market ranging from pink polyester to a metallized moisture vapor barrier (MVB) bag. Which bag is right for the job? What type of protection does your electronic board or device need? Why so many choices of ESD bags for packaging?

I History of ESD Control Bags

The packaging evolution of the ESD control bag and packaging material design has been a compromise between various desirable features. Ideally, users look for ESD bag materials that combine low cost with a myriad of properties such as: high ESD shielding effectiveness; permanent antistatic properties; humidity independent performance; eliminate contamination and corrositivity of packaged contents; excellent moisture vapor barrier properties; heat sealability and film transparency.

Traditionally, static-shielding bags are manufactured by depositing a thin metal coating such as aluminum over an anti-static polyester film substrate. The metallized layer protects the devices in the bag from electrostatic fields, while the insulative layers prevent direct contact with potential ESD hazards. At the low end of ESD bad product offerings are amine-free, anti-static polyethylene film bags that are transparent or pink in color, referred to as Antistatic (which is their only property). These bags are commonly referred to as "pink poly"

Over the past years, manufacturers have developed a number of new static dissipative materials that minimize of tribocharging while offering improved puncture resistance and durability. Durability is a particularly attractive property in most ESD bags where sharp-edged devices or printed circuit boards are loaded into the bags to minimize the threat of bag perforation.

Manufacturers are also developing environmentally friendly materials much more than they have been in the past. Historically, ESD protective packaging has similar environmental problems as any plastic material; disposal and material decomposition can present an environmental hazard. Recently, manufacturers have conquered some of the disposal problems and we now see more "recyclable ESD bags" on the market, such as those made from polypropylene.

II Types of ESD Bags

Let’s review the current technology for ESD bags. There are essentially three types or categories: antistatic bags, dissipative bags and metallized bags. The latter two categories are typically the high-end of ESD bag product offerings and tend to have three combined properties of protection, (1) antistatic, (2) dissipative and (3) shielding.

Antistatic Bags
Antistatic bags are typically coated with a topical antistat agent that helps minimize the generation of a static imbalance from triboelectric generation or contact and separation (i.e., definition of antistatic). Some antistatic bags are made with an antistat built into the films layers and tend to be more reliable and cleaner then the topically treated ones. A good bag has antistatic properties on both the inside and outside of the bag’s film construction.

Dissipative Bags
Bags with the films surface resistance in the dissipative range are preferred because charge dissipates across the surface at a controlled rate. Most dissipative bags also have the property of being antistatic. These are good general bags to be used in non-critical environments.

Metallized Shielding Bags
Metallized shielding bags have either a metal film embedded into the bag film construction or coated onto an existing layer. This metal film acts as an electrical

shield against electrical discharges from the outside of the bag. Depending on the energy and duration of the discharge and the thickness of the metal film, an ESD event is typically spread out over the outer surface of the metal film and if fully enclosed, i.e. the bag is sealed, then the charges current from the ESD event is contained to the outside (outer surface) of the metal film, i.e., providing a region of no electrostatic fields within the bag, thereby protecting the contents within. This effect is known as the Faraday Cage Effect and is commonly used in controlling ESD via metallized shielding bags, conductive bags and the conductive tote box with a cover.

There are two common types of metallized shielding bags varying by construction, the metal-in and the metal-out shielding bags. The metal-in (buried metal) shielding bags are the most common type currently used and are recommended for packaging of ESD sensitive (ESDS) components. They also tend to be superior to the metal-out construction in durability and cost. The metal-out shielding bags are also designed to protect against static induced damage. The metal layer is closer to the outside surface resulting in these bags having lower resistance readings than the metal-in which can be important in some applications.

Moisture Vapor Barrier (MVB) shielding bags are a special subset of metallized bags as they also have the property of EMI-RFI-ESD shielding. This is mainly accomplished by using a much thicker metal layer (about 10x thicker than standard metallized bags), which inhibits the moisture vapor transmission rate (MVTR) by a factor of over 20 times more compared to ordinary shielding bags.

In general, if you are storing ESDS devices for prolonged periods of time (6 months or more) or if the devices are sensitive to corrosion, than you should package these materials in either an MVB (Moisture Vapor Barrier) bag with a desiccant pack to absorb any moisture that was sealed in or a metal-in shielding bag with a desiccant pack. The difference between an MVB film and a metal-in film is about 1 magnitude in the moisture vapor transmission rate (grams of water/100 in^2/24 hours @ 100 ^oF). Moisture sensitive ESDS devices should only be packaged in an MVB bag.

