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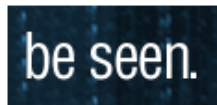
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Quantitative monitors minimize cost impact of ESD events on GMR heads

Disk Drive

by Vladimir Kraz,
Credence Technologies Inc.

No matter how much ESD protection is implemented, ESD events will still happen

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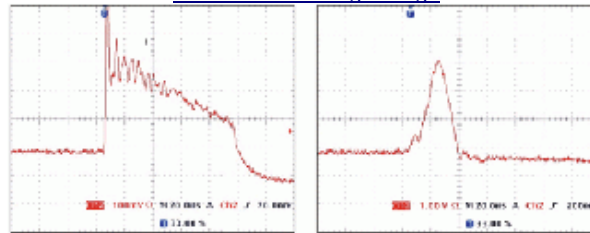


Figure 1. Comparison of currents in human body (left) and machine (right) model discharges from the same 50V. Note the difference in scale.

ESD-conscious companies spend millions of dollars on ESD-protective measures such as ionizers, static-dissipative floors and clothing, grounding, wrist-straps, static-voltage monitors and personnel training. The assumption is that if all these measures are implemented, ESD will no longer be a problem. Manufacturers of giant magnetoresistive (GMR) heads know better, however.

In contrast, ESD event monitors that generate information about when and where these inevitable ESD events have occurred provide GMR head manufacturers with measurable and clear-cut benefits. Using this information, production managers can determine where to best invest their ESD-protection dollars, correct ESD problems in real time, and correlate yield with the actual ESD environment.

In addition, workers can be made aware of what specific operation caused an ESD event and adjust their work habits accordingly.

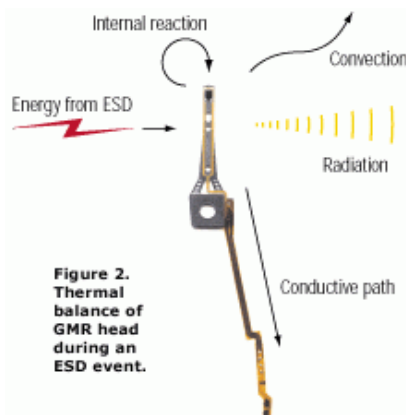


Figure 2. Thermal balance of GMR head during an ESD event.

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Properties of ESD events and physics of damage

An ESD event is a discharge of accumulated static voltage resulting in a very brief surge of current and a rapid drop of accumulated voltage on the charged surfaces. As it occurs, the ESD event generates an electromagnetic field, in essence behaving as a short-lived miniature radio station and manifesting itself very similarly to the way lightning causes "crackling" on a radio. By monitoring the unique electromagnetic signature of ESD events, it is therefore possible to know that one has occurred as well as how strong it



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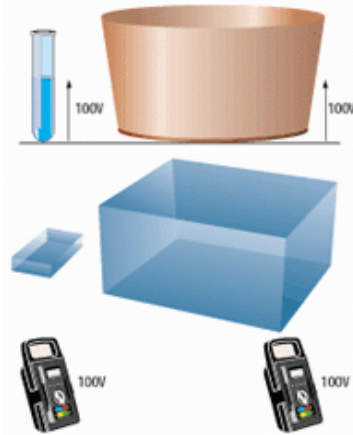
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was, the key parameter for assessment of potential damage to the heads.

There are three basic standardized models of ESD discharge: human body, machine and charge device. Although all are used to compare and assess the energy put into a GMR head, the most important factor is not which model is used but rather how much energy was injected into the GMR head during the discharge (see Figure 1).

Figure 3. The two containers, a test tube and a bucket, represent a small and large conductive object. Though both containers are filled with water to the same level (i.e. voltage) of 100V, they will clearly not produce the same effect when emptied (i.e. discharged). Similarly, if two metal objects of different size are charged to the same voltage, the larger object will contain proportionally more charge and will create an ESD event with much more energy than the smaller object.



Although the human body model has been the dominant culprit in the past, the machine model—due to increased levels of automation and the subsequently greater amount of handling of GMR heads by tools rather than hands—is gradually replacing it. Machine model discharge is also the deadliest because it infuses the most energy into the head. Although the charge device model is sometimes also considered to be a likely model for ESD events in GMR head handling, in order for this to be valid, the GMR head must be completely electrically insulated from other conductive objects. Otherwise it is actually a machine model.

GMR heads can be damaged by even the weakest of ESD discharges. In fact, the electromagnetic field generated by an ESD event occurring elsewhere, and without direct contact with the head, can cause damage. The field strength of this radiated electromagnetic emission depends on the strength of the event itself, physical configuration and the environment (antenna factor and reflections) and the distance between the discharge and the monitor.

