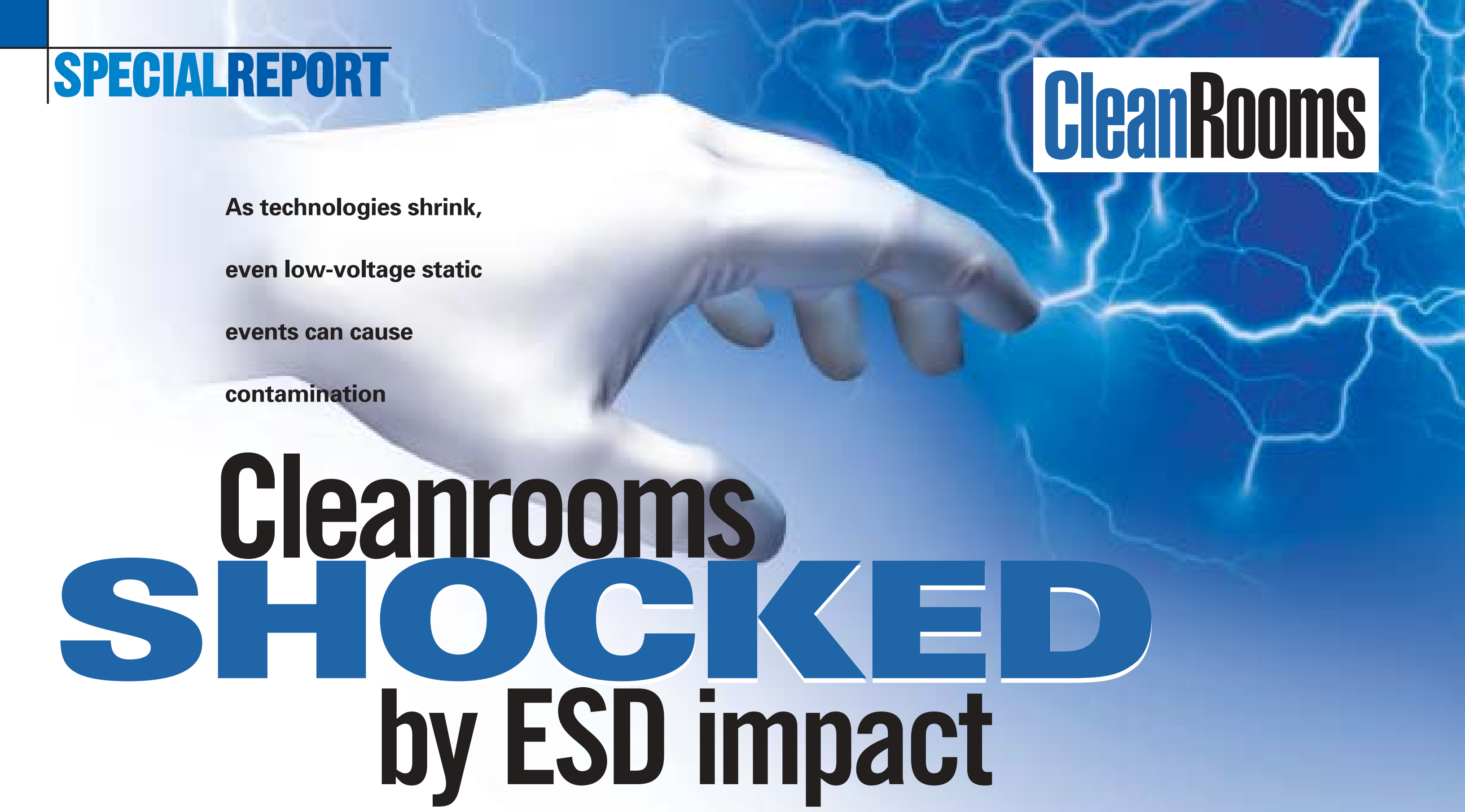
CleanRooms



**As technologies shrink, even low-voltage static events can cause contamination**

# Cleanrooms SHOCKED by ESD impact

**BY SARAH FISTER GALE**

ESD control programs are no longer optional for cleanrooms. Shrinking geometries are making delicate wafer technology even more susceptible to lower levels of electrostatic discharge (ESD), and small particles are drawn more easily to charged surfaces, which can wreak havoc on production quality and output.

There are several reasons the smaller technologies make semiconductor manufacturers more vulnerable to ESD, according to Steve Heymann, president of Novx Corporation (San Jose, Calif.; www.novx.com), supplier of ESD auditing, monitoring and training equipment. "The biggest problem is that the semiconductor industry is giving up its bullet proofing to make things smaller and faster." The oxide coating that once protected wafers has been stripped away to give the technology greater functionality and speed.

