

Understanding ESD and Its Prevention


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Introduction

It is estimated that ESD (Electro Static Discharge) damage costs American industry approximately \$5 billion each year. The cost of ESD damage is not simply manufacturing costs of the components but also component replacement costs, customer service and field service time not to mention the customer's perception of quality. ESD damage may not be immediately measurable as the greatest percentage of defects result in latent failures.

Latency of ESD damage is like a ticking time bomb waiting to go off at the worst possible time. NASA studies have concluded it is not possible to predict exactly when components damaged by an ESD event will fail. They also concluded there is no reliable test to determine if a component has latent ESD damage until after the failure has occurred. Once a component has failed due to an ESD event, a SEM (Scanning Electron Microscope) will reveal the damage which can be directly attributed to ESD.

ESD Latency (ESDL) failure is defined as damage to the structure that is not apparent at the time of its onset, but will reveal itself by facilitating a hard failure at a subsequent, normally nonfatal stress to which the device is subjected during ordinary use. An ESDL failure can occur either early in a component's life (early life failure) or later during its normal operating life (intrinsic failure).



"There is no reliable test to determine if a component has latent ESD damage until after the failure has occurred."

It is important to first understand what ESD is, how it happens and what its potential effects are before one can institute a plan of prevention.

What Is ESD and How Does It Happen?



Electrostatic Discharge is the rapid movement of charge from one object to another. Static electricity is a charge at rest. Static charge buildup, either positive or negative, occurs when materials are rubbed together or simply separated from each other. When an object picks up additional electrons from the surface that it was rubbed against or separated from, it becomes negatively charged. The surface that had given up these electrons is said to be positively charged. This method of charging results from the triboelectric effect.

Over the years, semiconductors have become smaller and denser with distances between internal elements in the micron range. To give perspective, the cross sectional diameter of an average human hair is nominally 10 um. Semiconductor

layers are also becoming thinner. This is all being done in order to create faster and more complex integrated circuits which have a smaller footprint. With these decreasing distances inside most integrated circuits, it tends to make them more susceptible to damage by an ESD event. Today, ESD prevention is even more important than ever before.

Materials that can generate a static charge can be classed into two categories.

Those that generate a positive charge by giving up electrons such as:

- ▶ Paper
- ▶ Fur
- ▶ Wool
- ▶ Human Hair
- ▶ Glass
- ▶ Human Skin
- ▶ Air

Those that generate a negative charge by picking up electrons such as:

- ▶ Wood
- ▶ Hard Rubber
- ▶ Acetate Rayon
- ▶ Polyester
- ▶ Polyurethane
- ▶ PVC (Vinyl)
- ▶ Teflon

The following table gives examples of activities that cause static buildup and the approximate voltage each activity generates:

Table 1. Voltage caused by various activities

Walking across a carpet	1 500-35000 Volts
Crossing your legs	300 Volts
Walking over an untreated vinyl floor	250-12000 Volts
Working at a bench	700-6000 Volts
Picking up a plastic envelope with work instructions	600-7000 Volts
Picking up a common plastic bag from the bench	1200-20000 Volts
Sitting in a work chair padded with polyurethane foam	1500-18000 Volts
Touching a doorknob or other metal object	1500-35000 Volts
Standing up from a chair	>100 Volts

One way you might know an electrostatic discharge event has happened is when you feel a shock, such as when you walk across a carpet and touch a door knob. When you feel a static shock, you are feeling the discharge of >3000 Volts. If the charge is below 3000 Volts, you will not feel anything but a sensitive electronic component will be damaged through an ESD event and you will not be aware that any damage has occurred.

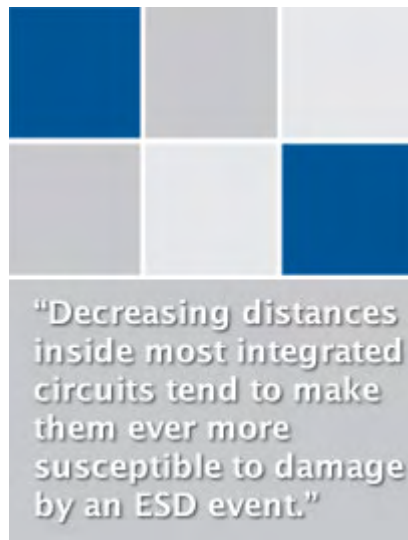


Table 2. Susceptibility ranges of devices exposed to ESD from a person

MOSFET	100-200 Volts
GaAsFET	100-300 Volts
JFET	140-10000 Volts
CMOS	250-3000 Volts
Schottky Diodes	300-2500 Volts
Bi-Polar Transistors	280-7000 Volts
Op Amp	190-2500 Volts
ECL	500-1500 Volts
SCR	680-1000 Volts

