Effective Management Of An ESD Environment In Production

Contact Information:
Vladimir Kraz
vkraz@bestesd.com
www.bestesd.com
+1-408-202-9454

Monitoring ESD Events As They Occur Is Critical To Ensure Quality

Vladimir Kraz, Credence Technologies

The traditional approach to ESD safety is concentrated mostly on individual components of a process, but not on the end result that they are supposed to achieve. ESD-conscious companies spend millions of dollars on ESD-protective measures such as static-dissipative floors, ionizers, special garments, grounding, wrist-straps, personnel training, etc. The assumption is that, if all these measures are implemented, there will no longer be an ESD problem. But, as we know all too well, this is not exactly the case. Regardless of the level of ESD protection implemented, ESD problems still persist.

How would a diligent ESD specialist in a production facility verify that his environment is ESD-safe? Many companies use their yield for such verification. However, this approach is expensive, offers no real-time information, and cannot pinpoint specific problems in the process. As such, it does not lead to proper and timely corrective measures.

So how do you effectively manage your ESD environment? How do you verify that your ESD environment is truly safe? How do you assure that your components are not exposed to ESD? How do you prove to your customers that the components and assemblies that you provide to them have not been exposed to damaging ESD?

This article outlines a results-based approach to managing an ESD environment.

The Growing Importance of ESD Management In Manufacturing

Increasing ESD sensitivity of components is a trend that we have observed in the recent years. There are several objective reasons why ESD is fast becoming an important factor in manufacturing processes:

- The geometry of integrated circuits is shrinking. It takes less energy to damage an internal trace or device in a 0.1µm IC than in a 0.25µm IC.
- High-frequency ICs cannot utilize adequate ESD protection on-chip because such protection invariably consists of low-pass filtering that slows down the rise and fall times, and limits frequency response.
- A higher number of pins increases the statistical probability of ESD damage to an IC. Large die sizes make such losses very expensive.
- Automation in IC handling means more metal-to-metal contacts and faster movement, thus increasing the probability of ESD damage.
- Magnetic heads, which are already extremely sensitive to ESD, are projected to have even higher sensitivity. In 2003, the damage level to magnetic heads is already within 1V for CDM (charged device model) or MM (machine model) discharge (Reference 1).
- Flat panels become larger while increasing their resolution. That dramatically magnifies the effect of ESD damage to even one thin-film transistor.

These trends will continue making ESD management an even more important and integral part of your manufacturing process.

The ultimate goal of an ESD program is to eliminate ESD exposure to sensitive components, or at least reduce it to safe levels. Just as with other business venues, the most efficient approach to managing your ESD environment is by the results. Simply having wrist straps and ionizers in your facility does not yet guarantee a safe ESD environment. Having factual information about your ESD environment at all times

and acting upon any problems in real time, on the other hand, provides you with assurance of ESD safety.

In most manufacturing environments, important parameters such as temperature, humidity, particle count, and others are monitored on continuous watch. The ESD environment is no different. If it is important to establish and maintain a safe ESD environment, it is no less important to have real-time and historical information about the actual status of ESD-related conditions. The only realistic way to control ESD exposure is to provide continuous monitoring of every parameter of importance, and to act upon the results.

ESD monitoring at every static-sensitive step of your manufacturing process will enable you to spend your ESD budget wisely by applying your ESD dollars where it is necessary and with the most effectiveness.

ESD Events

What constitutes ESD exposure? For device damage, it means the presence of ESD events, or discharges. For particle contamination purposes, it is static voltage.

The frequency and magnitude of ESD events is the ultimate metric of the ESD-safety of your production environment. Regardless of the level of ESD protection implemented, if you still have ESD events, something is not working. ESD events last an extremely short time, typically on the order of nanoseconds. The only residual information they leave is a damaged device. Real-time monitoring of ESD events allows you to identify those devices, provides you with a continuous assurance of ESD-safety, and alerts you to any problems as they occur.

