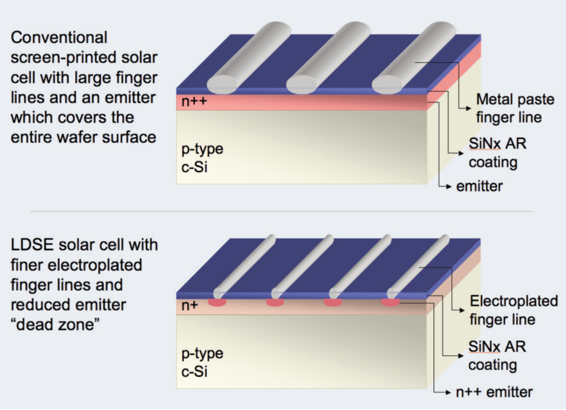
Laser-Doped Selective Emitters (LDSE) With a Green CW Laser

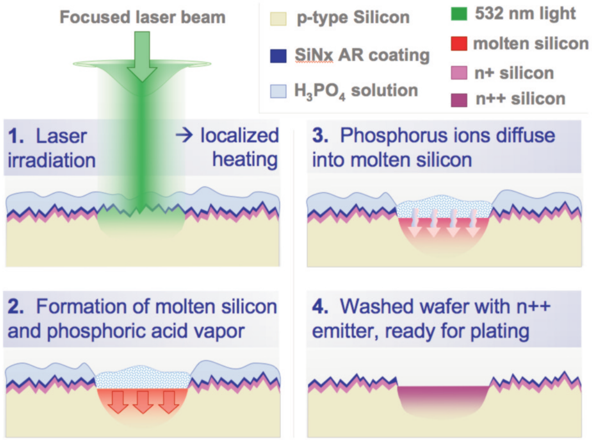
Crystalline-Silicon (c-Si) solar cells continue to be a leader amongst the various competing solar cell technologies. Reasons for this include stable supply of silicon, well-developed manufacturing processes, and, of course, the high and growing conversion efficiencies that can be achieved. Here, we report on Laser Doped Selective Emitters (LDSE) – a relatively straightforward, laser-based manufacturing process that has been shown to generate absolute cell efficiency gains of 1–2% over conventional cells.

A conventional p-type wafer c-Si solar cell has a thin but heavily-doped n^{++} region of silicon on the front surface. This region, generated via high-temperature phosphorus gas furnace diffusion, forms a p-n junction, directing current flow into a grid pattern of thin conducting strips on the cell surface. These are referred to as finger lines, and consist of a metallic paste material that is screen printed onto the cell surface and subsequently “baked-in” at high-temperature, creating electrical contacts to the heavily-doped n^{++} emitter region of the cell.



Basic differences between conventional screen-printed and LDSE/electroplated solar cell architecture

Several aspects of this conventional design place limits on cell performance: the screen printed finger lines are somewhat wide and tall, resulting in shadowing of incoming light; also, the n++ emitter region covering the entire cell front surface means reduced photovoltaic action for blue light that is absorbed closer to the wafer’s surface; and finally, there are several high-temperature process steps which can increase damage to the crystal structure.



Gaussian machining (top) and flattop machining (bottom) microscope image and 3D depth profile trace

In partnership with the ARC Photovoltaic Centre of Excellence at the University of New South Wales in Sydney, Australia, we have used LDSE processing combined with a light-induced plating (LIP) metallization technique to improve cell efficiency. Using Spectra-Physics’ Millennia® Prime™ 15 W, 532 nm CW laser, the result has been the fabrication of high-efficiency solar cells with minimal impact to the overall cell processing line and with fewer high-temperature steps.

By scanning the focused laser beam over the areas to be metalized, localized heavy doping regions in silicon are formed. Then, during the light-induced plating step, metal atoms in solution plate only on the doped regions, in what amounts to a self-aligning metallization process. The localized doping results in less “dead” area on the cell; and the shorter, narrower finger lines reduce losses due to shadowing of the incoming light.

