

ESD Hazards in Semiconductor IC Handlers

Our thanks to SIMCO for allowing us to reprint the following article.

OVERVIEW

In the semiconductor manufacturing industry, damage and yield losses attributed to the effects of static charges are well documented, along with the determination of many of the specific causes¹. If ESD controls are not implemented properly, integrated circuits in handling equipment (IC handlers) can be subjected to Charged Device Model (CDM), Field Induced Model (FIM), and Machine Model (MM) ESD failure modes. This article reviews what we have found to be the most serious failure modes with such equipment – that have consequently resulted in the largest amount of documented ESD damage.



Many different manufacturing operations utilize IC handling equipment. Automatic and semi-automatic equipment with the ESD issues described in this article can include all of the following operations: isolation, singulation, epoxy operations, plating, lead inspection, lead forming, ink marking, laser marking, many types of sorting operations with pick and place capabilities, device testing (both electrical and optical), and many types of final packaging operations (trays, tape and reel, IC tubes, metal rails, etc.).

Test Sockets

Test sockets in IC handlers are commonplace throughout the industry. There are two, separate, typical failure modes that have been verified to cause device damage. First, many of these sockets can charge dramatically during movement or friction in automatic processes, during heating and cooling functions, and when contacted by operating personnel to name a few.

When the sockets have become charged, their relatively large surface area can produce fields that can cause inductive charging of the parts about to be inserted into them. The charged part can then be discharged upon contact with the socket pins (FIM failure mode).

The second potential failure mode is as follows. If the socket becomes highly charged, the resulting field can cause inductive charging of the printed circuit board wiring on the test board. A discharge can then take place

from the board to the device as it enters the socket. This second potential damage mode is actually a “mini” Machine Model (MM) failure mode. Bathing the sockets continually in ionized air during the machine operations usually eliminates both failure modes.

By far, the highest yield losses (caused by IC handlers) we have observed over the years have occurred at test sockets...and during pick and place operations via collet problems described below. (Special attention to these two areas is highly recommended!)

Pick and Place Collets

Many IC handlers have mechanical structures that move devices from one place to another in the machine via vacuum pickup collets. We have found that most machine designs in the marketplace have well-grounded metal collets for this purpose.

However, the collets can be currently supplied to the end user with a wide variety of “suction cup boots” on the tips that can create ESD problems if not addressed. Specifically, we have found insulative, conductive and static dissipative plastic/rubber materials comprising the suction cups (boots) commonly supplied on OEM equipment of this kind. The ESD implications surrounding each type of “boot” is discussed below.



- **Insulative**

Regular plastic boots can be commonly supplied with IC handler collets and can be observed to charge routinely to >10Kv (not good). (Many times, the color of an insulative boot can be black - which is identical to the conductive boots that are also available – so be careful to not make selections based strictly on appearance!) Insulative boots are notorious for causing sizeable yield loss problems. First, when the insulative boot slides across the plastic/ceramic lids/bodies of integrated circuits during pick-up and drop-off, they can charge that surface. The device leads can become charged inductively from either the charge on the body of the IC or from the insulative boot itself (or both). Typically, devices can then be dangerously discharged when they reach their target container, tray, etc.

in the inner workings of the handler. Insulative (charge generating) boots have caused clearly the most amount of damage in our experience. We have been a part of many case studies where yield improvements were realized when conductive boots were implemented to replace insulative boots.

- **Conductive**

As the conductive plastic/rubber boots mate electrically with the grounded metal collets, no charge can be found at any time on this boot in the applications (which is good). Although being conductive does not insure that it will not charge the IC's insulative body/lid during contact (grounded conductors can cause charging problems on insulators²), we have historically found very low charging onto the devices as a result of contact with the vast majority of the commercially available conductive boots. However, we have been a part of a few studies where damage has occurred from the chip being charged (from other causes) as it entered the pickup area and then discharged by the conductive boot. (It is noted here that in these cases, yield losses involved mostly bare chip handling applications – not molded, finished IC applications.) It would seem then, that static dissipative boots would be the “best of all worlds” and the ideal material for this application. However, we found that not to be the case!

- **Static Dissipative**

Unfortunately, it has been our experience that although the dissipative nature prevents the quick discharges to bare chips (as opposed to conductive materials) quite a number of the static dissipative (10⁸-9 ohms/sq.) boots tended to charge the IC body/lid quite highly during contact. The charging was certainly dramatically higher than most conductive boots, which was an unexpected finding. In fact, we have been part of studies at facilities where a) insulative boots were replaced with conductive boots and yields went up...and then b) the conductive boots were replaced by static dissipative boots (expecting even higher yields) and the yields went back down!

As a bottom line, we recommend using the conductive boots (not static dissipative) and bathing the pick-up and drop-off areas in ionized air at all times. This combination has been more effective and has produced the highest yield improvements than any other combination (in our studies).

We also note here that we have observed more than a few cases where storage bins for the replacement boots at facilities had been unknowingly filled with both

conductive and insulative types together. Visually, it was impossible to distinguish the difference between the two types. Yield losses were coming and going – from machine to machine – in a totally random manor. Imagine the difficulty for the beleaguered quality personnel in those facilities in trying to make sense of those failures! Obviously, all boots should be measured and stored carefully.

