Enhancing the CIGS solar cell efficiency through integration of functional TCO layers: case of Yb-doped SnO_x

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Abstract

Herein we report on the improvement of the solar cell efficiency (CIGS based) through integration of multifunctional conversion layers. Efficient Down Shifting process is successfully achieved by doping tin oxide thin films with the Yb^{3+} optically active ions, elaborated by reactive magnetron sputtering. In addition to good transparency in the visible, around 80 %, and excellent transport properties; these films exhibit intense near infrared photons useful to solar cells. Under direct excitation of the SnO_x host matrix in the UV, the Yb^{3+} ions simultaneously emit NIR photons. We experimentally demonstrate, by means of PLE measurements, an efficient energy transfer from the host SnO_x to the Yb^{3+}. Thanks to the deep XPS chemical analysis we explore the atomic environment of the Yb^{3+} rare earths and gain insight understanding the conversion process. We show that the increase of the substrate temperature during the films growth sensitively enhance the emission and transport properties. Resistivities as low as 0.006 Ohm.cm and mobilities as high as 50.1 $cm^2/V.s$ were measured.

Integration of such functionalized layers, doped with 1.3 at.% of Yb and elaborated at only 100°C, into conventional CIGS based solar cells, to replace the standard ZnO layer, resulted in the improvement of the solar cell performances. Particularly its spectral response in the UV region; a net gain of the external quantum efficiency (EQE) was noticed (about 10% at 360 nm). It resulted also in a slight increase of the short-circuit current (J_{sc}) with about 0.77 mA/cm^2 together with a fill factor (FF) of 64,4 % , through conversion of UV photons to NIR ones, leading the increase of the solar cell efficiency of about 0.8 % . Such interesting results clearly show the potential of Yb-doped SnO_x layers for use as multifunctional TCO and conversion layers.

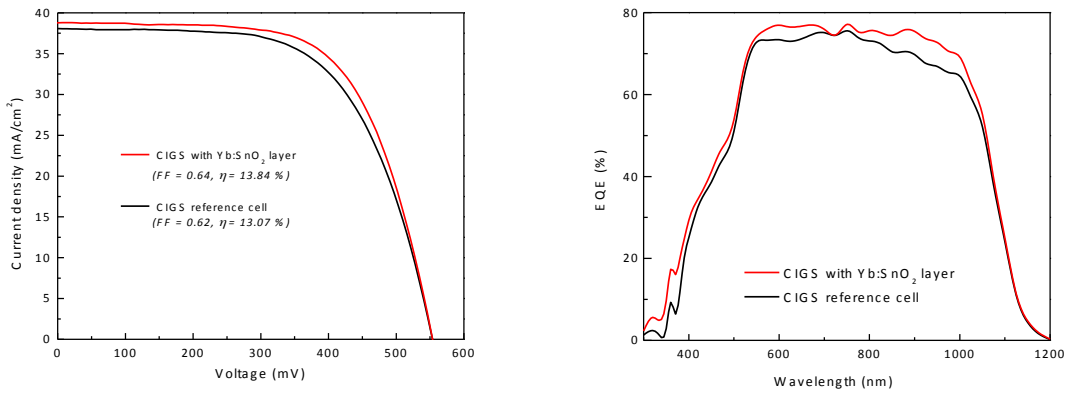

Figure 1a) -V characteristics under AM1.5G illumination; b) EQE spectra of CIGS solar cells : reference and that with $Yb:SnO_x$ DS layer