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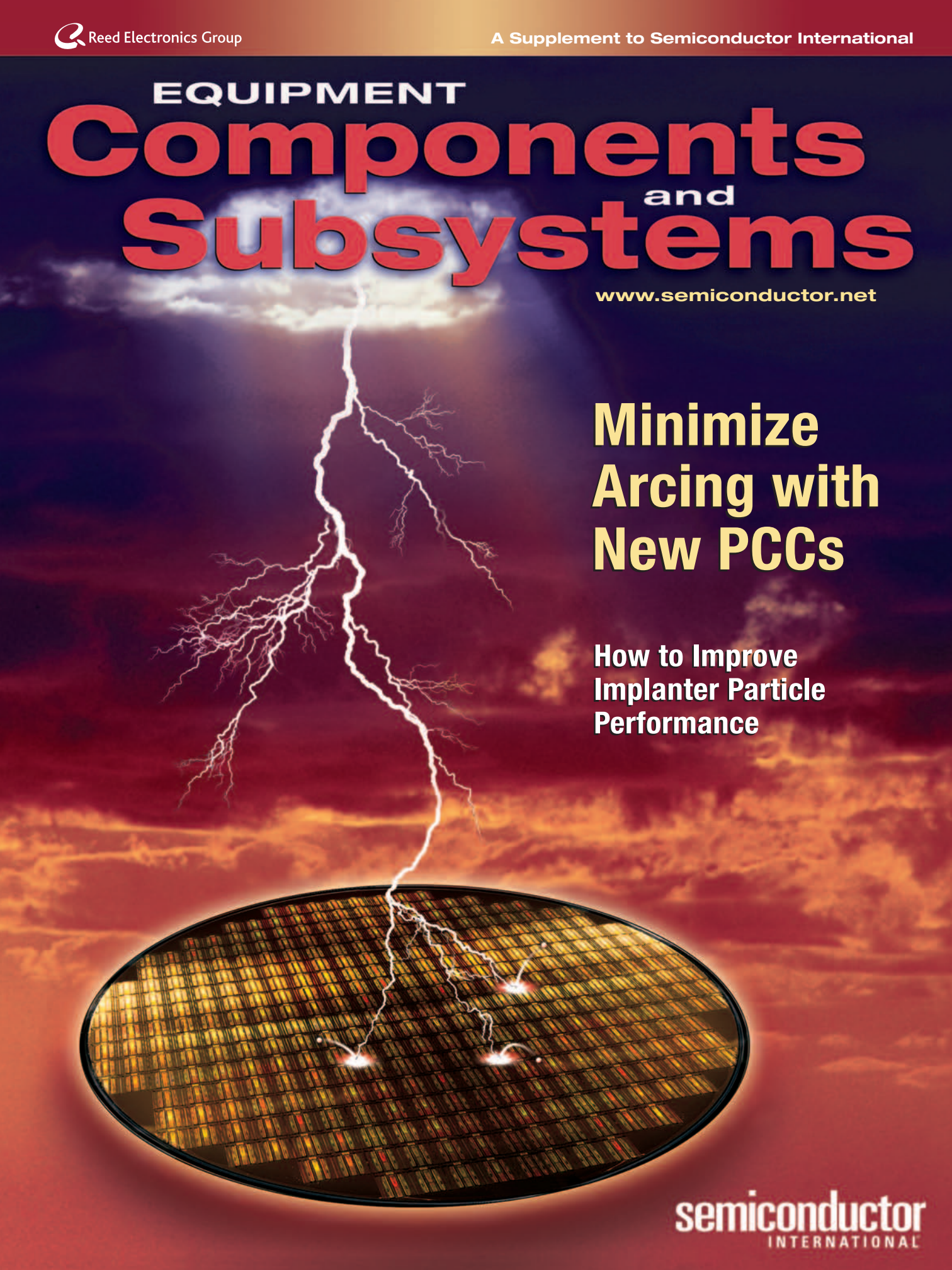

Minimize Arcing with New PCCs

How to Improve Implanter Particle Performance

semiconductor INTERNATIONAL

Power Conversion and Control

Reduces CoO and Improves Yield

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AT A GLANCE

New DC power control and conversion equipment can prevent arcing, a serious yield concern, while providing faster response times that improve uniformity.