Compounding that problem is the fact that smaller device features are vulnerable to smaller particles, which are harder to eliminate. The delicate circuitry can be damaged by lower voltage ESD events, which means there is a greater chance that faulty device will end up in a finished product.

The cleanroom industry must recognize that ESD is fast becoming a serious problem and it needs to be dealt with head-on, says Arnold Steinman, a member of the Board of Directors for the ESD association and the CTO of Ion Systems (Berkeley, Calif.; www.ion.com), a manufacturer of electrostatics management products and services. "ESD causes a number of problems in cleanrooms. Just the presence of static charge is a concern—whether discharges occur or not."

The writers of the International Technology Roadmap for Semiconductors (ITRS) agree. The ITRS 2003 warns that ESD can adversely effect every phase of semiconductor manufacturing in three ways: particle contamination due to static charge; ESD causing damage to devices and photomasks; and equipment malfunctions due to electromagnetic interference (EMI) produced by ESD. It also warns that shrinking geometries increase the impact of ESD in all of these situations. Defect density targets become more difficult to attain, less energy is required in an ESD event to cause device or mask damage, and ESD events that interrupt equipment will become more frequent as equipment microprocessor operating speeds increase. The ITRS 2003 contains recommendations for semiconductor manufacturers to reduce static charge to levels that prevent static problems.

This all means that semiconductor manufacturers have to prioritize ESD control. Until now, ESD control has been a nice-to-have issue, usually falling low on the list of priorities for cleanroom assembly and maintenance. But in a matter of years ESD could have devastating consequences to yields if manufacturers fail to address the need for greater control and monitoring in their cleanrooms. "Static levels must go down as newer, smaller technologies are introduced, so it is critical that a static control program be implemented now in every semiconductor factory," he says.

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**—Arnold Steinman,** *CTO of Ion Systems*

### All static is bad static

Initially, the presence of any static will cause particle contamination on the surface of tools and wafers, says Julius Tarangan, senior technical leader and corporate ESD manager at Western Digital (San Jose, Calif.; www.wdc.com). "Even in cleanroom environments particles are impossible to completely eliminate because the very process of manufacturing creates them." As technologies shrink, the critical particle size shrinks too. Those tiny particles are harder to eliminate with filters alone and they are much more susceptible to the attractive power of even low-voltage static. "Once a surface is charged, it will draw in any particles within its field," Tarangan says.

In semiconductor manufacturing, the majority of static-related problems occurs while the product is in the minienvironment, or when it is being transferred from the minienvironment by the production equipment. If a surface within those environments is charged it will attract whatever particles are present, defeating available laminar airflow systems.

With every drop in size, cleanroom managers will face a growing dilemma of how to control static charge and particle contamination. "You can't get rid of the particles so you need to eliminate the static charge," Steinman says.

Depending on what the particles are made of and where they land, the effect could be harmless or it could have destructive consequences. If the particle lands on a non-critical part of a product or tool it may have no effect, he says, but even a tiny particle on the wrong place of an exposed wafer surface can result in a device defect. If a wafer has 200 separate devices, one particle on one device reduces the yeild for the wafer by 0.5 percent. But the "wafer" in flat panel display manufacturing is a large sheet of glass that may only have four displays on it. Suddenly one tiny particle in the wrong place has a huge impact, reducing yield by 25 percent. "You could lose a lot of money from a single particle," Steinman says.

And that's before the static even discharges. A discharge, or ESD event has a completely different set of consequences for cleanrooms.

### Shocking events wreak havoc

An ESD event is the rapid, spontaneous transfer of electrostatic charge induced by an electrostatic field, usually occurring between objects at different electrostatic potentials. The resulting current produces radio waves that interfere with equipment operation, causing microprocessor lock-ups, corrupting memory, or changing the data being analyzed. "Equipment lockup is often misdiagnosed as a software or hardware problem, when ESD-induced EMI may be the true culprit," Steinman says. Because EMI is both radiated and conducted from the site of its occurrence, the ESD event may not be happening in the equipment experiencing the problem. This makes the event especially difficult to locate, reducing equipment availability and product throughput.

Even though the level of static charge may be too small to be noticed by personnel, a discharge can instantly melt metal lines or silicon, break through oxide layers or cause other damage. ESD events can damage production tools as well as cause random defects in products. ESD can damage features of photomasks used to "print" the patterns on wafers. These photomask defects are then patterned onto multiple wafers. And unlike the disk drive industry, where an ESD event causes immediate notable product failures, with wafers the ESD event can result in latent failures that don't immediately impact functionality, Heymann warns. "It doesn't kill, it wounds." When that happens, products can make it all the way through the production process and quality checks only to fail six months later at the client site, which costs even more money and destroys customer confidence.