The following properties of an ESD event are important for understanding the level of damage they may inflict:

- **Rise time.** The faster the rise time, the more damage inflicted on a device. This is because the energy supplied by an ESD event to the device cannot dissipate inside the device as quickly as it is being supplied, and thus damages the device by way of overheating. As an example, it is not uncommon for an IC to have a damage threshold of 5000V HBM (Human Body Model – relatively slow discharge with 10 or more nanoseconds rise time), and at the same time only 200V CDM (Charged Device Model – very fast discharge with sub-nanosecond rise time).
- **Peak magnitude of the event.** The higher the peak discharge current, the more damage is inflicted on the device.
- **The pulse width,** or more accurately, the "area under the curve" of the discharge. All other parameters being equal, the wider the discharge pulse, the more energy it injects into the device and the more damage it inflicts.

Figure 1 shows an ESD monitor that takes into account all of the above properties of ESD events, in addition to monitoring static voltage and ionization parameters. Shown are also typical data collected by an ESD monitor. Please note the multiple ESD events on the top line of the strip chart. Many ESD events in production are multiple. The first event is not always the strongest one. Ability to differentiate between individual ESD events and to assess their strength is another key parameter in verification of your ESD environment.

Static Voltage

Presence of static voltage in production environment indicates the possibility of particle contamination caused by static attraction and potential for occurrence of ESD events. Static voltage can be measured in two distinct ways, either the voltage on the charged object or the induced voltage.

- In those instances where static voltage can cause particle attraction, the most relevant type of monitoring is voltage on charged object. Examples would include wafer and flat panel handling. In these cases, sensor element of the static voltage monitor should be placed at fixed distance from the object in question, such as passing wafer, in order to obtain consistent repeatable readings.
- In cases where induced voltage can cause discharges, this would be the most relevant parameter to monitor. Examples of such applications would include handling of reticles and magnetic heads of disk drives. In these cases, a miniature static voltage sensor, preferably capable of monitoring ESD events as well, should be placed as close as possible to the location where the sensitive components are handled. The readings then would reflect the voltage to which these components are charged by passing charged objects.

Knowledge of static voltage alone is in no way an indication of safe ESD environment. Damaging ESD events can and do happen when there is no indication of static voltage. For example, static charges may develop extremely quickly when the two dissimilar materials are separated (i.e., an IC is lifted from its tray) and

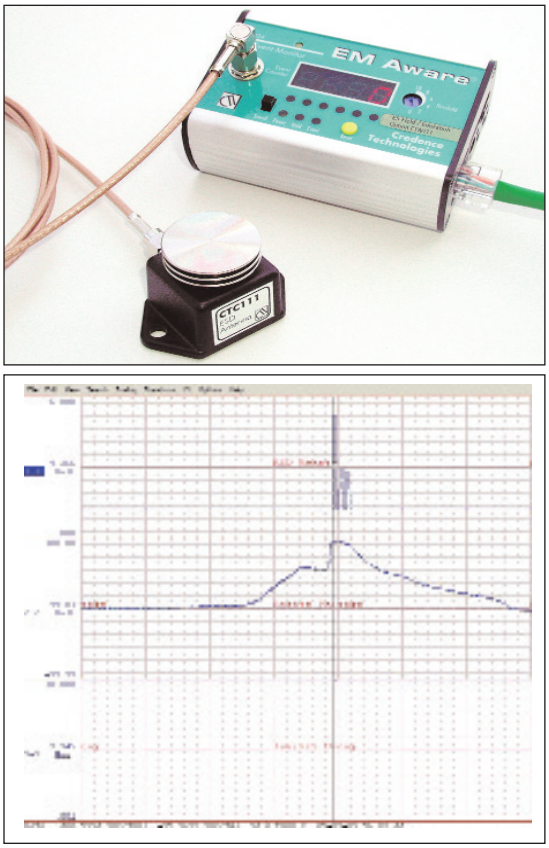

Figure 1: ESD monitor and typical collected data

immediate discharge may follow. A static voltmeter has very little chance of detecting such rapid occurrence. ESD event monitoring in these cases would be more appropriate, since it can be combined with static voltage monitoring to provide more comprehensive information for continuous verification of the ESD environment.

