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### A silver lining using graffiti technology

A new machine sprays front side contacts onto cells

Until now, silver front contacts and bus bars have been applied to solar cells with screen printing. Although the process is considered reliable, as cells become thinner the danger of breakage increases. US-based company Optomec now offers an alternative: its machine sprays silver stripes onto the silicon like an inkjet printer. It's not only gentler than screen printing, but it also increases cell efficiency.

Marketing people sometimes tend to exaggerate. According to Mike O'Reilly, Optomec's new product is »rocket fuel« for the PV industry. The next few years will show whether this contention holds or not. But from a technical perspective, there is some truth in O'Reilly's statement: like a rocket, the printing unit, which was introduced to the public for the first time by US company Optomec at the European PV conference in Milan, uses a series of jet nozzles. Stefan Glunz, head of the silicon solar cell department at the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, believes that someday this device could replace the common screen printing process used for producing solar cells – and therefore eliminate a significant cause of broken wafers in cell production. Indeed, the thinner the silicon wafers, the less they can withstand pressure from the squeegee inside a screen printing machine, which presses silver paste through a screen onto the cell surface to form contacts and bus bars on the silicon. Furthermore, the contacts applied during screen printing have a sponge-like texture when viewed under an electron microscope – and, consequently, have poor electrical qualities.

Research institutes all over the world are working at full speed to find a contact-free method to replace conventional screen printing. The nozzles in Optomec's Aerosol Jet Deposition System may be the solution. The jets function according to a principle similar to inkjet printing: a series of 79 nozzles float inside the machine just 3 mm above the delicate cell surface and spray a fine stream of tiny metal particles onto the cells. Without even

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touching the cells, which are being transported beneath the nozzles, a pattern made up of nearly 40  $\mu\text{m}$  thick silver lines is deposited on the cell's front. Later, these lines will become the horizontal contact. Then, two slightly larger nozzles spray 1.5 mm wide bus bars onto the silicon. When the pattern on the front is complete, it's burned into the cell in a firing furnace. This process, which diffuses the thin silver layer into the silicon, is the same as with traditional screen printing. But unlike screen printing, the particle layer that remains is barely conductive. For this reason, in a second step, called Light Induced Plating, silver is deposited on the seed layer. This causes the bus bars to grow to a width of 70  $\mu\text{m}$ , which is only half as wide as bus bars applied in screen printing. Yet, the bus bars are 15  $\mu\text{m}$  high, which is significantly thicker than screen printed bus bars. Furthermore, jet-deposited contacts only block about 4.5 percent of the cell surface area compared to 6.5 percent with screen printing. At least that's the conclusion drawn by ISE, where the system has undergone thorough testing for the last 18 months. Finally, the contacts don't look much like a sponge under magnification, but rather like solid metal. All of this means that jet-deposited front side contacts have a significantly lower resistance than their antiquated counterparts produced with a screen printer. This can be easily demonstrated, as tests conducted by Glunz and his colleagues at ISE have shown: with multicrystalline cells, efficiency rose on average from 15.5 to 16.2 percent. The scientists also achieved higher efficiencies with monocrystalline wafers: in Milan, Matthias Hörteis from ISE presented efficiencies up to 18.3 percent with monocrystalline standard cells.

The printing speed of the machine, which Optomec has christened the M3D (Maskless Mesoscale Material Deposition), is comparable with the speeds of common screen printing machinery. It takes around three seconds to deposit one wafer, says Optomec manager O'Reilly. In the future, that time could be cut in half to about 1.5 seconds. That means the machine could deposit contacts on 2,400 wafers per hour, which would put the machine in the same league as the high-power screen printing machines produced by world market leader Baccini SpA.

Q-Cells AG, which until now purchased its printing machines from Baccini, seems to have some faith in Optomec's technology. Not only has the Thalheim-based company participated in the testing at ISE, but according to reports, it plans to install a pilot line using the nearly \$600,000 to \$700,000 device in the coming year. That will make Q-Cells the first cell manufacturer worldwide to use this technology.

The machine was not specially developed for PV applications. Originally, it was designed to print electronic circuits, says O'Reilly. Printing circuits also requires the application of aerosols in very thin streams. For PV applications, Optomec adapted the aerosol to common silver paste. This

paste is diluted in a tank inside the machine and then transformed into an aerosol, using a gasification method, by a stream of nitrogen. This mixture travels through a pathway to the nozzles, where a second gas stream concentrates it into a thin jet (see graph, p. 105). Moreover, the carrier gas prevents the silver ink from sticking to the nozzles. That's one significant advantage over inkjet printing, which has been considered a potential candidate for cell front side electroplating for some time. Inkjet printing has yet to prove a viable solution for cell contacts, since the nozzle heads have a tendency to clog.

ISE researcher Glunz doesn't feel it's too much of a disadvantage that cell manufacturers using this system will need to conduct some form of electroplating as well: the industry is increasingly using these types of processes to optimize the contact conductivity in larger cells.

This technology also has a certain charm, since there's still plenty of room for improvement. For instance, the nozzles can be adjusted to spray lines that are thinner than 20  $\mu\text{m}$  – that would further reduce cell shadowing. Or, instead of silver particles, the machine could spray tungsten or copper, which might even improve connection to the cells, says Glunz. After all, the electroplating bath reduces waste of expensive silver paste, since it can use considerably less expensive silver bullion bars.

Nevertheless, the process has at least one big disadvantage: the cell backside is printed with aluminum using conventional screen printing, admits O'Reilly. »Sometime in the future« that might change, he notes. When that happens, we'll really have an idea of what this rocket spray jet can do. Christoph Podewils

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Is this what »rocket fuel« looks like?: US-based company Optomec believes its machine will revolutionize the printing processes used in solar cell production.

The system's print head: It's easy to see all 79 of the nozzles that spray the silver aerosol onto the cells.

It takes some effort to spray semi-fluid silver paste onto silicon: In one tank, the paste is thinned significantly. Using a gasification process, the paste is

turned into a fog with a nitrogen stream so that only small droplets are transported to the print head. At that point, a special device in the nozzle ensures the aerosol is heavily concentrated with the help of a second gas stream – or focussing gas – before it reaches the cell. On the one hand, this prevents the nozzles from clogging; on the other, it allows the machine to spray very fine lines.

PHOTON International 2007-11 November, page 103

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