Again, shrinking geometries have a direct correlation to the increasing effect of ESD events because lower-level charges can blow out the smaller circuit features.

Every reduction in size increases susceptibility to lower voltage levels, Heymann says. "Two years ago, some wafers could withstand 1500 volts without incidence." Today the SEMI E78 Standard for Electrostatic Compatibility suggests that the semiconductor industry strive to keep static charge below 100 volts, and by 2009 the expected recommendation is 25 volts.

"To put that in perspective," Tarangan says, "the average volt a person gets after they walk on carpet then touch a doorknob is 4000 volts."

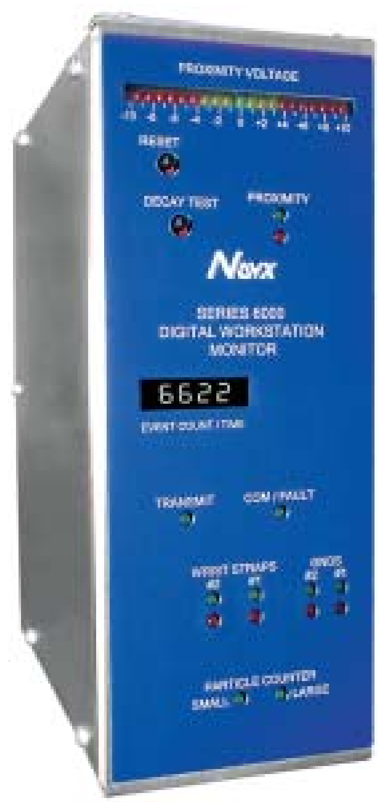
The E78 standard is intended to educate manufacturers about the impact on productivity caused by static charge in semiconductor manufacturing environments, and to guide them to solutions. The original standard was published in 1998, updated in 2002 and is in the process of being rewritten again this year. The frequent updates are intended to keep up with the growing impact of ESD on the semiconductor industry and to tie the E78 publication in with the release of ITRS updates every two years.

### The great ESD event of 1995

In the next ten years, it is not unlikely to assume that no amount of static charge will be tolerable in cleanrooms. That is already the case in the disk drive industry, and experts agree that semiconductor manufacturers can learn a valuable lesson from the disk drive industry's historic and painful battle with ESD.

Unlike wafer makers who can watch the incremental effects of static discharge with each reduction of product size and adjust their ESD efforts accordingly, disk drive makers were blindsided by its effect in 1995. Before then, disk drive heads could withstand 500 to 1000 volts of discharge with little impact to their functionality. ESD was a non-issue for that industry, until the introduction of magneto-resistive (MR) heads into mass production in 1995. The MR head was a seemingly revolutionary advance because it allowed much higher areal densities to be used on the platters than was possible with older head designs, greatly increasing the storage capacity and the speed of the drive. Because the MR head was not generating a current directly the way standard heads did, it was several times more sensitive to magnetic flux changes in the media, allowing the use of weaker written signals, which let the bits be spaced closer together without interfering with each other, improving capacity by a large amount.

What the disk drive manufacturers didn't realize was that the new MR heads were at much greater risk of damage to even the smallest ESD event. They were completely unprepared to handle the new technology's sensitivity to ESD—which dropped from 1000 volts to less than 20 volts. The result was cata-




**The microprocessor-based Series 6000 digital workstation notifies the user of any ESD occurrence that goes above a specfic threshold. (Photo courtesy: Novx Corp., San Jose, Calif.)**

strophic. Companies bankrupted, stock prices fell and in some cases yields dropped by 90 percent. The chaos was traced back to ESD and suddenly everyone in the industry was scrambling to understand what static discharge was, and more importantly how to control it. There were no standards in place at the time requiring static control to such low levels, and few ESD experts existed to help guide the industry toward solutions.

"It was a race against time to find the best way to neutralize sources of ESD," Tarangan says. There were few products on the market to handle the problem, and a crop of new companies quickly appeared, offering brand new products, such as ionizers, specialized grounding strips and ESD monitors in an attempt to eliminate all static charge from the manufacturing environment. "We were the guinea pigs for these products," Tarangan says of the disk drive industry. "We needed to make sure there were zero volts at all times and figure out a way to monitor for changes."