Data collected while monitoring static voltage exposure would help in identifying proper placement of ionizers, selection of materials used in the process and grounding needs.

Ionization Properties

Ionization is one of the key components in managing a safe ESD environment. Properly implemented, ionization offers substantial reduction in ESD exposure. However, even the best ionizer may not be effective if it is not properly installed and maintained. Some of the specific problems are:

- Poor installation: an ionizer needs to be installed in such a way that it provides adequate airflow to the area where sensitive components are being handled. Often, the ionizer installation is guided by mounting convenience rather than by the needs of the application. The end result is that the airflow doesn't reach the workplace in a proper way and the ESD safety is compromised.
- Air blockage: if there is anything that obstructs the air path between the ionizer and the workplace, it renders useless an otherwise perfectly working ionizer.
- Lack of maintenance: if the ionizer is not maintained on a regular schedule (such as cleaning and replacement of tips), it may stop functioning properly after some period of time.
- Balance (offset) fluctuations: if ionizer balance has drifted significantly, which is not a rare occurrence in production environment, it may begin to charge components within its reach rather than discharging them.

As we see, relying on the mere presence of an ionizer gives a false sense of security. Real-time information about ionizer performance may prove to be invaluable.

There are two main parameters of ionization: decay and balance. Decay (i.e., the ability to reduce electrostatic charge) is the most fundamental property of an ionizer. During the installation and periodic maintenance, decay and balance are checked with a charge plate monitor (CPM). Often, these parameters are not measured in the place where handling of sensitive components actually occurs .

As shown in Figure 2, the CPM is placed directly under the ionizer according to the existing standards, and the ionizer decay is then tested and the balance is adjusted to zero. However, in the area where sensitive components are handled, ionization parameters may differ substantially. Thus, one can have an impression of perfect ionization at the place where CPM is set for such test and in compliance with the factory standards, but receive inadequate performance where it really matters. A miniature ionization monitor placed in the component handling area would continuously validate ionization performance and alert of any failures of ionization in real time.

During normal use, the conditions may change. The ionizer can be moved, the layout of workplace can change, air flow can be blocked (either temporarily or permanently), the ionizer's emitters can get dirty or the ionizer can simply fail. Periodic checks and maintenance cannot provide the timely alarm that would prevent significant ESD exposure and associated losses. Only continuous monitoring of ionization performance in the relevant areas can assure you of proper results and provide a real-time alarm should decay fail.

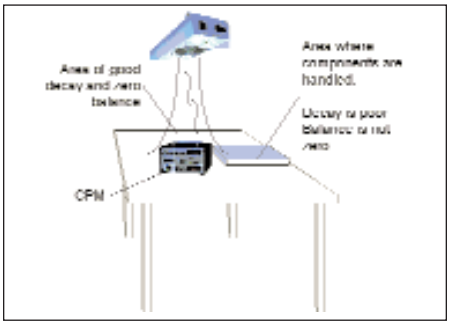

Figure 2

Ionization balance is another critical parameter of an ionizer. Properly adjusted and maintained, an ionizer provides very low offset (balance). Continuous monitoring of ionization balance will give you assurance of proper ionization balance at all times and will alert you in real time if it goes out of specification.

Other Potential Ionizer Problems

But would monitoring of just ionizer balance provide assurance of good ionization at the critical location? Well, zero balance reading may indicate any of the following:

- The ionizer is off
- The ionizer is turned away
- Air flow is blocked
- Air blows into grounded metal surface
- The ionizer is working perfectly well

Only continuous comprehensive monitoring of both the balance and the decay would provide assurance of actual status of ionization at the critical locations.

A case in point is shown in Figure 3. This is a die attach tool used at the back-end semiconductor operation. The tool removes die from the wafer (seen on the back) and places it onto a lead frame (left bottom). Discharges were observed during these two operations using ESD monitors placed in the critical locations, that is, at die separation and at die placement.

In order to alleviate the problem, an ionizer blower was installed on the right of the tool as shown. As seen, the airflow from this ionizer is directed towards grounded metal surface, which puts immediate end to ionization. Even if no metal wall was present, the airflow is not directed to the areas where the sensitive devices are being handled (such as the wafer) and where the discharges of importance may occur.

