Research improves performance of next-generation solar cell technology

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Researchers from the University of Toronto, the King Abdullah University of Science & Technology (KAUST) and Pennsylvania State University (Penn State) have created the most efficient solar cell ever made based on collodial-quatum-dots (CQD). The discovery is reported in the latest issue of *Nature Materials*.

Quantum dots are nanoscale semiconductors that capture light and convert it into an energy source. Because of their small scale, the dots can be sprayed on to flexible surfaces, including plastics. This enables the production of solar cells that are less expensive to produce and more durable than the more widely-known silicon-based version. In the work highlighted by the *Nature Materials* paper entitled "Collodial-quantum-dot photovoltaics using atomic-ligand passivation," the researchers demonstrate how the wrappers that encapsulate the quantum dots can be shrunk to a mere layer of atoms.

"We figured out how to shrink the passivating materials to the smallest imaginable size," states Professor Ted Sargent, corresponding author on the work and holder of the Canada Research Chair in Nanotechnology at U of T.

A crucial challenge for the field has been striking a balance between convenience and performance. The ideal design is one that tightly packs the quantum dots together. The greater the distance between quantum dots, the lower the efficiency.

However the quantum dots are usually capped with organic molecules that add a nanometer or two. When working on a nanoscale, that is bulky. Yet the organic molecules have been an important ingredient in creating a colloid, which is a substance that is dispersed in another substance. This allows the quantum dots to be painted on to other surfaces.

To solve the problem, the researchers have turned to inorganic ligands, which bind the quantum dots together while using less space. The result is the same colloid characteristics but without the bulky organic molecules.

"We wrapped a single layer of atoms around each particle. As a result, they packed the quantum dots into a very dense solid," explains Dr. Jiang Tang, the first author of the paper who conducted the research while a post-doctoral fellow in The Edward S. Rogers Department of Electrical & Computer Engineering at U of T.

The team showed the highest electrical currents, and the highest overall power conversion efficiency, ever seen in CQD solar cells. The performance results were certified by an external laboratory, Newport, that is accredited by the US National Renewable Energy Laboratory.

"The team proved that we were able to remove charge traps - locations where electrons get stuck - while still packing the quantum dots closely together," says Professor John Asbury of Penn State, a co-author of the work.

The combination of close packing and charge trap elimination enabled electrons to move rapidly and smoothly through the solar cells, thus providing record efficiency.

"This finding proves the power of inorganic ligands in building practical devices," states Professor Dmitri Talapin of The University of Chicago, who is a research leader in the field. "This new surface chemistry provides the path toward both efficient and stable quantum dot solar cells. It should also impact other electronic and optoelectronic devices that utilize colloidal nanocrystals. Advantages of the all-inorganic approach include vastly improved electronic transport and a path to long-term stability."

"At KAUST we were able to visualize, with incredible resolution on the sub-nanometer lengthscale, the structure and composition of this remarkable new class of materials," states Professor Aram Amassian of KAUST, a co-author on the work.

"We proved that the inorganic passivants were tightly correlated with the location of the quantum dots; and that it was this new approach to chemical passivation, rather than nanocrystal ordering, that led to this record-breaking colloidal quantum dot solar cell performance," he adds.

As a result of the potential of this research discovery, a technology licensing agreement has been signed by U of T and KAUST, brokered by MaRS Innovations (MI), which will will enable the global commercialization of this new technology.

"The world - and the marketplace - need solar innovations that break the existing compromise between performance and cost. Through U of T's, MI's, and KAUST's partnership, we are poised to translate exciting research into tangible innovations that can be commercialized," said Sargent.

Provided by University of Toronto