Design improvements boost efficiency of III-V solar cells

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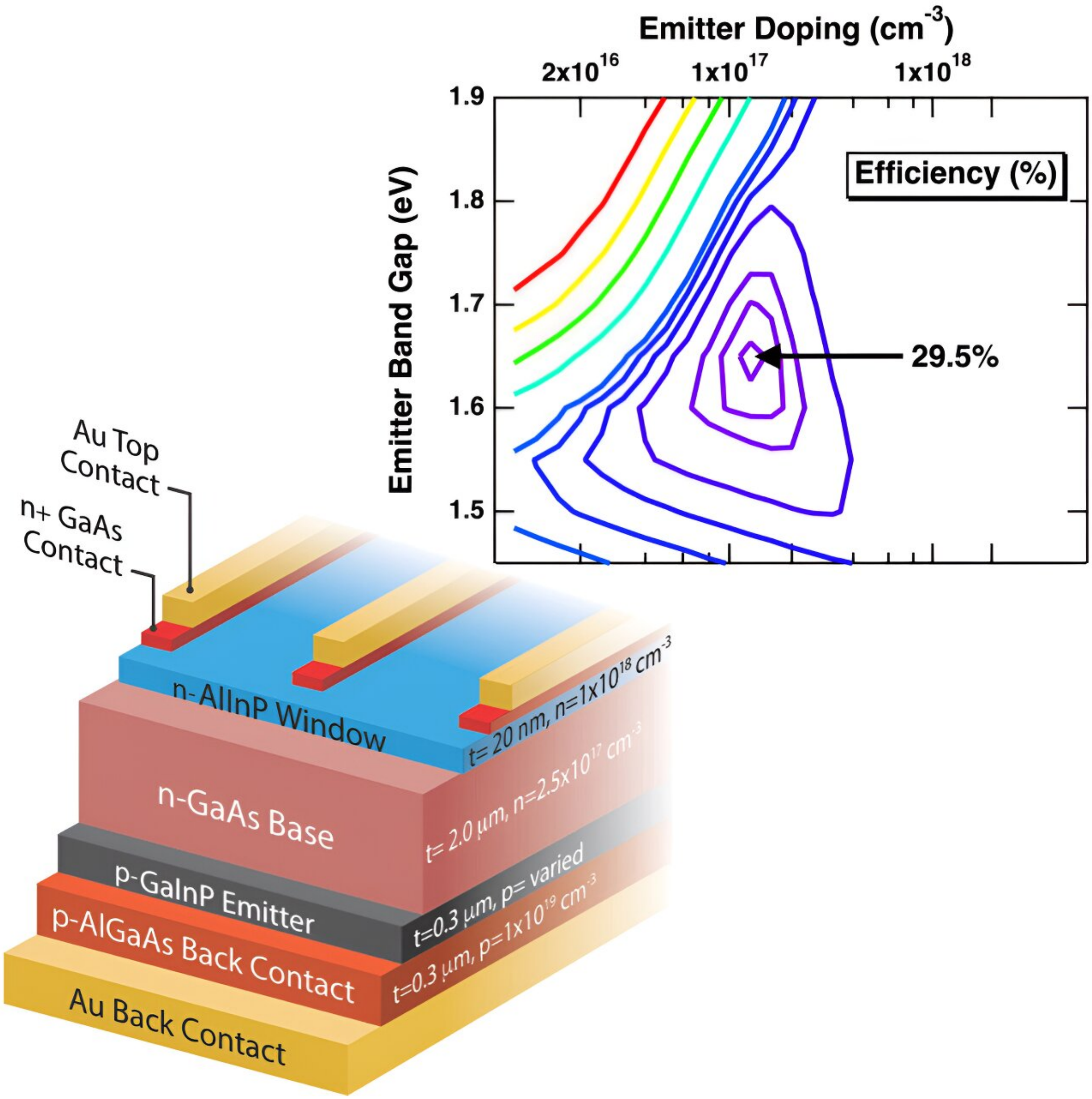

Credit: *Cell Reports Physical Science* (2023). DOI: 10.1016/j.xcrp.2023.101541

Researchers at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) were able to squeeze some extra efficiency out of their solar cells through careful design of the materials in the cell stack.

Relying on both computational and experimental studies, the scientists grew a gallium arsenide (GaAs) heterojunction solar cell using dynamic hydride vapor phase epitaxy (D-HVPE) with a certified efficiency of 27%, the highest efficiency ever reported for a single-junction GaAs cell grown using this technique.

The research is the latest effort by NREL researchers to make III-V solar cells more affordable for terrestrial applications. The III-V cells derive their name from where the materials used to make them are positioned on the periodic table of elements and are widely used to power space-faring technologies. D-HVPE offers the potential to be a lower-cost method of synthesizing these cells compared to incumbent techniques.

The study provides a road map to improving the performance of solar cells via optimization of the doping and bandgap of a device layer called the "emitter" to minimize the impact of defects on device efficiency. The results are theoretically applicable to materials beyond III-Vs that use heterojunctions such as silicon, cadmium telluride, or perovskites.

"No matter how hard you try, with whatever method you choose to make them, solar cells will always contain some defects thanks to entropy. By using a heterojunction structure, with carefully designed emitter properties, you can minimize the adverse impact of these defects on efficiency, even though you haven't done anything to reduce their concentration," said Kevin Schulte, a scientist in NREL's High-Efficiency Crystalline Photovoltaics group and lead author of the new paper published in the journal *Cell Reports Physical Science*.

"Furthermore, the relative efficiency improvement scales with defect concentration. While the baseline D-HVPE cell already had a high efficiency, a device that had a higher defect concentration would receive a higher relative efficiency boost using the methods described in the paper."

The paper, "Modeling and Design of III-V Heterojunction Solar Cells for Enhanced Performance," was co-authored by John Simon, Myles Steiner, and Aaron Ptak, all of whom are with NREL.

Aaron Ptak, a senior scientist at NREL, provides an overview of the D-HVPE lab to Secretary of Energy Jennifer Granholm (right) and Nancy Haegel, director of the National Center for Photovoltaics at NREL. Ptak co-authored a newly published paper into improving the efficiency of III-V solar cells, which were made using the D-HVPE reactor. Credit: Werner Slocum, NREL

Along with the GaAs base layer, the solar cell relied on an emitter layer of gallium indium arsenide phosphide (GaInAsP). Together the two different layers make up the heterojunction. Researchers modeled the effect of varying the zinc doping density and bandgap of the emitter layer, which is realized by varying the relative concentrations of gallium, indium, arsenic, and phosphorus during layer growth, on cell efficiency. The modeling identified optimal choices for these two parameters that maximize device efficiency.

The researchers then synthesized cells using the guidance of the modeling and achieved model-predicted efficiency enhancements. The rear heterojunction solar cell that served as a baseline used an emitter comprised of GaInP and had a reported efficiency of 26%. By reducing the doping in the emitter and changing its composition from GaInP to the lower bandgap GaInAsP, the efficiency increased to 27% even though the rest of the device was exactly the same.

The benefits of heterojunctions are generally known, although experimental demonstrations of III-V heterojunctions are limited to a handful of combinations, the researchers noted.

"We took this concept that was known but not quantified this way and mapped it out," Schulte said. "We showed the modeling matches what we see experimentally, showing that it is a powerful tool for solar cell design."

More information: Kevin L. Schulte et al, Modeling and design of III-

V heterojunction solar cells for enhanced performance, *Cell Reports Physical Science* (2023). DOI: 10.1016/j.xcrp.2023.101541

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