Obviously, this placement of the ionizer made no difference to ESD exposure to the dies, which was verified by monitoring the process with ESD monitors. However, when the ionizer was repositioned properly, the frequency of occurrence and magnitude of ESD events diminished substantially. If an

ionization decay monitor were positioned in the place of handling the dies (bottom left of Figure 3) from the beginning, it would have shown lack of ionization right away, prompting the manufacturer to position the ionizer properly.

Another area where knowledge of ionization parameters at all times is critical is mini-environments. Gaining access to an ionizer placed inside a mini-environment necessitates halting the process; therefore, there is natural reluctance to do periodic maintenance of the ionizer. Should the ionizer inside fail to perform within specification, wafers or other components can become highly charged, causing difficult-to-trace quality issues. A miniature, non-intrusive sensor positioned inside the mini-environment and providing output to a facility monitoring system or to an outside display would immediately alert personnel of any unacceptable deviations in the ionizer's performance.

Grounding

Grounding is the most critical component of ESD safety. Without proper grounding there can be no assurance of ESD performance.

Personnel Grounding

Wrist straps are essential in dissipating charge from operators and assuring safety of handled components. But again, mere presence of the wrist straps is no assurance of proper personnel grounding. For example, the wrist strap could be worn over a sleeve so as to produce no grounding effect whatsoever; it may not be plugged in the grounding terminal; the grounding terminal itself can be disconnected from the ground; the wrist strap may be loose and make poor or partial contact.

It would be instrumental for an ESD specialist to walk through a production area and to take notice on how many such occurrences are there. Even if the wrist strap appears to be worn properly and is plugged in correctly, the connection between human hand and the wrist strap can vary a great deal. For typical electronics assembly operation, electrical resistance between operator and the wrist strap is set to maximum of 35 Mohms. For ESD-critical processes where rapid dissipation of charges is a must, such resistance is limited typically to 10 Mohms. Operators with dry skin often have such resistance much higher than set limits.

In many factories often only periodic checks of the wrist straps are prescribed. Such periodic testing assures only that the wrist strap by itself is in order at the beginning of the workshift. It offers no assurance whatsoever that the operator actually wears it, wears it properly or plugs it in the grounded socket.

If it is important to have the operators properly grounded, it is important to assure that they are grounded properly at all times. Continuous wrist strap monitors provide such assurance. Connected to a facility monitoring system, they give supervisors comprehensive real-time and historical information on proper personnel grounding. Local alarms on the

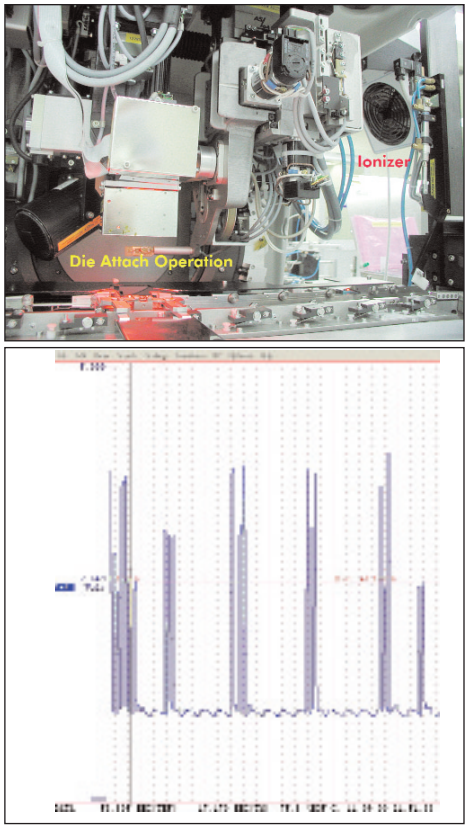

Figure 3: Die-attachment setup with poorly positioned ionizer and captured ESD event using ESD monitor

monitors can help to ensure that operators wear their wrist straps properly during the entire workshift.

