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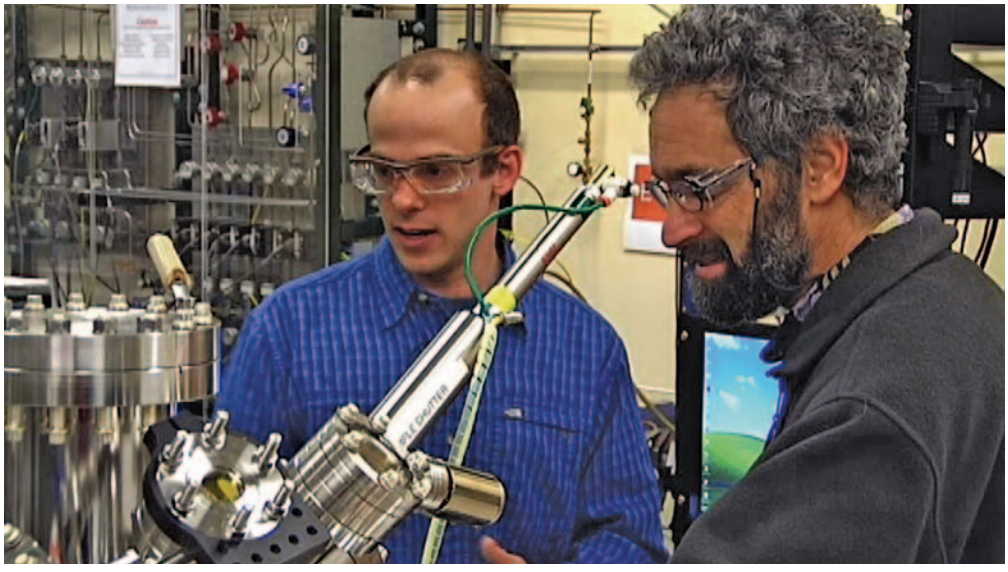
NREL Advances a Unique Crystalline Silicon Solar Cell

A deposition process developed at the National Renewable Energy Laboratory (NREL) is a key technology for creating a new type of solar cell: a film-based cell consisting of a layer of highly aligned crystalline silicon (c-Si) deposited on a flexible metal substrate. The process could marry the best features of c-Si solar cells and thin-film solar cells, resulting in efficient and inexpensive solar modules that are also flexible and lightweight.

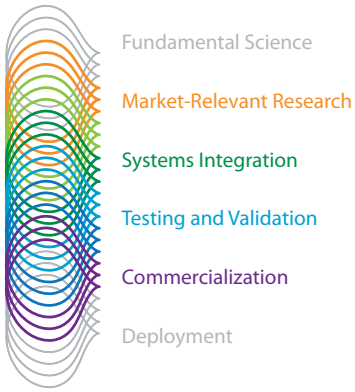
Most solar cells sold today are made of c-Si, usually formed by sawing large crystals or ingots of silicon into wafers, which are thick, rigid, and brittle. Competing with c-Si solar cells are newer thin-film solar technologies that can be deposited on flexible substrates and are less expensive than c-Si, but tend to achieve lower solar conversion efficiencies—that is, they convert less of the sunlight hitting them into electricity.

However, a startup company called Ampulse Corporation has a vision for a new type of c-Si solar cell: one grown in thin layers on flexible metal substrates. Both the metal substrate and the c-Si film are biaxially textured, that is, they consist of large crystalline grains lined up nearly perfectly, so they behave similar to a single crystal. The approach is expected to yield a new film-based solar cell that has the efficiency of conventional c-Si solar cells, along with the lower cost and flexibility offered by thin-film solar cells. NREL's hot-wire chemical vapor deposition (CVD) technology provides a critical technical contribution to the creation of this innovative solar cell.



NREL scientists Chaz Teplin and Howard Branz work with a hot-wire chemical vapor deposition system to grow silicon films for Ampulse Corporation. *Photo by Tom McDonald, NREL/PIX 17432*

The Spectrum of Clean Energy Innovation



Through deep technical expertise and an unmatched breadth of capabilities, NREL leads an integrated approach across the spectrum of renewable energy innovation. From scientific discovery to accelerating market deployment, NREL works in partnership with private industry to drive the transformation of our nation's energy systems.

This case study illustrates NREL's innovations in Market-Relevant Research through Commercialization.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

The Ampulse story actually begins at another of the U.S. Department of Energy (DOE) national laboratories, namely Oak Ridge National Laboratory (ORNL). Researchers at ORNL were struggling to create thin, biaxially textured films of superconducting material for the fabrication of superconducting wires.

