NREL demos first growth of AlInP and AlGaInP by HVPE

Adding aluminium to D-HVPE enables parity on efficiency with solar cells made by more costly MOVPE

The US National Renewable Energy Laboratory (NREL) says that it has integrated an aluminium source into its hydride vapor phase epitaxy (HVPE) reactor then demonstrated the growth of aluminum indium phosphide (AlInP) and aluminum gallium indium phosphide (AlGaInP) for what is claimed to be the first time by this technique.

"There's a decent body of literature that suggests that people would never be able to grow these compounds with hydride vapor phase epitaxy," says Kevin Schulte, a scientist in NREL's Materials Applications & Performance Center and lead author of the paper 'Growth of AlGaAs, AlInP, and AlGaInP by Hydride Vapor Phase Epitaxy' (ACS Applied Energy Materials (12 December 2019) https://doi.org/10.1021/acsaem.9b02080). "That's one of the reasons a lot of the III–V industry has gone with metal-organic vapor phase epitaxy (MOVPE), which is the dominant III–V growth technique. This innovation changes things," he reckons.

III–V solar cells are commonly used in space applications. Notable for high efficiency, these types of cells are expensive for terrestrial use, but researchers are developing techniques to reduce those costs.

A method pioneered at NREL relies on the new growth technique dynamic hydride vapor phase epitaxy (D-HVPE). Traditional HVPE, which for decades was considered the best technique for producing light-emitting diodes and photodetectors for the telecoms industry, fell out of favor in the 1980s with the emergence of MOVPE. Both processes involve depositing chemical vapors onto a substrate, but the advantage belonged to MOVPE because of its ability to form abrupt heterointerfaces between two different semiconductor materials, a place where HVPE traditionally struggled. NREL says that that has changed with the advent of D-HVPE.

The earlier version of HVPE used a single chamber where one chemical was deposited on a substrate, which was then removed from the chamber. The growth chemistry was then swapped for another, and the substrate returned to the chamber for the next chemical application. D-HVPE relies on a multi-chamber reactor. The substrate moves back and forth between 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 potentially be produced in under a minute by D-HVPE, it is reckoned.

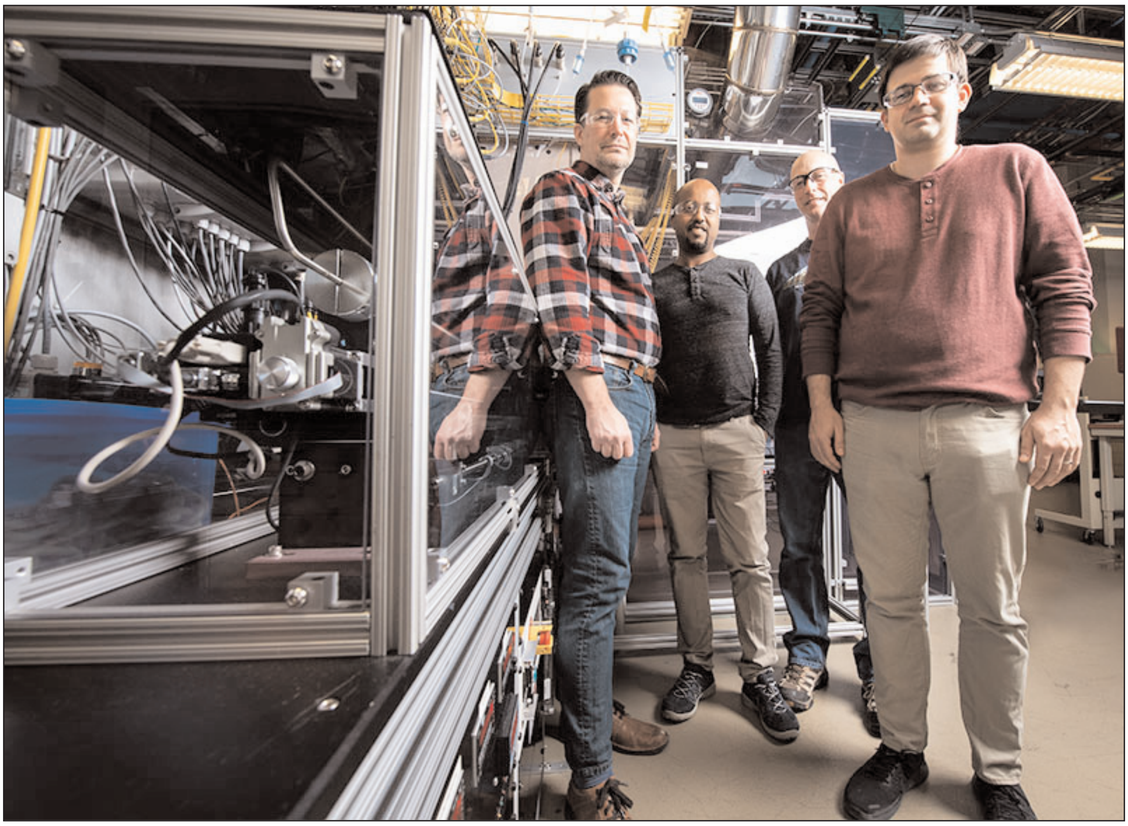
Sample aluminium III-V solar cells, grown using HVPE, are shown as Alx(Ga1-x)0.5In0.5P thin films after removing the GaAs substrate bonded to a glass handle substrate for transmission measurements. The difference in color is due to the difference in the composition of Al and Ga. Specifically, yellow samples are AlInP (no Ga) and orange samples are AlGaInP. Photo by Dennis Schroeder, NREL.