In both cases, the bags MUST be sealed to properly keep moisture out.

For all other ESDS (ElectroStatic Discharge Sensitive) devices [that are not moisture sensitive], a metal-in, metal-out or a clear dissipative bag can be used. Heat sealing is much preferred, however, you can often fold over the top of the bag and close with an ESDS sticker for adequate protection.

ESD bags should be inspected before reuse by an internal statistical sampling plan as they typically have a finite reuse life.

If an ESD program is laid out very well and is extremely disciplined so threat the threat of ESD events are almost squelched in both the handling and transportation processes, then a good dissipative bag may be sufficient for the storage of most ESD sensitive devices. There are very few actual programs out there that are implemented so effectively.

Most ESD programs use shielding bags because it increases its level of confidence and makes it more foolproof. Shielding bags serve two purposes, preventing the ESD sensitive components sealed within the bag from charging up via field induction and minimizing the damage from a direct contact (outer bag surface) with an ESD event. Some high quality films (ESD shielding bags) can withstand up to a 30 kV discharge.

III Features & Benefits of ESD Bags

(Chart of types, construction, features & benefits)

Table I - Features of ESD Bags

METAL IN		METAL OUT		EMI-MVB		DISSIPATIVE		ANTISTATIC	
Features	Benefits	Features	Benefits	Features	Benefits	Features	Benefits	Features	Benefits
These bags provide shielding of electrostatic fields when properly sealed						Film surface in dissipative resistance range	Controlled discharge when grounded	Simple design and construction	Low cost
Buried metal layer	Lasts longer, is cost effective and durable	Metal outer layer	Provides more rapid charge dissipation when the bags is grounded	Multi-purpose	Protects contents from ESD, moisture and EMI/RFI	Can be ultra clear	Maximum optical clarity for visual identification & bar code reading	Antistatic agent or material on/in film	Minimizes tribocharging
Greater than 40% light transmission	Allows for identification of bag contents without opening bag	Anti-abrasion exterior	Lower charge retention	Polyester layer	Provides pull strength	Most are humidity independent	Electrical properties don't wear off	Ideal for hardware or non-ESD assemblies	Adds to overall ESD program
Most common shield bag on market	Easy to get, cost effective	Greater than 40% light transmission	Allows for identification of bag contents without opening bag	Polyethylene layer	Provides puncture strength and can be heat sealed				
				Extra thick metal layer (about 10x thicker than	Greatly enhances EMI/RFI and MVB				

				MI/MO films)	protection				

III Shielding (Faraday) vs Non-Shielding bags

Table II - Device Damage Thresholds for Various ESD Bag Types [1]

Material	Damage Threshold Voltage (V)	
	New Bags	Used Bags*
Conductive Cardboard	2,500	
Insulative Bag	4,000	
Antistatic (pink poly) Bag**	4,500	
Static Dissipative Bag	5,000-6,000	
Antistatic Bubble Wrap**	4,500-6,500	6,000
Antistatic Foam Wrap**	>6,500	
Metallized Shielding Bags (3 types)	6,500-8,000	5,000-6,000
* New bags were crimped or folded to simulate use **Antistat bags can dry out with time and become huge static generators		

The above table was derived by a set of experiments performed by Lucent Technologies [1]. The voltages indicate the level at which the device was damaged by direct discharge to the bag. This shows that metallized shielding bags are the most protective when first used, but as used they degrade to provide ESD protection similar to good as antistatic bubble wrap bags.

Note: the bubble wrap uses the air gap (spacing), dielectric of air, as a protective means for withholding damaging ESD from it's contents, similar to clam shell packaging. For an ESD from a 10 cm diameter electrode, the spark-gap length is about 0.12 inches for every 10 kilovolts of peak voltage at 760 mmHg and 25^{o}C, so the air gap needs to be much larger than the spark gap to provide adequate ESD protection [7].

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IV Packaging Standards

The standard MIL-B-81705C, Military Specification for Barrier Materials, Flexible Electrostatic Protective, Heat Sealable, states that there are three classifications of barrier materials (bag films) that make up ESD-protective bags, see Table III below.