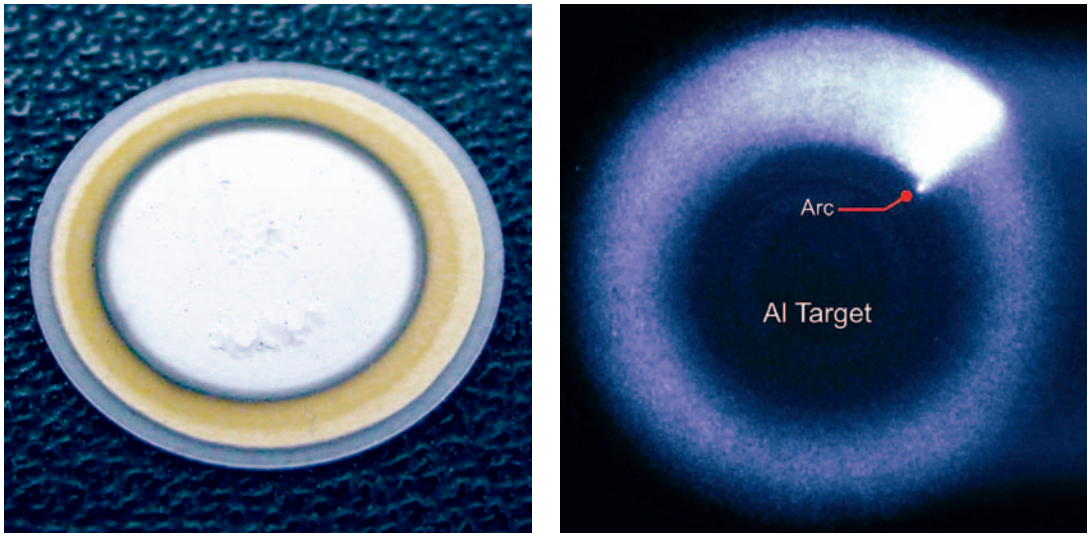
It's tough being a capital equipment manufacturer these days. Your customers want you to deliver the latest processes, geared for ever-smaller geometries, in less time — and they want you to invest more in the development process. At the same time, they want the tools to have faster throughput, higher yields, greater reliability and lower operating costs, for a low total cost of ownership (CoO). They also want them with built-in expandability and capable of handling a wider range of processes. Oh yes, and they always want to pay the lowest price possible.

The global market makes the business even more challenging. It's not enough to deliver the lowest CoO. Your process systems have to be able to operate in different regions around the globe, with varying voltages, reliability and quality of electrical power, as well as quality and availability of water.

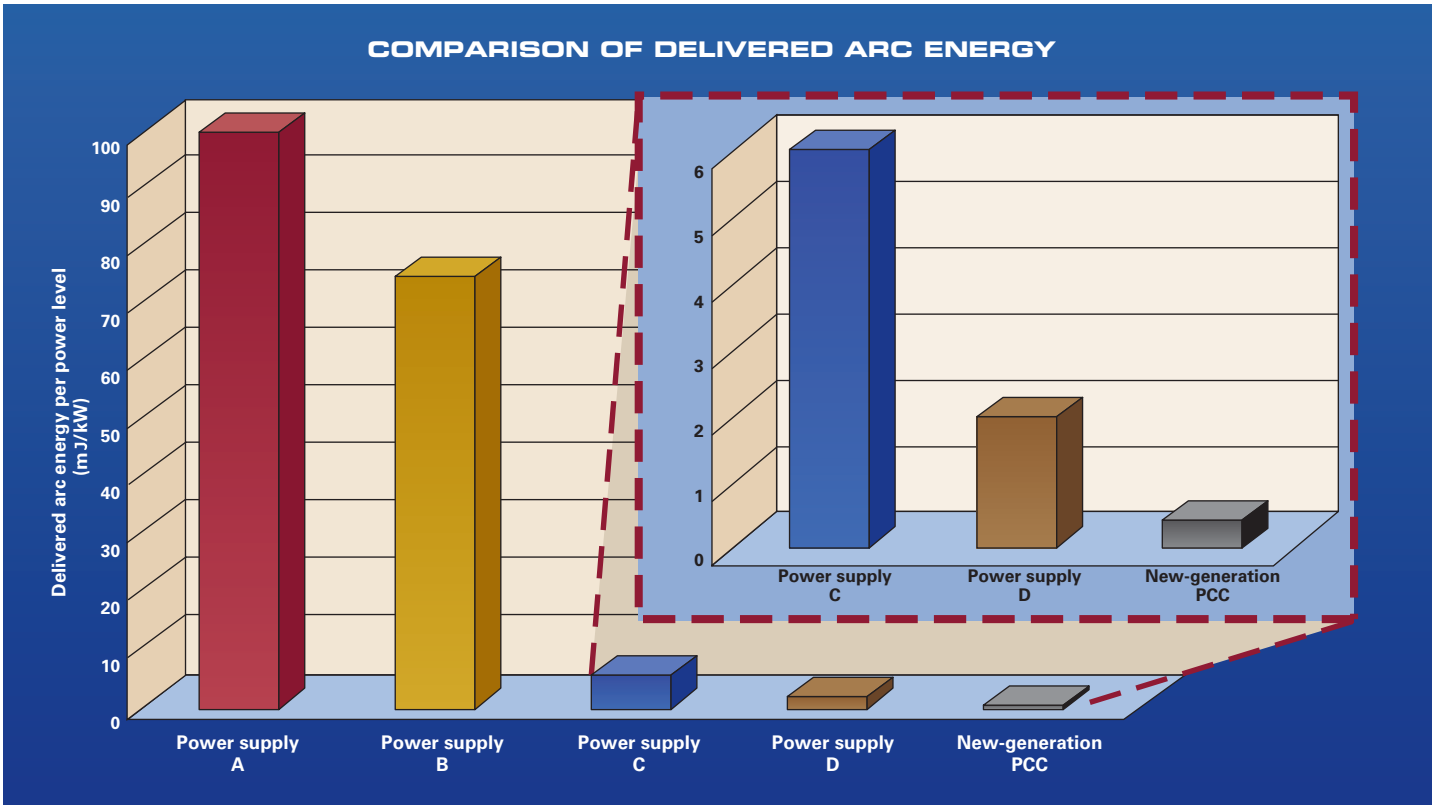
The situation is complicated by today's economic environment in which process toolmakers are faced with shrinking R&D budgets, making it even more challenging to keep pace with technological demands. With steadily shrinking design cycles, it is increasingly critical to be able to quickly move new process tools out of the lab and into a production environment.