### It ain't just a river in Egypt

Today you wouldn't dream of building a disk drive manufacturing facility without building ideal ESD control conditions into the specs for the building and establishing strict ESD control methods. All disk drive manufacturers have comprehensive ESD control programs in place that include extensive grounding, ionizers to neutralize the charge on all insulated and isolated surfaces, sensors that sit near the equipment to monitor for static fields, and alarm systems that go off if static builds up in the area or a person or piece of equipment loses grounding.

In the semiconductor industry, however, some people still consider ESD control an optional issue of yield improvement, not a necessity for market viability. "The semiconductor industry is still very early in the education curve of understanding what's happening," Heymann says. "They are still in denial."

But that attitude is beginning to change. The ITRS and E78 standard are educating manufacturers and guiding them toward stricter methods of control and monitoring. At the same time end users are working closely with tool manufacturers, putting a lot of pressure on them to build ESD control features into their products, including ionizers, monitors and the use of static dissipative materials within the tool enclosures, says Chris Long, senior engineer responsible for ESD and contamination control in the microelectronics division of IBM (Burlington, Vt.; www.ibm.com) and the cochairman of the ITRS. "We are starting to push pretty hard for suppliers to meet our ESD specifications." Most of the suppliers don't have a problem with their demands, and Long predicts that within a year including ESD controls in semiconductor tools will be standard operations procedures for all manufacturers. "We aren't taking our eyes off ESD," he says. "As you go down the technology curve, it will become a life or death situation for the semiconductor industry. Without ESD control, the smaller technology nodes and smaller particles will kill you."

"The good news is that battling ESD is not rocket science, it's just basic physics," says Bert Stephens, an engineer at KLA-Tencor (Milpitas, Calif.; www.kla-tencor.com), a yield management and process control solutions provider. You need a sound ESD program that includes proper grounding, the use of static dissipative materials, ionization and ESD monitoring.

That's beginning to happen as more manufacturers are attempting to manage ESD events through stricter control guidelines, Heymann says. "Over the last two years, ESD has had a greater impact on yields across the industry, and yield impact is the only catalyst for encouraging greater ESD controls."

Fortunately today there are many tool and equipment manufacturers that specialize in ESD monitors, grounding equipment, ionizers and ESD control services for cleanrooms. The ESD association (www.esda.org) offers an extensive buyers guide with links to dozens of providers of the tools required to build a comprehensive ESD control program.

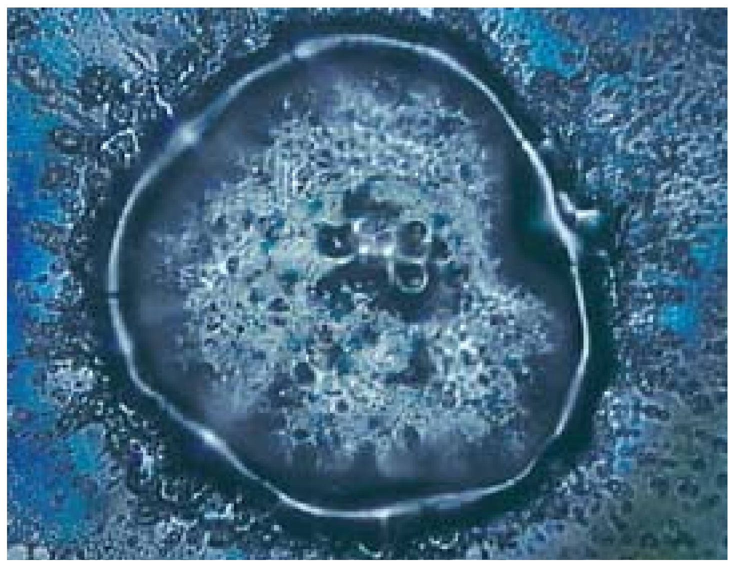
### Grounding, ionizers, monitors and training

Beginning in the cleanroom environment, grounding is the first step. Everything ranging from floating floors and tables, to equipment and personnel needs to be properly grounded to reduce the risk of static build up. Stationary employees rely on wrist straps, whereas mobile workers require heel grounders and static dissipative materials in their shoes.

Many companies, including Static Solutions (Marlboro, Mass.; www.staticsolutions.com) 3M (Minneapolis, Minn; www.3m.com), and Desco Industries (Chino, Calif.; www.desco.com) offer everything from specially grounded carts and containers, to floor mats, shoe and clothing grounders, wrist straps, flexible packaging and grounded workstations, all designed for the cleanroom environments. However, grounding is not a complete solution, Stephens warns. "If you depend on grounding to mitigate ESD, it won't work, because few perfect grounding systems exist."