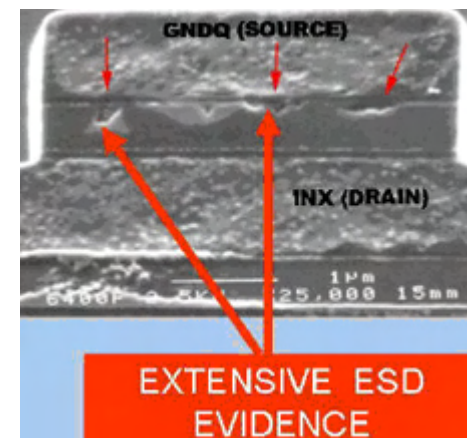
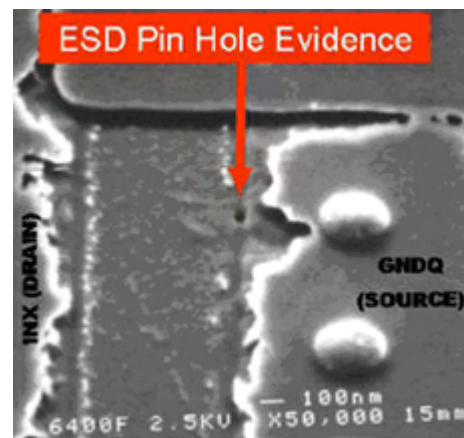
NASA research has concluded that potential failure mechanisms/modes resulting from ESD damage include:

- ▶ Field/Gate Oxide Rupture
- ▶ Dendrite Formation
- ▶ Hot Spots due to silicon damage
- ▶ Melted Channels (connecting these hot spots)
- ▶ Increased Leakage Current
- ▶ Junction Burnout
- ▶ Drain-Source Short
- ▶ Risetime Effects (timing)
- ▶ Enhanced Interconnect Electromigration
- ▶ Resistor Damage

What Does ESD Look Like?

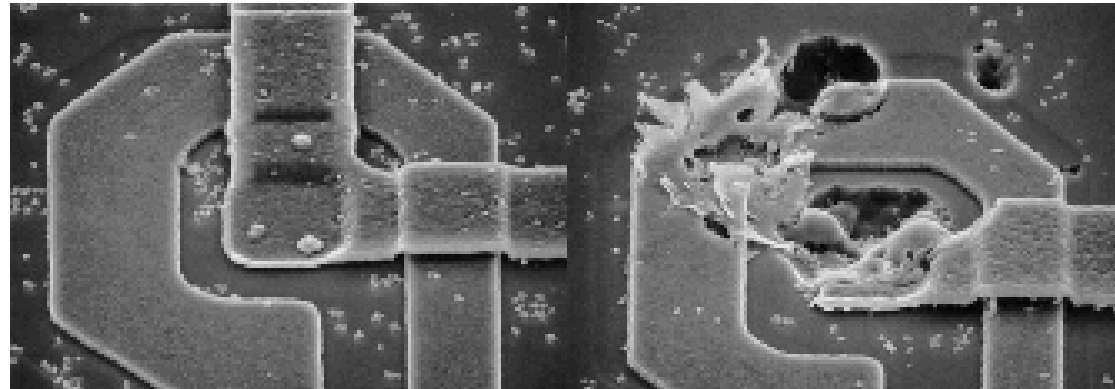
While it is difficult to visualize exactly the nature of ESD damage with only the naked eye or a magnifying glass, SEM photomicrographs reveal the catastrophic or latent forms of semiconductor damage resulting from an ESD event.

Some of the aforementioned damage appears in the following illustrations. Pay close attention to the magnification factor indicated on the illustrations and the accompanying scale. Some of the damage measures 1 μm or less and to visualize this microscopic defect requires magnification in the thousands or 10s of thousands before it becomes visible to the human eye.

