PHOTODEGRADATION PROCESSES IN ORGANIC-INORGANIC PEROVSKITE SOLAR CELLS

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Hybrid organic-inorganic perovskites (HOIPs) are promising photoabsorbing material for solar cells (SCs) due to high light absorption coefficient, band gap energy close to the optimal value, long lifetime of charge carriers (up to microsecond range) and possibility of low temperature (not more than 100 °C) synthesis from solutions [1–3]. Nowadays, perovskite SCs demonstrate more than 23% efficiency in laboratory conditions [4], however, we can't use them in mass SC production because they are easily degraded under influence of heat, oxygen, moisture, light soaking [5,6]. The main problem today is photodegradation, the mechanisms of which are not completely clear.

In this work, we analyzed photostability of the HOIP SCs with different chemical composition of perovskite layer: (1) $MAPbI_3$, (2) $Cs_{0.15}FA_{0.85}PbI_{2.7}Br_{0.3}$, (3) $Cs_{0.05}(MA_{0.15}FA_{0.85})_{0.95}PbI_{2.55}Br_{0.45}$, where MA is methylammonium ($CH_3NH_3^+$), and FA is formamidine ($NH_2CH{=}NH_2^+$). We used a Proscan MS122 UV-Vis-NIR spectrometer for measurement of transmission spectra, Nanofinder HE (LOTIS-TII) confocal spectrometer for recording photoluminescence (PL) and electroluminescence (EL) spectra, as well as PL kinetics and PL mapping. A Keythley 2400 source-meter was used for registration of I-V characteristics of SCs. White LED (5700 K, 1000 W/m^2 was applied as a source of photodegradation.

Studies show that photostability of perovskite SCs depends on the complexity of the lattice. So, for all samples a red-shift of PL mass center under continuous laser illumination was observed and it depends on the composition of perovskite layer (the more ions lead to the greater red-shift), which is due to ions migration in complex perovskites. Also it was found strong influence of back Au-contact on photoinduced processes in perovskite SCs, which manifested in stabilization of perovskite ions due to the formation of random potential relief forming ionic traps in the gold regions.

Obtained PL and EL spectra for fresh, degraded and restored in the dark perovskite SCs demonstrate the formation of defects at the interfaces between the perovskite and transport layers, which prevent the extraction of photogenerated charge carriers and increase the photoluminescence intensity, and formation of nonradiative recombination centers during photodegradation with white LED, the rate of elimination of which in the dark is insufficient to restore the original parameters in actual operation. Last conclusion is also confirmed by measured I-V characteristics. Besides, measured kinetics of short-circuit current and open-circuit voltage for different sample sites show that photodegradation occurs spatially inhomogeneously, which may be due to the defective perovskite lattice structure.

Results are useful for further study of photostability of organic-inorganic perovskite solar cells.

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