Table III - Classification of Barrier Materials – MIL-B-81705C

Type I		Watervaporproof, electrostatic protective, electrostatic and electromagnetic shielding
MVB/EMI	**Class 1**	Unlimited use
	Class 2	For use on automated bag making machines only
Type II		Transparent, waterproof, electrostatic protective, static dissipative

Dissipative	**Class 1**	Unlimited use
	Class 2	For use on automated bag making machines only
Type III		Transparent, waterproof, electrostatic protective, electrostatic shielding
MI/MO	**Class 1**	Unlimited use
	Class 2	For use on automated bag making machines only

A table of most of the ESD packaging standards is provided in Table IV. The ESD Association is heavily involved in re-writing some of the most commonly used packaging standards as well as their current packaging standards. ESD-DS20.20 is assimilating all their ESD control standards into one reference document and the non-draft version of this standard will essentially replace the MIL-STD-1686 possibly near the end of 1999.

TABLE IV – Packaging Standards

Standard Number	Standard Description	Type	Application(s)
EIA (Electronics Industry Association)			
ANSI/EIA-541-88	Packaging Material Standards for ESD Sensitive Items	S	Packaging materials
ANSI/EIA-583-91	Packaging Material Standards for Moisture Sensitive items	S	Packaging materials
U.S. Government (Federal Test Method & Military Standards)			
MIL-HDBK-773, 1988	Electrostatic Discharge Protective Packaging	S	Packaging
FTM STD. NO. 101C, Method 4046.1, 1982	Test Procedures for Packaging Materials Electrostatic Properties of Materials	STM	Determine electrostatic properties of materials in film & sheet form

Institute for Interconnecting and Packaging Electronic Circuits (IPC)			
ANSI/IPC-A-610, 1996	Acceptability of Electronic Assemblies	S	General ESD control practices
Electrostatic Discharge Association (ESDA) Standards			
ANSI/ESD S11.31-94	ESD Shielding Materials – Bags	STM	Shielding bags
ESD DS20.20-1998	Protection of Electrical and Electronic Parts, Assemblies and Equipment	S	ESD Control Program
ANSI/EOS/ESD S8.1-1993	Symbols – ESD Awareness	S	Symbols for ESD packaging/awareness

V Packaging Precautions

ESDS devices should always be kept in an enclosed antistatic shielding bag, conductive closed tote, or bin when not being handled at an ESD controlled workstation. This includes inventory storage, transportation, and work-in-process. Further precautions during transportation include using dissipative carts with conductive wheels or drag chains in conjunction with a conductive or dissipative floor when transporting ESDS devices in their shielded containers. The standards to help characterize and qualify packaging materials are ANSI/ESD S11.31 for shielding bags, ANSI/EOS/ESD S8.1 for proper use of package markings, ANSI/EIA-541 and ANSI/EIA-583 for packaging materials, refer to Table III.

VI ESD Bag Questions and Answers [6]

Q. During the past few months I have been trying to change our old process of transporting our circuit boards around our factory from the use of 'CONDUCTIVE BAGS' to the use of 'DISSAPATIVE BAGS'. I have been unsuccessful due to the fact I cannot prove that this will benefit the reliability of our products.
How can it be proven 'Practically' or 'Theoretically' to Justify the extra costs incurred in the use of dissipative bags?

A. You have a good question. There is a white paper talking about discharge times that may help. The more conductive an item is, the greater the energy density in an ESD event. By slowing the charge transfer (ESD event) down with a more resistive material (dissipative), you can minimize the risks associated with conductive ESD events. With a dissipative material, instead of an ESD event, you will have a current ‘bleeding’ or charge balance that is better controlled.

White Paper: http://www.esdsystems.com/whtpaper/discharg.htm.

Q. I have two questions about one material. Anti-stat bags. 1. How effective are anti-stat bags with a relative humidity of less than 20 % and temperatures as high as 110 degrees Fahrenheit. 2. How do you put a spec on an anti-stat (ohms/sq. etc.) bag to ensure maximum protection and re-use?

A. The clear static dissipative polyethylene (PE) that high quality vendors use in their bags is far superior than the "topically treated washed" pink poly products.

Dissipative and metallized shielding bags are made with volume loaded polyethylene which cannot be washed off and is inherent in the film. The PE resin that we use and all the additives are developed to minimize contamination.

The antistatic dissipative clear bags are pre-conditioned and tested at both 50% and 12.5% RH levels to have a surface resistivity of less than 1x10^11 ohms. (old nomenclature = ohms/square)

Testing:
You can perform two test to ensure the proper operation of the bags:

1. perform a resistance test on the bag film to < 1x10^11 ohms @100 volts [using two five pound electrodes and megohmeter per ESD S11.31-1994 and ESD DS20.20-1998]
2. perform a tribocharge test, yielding static decay of less than or equal to 140 milliseconds, per FTMS 101C, Method 4046

Q. What is the recommendation or guidelines in determining when Anti Static shielded bags are no longer any good, i.e. crinkled or have small puncture holes, and put out of service?

