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Team develops semi-transparent solar cells with thermal mirror capability

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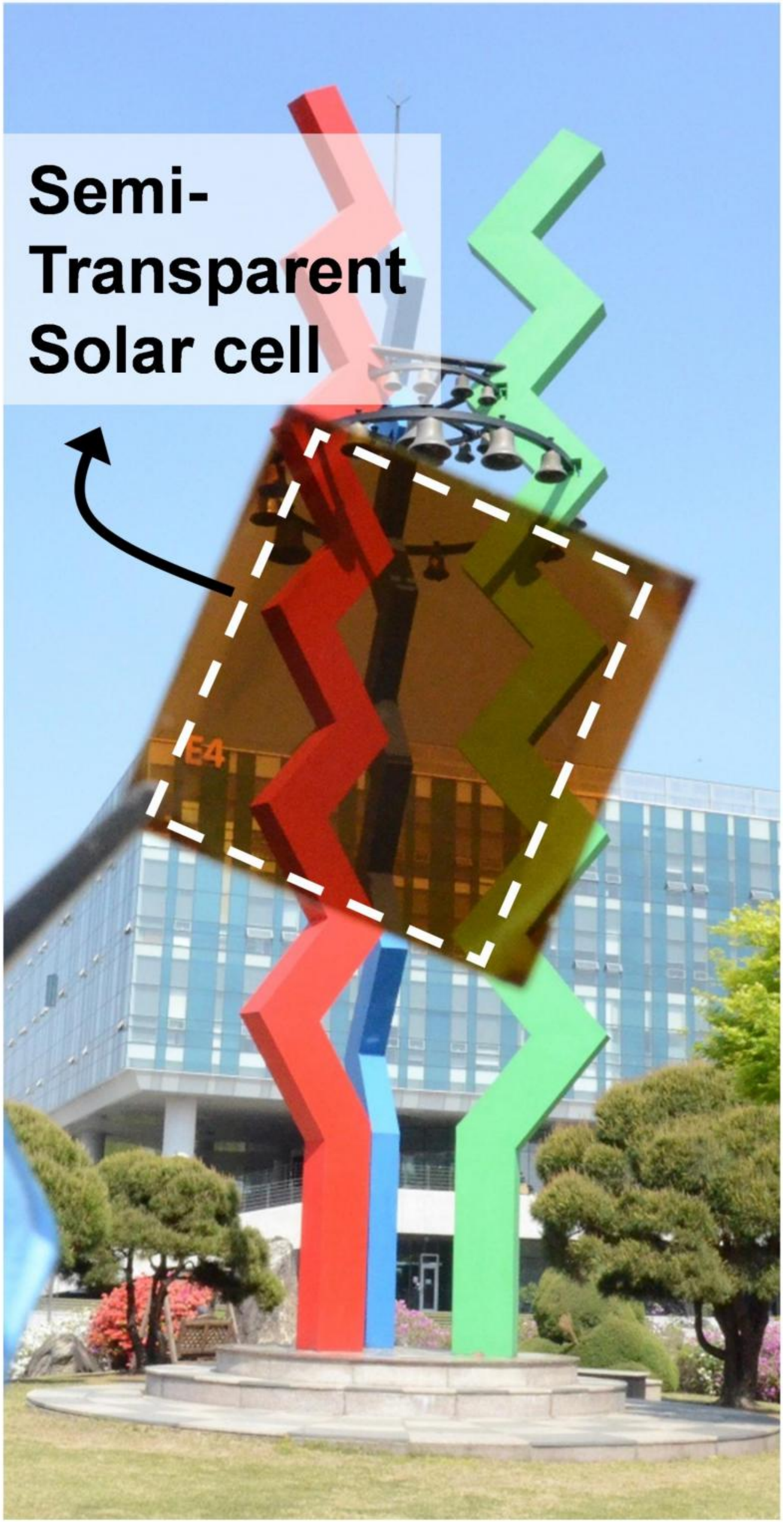
Semi-
Transparent
Solar cell
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Semi-transparent Perovskite Solar Cell. This picture shows a prototype of a semi-transparent perovskite solar cell with thermal-mirror functionality. Credit: KAIST

