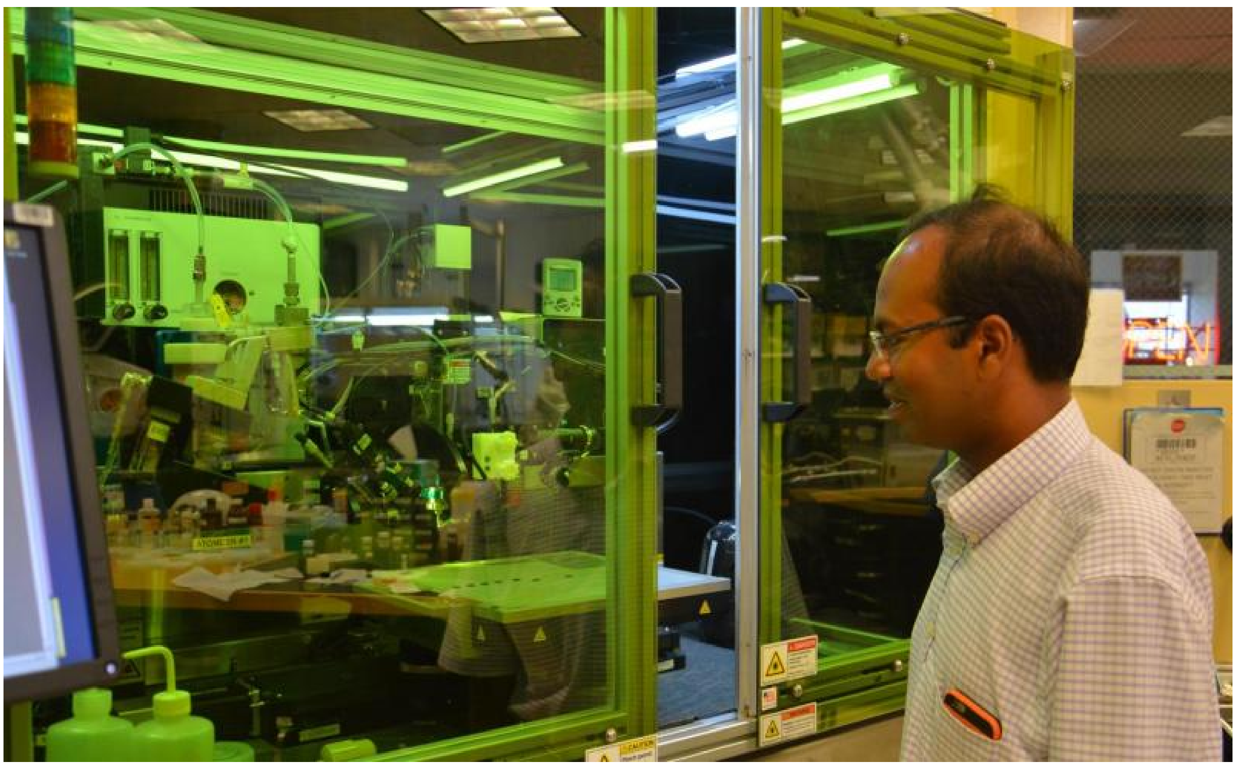
AFRL researchers explore automation, additive technologies for cost efficient solar power

July 19 2017



Dr. Santanu Bag, a project scientist at the Materials and Manufacturing Directorate, Air Force Research Laboratory, is exploring cost-efficient manufacturing of solar cells using additive technology. Credit: Air Force Office of Scientific Research

Inspired by newspaper printing, and taking cues from additive manufacturing technology, researchers at the Air Force Research Laboratory are exploring new ways to make solar cells more cost efficient—increasing application potential in the process.

"Sun is abundant, and it's free," said Dr. Santanu Bag, a project scientist at the Materials and Manufacturing Directorate, AFRL. "Solar cells can generate electricity in an environmentally friendly way, but current, complex fabrication costs make the technology expensive. We're looking at new ways to use materials and manufacturing technologies to make these less expensively."

Though research into solar cells began in the 1950s, the technology for making them is complex and labor intensive. At a basic level, to fabricate solar cells, engineers rely on extremely pure, single-crystalline silicon. The pure silicon is extracted from an original material such as quartz or sand and is transformed into thin wafers. The silicon wafers are chemically treated to form an electric field, with a positive and negative polarity. These silicon semiconductors, or solar cells, are encapsulated in a support to form a photovoltaic module, where they are then able to collect and transform sunlight into an electric current.

This multistep, labor intensive process is time-consuming and uses highly sophisticated equipment, requiring a number of technicians and engineers to create the end product. Quality control is key, as a discrepancy during any stage of the manufacturing process could have an effect on the performance of the cells.

This high cost of manufacturing has prohibited widespread use of solar power, despite its cost saving potential.

"If you want to make solar competitive, you need to make solar cells more efficient and cost effective," said Bag.

Inspired by the concept of newsprint where rolls of paper are printed with ink to create newspapers, Bag and his team looked for alternatives to inorganic, hard silicon in search of a material able to transform solar into energy—and be printed in the process.

"Silicon cells use purely inorganic materials, which by nature are very hard," said Bag. "We needed a material that was easy to print and at the same time able to capture sunlight. We determined an inorganic-organic hybrid material would be easy to print and could still harvest solar energy."

Bag's material of choice, thin-film perovskites, have an excellent light absorbing capability and power conversion efficiencies that have improved tremendously compared to the more than 30 years it took for silicon solar cells to improve to today's levels. Only recently has this material been explored for its solar power ability, with Bag among the researchers expanding the field.

"The material has been around since the 1990s and was used to make test-level, light-emitting diodes. Researchers knew it had solar ability, but this was not the focus at the time," said Bag.

In Bag's study, perovskite precursor material was atomized using ultrasonic waves to form extremely fine, aerosol droplets able to be transferred into the print nozzle of an aerosol-jet spray printer. Using computer-aided design tool paths, a surface was then coated with the material using the direct-write printer, forming a solar cell with a 15.4 percent efficiency on a flat surface.

Bag and his team also demonstrated the ability to print these solar cells on a 3-D surface with a 5.4 percent efficiency—marking the first time this has been shown in the field of printed photovoltaics.

"We have not optimized conditions for 3-D printing of these yet, but we know it can be done. Once you know how to print it, it has huge potential for other applications," said Bag.

For the Air Force, the applications for this material and the new printing process are enormous. The method can be used to print flexible solar cells on clothing, to create self-powered robotics and light-emitting devices and even to make flexible, self-powered sensors, to name a few.

Bag, along with fellow researchers Dr. Michael Durstock, Soft Matter Materials Branch Chief at the AFRL Materials and Manufacturing Directorate, and James Deneault, a research engineer at Universal Technology Corporation, have filed a patent application for the technology. Though this research is still in its early stages, the impact of the new manufacturing processes has great potential for the future.

"Understanding ways to make and print this material more efficiently at the most basic level can lead to future cost savings," Bag concluded.

More information: Santanu Bag et al. Aerosol-Jet-Assisted Thin-Film Growth of CH3 NH3 PbI3 Perovskites-A Means to Achieve High Quality, Defect-Free Films for Efficient Solar Cells, *Advanced Energy Materials* (2017). DOI: 10.1002/aenm.201701151

Provided by Air Force Office of Scientific Research

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