NREL develops dual-chamber dynamic HVPE, targeting III–Vs solar cells at $0.20–0.80 per watt

Research continues in order to reduce the cost of both the substrate and the chemical deposition process

The US Department of Energy's National Renewable Energy Laboratory (NREL) is working to refine the hydride vapor phase epitaxy (HVPE) technique, which holds the potential to produce cheaper, more efficient solar cells capable of producing more electricity.

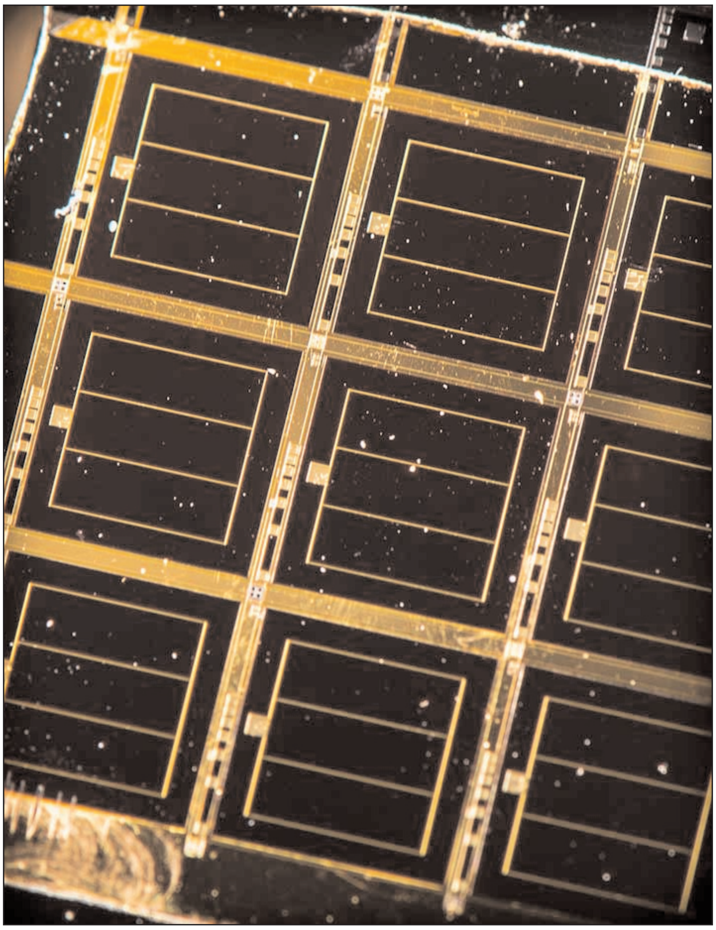
"HVPE has been around since the '50s and '60s. We fondly refer to it as our brand new, 50-year-old growth technique," says Aaron Ptak, a senior scientist who joined NREL in 2001.

Solar panels such as those on NASA's Mars rovers (sent to the planet in 2003) use solar cells made from gallium arsenide (GaAs) and gallium indium phosphide (GaInP), which have high solar energy conversion efficiency about 27%. To apply that same technology on Earth (where the average rooftop solar panel is 15% efficient), the cost would be astronomical. "You can only buy gallium arsenide cells if you're willing to pay $100–300 a watt," says David Young, a senior scientist with expertise in silicon solar cells who joined NREL in 2000.

That is far costlier than what NREL estimates to be the average price of utility-scale solar: less than $1 a watt. Silicon solar cells dominate the market, and scientists calculate that those are nearing the upper practical limit of efficiency, at 27%.

Dual-chamber reactor improves on old process

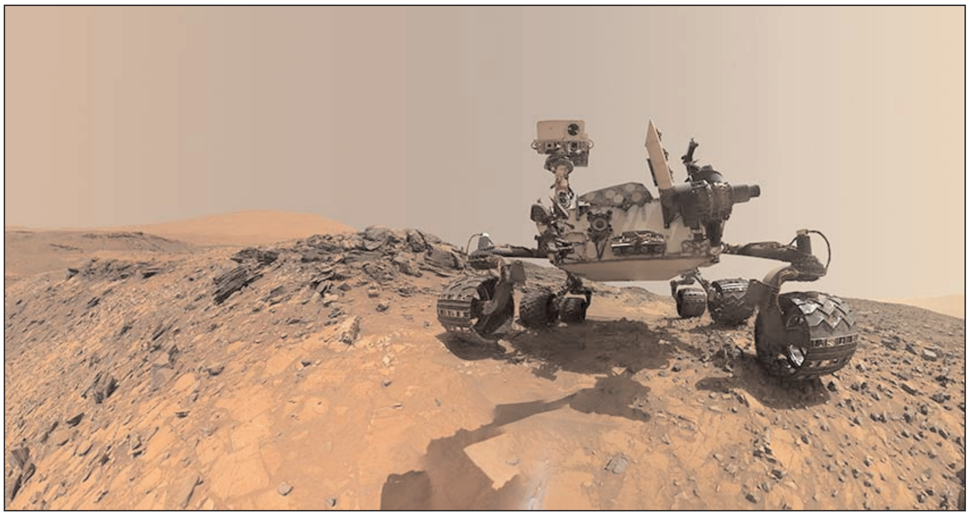
The existing metal-organic vapor phase epitaxy (MOVPE) process for making III–V solar cells deposits the elements layer by layer in a time-consuming process. "You essentially dose pre-engineered chemicals onto a hot wafer, and they will deposit as thin-film layers with the same lattice spacing as the wafer," says Young. "Multi-layer devices are formed by changing the gas mixture to form different compositions of stacked thin films," he adds. "MOVPE can grow very complicated structures — or devices like solar cells — but it is expensive and slow."