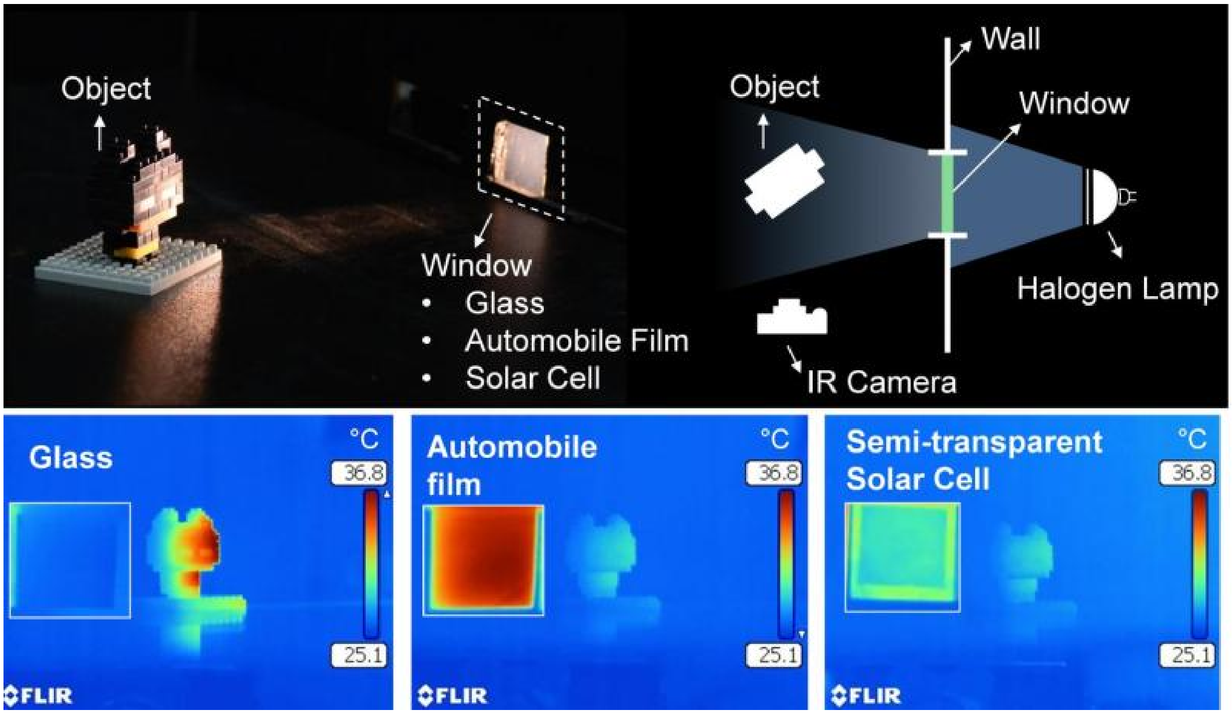
Modern architects prefer to build exteriors designed with glass mainly from artistic or cost perspectives. Scientists, however, go one step further and see opportunities from its potential ability to harness solar energy. Researchers have thus explored ways to make solar cells transparent or semi-transparent as a substitute material for glass, but this has proven to be a challenging task because solar cells need to absorb sunlight to generate electricity, and when they are transparent, it reduces their energy efficiency.

Typical solar cells today are made of crystalline silicon, but it is difficult to make them translucent. Semi-transparent solar cells under development use, for example, organic or dye-sensitized materials, but compared to crystalline silicon-based cells, their power-conversion efficiencies are relatively low. Perovskites are hybrid organic-inorganic halide-based photovoltaic materials, which are cheap to produce and easy to manufacture. They have recently received much attention as the efficiency of perovskite solar cells has rapidly increased to the level of silicon technologies in the past few years.

Using perovskites, a Korean research team led by Professor Seunghyup Yoo of the Electrical Engineering School at the Korea Advanced Institute of Science and Technology (KAIST) and Professor Nam-Gyu Park of the Chemical Engineering School at Sungkyunkwan University developed a semi-transparent solar cell that is highly efficient and, additionally, functions very effectively as a thermal-mirror.

