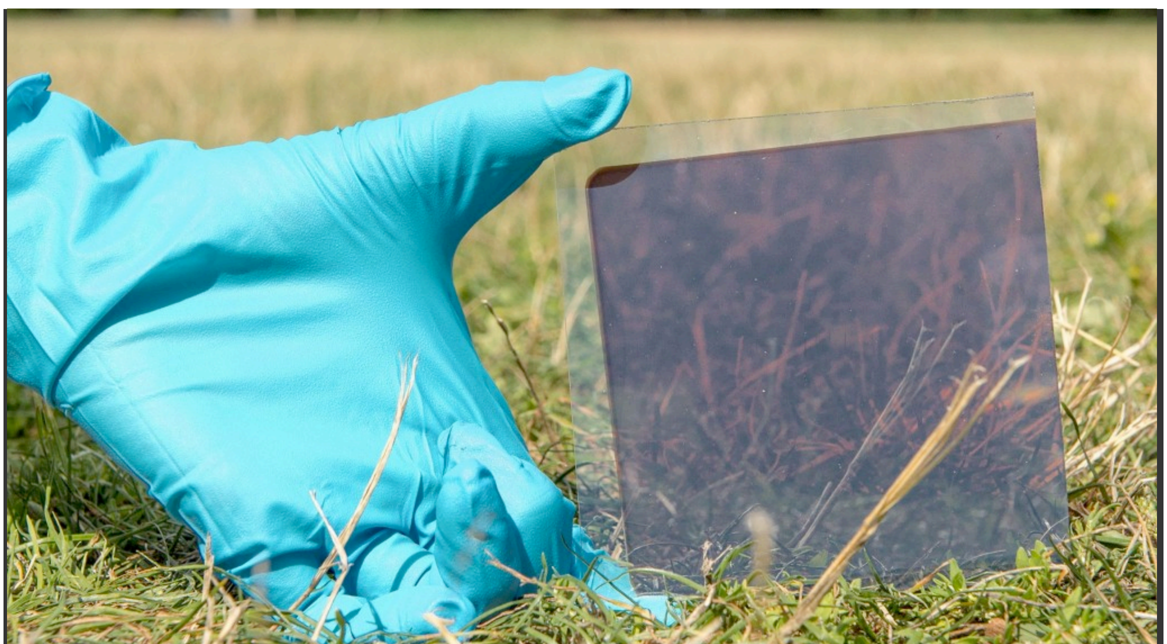
NOVA NEXT

Why It Takes Decades to Produce a New Solar Material

By Tim De Chant on Wed, 26 Feb 2014

The solar industry is abuzz over a relative newcomer that burst onto the scene less than a decade ago and has risen rapidly through the ranks. The all-star rookie has also been published in high-impact academic journals in the last few years, but it isn't a newly minted professor or a hot solar startup. It's a material known as perovskite.

Materials scientists started testing perovskite's sun-capturing qualities in the 2000s, and by 2009, a team lead by Tsutomu Miyasaka from Toin University of Yokohama in Japan had produced a solar cell that converted 3.8% of the sun's light into electricity, a respectable amount for such a new material. Just last fall, another group lead by Henry Snaith from the University of Oxford published a breakthrough—their perovskite solar cells were 15.4% efficient.



One of Henry Snaith and colleagues' perovskite solar cells

In a world where gains of fractions of a percent are lauded, such a leap was unprecedented. “Very few come in out of the cold and have a 15% conversion efficiency.” says David Ginley, a research fellow at the National Renewably Energy Laboratory.

“It’s exciting,” says Michael McGehee, a professor of materials science at Stanford University. “It’s a new material with a lot of potential.”

That excitement is evident in recent news coverage. Even*Nature*, a well-respected academic journal, hailed Snaith as one of the 2013’s “ten people who mattered.” “This year, Snaith amazed materials researchers by massively boosting the efficiency of solar cells made with perovskite semiconductors,” they wrote.

