technology review
Published by MIT

March/April 2012

MAGAZINE: FEATURE

Alta Devices: Finding a Solar Solution

Looking to enter a highly competitive solar market, Alta Devices hopes to use a combination of technological advances and manufacturing savvy to succeed where many others have crashed and burned.

By David Rotman

Figure 1Suited up: CEO Christopher Norris holds a gallium arsenide wafer used in making Alta's solar cells. Behind him is a custom-designed reactor used to grow thin layers of the semiconductor. Credit: Gabriela Hasbun

Alta Devices is a small but well-funded startup located in the same nondescript Silicon Valley office building that once served as the headquarters for Solyndra, the infamous solar company that went bankrupt last year after burning through hundreds of millions of dollars in public and venture investments. Whether the location has bad karma is still not clear, jokes Alta's CEO, Christopher Norris. But Norris, a former semiconductor-industry executive and venture capitalist, does know that the fate of his company will hinge on its ability to navigate the risky and expensive process of scaling up its novel technology, which he believes could produce power at a price competitive with fossil-fuel plants and far more cheaply than today's solar modules.

On a table in Alta's conference room, Norris lays out samples of the company's solar cells, flexible black patches encapsulated in clear plastic. They look unremarkable, but that's because the key ingredient is all but invisible: microscopically thin sheets of gallium arsenide. The semiconductor is so good at absorbing sunlight and turning it into electricity that one of Alta's devices, containing an active layer of gallium arsenide only a couple of micrometers thick, recently set a record for photovoltaic efficiency. But gallium arsenide is also extremely expensive to use in solar cells, and thin films of it tend to be fragile and difficult to fabricate. In fact, Alta's innovations lie not in choosing the material—the semiconductor has been used in solar cells on satellites and spacecraft for decades—but in figuring out how to turn it into solar modules cheap enough to be practical for most applications.

The company, which was founded in 2007, is based on the work of two of the world's leading academic researchers in photonic materials. One of them, Eli Yablonovitch, now a professor of electrical engineering at the University of California, Berkeley, developed and patented a technique for creating ultrathin films of gallium arsenide in the 1980s, when he worked at Bell Communications Research. The other, Harry Atwater, a professor of applied physics and materials science at Caltech, is a pioneer in the use of microstructures and nanostructures to improve materials' ability to trap light and convert it into electricity. Andy Rappaport, a venture capitalist at August Capital, teamed up with the two scientists to found Alta, recruiting fellow Silicon Valley veteran Bill Joy as an investor and, with the other cofounders, building a management team that included Norris. The goal: to make highly efficient solar cells, and to make them more cheaply than those based on existing silicon technology.

It is at this point that many solar startups have gone wrong, rushing to scale up an innovative technology before understanding its economics and engineering challenges. Instead, Alta spent its first several years in stealth mode, quietly attempting to figure out, as Norris puts it, whether its process for making gallium arsenide solar cells was more than a "science experiment" and could serve as a viable basis for manufacturing.

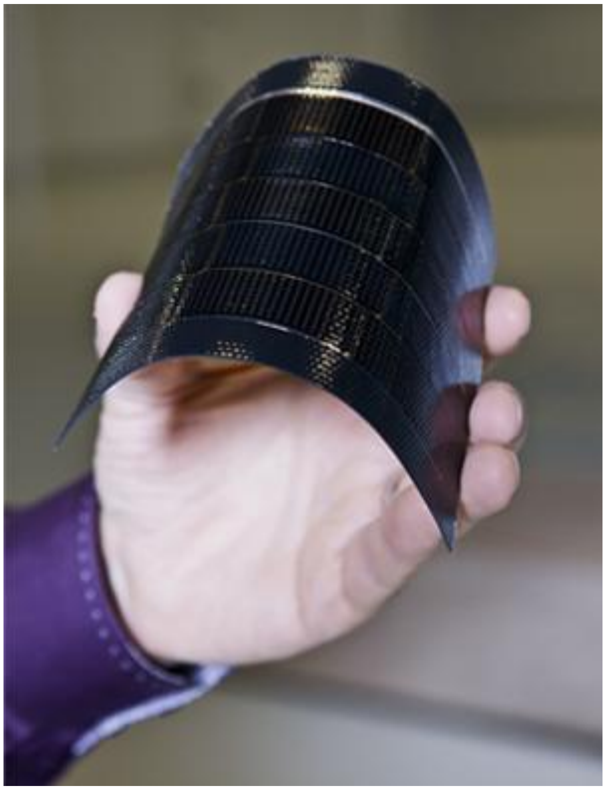

Figure 2 Flexible power: Alta's solar cells can be made into bendable sheets. In this sample, a series of solar cells are encapsulated in a roofing material. Credit: Gabriela Hasbun