The team has developed a top transparent electrode (TTE) that works well with perovskite solar cells. In most cases, a key to success in realizing semi-transparent solar cells is to find a TTE that is compatible with a given photoactive material system, which is also the case for perovskite solar cells. The proposed TTE is based on a multilayer stack consisting of a metal film sandwiched between a high refractive-index (high-index) layer and an interfacial buffer layer. This TTE, placed as a top-most layer, can be prepared without damaging ingredients used in perovskite solar cells. Unlike conventional transparent electrodes focusing only on transmitting visible light, the proposed TTE plays the dual role of passing through visible light while reflecting infrared rays. The semi-transparent solar cells made with the proposed TTEs exhibited average power conversion efficiency as high as 13.3 percent with 85.5 percent infrared rejection.

The team believes that if the semi-transparent perovskite solar cells are scaled up for practical applications, they can be used in solar windows for buildings and automobiles, which not only generate electrical energy but also enable the smart heat management for indoor environments, thereby utilizing solar energy more efficiently and effectively.



A Heat Rejection Performance Comparison Experiment. This picture presents thermal images taken by an infrared camera for comparing the heat rejection performance of bare glass, automotive tinting film, and a semi-transparent perovskite solar cell after being illuminated by a halogen lamp for five minutes. Credit: KAIST

This result was published as a cover article in the July 20, 2016 issue of *Advanced Energy Materials*. The research paper is entitled "Empowering Semi-transparent Solar Cells with Thermal-mirror Functionality."

The team designed the transparent electrode (TE) stack in three layers: A thin-film of silver (Ag) is placed in between the bottom interfacial layer of molybdenum trioxide (MoO_3) and the top high-index dielectric layer of zinc sulfide (ZnS). Such a tri-layer approach has been known as a means to increase the overall visible-light transmittance of metallic thin films via index matching technique, which is essentially the same technique used for anti-reflection coating of glasses except that the present case involves a metallic layer.

Traditionally, when a TE is based on a metal film, such as Ag, the film should be extremely thin, e.g., 7-12 nanometers (nm), to obtain transparency and, accordingly, to transmit visible light. However, the team took a different approach in this research. They made the Ag TE two or three times thicker (12-24 nm) than conventional metal films and, as a result, it reflected more infrared light. The high refractive index of the ZnS layer plays an essential role in keeping the visible light transmittance of the proposed TTE high even with the relatively thick Ag film when its thickness is carefully optimized for maximal destructive interference, leading to low reflectance (and thus high transmittance) within its visible light range.

The team confirmed the semi-transparent perovskite solar cell's thermal-mirror function through an experiment in which a halogen lamp illuminated an object for five minutes through three mediums: a window of bare glass, automotive tinting film, and the proposed semi-transparent perovskite solar cell. An infrared (IR) camera took thermal images of the object as well as that of each window's surface. The object's temperature, when exposed through the glass window, rose to 36.8 Celsius degrees whereas both the tinting film and the cell allowed the object to remain below 27 Celsius degrees. The tinting film absorbs light to block solar energy, so the film's surface became hot as it was continuously exposed to the lamp light, but the proposed semi-transparent solar cell stayed cool since it rejects solar heat energy by reflection, rather than by absorption. The total solar energy rejection (TSER) of the proposed cell was as high as 89.6 percent.

Professor Yoo of KAIST said, "The major contributions of this work are to find transparent electrode technology suitable for translucent perovskite cells and to provide a design approach to fully harness the potential it can further deliver as a heat mirror in addition to its main role as an electrode. The present work can be further fine-tuned to include colored solar cells and to incorporate flexible or rollable form factors, as they will allow for greater design freedom and thus offer more opportunities for them to be integrated into real-world objects and structures such as cars, buildings, and houses."

More information: Hoyeon Kim et al. Empowering Semi-Transparent Solar Cells with Thermal-Mirror Functionality, *Advanced Energy Materials* (2016). DOI: 10.1002/aenm.201502466

Provided by The Korea Advanced Institute of Science and Technology (KAIST)

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