They found that a biaxially textured metal foil was an ideal substrate, because the crystal structure of the foil guided the crystal growth of the superconductor. But the metal interacted with the superconducting material, so the ORNL researchers added a buffer layer to the textured metal that still allowed the texture to guide the crystal growth. The resulting technology is called RABiTS, for "rolling-assisted biaxially textured substrates."

Ampulse was formed to see if ORNL's RABiTS technology could be applied to solar cells by depositing silicon onto the flexible RABiTS foil. Because NREL researchers had unique expertise in depositing c-Si layers using hot-wire CVD technology, Ampulse aimed to draw on the technical expertise at both ORNL and NREL to create a new type of c-Si solar cell. NREL researchers had been exploring the deposition of biaxially textured silicon onto materials similar to the RABiTS foil and brought that experience to the Ampulse project.

Hot-wire CVD technology employs a metal filament that is typically heated to around 2,000°C. Silane gas is introduced to the chamber and the hot filament decomposes the gas, allowing silicon layers to deposit onto the substrate. NREL has optimized the hot-wire CVD process to grow c-Si on test wafers of silicon and is now working with Ampulse to adapt the technology for metal-foil substrates with buffers developed at ORNL.

Because Ampulse was started as a company with very low overhead (see sidebar), nearly all of its initial funding went toward research efforts at ORNL and NREL, carried out through Cooperative Research and Development Agreements (CRADAs), including a $500,000 CRADA with NREL. Ampulse also received a total of $900,000 from DOE's Technology Commercialization and Deployment Funds at NREL and ORNL. Thus far, the research and development effort is paying off, with NREL and Ampulse teams collaborating to produce working biaxially textured c-Si solar cells using the RABiTS technology.

The arrangement also provides additional benefits to Ampulse. For instance, Ampulse has ordered a process development tool for film-based c-Si solar cells that will soon be installed in NREL's Process Development and Integration Laboratory (PDIL), allowing the company's research to benefit from a range of equipment already installed there. The PDIL offers unique process development and integration capabilities for solar cells, allowing researchers from NREL, the solar industry, and universities to fabricate and study a wide range of solar cell technologies. The new tool will assist with the research and development and prototype production of the Ampulse solar cell, and it will also serve as a small-scale production platform, helping to bridge the gap between the development effort and the scale-up to full commercial manufacturing.

As Ampulse continues to grow as a company, NREL continues to support the company's research efforts in silicon deposition. Ampulse plans to use roll-to-roll technology—similar to the high-speed presses used for newspapers—to produce its flexible, lightweight solar cells in a range of thicknesses. Because thicker silicon can capture more sunlight, Ampulse expects the final products to have solar conversion efficiencies ranging from 12% to 20%, depending on the silicon thickness and cell architecture.

Ampulse Corporation: A New Model for Technology Transfer

The creation of Ampulse Corporation involved unique relationships among the managers of NREL and ORNL and two venture capital funds, and it could serve as a model for future technology transfer efforts.

Both national laboratories are managed and operated in part by Battelle Memorial Institute: ORNL is managed by a partnership between Battelle and the University of Tennessee, and NREL is managed by the Alliance for Sustainable Energy, LLC, which is equally owned and governed by Battelle and MRIGlobal.

Battelle, in turn, is the sole limited partner in Battelle Ventures, a venture capital firm focused largely on the intellectual property generated at the national laboratories that Battelle manages or co-manages. And Battelle Ventures has an affiliate fund, Innovation Valley Partners, which is based in Tennessee and backed by business leaders in eastern Tennessee.

Because of the two funds' relationship with ORNL and their familiarity with the RABiTS technology, Ampulse received $2 million in seed funding from Innovation Valley Partners and Battelle Ventures in early 2008. The company in its early phase operated with very low overhead, so a large part of its initial funding went toward research at the two national laboratories. Meanwhile, a group of strategic consultants worked to advance Ampulse's technology and its business and market models.

By July of 2008, having judged the technology concepts and business model worthy of a commercialization effort, Ampulse established its headquarters in Golden, Colorado, near NREL. The company now has nine employees and six full-time consultants, as well as a board of directors and technical advisory team. Ampulse continues to make progress in raising further venture capital and equipment financing while advancing the development of its solar cell technology.

National Renewable Energy Laboratory

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