Area: Perovskite solar cells

LOW-TEMPERATURE PREPARED NIOBIUM-DOPED AMORPHOUS TITANUM OXIDE COMPACT LAYER IN HIGHLY EFFICIENT AND DURABLE PEROVSKITE SOLAR CELLS

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Perovskite solar cell (PSC) is one of the most promising next generation solar cells due to their high conversion efficiency and potential for low cost production. Up to now, the best (certified) conversion efficiency has reached to 22.1%, approaching close to theoretical limit. Therefore, development of peripheral technologies such as durability, lead-free, and low-temperature process becomes argent and important issues.

We have focused and tried to develop a low-temperature (and low cost) preparation process of PSCs to achieve both high efficiency and high durability. Additionally, this technic enables to make a flexible device which can be installed at any place where is difficult for a conventional Si-solar cells due to their heavy weight, and reduced transport cost by light weight and flexibility. Metal ion dope is an efficient way to change/improve inherent properties of metal oxide semiconductors, e.g., SnO_2 and TiO_2. We carried out doping of a Nb ion to amorphous TiO_x as a low-temperature prepared compact layer (CL) for PSCs combining with brookite TiO_2 nano-particles.

We prepared Nb undoped and doped TiO_x amorphous CLs combining with a brookite nanoparticle-based mesoporus layer for PSCs dried at less than 150 °C with Nb doping ratio from 1 to 5%. For a cation and halogen mixed $(FAPbI_3)_{0.85}(MAPbBr_3)_{0.15}$ perovskite (FA-MA)-based device, the best conversion efficiencies of 19.1% and 19.6% were obtained for 100 °C and 150 °C prepared devices (aperture area: 0.25 cm^2), respectively, and hysteresis in *J-V* curves was reduced compared to Nb un-doped device. By replacing the mixed perovskite with more stable $FA_{0.85}Cs_{0.15}PbI_3$ perovskite (FA-Cs), we successfully achieved the best conversion efficiency of up to 19% on a durable PSC prepared less than 130 °C. The FA-Cs perovskite-based device kept (or improved) its conversion efficiency over 2 month under dry condition, and after 1h stability test with 0.84 V bias, under 1 sun irradiation, and ambient condition, 85% efficiency could be remained without any encapsulation (Figure 1).

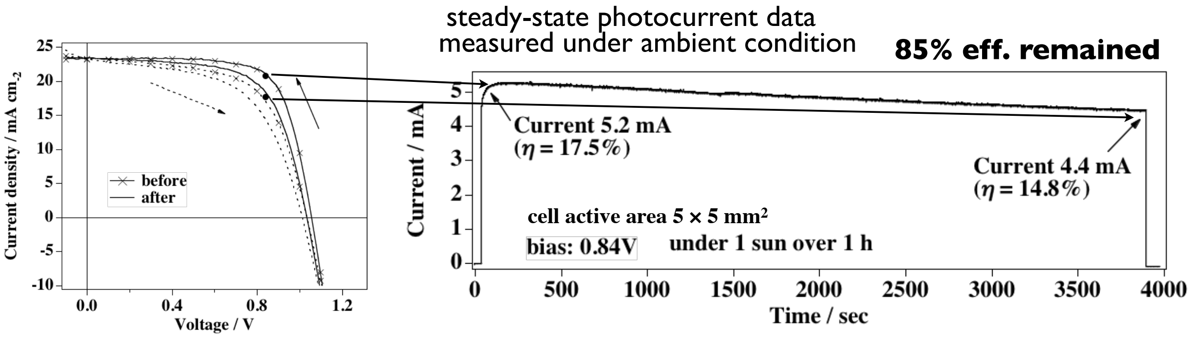

Figure 1: *J-V* curves before and after 1h stability test (left), and steady-state photocurrent of a FA-Cs PSC under ambient condition without any encapsulation (right).

References: NREL. Photovoltaic Research.http://www.nrel.gov/ncpv/ images/efficiency_chart.jpg (accessed June 2017). T. Miyasaka, *Chem. Lett*., **2015**, *44*, 720–729. A. Kogo, Y. Sanehira, M, Ikegami, T. Miyasaka, *Chem. Lett*. **2016**, *45*, 143−145. A. Kogo, Y. Sanehira, M. Ikegami, T. Miyasaka, *J. Mater. Chem. A* **2015**, *3*, 20952− 20957. A. Kogo, M. Ikegami, T. Miyasaka, *Chem. Commun*. **2016**, *52*, 8119−8122. *Chem. Lett*. **2017**, *46*, 530. Y. Numata, A. Kogo, Y. Udagawa, H. Kunugita, K. Ema, Y. Sanehira, T. Miyasaka, *ACS Appl. Mater. Interfaces*, **2017**, DOI: 10.1021/acsami.7b02924.