Figure 4. The EM Aware ESD event monitor is a specialized microwave receiver tuned to specific properties of ESD events. In a 0.5-V output version (4.20mA is also available), the system generates 1V of continuous signal when it is plugged into an FMS telling it that it is present and operational. Events are indicated as pulses with magnitude of 1.25 to 5V on a logarithmic scale depending on each event's magnitude. For extremely tight spaces, the EM Aware has an optional remote antenna CTC113 (0.75" cube), and to monitor currents caused by ESD events in ground wires or power cables, a special conducted remote antenna CTC117 is available.



Certain factors are difficult, if not impossible, to take into account. For example, the longer the wires are connected to a GMR head assembly, the better the antenna and the higher the radiated emission. Another factor is the abundance of conductive cleanroom surfaces, which reflect radiated emission from ESD events and add to the inherent inaccuracy of electromagnetic field measurements.

To reach laboratory-level measurement precision, much work remains to be done, but measurements can be made with adequate accuracy for pragmatic assessment of the danger of ESD events.

Most ESD-related damage to GMR heads is actually caused by the heat resulting from the energy injected by the discharge. Figure 2 represents the thermal balance of a GMR head exposed to an ESD event. As shown, the energy from the ESD event enters the head either by direct current flow or via induction of voltage and currents. There are only three known ways for the resulting heat-energy generated to exit the GMR head: convection, radiation and conduction.

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If the energy arrives too fast and in large doses, not enough of it can escape via conventional routes soon enough and most of this energy will end up contributing to melting the head. Therefore, the power (energy/time) of the incoming energy is the most important factor in the mechanism of GMR head damage.

Why bad ESD events happen to good GMR heads

The reason that ESD events are inevitable despite all precautions comes down to the way electrostatic charges accumulate and dissipate. It takes no time at all to generate an electric charge—just separate two objects made of dissimilar materials or rub them against each other and the charge is there in an instant. Therefore, as long as anything at all moves on the production floor, electric charges will be created.

For the safety of both personnel and components, the path to the ground (including wrist straps) has high resistance (typically, 1 Megohm or higher). This resistance limits discharge current to a safe level because if the resistance is too small, a person or a component may be electrocuted or destroyed when exposed to high voltage. The high resistance to ground, however, also slows down the discharge time. Because the charges are created all the time, an ESD event is probable during the moments after the charge is created and before it is dissipated down to a safe level.

Without ionizers many static-sensitive industries would be in much worse shape than they are today. A partially conductive flow of air provides a discharge path from all the enveloped charged objects to the ground dissipating the charges. The only problem is that the resistance of ionized air is very high, and it takes a relatively long time to provide effective discharge. According to the ANSI/EOS/ESD-S3.1-1991 standard, it takes 30 seconds for a perfectly working ionizer to discharge a 6-in. x 6-in. metal plate from 1000V to 100V. So, while an ionizer is slowly dissipating charges generated during normal operations, a GMR head may be exposed to dangerous voltages.

Thus, while ESD-protective measures are aimed at dissipating charges as quickly as possible before they manifest themselves in an ESD event, no protection measure can guarantee that the environment is completely discharge-free. Instead, what needs to be known is whether the environment is safe for the GMR heads.

Static-charge monitoring

A commonly used methodology for assessing the ESD-safety of an environment is monitoring static charge. Although at first glance, this seems perfectly logical (because if there is no charge, there is no possibility for discharge), in reality, creating and maintaining a zero-charge environment is impossible. Any movement generates charges that cannot be instantly dissipated, while maintaining very low charge environments is prohibitively expensive—sometimes more expensive than the yield losses of GMR heads damaged by ESD. The real requirement is to determine which charges present a danger to the GMR heads and where to invest ESD protection dollars for the greatest return.

In production environments, charges are assessed using static field meters, however, these meters measure only the electric field produced by static voltage, which is not the only measure of how strong the resulting ESD event will be (see Figure 3). As shown, a small object carrying 100V may generate much less damage than a large one with only 20V. (Figure 2 illustrates the difference in scale for two different types of discharge from the same voltage). The equation for the charge is:

$$Q = CV$$

Where

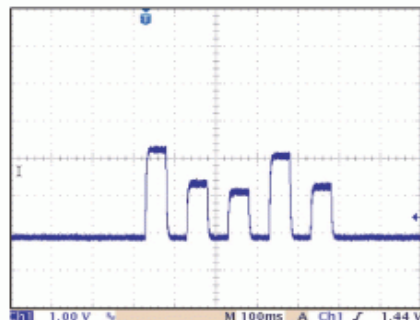
Q = charge (Coulombs)

C = capacitance of object

V = voltage

Thus, the amount of charge depends as much on the object capacitance as on voltage, and it is impossible to estimate how strong the discharge would be looking at voltage alone.