Even in a cleanroom environment built with ESD grounding in mind, workstations get moved or come unscrewed, conductors aren't grounded properly, and insulating materials, such as Teflon, glass and plastic cannot be grounded, making it difficult to eliminate static from those tools and pieces of equipment.

To complement the grounding, you need ionizers to eliminate the charge that accumulates on insulated and isolated surfaces in cleanrooms. You can't prevent static build up even under the best circumstances, so the alternative is to eliminate it when it occurs, Long says. "It's a basic block and tackle approach."



Damage to a magneto-resistive head due to ESD.

Ionizers eliminate static by supplying positive and negative charges into the air, which neutralize surfaces where static has collected. When the ionized air comes in contact with a charged insulating surface, the charged surface attracts air ions of the opposite polarity. As a result, the static charge on the insulator is neutralized. Air ions of both polarities are required for neutralization, because both polarities of static charge are present in manufacturing areas.

Ionizers can neutralize down to one volt, or even zero, if necessary and provide added support to areas where grounding alone won't suffice. Ionizers are placed on the ceiling wherever laminar airflow occurs, and one ceiling ionizer will cover roughly 40 square feet of a room. Ionizers can be placed on or above work surfaces, built into production equipment or part of handheld blowoff guns or nozzles. Ion Systems, Desco, Simco and other manufacturers offer a variety of ionizers for cleanrooms use.

To round out the ESD control program equipment, you need event monitors to alert staff when grounding systems aren't working or charges build up on critical surfaces. Monitors are placed as close to equipment as possible, usually within 10 inches, and are set to go off if a static field builds up on or near the surface.

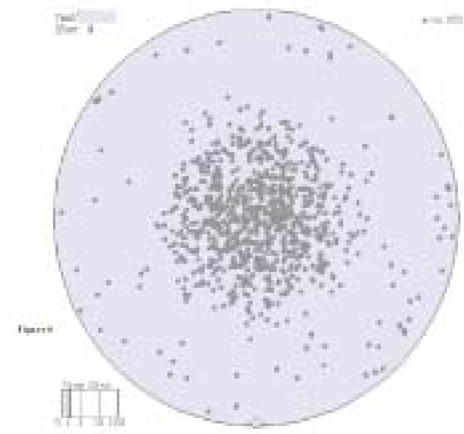
**Product damage caused by ESD.**

ESD event monitors generate information about when and where ESD events occur providing cleanroom staff with real-time information so they can correct ESD issues with minimal impact to yield. The ongoing data also helps the manufacturer track ESD occurrences so it can identify where to focus its ESD efforts and dollars, and correlate yield with the actual ESD environment. Workers also can see how their behavior in the environment affects ESD events and adjust their work habits accordingly.

Along with ESD monitoring and grounding equipment, manufacturers need to make better equipment and tool choices to reduce the chance of ESD in cleanrooms.

Static dissipative materials need to be used whenever possible to replace traditional insulative materials in cleanrooms. Static dissipative materials drain charges at a controlled rate and attract less particle contamination to surfaces than an insulative material because the dissipative material does not accumulate charges on its surface (Triboelectric Generation). For example, Nippon Fusso, a fluoropolymer coating manufacturer, based in Japan (www.nipponfusso.com), markets an anti-ESD coating for hard anodizing. The coating formula has anti-electrostatic properties to reduce the chance of triboelectric static charge build up.

Besides producers like Nippon Fusso, many equipment manufacturers are making better choices with regard to ESD in their tools, from putting ionizers in minienvironments to using static-dissipative materials in place of plastic for windows. "But you have to ask for it," Heymann says. "Demand from customers is the only thing that will drive tool makers to adjust their products to meet the ESD standards."



**Surfscan of contaminated wafer.**

And finally you need comprehensive ESD training for employees. All the ESD equipment and monitoring in the world won't solve your problems if people don't use it correctly. Employees need training on how to properly use grounding tools, how to respond to monitors, and more importantly what will happen if they don't. That learning curve needs to be conquered before ESD becomes an issue for yield.

#### Warning: time is running out

Solving ESD is not a big deal, but not solving it is," Steinman cautions. As geometries shrink and ESD susceptibility drops, they will have a steadily increasing effect on yields for semiconductor manufacturers. And, ESD programs can't be accomplished in a few days. They take time to implement.

"The sooner you start the better off you will be," Tarangan says. "You can't just drop these products in, you need to perfect them within your environment." He encourages manufacturers to start ESD control programs a year in advance of their projected needs. "Otherwise," he says, "you'll get caught with your pants down, like we did."