Remnants of the science experiment are still visible in the modest lab at the back of Alta's offices. Small ceramic pots sit on electric hot plates—relics of the company's early efforts to optimize - Yablonovitch's technique of "epitaxial liftoff," which uses acids to precisely separate thin films of gallium arsenide from the wafers on which they are grown. Elsewhere in the lab the equipment gets progressively larger and more sophisticated, reflecting the scaling up of the process. Near a viewing window that allows potential investors to peer into the lab without donning clean-room coverings is one of the jewels of the company's development efforts: a long piece of equipment in which batches of samples are processed to create the thin-film solar cells. It's convincing evidence that the early work with pots and hot plates can be transformed into an automated process capable of the yields necessary for real-world manufacturing.

SOLAR LIFTOFF

When Bill Joy, a cofounder of Sun Microsystems and now a leading Silicon Valley venture capitalist, first saw the business plan for what became Alta Devices, he and his colleagues at Kleiner Perkins Caufield & Byers were already looking for high-efficiency thin-film solar technology. Joy keeps a running list—currently about 12 to 15 items long—of desirable technologies that he believes he has "a reasonable chance of finding." Solar cells that are highly efficient in converting sunlight and that can be made cheaply in flexible sheets could provide ways to dramatically lower the overall costs of solar power. Gallium arsenide technology was a natural choice for efficiency, but Alta's economics were what really interested the investors. "Their core competency was how to make it manufacturable," says Joy, who joined Rappaport as an investor within a few months.

Gallium arsenide is a nearly ideal solar material, for a number of reasons. Not only does it absorb far more sunlight than silicon—thin films of it capture as many photons as silicon 100 times thicker—but it's less sensitive to heat than silicon solar cells, whose performance dramatically declines above 25 °C. And gallium arsenide is better than silicon in retaining its electricity-producing abilities in conditions of relatively low light, such as early in the morning or late in the afternoon.

Key to reducing its manufacturing costs is the technique that Yablonovitch helped figure out decades ago. The semiconductor can be grown epitaxially: when thin layers are chemically deposited on a substrate of single-crystal gallium arsenide, each adopts the same single-crystal structure. Yablonovitch found that if a layer of aluminum arsenide is sandwiched between the layers, this can be selectively eaten away with an acid, and the gallium arsenide above can be peeled off. It was an elegant and simple way to create thin films of the material. But the process was also problematic: the single-crystal films easily crack and become worthless. In adapting Yablonovitch's fabrication method, Alta researchers have found ways to create rugged films that aren't prone to cracking. And not only do the thin films use little of the semiconductor material, but the valuable gallium arsenide substrate can be reused multiple times, helping to make the process affordable.

POWER NUMBERS

Solar cells vary in how efficiently they convert sunlight

Record solar-cell efficiency (best research cells)	
Gallium arsenide (thin-film)	28.3%
Crystalline silicon	25.0%
Multicrystalline silicon	20.4%
CIGS*	19.6%
Cadmium telluride	16.7%
Dye-sensitized cells	11.0%
Amorphous silicon	10.1%

**Copper indium gallium selenide*
Source: Progress in Photovoltaics, *December 29, 2011*

Research by Alta's founding scientists has also led to techniques for increasing the performance of the solar cells. Photovoltaics work because the photons they absorb boost the energy levels of electrons in the semiconductor, freeing them up to flow to metal contacts and create a current. But the roaming electrons can be wasted in various ways, such as in heat. In gallium arsenide, however, the freed electrons frequently recombine with positively charged "holes" to re-create photons and start the process over again. Work done by Yablonovitch and Atwater to explain this process has helped Alta design cells to take advantage of this "photon recycling," providing many chances to recapture photons and turn them into electricity.