Figures 5a and 5b. (a) Each ESD event is represented at the output of EM Aware monitor as a pulse with magnitude a function of energy of each ESD event. In order to ensure that no event is missed, the monitor measures ESD events in real time, stores information in its internal memory, and then makes this data available at the much slower rate acceptable for reporting to the FMS. (b) Machine model discharge characterization



curves at different voltages. With the EM Aware monitor placed at a known distance from the GMR-head handling area, it is possible to determine the strength of each ESD event based on the pulse magnitude of the output signal.



If the static voltage is detected on an insulator, the prediction of its destructive effect is even less obvious. An insulator consists of individually charged molecules that are electrically not connected to each other. When brought to a grounded surface, only a few nearby molecules will discharge leaving the rest of the charge intact and most likely not causing any harm to a GMR head. However, charge induced by an insulator on a conductive object is difficult to differentiate from the charge on an insulator itself, and a static field meter won't be able to tell the difference.

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In many situations a charged object never comes close enough to a GMR head to generate an ESD event. Yet, if a static field meter is the only measurement tool being used, time and money may be spent fighting a non-existent threat while a real one quietly does damage without being noticed.

ESD audits, an essential part of ESD management, involve the testing of many parameters of ESD protection, including quality of ionization, resistance of static-dissipative surfaces, grounding, presence of static voltages, etc. However, while in essence an ESD audit verifies that all ESD-preventive measures work properly, it doesn't verify the occurrence of ESD events themselves, or that the environment is ESD-safe.

The ESD environment is also fragile. A ground wire may break, ground connections may loosen up, an ionizer's performance may deteriorate, different workers may have different ESD "habits" and new objects may enter the work area as part of the normal work flow. Any combination of the above can change the ESD environment and introduce dangers that weren't there during an ESD audit.

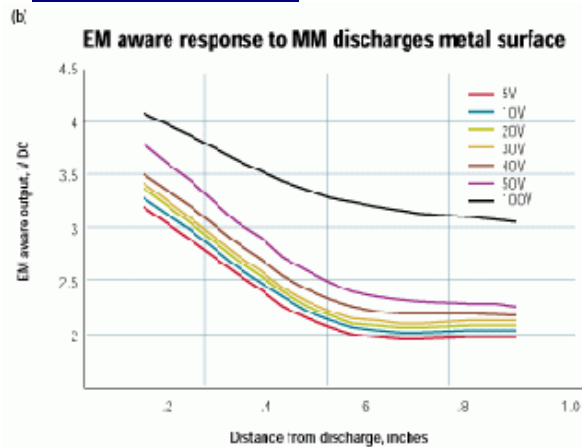
Detection and measurement of ESD events

The most practical way to catch ESD events is to monitor the unique electromagnetic signature that they generate. However, accurate measurement of specific properties of ESD events requires specialized RF/microwave equipment. For diagnostic and troubleshooting purposes, for example, ESD specialists use high-speed oscilloscopes with specialized antennae in order to capture and display the ESD events. Although this is a very effective way of identifying ESD event sources and measuring their properties, the technique cannot be used on a continuous basis, because the tools are expensive and bulky and require special training.

A more practical tool for day-to-day use is a dedicated ESD event monitor. These detectors sound an alarm whenever the magnitude of an ESD event exceeds a preset threshold, indicating both that the GMR head has been exposed to a potentially dangerous ESD event and that the ESD-protection measures do not perform adequately. Knowing this, the production manager can quickly move to recheck and discard defective GMR heads, and make corrections to the ESD environment. The shortcoming of these early systems, however, is that they give no indication of exactly how strong the ESD event was—whether just barely above the threshold or exceeding it by a large amount. Unlike parametric data, such as temperature or particle count, events cannot be shown as continuous reading. And ESD events happen very quickly, often with intervals between them measured in microseconds, which means there is no mechanism for collecting and communicating the data to the facility monitoring system (FMS).

Conclusion

Later-generation event monitors located at the workbench or process tool and specifically designed for in-process real-time monitoring of ESD events in cleanroom and other industrial environments, cannot only accurately detect ESD events, but also measure their magnitude and provide real-time communication to an FMS (see Figure 4). ESD events should be measured where they occur and an event monitor placed on each workstation will accurately tell both where the ESD event happened and how strong



it was (see Figure 5a/b). As in measuring any other physical parameter, the closer the sensor is to the area to be measured, the better the signal/noise ration and the more accurate the results.

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Vladimir Kraz is founder and president of Credence Technologies, Inc. a provider of innovative instrumentation for measurements of electromagnetic fields for EMC and ESD applications. He has Masters Degrees in electrical and mechanical engineering, both from universities in the former USSR, and holds several U.S. patents in the field of communications and instrumentation.

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