It's not a surprise, then, that reducing CoO is a real competitive advantage, or that process tool manufacturers are always on the lookout for ways to reduce the CoO on their products. A new generation of DC power conversion and control equipment (PCC), capable of providing a "global" range of power for plasma-based process tools, offers equipment manufacturers opportunities to reduce system CoO by reducing system and operating costs, increasing yields and improving reliability.

To deliver on their promise of global power, this new generation of PCC needs to provide an unprecedented level of fast arc handling to maximize yields with the multi-process flexibility of delivering full power across a wide 300-1300 VDC voltage range, thereby providing very high current for low-impedance processes. Seamless installation with the varying voltage inputs found in North



1. Substrate arc damage, such as the meteor defects shown on the left, is a major yield concern. Arcing from the plasma to the substrate is shown in progress on the right.



America, Europe and the Asia-Pacific region eases integration concerns, and with a power factor greater than 0.94, an operational efficiency of greater than 90%, and a design capable of storing input energy (required to ensure a reliable power source in case of "brownouts"), advanced PCC contributes positively to the fab management. Finally, possession of flexible communication protocols allow easy transition from the lab to production environments.

PCC with the requisite voltage input and output ranges offers the process tool manufacturer a power delivery solution for all his plasma-based tools, regardless of process requirements or the global region for which they are intended. In doing so, they enable tool manufacturers to simplify system design by eliminating the requirement for separate power supplies for systems intended for different geographical regions. This, in turn, allows them to reduce their component inventories. Simplifying design and reducing component inventories both reduce system costs, thereby helping increase a tool manufacturer's competitive advantage two ways: first, by enabling a reduction in the price of its process tools, and second, by delivering considerable advantages to the customer purchasing the tools.

Fab benefits

Fabs that purchase tools using this new-generation PCC will gain considerable benefits in terms of reduced total CoO for the tool because of simplified material management, reduced operating costs, increased yields and improved reliability.

Simplified materials management — Materials management is simplified in a couple of ways. Increased process flexibility can reduce the number of different types of process tools required in a fab, thereby simplifying spares procurement and inventory management. The fab also ends up needing fewer types of power supplies. In addition, this greater process flexibility translates into increased fab efficiency since it allows the fab manager to more easily switch manufacturing focus, as required by market pressures to maximize profitability.

This greater process flexibility translates into increased fab efficiency.

Reduced operating costs — The high power factor and power efficiencies delivered by this new generation of PCC further helps to increase profitability by reducing tool operating costs. As most fab managers know all too well, power companies tend to add expensive surcharges when a fab induces power factors much below 0.90. In some cases, pre-

2. A comparison of arc energy delivered by power supplies and new-generation power conversion and control equipment.

Arcing, of course, is the single largest factor to consider when discussing yield-reducing process damage.

vious-generation power supplies offered power factors as low as 0.70, 25% less than the 0.94 power factor available from new-generation PCC. A greater than 0.94 power factor offers considerable savings when it comes time to pay a fab's utility bills — a savings that can help increase overall profitability.

Higher power utilization efficiencies — Greater than 90% with the new-generation PCC, this helps to further reduce operating costs by reducing the amount of "waste" power that must be dissipated as heat through fab cooling systems. Lowering the demand on the cooling system again translates into a lower utility bill. In addition, with their higher efficiencies, this new PCC can be air, rather than water, cooled. This, in turn, simplifies system installation, further lowering operating costs by reducing the need for water circulation and purification systems in the fab. Eliminating the need for water cooling can also help free up valuable fab real estate.

