Effect of Annealing Temperature on the performance of E-beam Evaporated TiO$_2$ Photoelectrode for the application of Perovskite Solar Cells

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[Introduction] Solid-state sensitized heterojunction solar cells are presently under intense investigation because they present a promising avenue towards cost-effective and high efficiency solar power conversion [1]. These devices use molecular dye or semiconductors in form of quantum dots or extremely thin absorber layers as light harvesting agents. Perovskite (CH$_3$NH$_3$)$_2$PbI$_3$ nanocrystals have attracted attention as a new class of light harvesters for mesoscopic solar cells [2]. The aim of this work is to investigate the effect of annealing temperature on the performance of TiO$_2$ photoelectrode. The TiO$_2$ films have been deposited on ITO substrate by electron beam evaporation at room temperature. The properties of as-deposited (ASD) and annealed (ANN) TiO$_2$ films have been investigated and discussed.

[Experimental] The TiO$_2$ films were deposited on indium-doped tin oxide (ITO) substrate by Electron-beam evaporation system at room temperature [3]. After the chamber was evacuated to a background pressure below 4 x 10$^{-6}$ Torr. The film thicknesses of all the TiO$_2$ films were around 150 nm measured by computer controlled crystal. Perovskite was layered on TiO$_2$ by spin-coating method. The α-NPD and MoO$_3$ were used as hole-transport material. The prepared TiO$_2$ films were characterized by using X-ray diffractometer (XRD), UV/VIS spectrophotometer, field emission scanning electron microscope (FE-SEM). The active cell area was 0.38 cm$^2$. The photovoltaic performances of DSCs were measured using a semiconductor parameter analyzer and solar simulator AM 1.5.

[Results and discussions] Figure 1(a) shows the ($\alpha h$$\nu$)$^{1/2}$ versus photon energy curve which is drawn by the help of Tauc formulae [4]; The ANN-TiO$_2$ shows the band gap $E_g$=2.25 eV which is red-shifted from the ASD-TiO$_2$ film (3.33 eV), which may be due to crystal formation. From Fig. 1(b), ASD-TiO$_2$ shows fully amorphous structure where ANN-TiO$_2$ have high crystalline with rutile and anatase phases. The prepare TiO$_2$ has also strong perovskite peak. The Fig. 1(c) displays the difference of absorbance spectrum which is defined as D= (Absorbance of ANN-TiO$_2$ films)-(Absorbance of ASD-TiO$_2$ films). It is cleared that the perovskite can absorb the light, so this electrode is very photo-active. Inset of Fig. 1(c) shows the FESEM image of Perovskite layer on TiO$_2$ film, which is uniformly distributed whole the surface. Moreover solar cell assemblies by ANN-TiO$_2$ shows the better photovoltaic performance than the solar cell by the ASD-TiO$_2$ films.

[Conclusion] The TiO$_2$ films were successfully fabricated on ITO substrate by electron-beam evaporation system. The ANN-TiO$_2$ films had good crystallinity. The solar cell with ANN-TiO$_2$ films showed good performance.

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Fig. 1 (a) ($\alpha h$$\nu$)$^{1/2}$ versus photon energy curve; (b) XRD pattern for TiO$_2$/PRV, ANN-TiO$_2$, ASD-TiO$_2$, bare-ITO; and (c) Difference of absorbance spectrum, Inset (c1) SEM image of Perovskite layer on TiO$_2$ film.

[References]  