Silicon Ink for High-Efficiency Solar Cells Captures a Share of the Market

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Liquid silicon has arrived. With it comes a power boost for solar cells and dramatic cost savings for cell manufacturers.

R&D 100 2011

Innovalight invented Silicon Ink. NREL guided its path to optimal use in solar cells. This partnership tells a compelling story of how to shorten the timeline from development of a new product to commercialization.

Silicon Ink is a nanotechnology-based product that dramatically improves both the cost and conversion efficiency of silicon solar cells in the manufacturing environment. With the ink, one manufacturing step is added using a solar industry standard screen printer, which produces an immediate increase in solar cell efficiency.

In the highly competitive world of solar cell production, efficiency improvements are generally measured by tenths of a percentage point. Silicon Ink improves the sunlight-to-electricity conversion efficiency of monocrystalline solar cells by 1% or more absolute, which equates to a 6% improvement based on a starting cell efficiency of 17.5%. Depositing the ink adds only one low-cost step to an existing solar cell production line.

The use of Silicon Ink can transform a 35-megawatt (MW) production line into a 37-MW line. This additional output generates additional revenue for cell manufacturers. Given that the technology solution comes at a very low marginal cost, cell manufacturers can improve profitability by as much as 20%.

Manufacturers have reached a limit in the conversion efficiency, or output power, of silicon solar cells using current production methods. This new product from Innovalight is the only commercially available solution that provides a simple upgrade to produce higher-power-output solar cells at lower costs. Five of the world's leading solar cell producers have signed licenses to use Silicon Ink in their production lines.

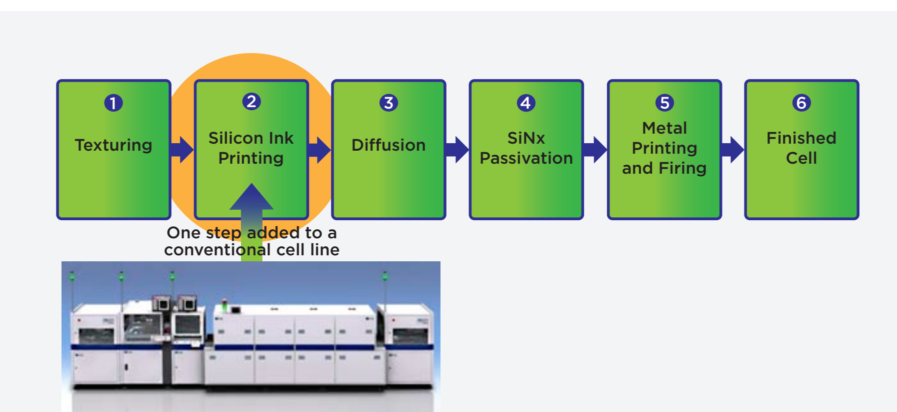
About 15 gigawatts of solar cells were produced worldwide in 2010. To continue to grow this market, solar cell manufacturers must continue to upgrade their products, reduce their costs, and improve their profitability.

The Breakthrough Moment

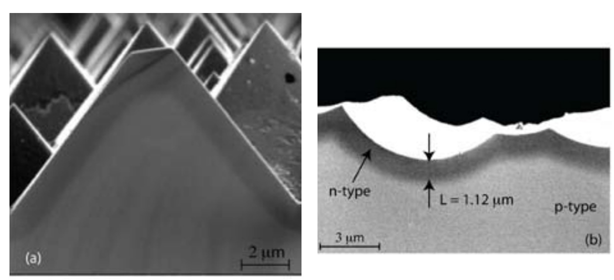
Prior to the invention of Silicon Ink, silicon had been provisioned in manufacturing in only two ways—as a solid or a gas. Many entities had tried and failed to turn silicon into a liquid that could be printed onto surfaces. Innovalight has done just that. The company developed a completely new form of silicon through an innovative research and development undertaking spanning several years. After the invention came the questions: How does a small start-up company such as Innovalight validate this product? And how can it be applied to solar cells?

This is where the world-leading scientific expertise and research laboratories at NREL became of paramount importance. In work that spanned 4 years, Innovalight and NREL joined efforts in the "proof of concept" phase of developing Silicon Ink for optimal use with solar cells.