Lead Cutters/Formers

Many times we have seen CDM IC damage occur right at the point where leads of the device are either cut to size or formed in some way. A charged device can be dangerously discharged during these operations. We recommend two implementations to be safe here. First, make the cutters or lead formers out of static dissipative materials (to slow down quick discharges). Secondly, insure that the part is uncharged (via ionization typically) as it reaches the contact points at this operation.

Metal Chutes: Many people assume that grounded metal chutes and input/output packaging rails that provide passageways for IC's in handling equipment eliminates any possible ESD issues. Unfortunately, that is not the case. IC's, with plastic or ceramic bodies, can charge greatly sliding along grounded metal surfaces. We have observed charging on IC's in the thousands of volts on occasion as they travel down chutes and into rails in handlers.

A very common failure mode in many machines follows this scenario: The device's plastic body becoming charged by friction as it slides on its grounded metal chute. That in turn charges up the floating circuit leads via induction. Test sockets or lead cutters, etc., as described earlier, then discharge the charged device lead frame dangerously.

It is important to determine the charging on each particular device type that is handled by a machine, as the overall charging can be drastically different from device to device! To be safe, ionization should be used to remove charge from the device before it reaches the discharge mechanisms.

Input Bowls for Discrete Devices

Some IC handlers have metal bowls at the input that accept discrete components in bulk fashion. A vibrating mechanism aligns the parts and sends them in single file fashion into the input chute of the machine. Devices can charge significantly when vibrating in these bowls, leading to potential CDM damage in the bowl itself or later on “down the road” in the machine. Ionizers should be positioned above these bowls to bathe the parts constantly during this process.

Plastic Guards

On many IC handlers, especially those that have long chutes for devices to travel, plastic guards are employed to cover the points at which moving equipment, collets,

test sockets, etc. contact the devices. If this guard is high in charge generation, FIM ESD damage can result as the devices charge inductively underneath in the resulting field. The majority (but not all!) of these guards are originally supplied from the OEM correctly – with ESD-safe non-charge generating plastics. However, even these ESD-safe materials can age and deteriorate over time. We have witnessed some yield loss situations directly attributable to these guards becoming charge generating after a few years of service. We encourage facilities to include checks of these guards in their routine, internal ESD audit checks.

Packaging/Handling Materials

Device charging issues have also been documented with a number of types of handling materials and we include them here for completeness.

Devices can charge significantly when sliding in metal canisters in bulk form before placement into input bowls of IC handlers that dangerously discharge the parts. Again, metal canisters can and do charge up plastic/ceramic devices sliding around inside of them. In addition, the devices inside can become charged by sliding on each other as well. This is not the best of ESD container techniques.

Caution is also advised with many of the “ESD-safe” trays that are commonly used in IC handlers. For the most part, the static dissipative and conductive plastic trays are fine from a non-charging perspective. However, many of the trays with openings do not provide Faraday shielding protection and parts can become charged during transportation, storage, etc. – even when in the center of a number of trays stacked together. (This is the also the case for some of the black conductive types that people assume must be good shielding containers –

especially when trays are stacked on top of one another.) Unless testing is done that verifies the good shielding performance, we recommend very highly that these trays be transported and stored in additional Faraday shielding containers (such as static shielding bags, conductive totes with lids, etc.).

Clear, antistatic IC tubes can also lose their properties over time and cause the parts sliding inside of them to become charged. We have observed many cases of IC handlers that are using and re-using the same tubes for long periods of time. We recommend adding the IC tube tests as well to the facility’s routine, internal checks.

SUMMARY

If ESD controls are not implemented properly, integrated circuits in handling equipment (IC handlers) can be subjected to Charged Device Model (CDM), Field Induced Model (FIM), and Machine Model (MM) ESD failure modes. Some of the most common and most costly problems were presented here.

Substantial amounts of charged device model ESD damage are not only possible but are probable in semiconductor die attach operations if the necessary ESD controls are not in place. Yield losses due to CDM and MM electrical damage due to these operations can be substantial¹. Eliminating the potential risks is critical for state-of-the-art reliability and profitable operations.

REFERENCES:

1. R.J. Peirce, “CDM ESD Failure Analysis,” *Solid State Technology*, May 2007.
2. R.J. Peirce and Craig Zufelt, “Limitations of ESD Gloves and Finger Cots,” *Surface Mount Technology* (Feb. 2007)

About the Author

Roger J. Peirce is Director of Technical Services for Simco Ionization for Electronics Manufacture, an ITW Company. Previously, he provided ESD consulting services for the last 20 years to the semiconductor and electronics manufacturing community for ESD Technical Services – a consulting company he founded in 1986. Over that timeframe he provided consulting services in over 2,000 facilities. He co-founded Voyager Technologies in 1983 to design innovative ESD test equipment, and started his 13-year career at Bell Labs in Murray Hill, NJ in 1970. (rpeirce@esimco.com)