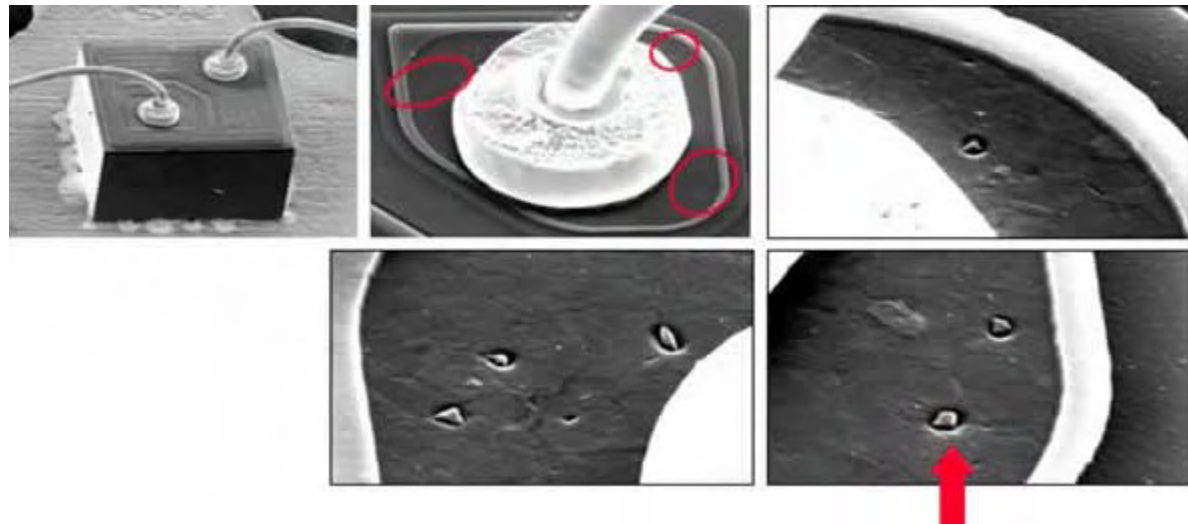


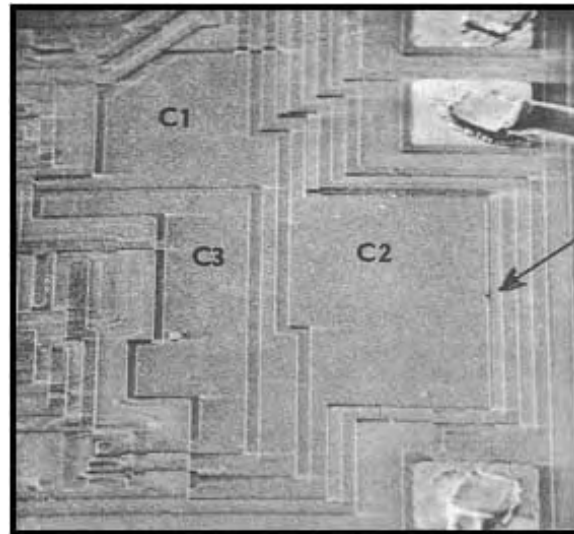


NASA SEM
 Photomicrographs
 of a semiconductor
 device before (left) and
 after damage (right)
 from an ESD event

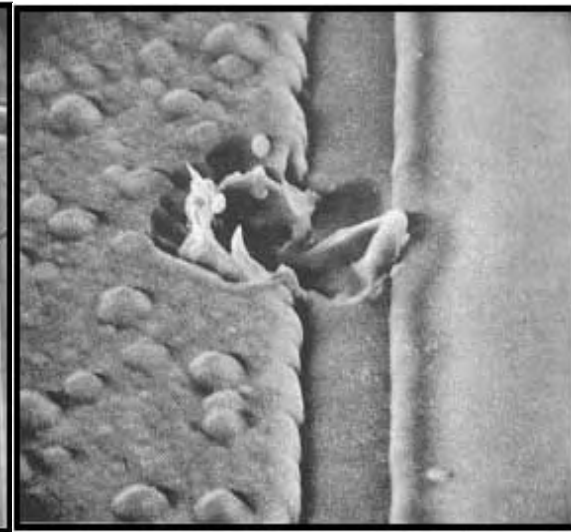


Rolm SEM
 Photomicrographs
 showing ESD damage
 to a bi-polar transistor
 at various
 magnifications





Surface damage in the C2 MOS capacitor 175X



Surface damage at 4300X

Preventing ESD

The environment in which ESD sensitive devices are worked on or stored must be controlled as much as possible in order to prevent static buildup and eventual discharge.