Despite these advances, MOVPE still held another advantage: the ability to deposit wide-bandgap aluminium-containing materials that enable the highest solar cell efficiencies. HVPE has long struggled with the growth of these materials due to difficulties with the chemical nature of the usual aluminium-containing precursor, aluminum monochloride.

The researchers always planned on introducing aluminium into D-HVPE, but first focused their efforts on validating the growth technique. "We've tried to move the technology forward in steps instead of trying to do it all at once," says Schulte. "We validated that we can grow high-quality materials. We validated that we can grow more complex devices. The next step now for the technology to move forward is aluminium."

Schulte's co-authors from NREL are Wondwosen Metaferia, John Simon, David Guiling and Aaron J. Ptak. They also include three scientists from Kyma Technologies Inc of Raleigh, NC, USA (which provides wide-bandgap semiconductor crystalline materials and crystal growth equipment). The firm developed a method to produce a unique aluminium-containing molecule, which could then be flowed into the D-HVPE chamber.

The researchers used an aluminium trichloride generator, which was heated to 400°C to generate an aluminium trichloride from solid aluminium and hydrogen chloride gas. Aluminium trichloride is much more stable in the HVPE reactor environment than the monochloride form. The other components — gallium chloride and indium chloride — were vaporized at 800°C. The three elements were combined and deposited on a substrate at 650°C.



NREL researchers (from left to right) Aaron Ptak, Wondwosen Metaferia, David Guiling and Kevin Schulte are growing aluminium-containing materials for III-V solar cells using HVPE. Photo by Dennis Schroeder, NREL.

Now that aluminium has been added to the mix of D-HVPE, the researchers reckon that they should be able to reach parity with solar cells made via MOVPE. "The HVPE process is a cheaper process. Now we've shown a pathway to the same efficiency that's the same as the other guys, but with a cheaper technique. Before, we were somewhat less efficient but cheaper. Now there's the possibility of being exactly as efficient and cheaper"

Using D-HVPE, NREL has previously been able to make solar cells from gallium arsenide (GaAs) and gallium indium phosphide (GaInP). In these cells, the GaInP is used as the 'window layer', which passivates the front surface and permits sunlight to reach the GaAs absorber layer below where the photons are converted to electricity. This layer must be as transparent as possible, but GaInP is not as transparent as the aluminium indium phosphide (AlInP) used in MOVPE-grown solar cells. The existing efficiency record for MOVPE-grown GaAs solar cells that incorporate AlInP window layers is 29.1%. With only GaInP, the maximum efficiency for HVPE-grown solar cells is estimated to be only 27%.

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"The HVPE process is a cheaper process," notes Ptak, a senior scientist in NREL's National Center for Photovoltaics. "Now we've shown a pathway to the same efficiency that's the same as the other guys, but with a cheaper technique," he adds. "Before, we were somewhat less efficient but cheaper. Now there's the possibility of being exactly as efficient and cheaper."

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