This was done in two ways: (1) under a PV Incubator subcontract funded by the U.S. Department of Energy (DOE) and NREL; and (2) within an Innovalight/NREL cooperative research and development agreement (CRADA). The latter included significant support from NREL internal scientists and interactions between NREL and Innovalight staff.



The Silicon Ink printing step uses a readily available commercial screen printer that meshes neatly and without disruption into an existing solar cell production line.



These NREL-produced scanning electron micrographs show the dopant contrast of (a) pyramid and (b) iso-textured wafers; high uniform doping from the Silicon Ink printing process was verified.

This involved scientists within NREL's Measurements and Characterization group measuring the cell's performance after Innovalight had modified a parameter such as the deposition technique; determining whether the change was beneficial or detrimental to the cell's performance; and establishing why that was the case. Others from NREL performed materials characterization; they studied the cell's structure on many levels and suggested approaches that led to improvement.

Under the CRADA, NREL scientists confirmed that the Silicon Ink technology demonstrated controlled localized doping of selective emitter structures. Both secondary ion mass spectrometry and scanning capacitance microscopy revealed abrupt lateral dopant profiles at ink-printed boundaries. Uniform doping of isosurfaces and pyramidal surfaces was verified using scanning electron microscopy dopant-contrast imaging.

During 2010, Innovalight completed the final phase of its NREL PV Incubator subcontract, demonstrating both 17%-efficient multicrystalline and 18.5%-efficient monocrystalline production silicon cells. Typical silicon solar cells today have conversion efficiencies of about 16%–17.5%, with multicrystalline cells at the low end of the range. Innovalight's achievement represents significant progress in the advancement of its unique Silicon Ink technology as an application in the production of high-efficiency solar cells.

The product fills an unmet need in the marketplace by assisting solar cell manufacturers who are under pressure to lower production costs. Competition is cutthroat—and that's good, because competition lowers prices to the consumer.

This innovation is a marriage of a unique semiconductor material, Silicon Ink, developed and manufactured by Innovalight, and a simple process to produce high-efficiency solar cells. NREL, home to the world's leading solar scientists and research facilities, validated the proof of concept.

Upgrading the Cell's Spectral Response

Innovalight's Silicon Ink and process is a selective emitter technology—meaning that it improves the spectral response, and therefore the efficiency, of a solar cell. Selective emitter cell architectures have long been proposed as the next evolutionary step toward improving the efficiency of standard screen-printed silicon cells. Separating the field region from the metal contact region, a selective emitter configuration allows a lighter emitter doping in the vast majority of the front surface of the solar cell, which reduces front-surface recombination and enhances blue response, while confining the heavily doped regions necessary for low contact resistance to relatively small surface areas immediately below the metal contacts. A strong blue response (i.e., the cell's responsiveness to the short-wavelength, high-energy portion of the solar spectrum) is indicative of a high-quality solar cell. Because this blue light is absorbed very close to the cell's surface, excessive recombination of the charge carriers at the front surface will diminish the blue response. The metal contact region also provides isolation from the field region, which tends to enhance open-circuit voltage.

Innovalight has patented and commercialized a novel method for forming a high-efficiency selective emitter on a silicon wafer using one low-cost step. By depositing the doped Silicon Ink in a pattern configuration slightly wider than the subsequently deposited front metal contact grid, a solar cell with both a lightly doped field region and a highly doped metal contact region is formed in a single step, making this one of the most economically competitive solar cell manufacturing methods in the industry.

For More Information

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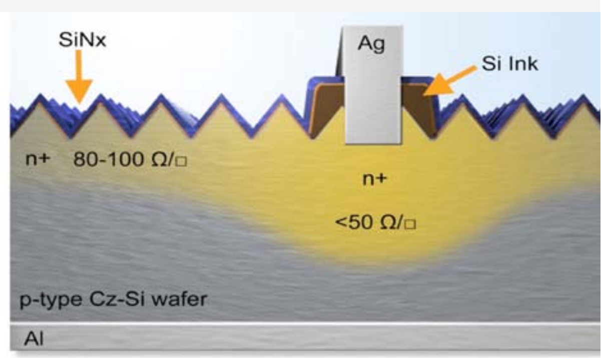

Cross-section view (drawing not to scale) of a crystalline silicon cell showing the precise application of Silicon Ink. The metal contact region (in gray) is lightly doped to minimize charge recombination; the electric field (in yellow) is heavily doped to minimize contact resistance.

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