Thus Alta's efficiency record: its cells have converted 28.3 percent of sunlight into electricity, whereas the highest efficiency for a silicon solar cell is 25 percent, and commonly used thin-film solar materials don't exceed 20 percent. Yablonovitch suggests that Alta has a good chance of eventually breaking 30 percent efficiency and nearing the theoretical limit of 33.4 percent for cells of its type.

The high efficiency, combined with gallium arsenide's ability to perform at relatively high temperatures and in low light, means that the cells can produce two or three times more energy over a year than conventional silicon ones, says Norris. And that, of course, translates directly into lower prices for solar power. Norris says a "not unreasonable expectation" is that the gallium arsenide technology could yield a "levelized cost of energy" (a commonly used industry metric that includes the lifetime costs of building and operating a power plant) of seven cents per kilowatt-hour. At such a price, says Norris, solar would be competitive with fossil fuels, including natural gas; new gas plants generate electricity for around 10 cents per kilowatt-hour. And it would trounce today's solar power, which Norris says costs around 20 cents per kilowatt-hour to generate.

Such numbers are tantalizing. But Norris is quick to bring up another: it costs roughly $1 billion to build a manufacturing facility capable of producing enough solar modules to generate a gigawatt of power, which is roughly the output of several medium-sized power plants. "I don't see any scenario where we would do this on our own," he says.

GHOST OF SOLYNDRA

Silicon Valley has been infatuated with clean tech since the mid-2000s, but it has yet to figure out something crucial: who will supply all the money necessary to scale up energy technologies and build factories to manufacture them? Venture investors might be skilled at picking technologies, but few of them have the deep pockets or the patience required to compete in a capital-intensive business such as the manufacturing of solar modules. The collapse of Solyndra, which built a $733 million factory in Fremont, California, is just the most recent reminder of what can go wrong.

Alta's lead investor Andy Rappaport says he usually stays away from investments in clean tech, including photovoltaics. Many investors in solar, he suggests, have bet that a startup could lower the marginal costs of manufacturing and thus "capture some market share." That's "a recipe for failure," he says, because "you need to spend hundreds of millions to build a factory before you know if you have anything of value." The strategy is especially risky now, because photovoltaics are becoming an increasingly competitive commodity business and prices continue to plummet, creating a moving target for new production. But rather than trying to create value by building manufacturing capacity, Rappaport says, Alta can profit from its intellectual property: "We have said simply and consistently that we can scale capacity faster and build a much stronger company by leveraging partnerships rather than raising and spending our own capital to build factories."

Current investors in Alta include GE, Sumitomo, and Dow Chemical, which recently introduced roofing shingles that incorporate thin-film photovoltaics *(see "Can We Build Tomorrow's Breakthroughs?" January/February 2012)*. Though these companies have invested in several rounds of funding—Alta has so far raised $120 million—eventually Norris would like to see deals, such as licensing agreements or joint ventures, in which manufacturers build capacity to produce Alta's solar cells or use the solar technology in their products. To do that, he says, Alta first needs to "retire the risk" of the production technology, demonstrating to prospective partners that the gallium arsenide solar modules can in fact be produced in an economically competitive way.

Less than a mile from its headquarters, Alta is gutting and renovating a building where Netflix used to warehouse DVDs, turning it into a $40 million pilot facility to test its equipment. Though the facility is far smaller than a commercial solar factory, it is still no small or inexpensive undertaking. Norris warily eyes the new columns required to reinforce the roof, which will need to hold heavy ventilation and emission-control equipment. But the Alta CEO becomes more buoyant as he approaches the nearly completed back section of the facility. There, in several white rooms, are the large custom-designed versions of the lab apparatus used to make the solar cells.

Whether Alta succeeds will depend chiefly on how well these manufacturing inventions perform. The cost of the pilot facility might pale next to the price tag for a commercial-scale solar factory, but it is still a critical investment for the startup. And even as Alta is busily trying to get the facility up and running by the end of the year, Norris says, it is taking a deliberate, methodical approach to the process of scaling up. That contrasts sharply with earlier solar startups that spent hundreds of millions in venture investments to build factories as fast as possible. But Alta's cautious approach should not be confused with a lack of ambition. The goal, says Norris, is to make this a "foundational, transformative technology."

David Rotman is Technology Review*'s editor.*