Those plaudits come with a small catch—they tacitly presume that perovskite will continue its rapid ascent. If it does, the material truly could be revolutionary. Currently, photovoltaics cost between $2 and $5 per watt depending on the scale of the installation. That’s significantly lower than just five years ago, though it’s still not competitive with coal or natural gas. But if perovskite continues to gain efficiency, it could tilt the playing field solidly in favor of solar power.

The target is 25% efficiency. Very few types of cells exceed that goal, and even fewer are commercially available currently. “A lot of people think that you need the efficiency of the cells to be up near 25% because if the efficiency is lower, you need a larger area to get the power, and the larger area, the more the installation costs are,” McGehee says. Perovskite made waves with how quickly it broke 15% efficiency, and unspoken assumption in many articles is that the material could breach 25% in a matter of years, not decades.

Snaith, whose team achieved the recent perovskite milestone, seems convinced that perovskite already has commercial potential. He has founded a company that’s striving to produce perovskite solar cells in mass quantity, which he says will happen in “three to five years.”

Snaith's compressed timeline mirrors the great strides perovskite has taken as a photovoltaic material. But the road from the laboratory to the rooftop can be filled with unexpected speed bumps, something known all too well by researchers and manufacturers of copper indium gallium selenide, or CIGS, a photovoltaic material that's just recently become available on the market. In fact, the story of CIGS could be viewed as a cautionary tale, one that might temper some of the excitement surrounding perovskite.

Bright Beginnings

CIGS began life as CIS, or copper indium selenide. It, too, is a semiconductor and was originally discovered in 1953 by Harry Hahn and his team at the University of Heidelberg. They published their discovery in *Zeitschrift für anorganische und allgemeine Chemie*, a German-language chemistry journal. It wasn't uncommon at the time for chemists to publish in German, though that may have been partly why it was overlooked as a photovoltaic until 1974 when Sigurd Wagner, a young Austrian scientist and a fresh face at Bell Labs, and his team published an article on how his lab-grown crystals that could capture the sun's rays.

An entry gate at Bell Labs in Murray Hill, New Jersey, where the first solar cell was demonstrated.

CIS crystals were expensive and proved difficult to grow, though, which was part of the reason why Larry Kazmerski, then a professor at the University of Maine, started searching for a better technique. It didn't take him long. Shortly after Wagner's first paper came out, Kazmerski told colleagues how he deposited CIS in a thin-film on a piece of glass. His first cells were between 4-5% efficient.

It was a promising development, but work on CIS was only one part of a larger government investment in solar power. In the 1970s, the National Science Foundation was directing large investments in solar power research for the U.S. government. Much of the money was going toward developing silicon-based solar cells. "Silicon, they knew, would do well eventually. That was the known semiconductor," says Kannan Ramanathan, head of the CIGS team at the NREL. "Yet they wanted to divest, take risks, and nurture thin films."

Work on CIS trundled along until 1981, when Boeing scientists Reid Mickelsen and Wen Chen announced at a conference in Orlando, Florida, that they had doubled Kazmerski's efficiency by depositing the material in a new way. Thin-films had arrived.

Though silicon remained the favored material, a handful of companies grew interested in thin-film cells and CIS in particular. They wagered that if they could get the chemistry right, thin-film cells would be vastly cheaper to produce than silicon cells, which had to be grown as crystals. Plus, CIS could be deposited on inexpensive glass, reducing weight and materials costs. For Boeing, which used solar cells on spacecraft, lightweight panels would translate into cheaper launch costs.

Meanwhile, the aerospace company's continued investment was yielding dividends. Chen and another colleague, John Stewart, figured out in the late-1980s that they could substitute gallium for some of the indium, further raising the efficiency. (That was what put the G in CIGS.)

Earlier that decade, oil company Arco had also begun exploring CIS and other thin-film technologies. During the energy crisis in 1979, the company had become a serious player in the nascent solar power industry. After throwing its weight behind CIS research, it quickly developed an alternative to Boeing's production technique. It wasn't quite as efficient, but was considered easier to manufacture. By 1988, the Southern California-based Arco Solar produced a four-square-foot module with 11% efficiency. That same year, they offered to permanently light the Hollywood sign using solar power.