Equipment Grounding

In a dynamic manufacturing environment, the quality of equipment grounding can be just as dynamic. Ground wires can be broken or loose, disconnected during maintenance and not re-connected again, and grounding terminals themselves may be disconnected from ground. In manufacturing environments where changes are made often, the probability of these occurrences is quite high. The mere presence of a grounding wire attached to a tool means nothing if this wire is not connected on the other end to proper ground. A static dissipative mat by itself provides no path to ground and no dissipation of charges if it is not grounded by itself.

Figure 4: Workstation monitor

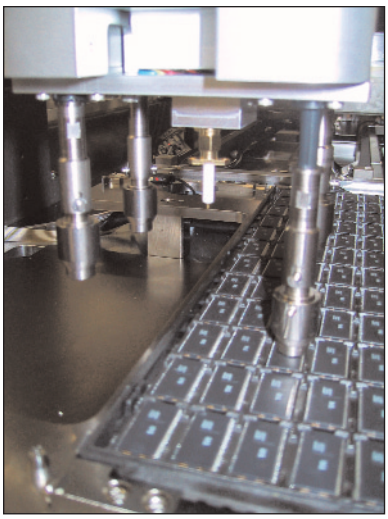

Figure 5: ESD monitor sensor in Epson NS7000 IC handler

Knowing that all equipment is properly grounded at all times is critical for continuous assurance of ESD safety, as well as for personnel safety. The following would define recommended properties of a comprehensive ground monitor:

- Continuous uninterrupted monitoring of all the parameters
- Compliance with ANSI/ESDA S.20.20
- Ability to monitor both metal grounds and static-dissipative grounds
- Low safe control voltage on all monitored objects , including dual wrist straps
- Sufficient information provided to a facility monitoring system

Figure 4 shows workstation monitor that provides simultaneous monitoring of two metal grounds, two dissipative grounds and proper ground connection of two operators in ESD-critical environment.

ESD Exposure in Tools

Automated handling introduces new challenges in controlling ESD exposure. Fast movement of the handler's robotic arms and the components, quick pick-up and placement of ICs on the pads, shuttles and in the trays, create a volatile ESD environment. Further, an IC is exposed to the dangerous levels of ESD in the IC handler ***after*** it has been tested (Reference 2). The problems associated with this are that:

- A defective IC can be shipped to a customer
- There is no feedback mechanism pinpointing the source of the failures that allows implementation of corrective actions.

Continuous ESD monitoring is now available in some IC handlers. The monitors are integrated into the operation of the handler itself. Miniature sensors are positioned on the robotic arms next to the ICs (see Figure 5) and next to the test sockets. During setup, the damage threshold for the ICs in test is entered. If an IC is exposed to an ESD event of the magnitude higher than the set threshold at any step in handling (either before, during or after the test), it is automatically placed in a separate tray for analysis and not shipped to a customer. If the frequency of occurrence of ESD events is too high, the handler can be stopped and issue an alarm for operator's intervention. This assures both the manufacturer and the customer that no IC exposed to ESD is shipped.

This method addresses another issue that plagues many of IC manufacturers, that is, latent damage when an IC still functions after ESD exposure, but fails later in actual use. In absence of hard evidence of ESD exposure, manufacturers can unknowingly ship ICs exposed to marginal ESD events, creating quality problems and poor relationship with their customers. Using continuous ESD monitoring, such ICs can be automatically put aside for further analysis. Should there be any issue with the customer regarding latent damage, all the records of ESD exposure will be available for analysis.

Conclusion

ESD issues are becoming more and more important with every advancement of technology. Assumption-based ESD management is no longer an option. A safe ESD environment cannot be guaranteed by mere inclusion of ESD-protective measures. As discussed, there can be no assurance of adequate performance without verification. A result-based approach will assure continuous ESD safety of your process, better customer relations and improved yield. ■

About The Author

Vladimir Kraz *is president of Credence Technologies. He can be reached by e-mail at vladimir@credencetech.com, or by phone at 831-459-7488.*

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Contact Information:
Vladimir Kraz
vkraz@bestesd.com
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