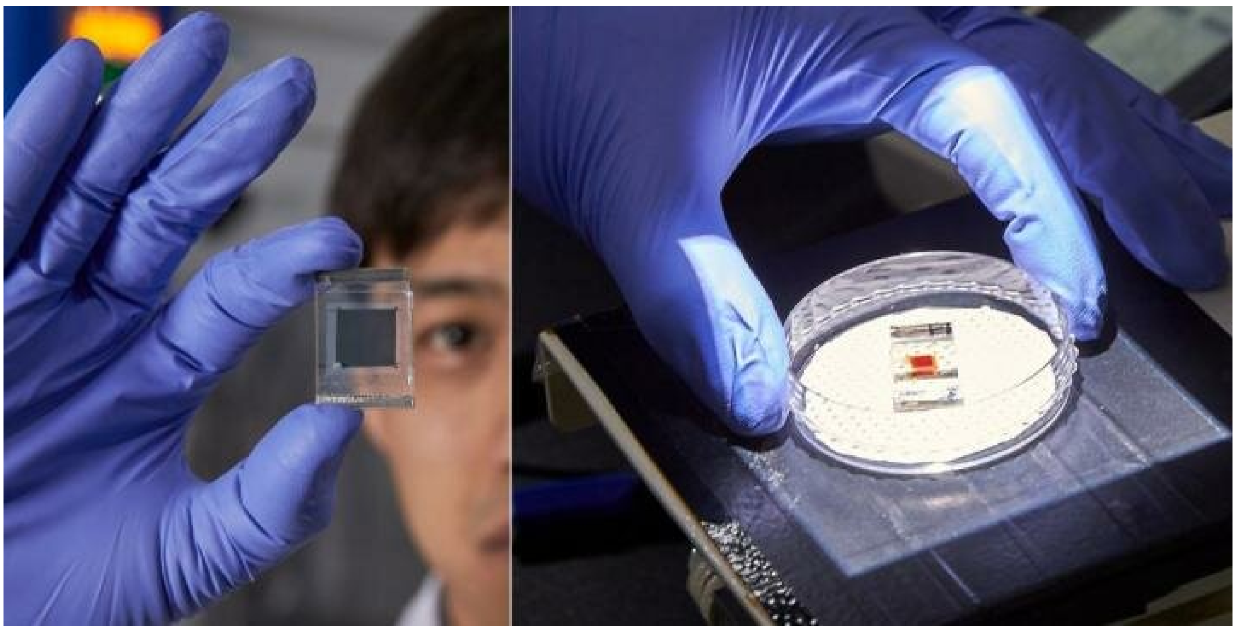
New class of solar cells, using lead-free perovskite materials

January 21 2019, by Joo Hyeon Heo



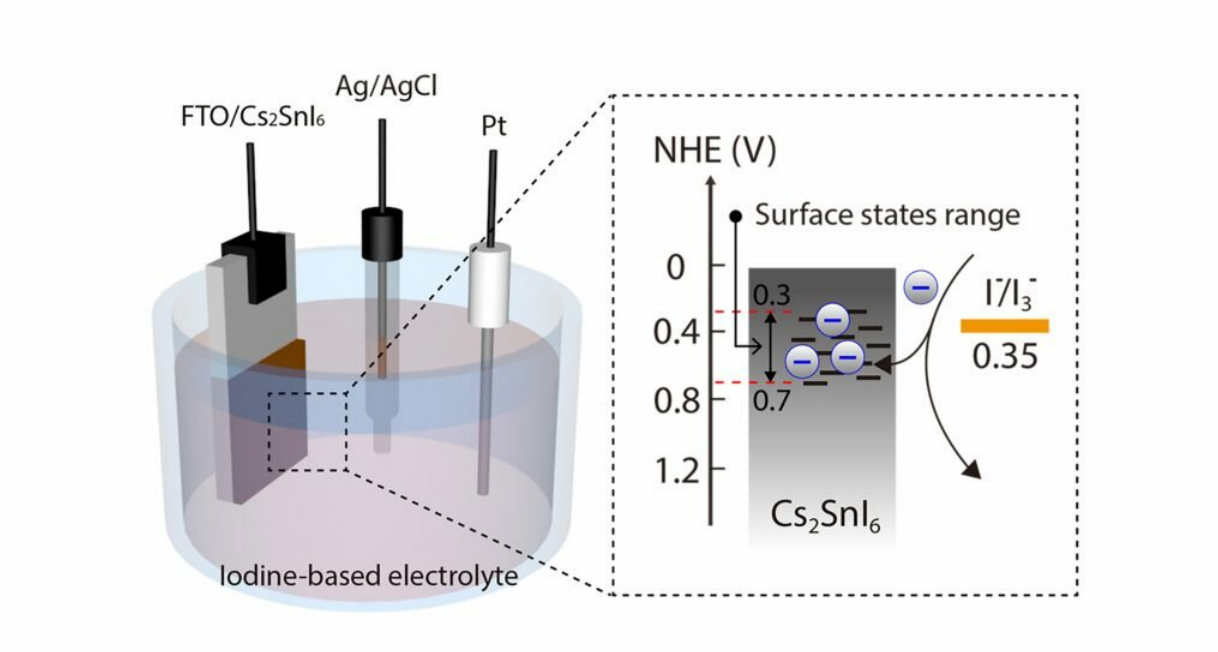
Lead-free Perovskite flim (left) and dye-sensitized organic solar cells (right). Credit: UNIST

Lead-based perovskites are promising materials for low-cost and high-efficiency solar cells. However, the intrinsic instability and the toxicity of lead (Pb) have raised serious concerns of the viability of Pb-based perovskites, hindering large-scale commercialization of solar cells and similar devices based on these materials. As an alternative solution, Pb-free perovskites were recently proposed to counter the toxicity of lead-based perovskites, yet it is of little use due to lower efficiencies.