A. All your answers are in the MIL-B-81705C Standard document. Specifically, an anti-static shielding bag (type III) can be considered no good if it meets any of the following conditions:

- the bag delaminates as defined in section 4.8.4.1 in MIL-B-81705C
- has a static decay rate exceeding 2.0 seconds
- does not attenuate EMI at least 10 dB
- punctures over 6.0 lbs,
- doesn't shield an ESD event under 30 kilovolts
- and has a surface resistivity greater than 1x10^12 ohms/sq both inside and out and less than 1x10^5 ohms/sq on the inside.

In general, a metallized shielding bag may still shield if it has crinkled or acquired small holes because of the Faraday affect, but it is safer to discard these bags and err on the conservative side. It would probably cost more to test and qualify the bag then to replace it.

Q. The static bags that electronic parts come, what are they made of and is the bag at a positive or a negative condition.

A. There are several types of static bags; shielding (metal-in, metal-out, moisture vapor barrier), antistatic and conductive. The most commonly used "static" or ESD bag is a shielding bag, which has all three properties listed above . A shielding bag has a layer of metal, usually aluminum (Al) (similar to Aluminum foil), that provides "shielding" producing a Faraday Cage affect. An ESD shielding bag has several properties:

- MECHANICAL (mechanically holds items within)

- ELECTRICAL SHIELDING: (Faraday cage) to minimize an electrical current (voltage discharge) or ElectroStatic Discharge (ESD) from penetrating the film thereby "protecting" the contents from being damaged by an ESD.
- ANTISTATIC: Non-tribocharging, or prevents the generation of an electrical charge through contact and separation of surfaces. Examples include when the object moves around within the bag or when you walk along the floor. Most of us have experienced the discharge after walking on a carpet, then touching a metal object such as, a door knob.
- CONDUCTIVE: A material is said to be conductive when it allows charge flow or electrical charge on the surface and can travel to a lower or higher potential. For example, when you connect the surface to a grounded (zero potential) point. It is good to have a conductive material in ESD from 10^5 to 10^9 ohms (from 100,000 Ohms to 10,000,000,000 Ohms). Anything over 10^{10} ohms (100,000,000,000) is considered insulative, and anything under conductive.

  A typical shielding bag is composed of three layers:

- polyester (0.0005 inches thick)
- aluminum on polyester (10 - 25 Angstroms, 1 Angstrom = 1x10^-10 meters)
- polyethylene. (0.0025 inches)

Q. In my company many rolls of bubble wrap, plastic bags, and PCB boxes (plastic cases) are listed as "Anti-static". While we all understand that these items will not produce serious static, many think that they will also protect the components inside from a static charge. My contention is that a significant amount of charge would pass through the bag/box and damage any ESDS item inside. Only a shielded bag would guarantee complete protection from ESD. The question really arises because a well-known and respected PCB manufacturer sends their PCBs' to us in anti-static plastic cases. The clear plastic case only lists "Anti-Static and we can not see any conductor strands within the plastic. What are your thoughts?

A. There are two ways to protect ESDS PCBs. One way is by shielding. The use of metallized shielding bags is a good way to protect the contents from external ESD. Another way to protect ESDS PCBs is to isolate them from external ESD with an air gap. There are "clam shell" packaging and other anti-static plastic packages that will give a spacing of about an inch of air between the outside plastic shell and the ESDS part inside. This "air gap" spacing can be an effective way to protect ESDS parts from external ESD as a 1" air gap acts as a dielectric to prevent discharges up to 30 kilovolts.

Q. If the ESD bag is of different thickness (total material thickness), will the electrical properties be different?

A. Yes, the volume resistivity of a material may become higher with a thicker bag. The higher the volume resistivity, the higher a voltage the material will stand off. Most high quality metal-in, metal-out or MVB shielding bags can withstand over 30 kilovolts. A thicker bag (thicker dielectric or metal film) will be able to hold up to a greater energy ZAP. The spacing of the ESDS device relative to the inner bag surface can have a similar effect. The greater the "air gap" the greater the protection from an ESD event penetrating the shielding bag into the ESDS device. It is the metal film that helps transfer this energy into a surface current [Faraday Cage Effect] rather than penetrating through the bag to the sensitive device.

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