Using D-HVPE, III–V solar cells could enter terrestrial markets, where their high conversion efficiency is desirable. Photo by Dennis Schroeder, NREL

Young and Ptak returned to HVPE, which fell out of favor in the 1960s when MOVPE caught on. HVPE had its difficulties. The process used a single chamber where one chemical was deposited on a substrate, which was then removed. The chemical was then swapped for another, and the substrate returned to the chamber for the next chemical application. The layers grown atop the wafer had to line up precisely to avoid defects in the solar cell. "If you can't get the interfaces right, you can't build up complex devices like a multi-junction solar cell," says Ptak, an expert in growing III–V solar materials.

The revamped version of HVPE — dynamic HVPE (D-HVPE) — relies on a dual-chamber reactor. The substrate moves back and forth between the chambers, greatly reducing the time to make a solar cell. A single-junction solar cell that takes an hour or two to make using MOVPE can be produced in two minutes by D-HVPE.



NASA's Curiosity rover relies on III–V solar cells. Photo by NASA.

So far, after four years of research and about 3000 samples grown, NREL scientists managed to set the bar at a single-junction GaAs cell with 25.3% efficiency. The record for such a cell is 28.8%, grown using MOVPE by a California company and "using a fancier structure that we can't grow," Ptak says.

"It's actually way higher than we thought we would get in this program," he adds. "When we started this program, we thought, 'OK, we're going to make cheap solar cells and they're going to be kind of bargain-basement solar cells, but they're going to be good.' What we have learned during the course of this project is we need to shoot higher… because the material quality that we're seeing, the device quality that we're seeing, is way better than we expected."

Potential emerging markets for III–V cells

Ptak and Young studied the potential markets for III–V solar cells made by the D-HVPE process at the end of 2016 while participating in Energy I-Corps, a Department of Energy program that helps researchers to determine potential markets for their technologies. Ptak says that the military is interested in the solar cells, which would be thin, lightweight, and flexible. People who operate drones also are interested.

Further research is needed to move D-HVPE beyond the laboratory, but that will require "multiple millions of dollars," Ptak notes. The current funding comes from the Department of Energy Solar Energy Technologies Office and from its Advanced Research Projects Agency-Energy (ARPA-E). "This could spin off into a company. We have an R&D technology that works really, really well. We have designs for a pilot-scale reactor, but we have no way to get from A to B. It's going to be very capital intensive to get to that step," he adds.

"Getting the right people to fund this has been a challenge," says Kelsey Horowitz (part of the Techno Economic Analysis Group in NREL's Strategic Energy Analysis Center), who leads the tech-to-market effort to get HVPE commercialized. She has forecast that solar cells made with D-HVPE technology could generate electricity at 20–80 cents per watt, but that price won't become a reality until D-HVPE solar cells are made in large quantities — and that is at least five years away. Until then, research efforts will continue to reduce both the cost of the substrate used and the chemical deposition process.

Horowitz's list of potential early adopters of D-HVPE solar cells includes big-box retailers with roofs that cannot support heavy silicon panels; bus companies — using regular fuel or electricity — that could turn to the technology to either improve fuel efficiency or range; and the US Army, which could equip soldiers' backpacks with the solar cells to generate power in the field.

"There are these intermediate markets where higher prices can be tolerated," she says. "Right now, III–Vs might be $300 a watt or that ballpark," says Ptak. "If you can get to $100 a watt or $70 a watt, there are large initial markets that you can open up at that price point in order to get your foot in the door, to start scaling up your manufacturing, and get your costs down to $1 a watt or 50 cents a watt," he concludes. ■

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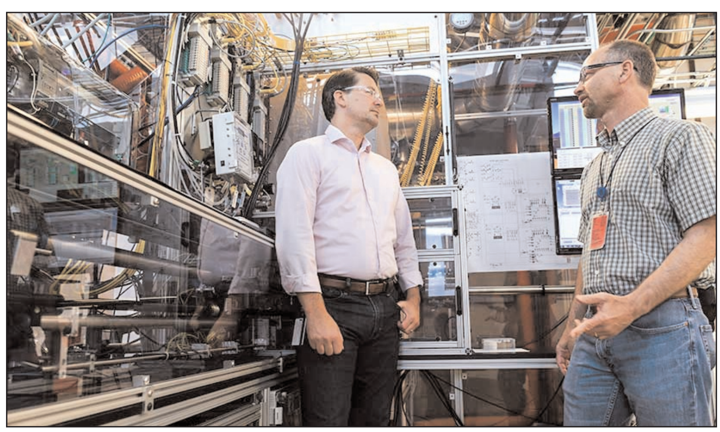

Aaron Ptak (left) and David Young think D-HVPE can produce solar cells cheaper and faster than the current method. Photo by Dennis Schroeder, NREL.