Despite the bravado, things weren't going well for the Arco Solar pioneer. Development problems plagued the run-up to production, frustrating its parent company. Plus, the solar power market wasn't growing as quickly as they had hoped. Looking to cut costs, Arco sold its solar division to Siemens in 1989.

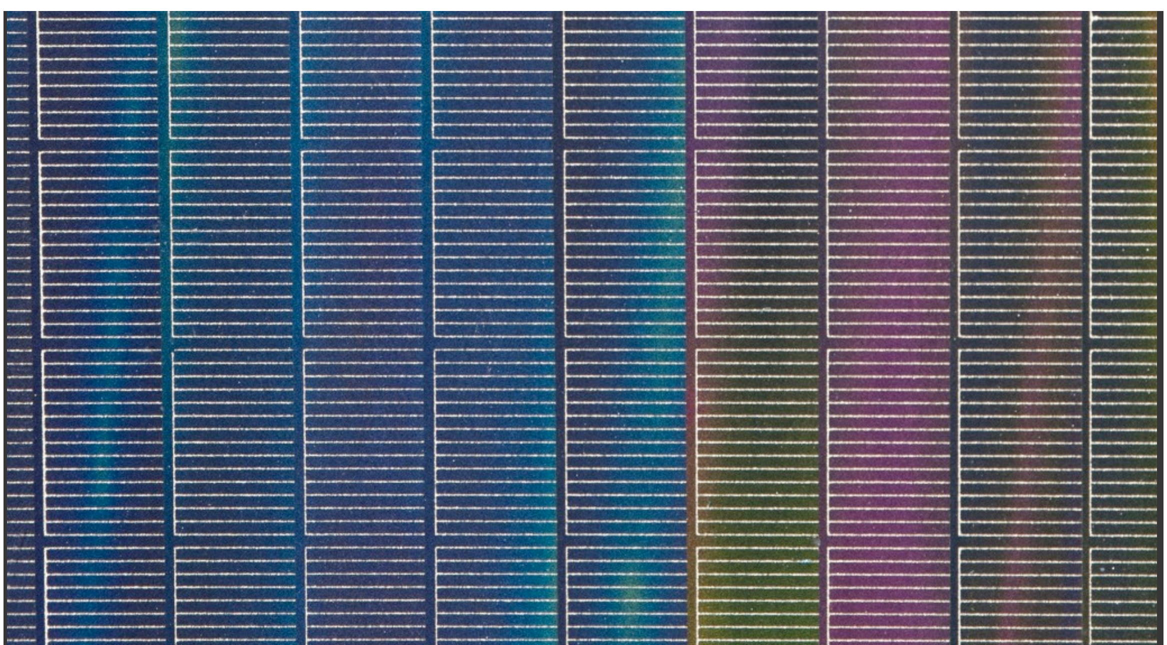
Boeing had also lost interest, and left their work to NREL. Researchers in academia and industry had to go back to the drawing board in an attempt to resolve the issues that plagued previous manufacturing efforts. But without the major players, the material that had shown so much promise in the 1970s and 1980s stumbled. It would be almost 10 years before the CIGS industry would recover.

Out from the Shadows

By the late 1990s, Siemens was feeling confident in its progress on CIGS and spooled up a pilot production line. The results of an early run were tested at NREL and scored higher than 10% efficiency. They were the first thin-film photovoltaics made outside of a lab to reach that landmark. But just as Arco had dropped its solar division after it made the 11% module, Siemens started looking for a buyer for the California-based division shortly thereafter. It eventually ended up with another oil company, Shell. (The division ended up being a hot potato; Shell would only own it for four years before selling it to Germany-based Solar World in 2006.)

The 2000s could have been another lost decade for CIGS, but then, in 2003, Germany began offering generous subsidies on solar power. That encouraged a number of universities and small companies to jump in the game, who, along with NREL, would end up carrying the torch when, a few years later, Shell “walked away” from their solar division, Ramanathan says.