A recent study, led by Professor Tae-Hyuk Kwon in the School of Natural Science at UNIST, represents a major step toward the development of a new generation of solar cells using lead-free perovskites. With its promising electronic properties, the new perovskite material has been demonstrated to function as a charge regenerator with dye-sensitized solar cells, thus enhancing both the overall efficiency and stability. Published in the November 2018 issue of *Advanced Materials*, the findings will open new possibilities for the application of lead-free perovskites in solar cells.

Among the various alternatives to lead, the research team used the vacancy-ordered double perovskite (Cs_2SnI_6). Despite their promising outlook, the surface states of Cs_2SnI_6 and their function remain largely unclear. Thus, a comprehensive study is necessary to clarify these features of Cs_2SnI_6 for the future design of Cs_2SnI_6-based devices.

Through this work, the team examined the charge transfer mechanism of Cs_2SnI_6 with the aim of clarifying the function of its surface state. For this purpose, a three-electrode system was developed to observe charge transfer through the surface state of Cs_2SnI_6. Cyclic voltammetry and Mott-Schottky analyses were also used to probe the surface state of Cs_2SnI_6, whose potential is related to its bandgap.

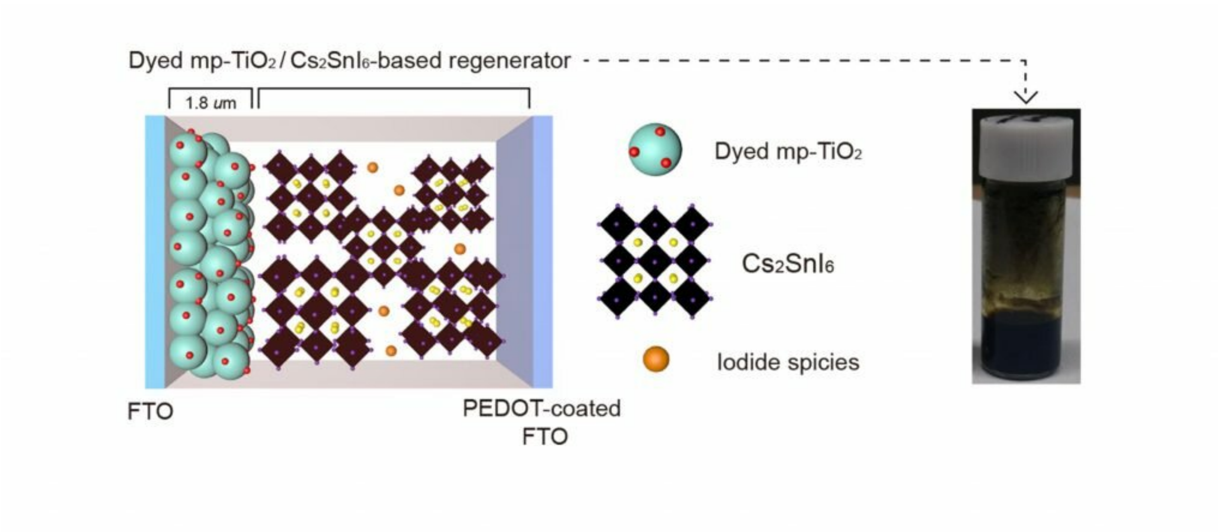


Above is the 3-electrode system for the observation of charge transfer through the surface state of Cs2SnI6. Credit: Ulsan National Institute of Science and Technology

Their analysis demonstrated that the surface state of Cs_2SnI_6 is highly redox active and can be effectively charged/discharged in the presence of iodide redox mediators. Besides, the preparation of a charge regenerator system based on Cs_2SnI_6 confirmed that charge transfer occurred through the surface state of Cs_2SnI_6.

"In case of Cs_2SnI_6, charge transfer occurred through the surface state of Cs_2SnI_6," says HyeonOh Shin in the Combined MS./Ph.D in Chemistry at UNIST. "This will aid in the design of future electronic and energy devices, using Pb-free perovskites."

Based on this strategy, the research team engineered hybrid solar cells, using a Cs_2SnI_6-based charge regenerator for organic dye-sensitized solar cells (DSSCs). Such solar cells generate electric current in the process where the oxidized organic dye returns to its original state.



Credit: Ulsan National Institute of Science and Technology

"Due to a high volume of electrical charges in organic dyes that show high connectivity with the surface state of Cs_2SnI_6, more electric current were generated," says Byung-Man Kim in the Department of Chemistry at UNIST, another lead author of this study. "Consequently, Cs_2SnI_6 shows efficient charge transfer with a thermodynamically favorable charge acceptor level, achieving a 79% enhancement in the photocurrent density compared with that of a conventional liquid electrolyte."

This study has attracted considerable attention among researchers, as it examined the charge transfer mechanism of Cs_2SnI_6 with the aim of clarifying the function of its surface state. Their results suggest that the surface state of Cs_2SnI_6 is the main charge transfer pathway in the presence of a redox mediator and should be considered in future designs of Cs_2SnI_6-based devices.

More information: HyeonOh Shin et. al., "Surface State-Mediated Charge Transfer of Cs_2SnI_6 and Its Application in Dye-Sensitized Solar Cells," *Advanced Energy Materials*, (2018).

Provided by Ulsan National Institute of Science and Technology