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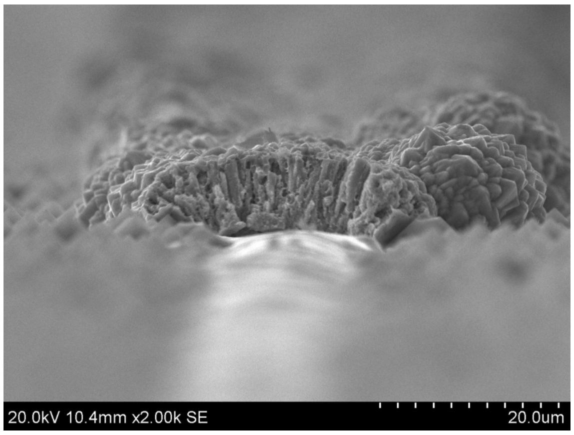
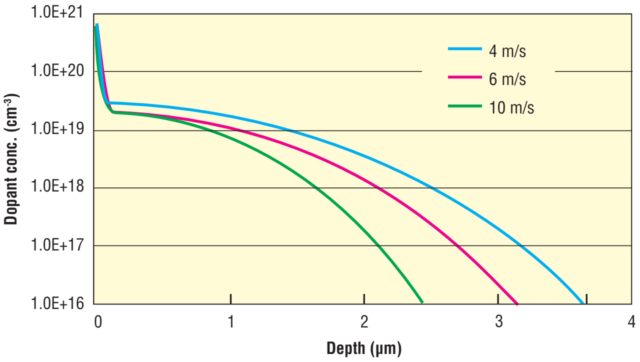
Various studies[1,2] have been conducted aimed at characterizing the performance of solar cells after LDSE processing with the Millennia laser. Data tabulated below show cell performance when processed at various beam scanning speeds:

Scan Speed	V_{oc}	J_{sc}	**FF**	**n**
0.5 m/sec	635 mV	37.4 mA/cm^2	78%	18.5%
2 m/sec	634 mV	37.4 mA/cm^2	78%	18.5%
6 m/sec	631 mV	37.6 mA/cm^2	77%	18.1%

While the best-performing cells are achieved at scan speeds of 2 m/sec and below, even the 6 m/sec scan speed resulted in good performance. For a 125 mm solar cell, 2 m/sec scan speed results in 10–12 seconds per wafer processing time; whereas the time for a 6 m/sec scan speed is in the 3–5 second range.



SEM image showing cross-sectional perspective of nickel-copper plated LDSE finger line. Image courtesy of UNSW.



SIMS data plot illustrating dopant concentration below the wafer surface for various LDSE scan speeds

With slower scan speeds, there is increased dopant diffusion deeper into the silicon wafer; whereas faster scan speeds result in shallower doping depths. Controlling the laser power can also control the strength and depth of the doping. Hence, depending on other aspects of the solar cell design, the dopant profile (and therefore junction depth) can be easily fine-tuned for optimal cell performance, which is a powerful tool to have both in the laboratory and on the production floor.

While there are various competing laser technologies for the LDSE process, Millennia Prime 532 nm CW lasers has established a proven track record of generating high-efficiency solar cells. And considering the high reliability of the laser, it is the perfect tool for the manufacture of next generation high-efficiency crystalline silicon solar cells.

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[1] *A. Sugianto et. al., Proc. 35th IEEE PVSC (2010)*

[2] *B. Tjahjono et. al., Proc. 25th EU PVSEC, (2010)*

Product: Millenia Prime

The Spectra-Physics Millennia® Prime™ laser is an excellent tool for LDSE processing. It offers high CW output power (15 W) at the 532 nm wavelength with excellent beam quality, which is important for maximizing the intensity at the workpiece. Furthermore, the stable, reliable, and robust performance of the laser are well suited for exceeding the demands of today's high-volume, high-yield, and high-uptime manufacturing environments.

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