The handful of smaller companies kept at it, encouraged by government subsidies and an influx of venture capital, fine-tuning their materials and lowering their production costs. Then, as so many times before, they ran into a series of unexpected problems. While many companies had become adept at producing cells in the lab, they couldn’t replicate that success on a large scale. Some of these delays were blamed on an incomplete scientific understanding of the CIGS material. William N. Shafarman, a professor at the University of Delaware, and Lars Stolt, a professor at Uppsala University, wrote in 2003 that the “lack of a science base has been perhaps the biggest hindrance to the maturation of $Cu(InGa)Se_2$ solar cell technology as most of the progress has been empirical.” At many companies, the cart had gotten in front of the horse.



Close-up of a CIGS solar panel at Biosphere 2 in Arizona

That lack of understanding would catch up with manufacturers a few years later when product testing company TÜV Rheinland documented a sharp spike in the number of failures among thin-film panels, including CIGS and other types, during the damp-heat test, where panels are subjected to 1,000 hours of 85˚ F and 85% humidity. Between 2005-2007, 70% of thin-film panels failed, more than double the failures for 1997-2005. They had to go back to the drawing board, again.

Meanwhile, manufacturers also had to perfect how the cells would be packaged and connected. Each wire, sheet of glass, and piece of aluminum had to be tested for durability and reliability. They had to simulate everything from snafus that might take place during installation to 20 years of heat and moisture. Thanks to accelerated testing, the process doesn't take 20 years, but it can still take many months to several years.

Bert Haskell, the CTO at Pecan Street, oversaw these tests in an earlier job as director of product development at Heliovolt, an Austin, Texas-based CIGS company. There, he and his team would subject completed panels to a grueling regimen of abuse. They'd yank on connecting cables, drop one-and-a-half-pound ball bearings onto the glass, and fire chunks of ice at the panels at 50 mph. They'd subject them to high humidity and drastic fluctuations in temperature. They'd bake them and they'd freeze them. "Those tests, you might run those for 90 days or six months before you get results back," Haskell says. It was quicker than waiting 20 years, but it wasn't instantaneous.

CIGS solar panels covered the exterior walls of Germany's winning entry in the 2009 Solar Decathlon.

Add it all up, and you quickly realize that just testing the non-photovoltaic part of the module took several years. Some tests could occur in parallel with work on the CIGS cells themselves, but in the end, the entire package still had to be tested and certified.

It wasn't until the mid-2000s that CIGS-based solar panels began to trickle into the market, more than 30 years after the material's initial discovery as a photovoltaic. Today, CIGS cells remain costly relative to silicon cells and have captured just a few percent of the market. The future could still be bright, but it will require many more years of sustained funding, research and development.

A Long Road Ahead

Judging by the challenges CIGS confronted, it's likely that perovskite solar cells have a long road in front of them. Though the material has shown great promise, moving out of the lab and into production isn't the same as producing high-efficiency cells in the lab. It takes time. "The development time for most technologies is 20 to 30 years," says Ginley, the NREL scientist. "That's pretty damn canonical."

Haksell agrees. “When a scientist discovers a new material in the lab that has some kind of unique property, going from that to the point where it’s applied in a useful product, it just takes a long time.” (I followed up with Snaith regarding his three-to-five-year commercial timeline for perovskite solar cells, but haven’t heard back.)

Perovskite’s biggest stumbling block could be water. While most solar cells don’t react well to water, perovskite’s current formulation is an ionic salt, which means it’s highly susceptible to water damage, both McGehee and Ginley tell me. Solar manufacturers work hard to keep their products sealed, but water has a tendency to work its way into the smallest of gaps, including those cracks that happen during installation or any of the many heating and cooling cycles solar panels endure. Reformulating the material while keeping the basic chemical structure could reduce the potential for water damage, but that would require years more research.

“There’s still a lot of questions that need to be answered,” McGehee says of perovskite. “It is exciting and I don’t want to take away from it in any way, but we still need to have a wait and see attitude before we’ll know if this is going to be a commercial success.”

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