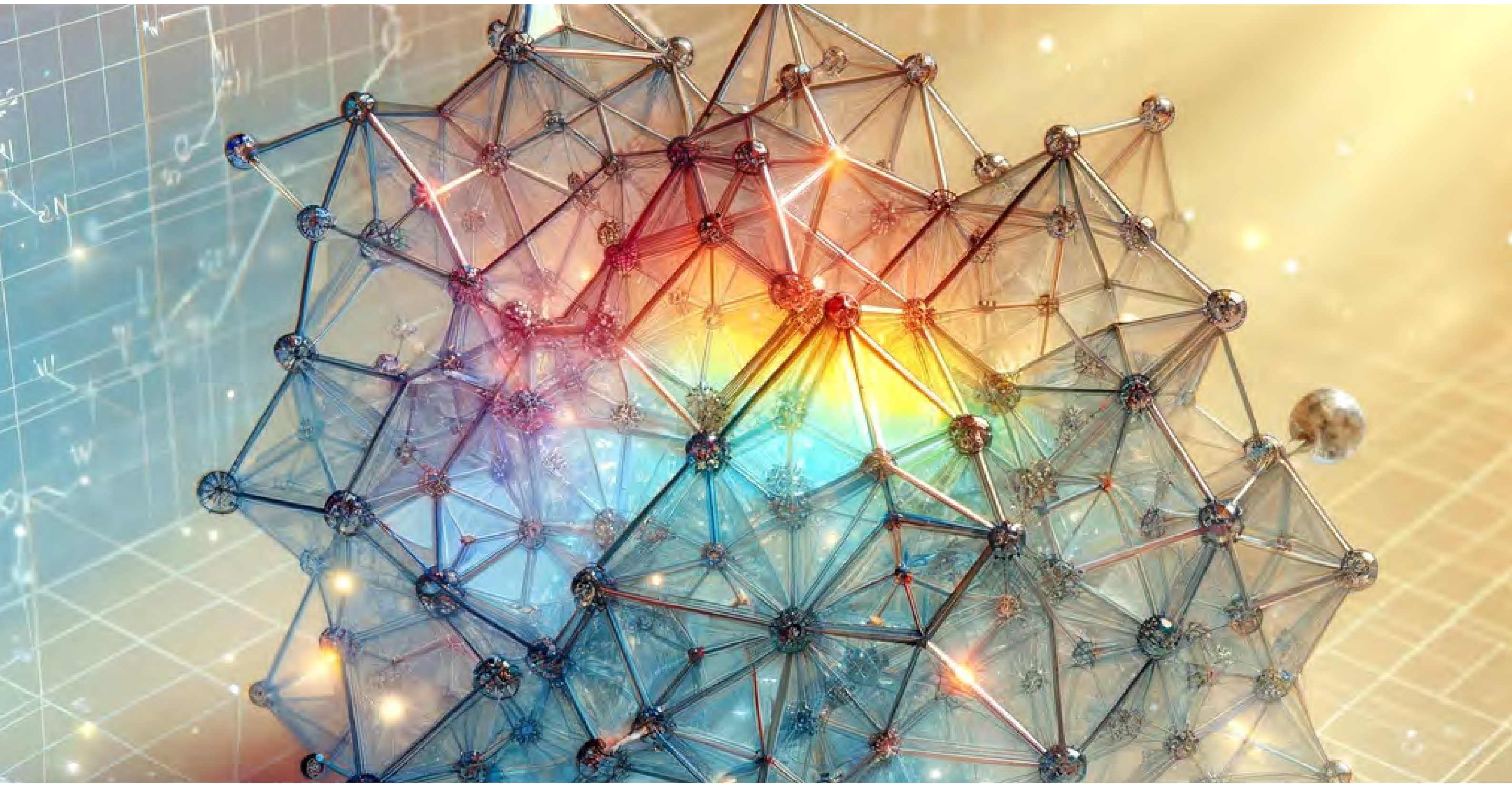
Chemical and Biomolecular Engineering

Getting the most out of the sun



NUS CDE researchers combine perovskite and organic semiconductors to create next-generation thin-film photovoltaic cells.

Photovoltaic cells, fundamental components of solar panels, continue to be a cornerstone in the renewable energy sector and are poised to surpass coal as the world's largest source of power capacity in the next few years.

At the College of Design and Engineering (CDE), National University of Singapore (NUS), researchers such as Assistant Professor Hou Yi from the Department of Chemical and Biomolecular Engineering continue to innovate at the forefront of solar technology, designing photovoltaics that are more efficient at converting sunlight into electricity.

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Some of Asst Prof Hou's inventions include solar cells composed of perovskite and organic semiconductors, which complement each other to offer both flexibility and efficiency that leapfrog conventional counterparts. These advancements are a crucial cog in the engine steering the world toward a greener and more sustainable future, unlocking more of the sun's potential to provide a clean and abundant source of power.

Mix and match

While conventional, silicon-based solar panels have become a common means of harvesting the sun's energy, they are also quickly nearing their theoretical maximum efficiency, known as the Shockley-Queisser limit.

An approach to work around this barrier involves employing a different material, such as perovskite, which excels at absorbing light compared to silicon. It also exploits untapped regions of the solar spectrum. By integrating thin perovskite layers with other solar cell technologies, in a configuration known as tandem solar cells (TSCs), researchers have exceeded the efficiency limits of single-material solar cells.

At NUS CDE, researchers are exploring the use of organic semiconductors in place of silicon, and in tandem, which could lead to more adaptable and flexible ultra-thin solar cells for applications like vehicle- and building-integrated photovoltaics.

"Perovskite/organic TSCs offer a blend of flexibility and efficiency that surpasses traditional solar technology with their tuneable chemical composition and bandgap," says Asst Prof Hou. "However, their performance still lags behind other thin-film technologies."

These TSCs face issues like open-circuit voltage losses, impacting the cell's efficiency in converting solar energy into electricity. Additionally, their performance is further impeded by inefficiencies in the layers that connect different parts of the cell.

Rolling out efficient ultra-thin solar cells

Asst Prof Hou's research team implemented two key strategies to address these challenges. Firstly, they used benzylphosphonic acid to passivate the nickel oxide hole-transport layers (HTLs) — the 'highway' for moving positive charges towards the metal electrode. This modification reduced surface recombination losses, enhancing the open-circuit voltage in the perovskite layer, and thus the power conversion efficiency of the cell.

The second strategy involved engineering a four-nanometre-thick interconnecting layer of iridium zinc oxide (IZO), sandwiched between organic bathocuproine and molybdenum oxide. With its excellent electrical and optical properties, the layer improved electrical conductivity and boosted near-infrared light absorption.

Together, the passivated nickel oxide and IZO layers enabled the perovskite/organic TSC to achieve an impressive power conversion efficiency of 23.60%, with high stability maintained over 20 days of continuous use.

Additionally, Asst Prof Hou's research revealed crucial insights into the design of interconnecting layers in perovskite-based TSCs. Discussing the complex interplay between the surface coverage of the layers, the directional movement of charge carriers and the lifespan of electron-hole recombination processes, the team's findings provide a blueprint for optimising interconnecting layers to enhance the overall efficiency of TSCs.

"We are excited by the outcomes of our research, which shows the great potential of perovskite/organic TSCs to rival or even surpass the performance of other existing thin-film TSCs in module sizes," says Asst Prof Hou. "Further innovation in narrow-bandgap organic materials, improving the stability of HTLs and suppressing phase segregation in wide-bandgap perovskites are vital next steps for advancing these solar cells."

The team's findings were published in *Nature Energy* on 20 January 2022. ◆