Increasing power factor and efficiency also allows a fab to facilitize with smaller gauged cabling and smaller breakers and switches. When you consider the miles of cabling and the hundreds of breakers and switches used in a fab, the potential savings becomes very clear.

Increased yields — New-generation PCC helps increase yields by delivering a higher level of run-to-run uniformity, superior arc management, and improved power stability, as well as very precise and repeatable turn-on/turn-off process timing.

Arcing, of course, is the single largest factor to consider when discussing yield-reducing process damage. An arc is a high current-density discharge that can occur during the powered plasma process. It is characterized by thermionic emissions on the surface of the electrode, substrate or chamber walls that reach sufficiently high temperatures to thermally liberate electrons. Typically, arcs last between a fraction of a microsecond to several milliseconds, although it is possible to create continuously burning arcs. This phenomenon often results in lost yields, and can potentially damage the processing equipment. The new PCC minimizes the effects of arcing events across multiple processes by offering flexible arc management controls. For example, micro-arc shutdown times of 5-25 µsec, hard-arc shutdown times of 30 µsec to 40 msec, and arc detection threshold levels of 20-400 VDC. In addition, advanced PCC can deliver as little as one-quarter the arc energy delivered by previous-generation, industry-standard power supplies (0.3 mJ/kW vs. 2 mJ/kW). These capabilities prevent substrate damage in the form of "meteors" on the film surface, thereby enabling higher yields.

Figure 1 shows meteor defects on a substrate caused by arcing, and an arc in progress. Figure 2 compares arc energy delivered by PCC and older-generation power supplies.

In addition, the most advanced of the new PCC offers an optional configurable feature that helps to reduce arc damage, thereby further enabling higher yields. This feature enables synchronous arc handling in multiple-cathode systems, where a mosaic pattern of cathodes is used to provide power to the plasma. In such cases, there is a danger that an arc from one cathode could continue to draw energy from surrounding cathodes after the arcing cathode is shut down. When an arc occurs, this feature shuts down not just the offending cathode, but those surrounding it to prevent the arc from continuing to draw energy. Enabling multiple target operation in a single chamber provides uniformity across large area substrates, while optimizing overall target costs. At the same time, the advanced PCC offers a master/slave option configuration that allows the end user to run a single large target at significantly higher power levels if that offers superior performance for a particular process.

The most advanced of the new PCC offers an optional configurable feature that helps to reduce arc damage.

Run-to-run uniformity often relies on very precise and repeatable turn-on/turn-off timing to control the metal sputtering process. Failure to carefully control this process caused by the complex operating system's communication latency can result in non-linear deposition rates that can negatively impact yields. Since they are connected directly to the plasma, a power supply can minimize the latency issues that result when the system controller is used to control power delivery. New-generation PCC offers the capability to count down the actual energy (in watt-seconds or joules) that should be delivered to the chamber, accounting for such factors as arc events, power ramping algorithms and other process variations. Once the countdown is completed, the PCC turns off the power on its own.

In general, it takes ~15 minutes to replace a new-generation PCC module, as opposed to the two hours it would likely require to replace an entire non-modular power supply.

This "energy-delivered countdown timer" — known as joule mode — can be updated every 1 msec. The PCC remains aware of what happened the millisecond before, maintaining full accountability. As a result, each process run — given the accuracy of the measurement system — has exactly the same amount of delivered energy, resulting in highly uniform run-to-run deposition. This feature is of particular benefit to those processes intended to deposit extremely thin films.

Improved reliability — In order to enhance reliability, companies delivering new-generation PCC have made significant investments in new analytical software and testing, as well as implementing accelerated life testing and environment stress screening to raise the bar on field reliability. In addition, to reduce system downtime, the most advanced new-generation PCC should incorporate a

modular design that facilitates routine maintenance and minimizes downtime in the unlikely event of a power supply issue. Such modular designs, combined with proper training of fab maintenance personnel, would allow on-site fab workers to quickly change out modules as required, without depending on the arrival of the tool manufacturer's support personnel, to return a tool to operation. In general, it takes ~15 minutes to replace a new-generation PCC module, as opposed to the two hours it would likely require to replace an entire non-modular power supply.

Conclusion

The new generation of PCC offers the semiconductor — or any other industry with metal sputtering applications — considerable total CoO benefits. They can accommodate any level or quality of power available in the world, providing the industry with the first class of truly "global" power supplies. Their wide range of power results in increased process-to-process flexibility. In addition, the benefits offered by this PCC increase system reliability, reduce fab and tool operating costs, and simplify materials maintenance. Perhaps most importantly, the equipment can improve run-to-run process uniformity and minimize defects for increased yields. •

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