Humidity must be held above a certain level in order to lessen the amount of static charging. The dryer the air, the more rapidly different materials will charge.

Handling and shipping requirements must also be observed in order to eliminate the possibility of an ESD event occurring while the part is in storage or transport. One can observe all the proper practices however, if not properly packaged, all earlier ESD preventive measures are for not. All packaging materials must be ESD safe. Stretch wrap and bubble wrap must be of the low charging variety. These are commonly pink in color. Liners for expanded foam packaging, which protect large and heavy parts from physical damage, should also be of the low charging variety. Assemblies should be packaged within conductive bags and these bags heat sealed to protect the contents. An unsealed conductive bag offers little if any protection from ESD events. Placing an ESD sensitive assembly on top of a conductive bag offers absolutely no protection to the device. All foam packing materials should be conductive in nature or at least low charging. Conductive foam is generally black in color and low charging foam is usually pink.

Transportation of parts for kitting, repair or assembly should be conducted using grounded carts and conductive totes or trays. A grounding chain which drags the floor should be installed on all carts utilized in ESD safe areas. Conductive totes or trays serve well to protect sensitive electronic assemblies being either carried or transported on a cart within the plant.

In a plant environment, it is important to designate, mark and equip areas where ESD sensitive equipment is handled as ESD Safe Areas. Personnel who are working in or traversing ESD Safe Areas should be outfitted with personal grounding equipment and strictly adhere to best practices.



At this point, it is important to discuss the type of grounding to be utilized. The desired method is to employ a resistive ground. This style of ground exhibits about 1 MΩ of resistance between the entity being resistively grounded and a common ground point. Wrist straps and shoe grounders contain this form of grounding mechanism. It is important to utilize a resistive ground as it serves to drain off static charges as they are being developed. Direct connection to ground represents a lightning rod and actually promotes ESD events.

Static dissipative footwear is a must. Heel or toe grounders should be worn at all times within the ESD safe area. Static dissipative shoes are a good alternative. Shoe grounders should be tested daily prior to use. The footwear tester verifies the 1 MΩ resistance and will determine if the resistivity is either higher or



lower than the desired range. Depending on the type of flooring, a floor conductivity treatment, usually employing zinc, should be applied. Tektronix has determined, through repeated conductivity studies that it is unnecessary to continually strip and retreat concrete floors as they exhibit adequate conductivity if kept free of dust and dirt.

With many of today's fabrics being synthetic, most clothing can build up charges high enough to cause an ESD event. Either the individual should wear 100% cotton clothing or an Anti-Static Lab Coat or Smock to mitigate static buildup caused by clothing.

Inside the ESD safe area, benches and workstations should have a static dissipative work surface which has been effectively connected to a common ground.

It should also provide provisions to connect wrist straps for use by workers. Shoe grounders are ineffective when an individual is seated so wrist straps must be utilized for worker static charge dissipation. Wrist straps should be tested on a daily basis for proper conductivity. Some firms use a continuous monitor on wrist straps which sounds an alarm when the straps are unused or the conductivity changes. Workstations should be kept clear of all unnecessary items to lessen the possibility of these items building a static charge. A topical antistat should be used on items that are necessary for the conduct of work if they are not of ESD safe materials or can not be resistively grounded.

Soldering and rework stations should be appropriately grounded. In some cases it is advisable to use an ionizer to diminish the possibility of static buildup in the area. Grounded chairs also help diminish charging at the workstation. Edge connector shorting bars also lessen the possibility of static buildup during repair/rework processes.



Conclusion

In summary, an ESD Prevention Program is absolutely necessary for any company dealing with electronic equipment. Once the program is instituted, constant compliance monitoring is necessary to keep from allowing employees from slipping back into old habits. Many companies that have instituted a strict ESD Prevention Program have seen a reduction in component related failures as high as 75%. With such a decrease in failures over the product lifetime, the investment is miniscule when compared to the cost savings long term.



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