SnO$_2$ Nanowall-arrays Coated with Rutile-TiO$_2$ Nanoneedles for High Performance Dye-sensitized Solar Cells

Dipak V. Shinde, a Rajaram S. Mane, a,b In-Hwan Oh, c Joong Kee Lee, c and Sung-Hwan Han* a

* Inorganic Nanomaterials Laboratory, Department of Chemistry, Hanyang University, Seongdong-gu, 133791 Seoul, Republic of Korea.

Characterizations

Crystal structure of SnO$_2$ nanowalls electrodes was determined using X-ray diffractometer (Rigaku D/MAX 2500 V, Cu Ka, $\lambda = 0.15418$ nm). The thickness and morphology of the SnO$_2$ nanowall electrodes were checked with a scanning electron microscope (SEM, Hitachi S-4200). Solar-to-electric power conversion efficiency of the devices were measured by, incorporating individual and dual-sensitized SnO$_2$ electrodes into a thin layer sandwich-type cells. A Pt-coated FTO was used as counter electrode which was prepared by drop casting 0.04 M isopropanol solution of chloroplatinic acid on FTO followed by heating at 450 deg for 20 min., using a spacer film (50 $\mu$m thick polyester film) and an electrolyte Iodolyte An-50. Cell performance was measured by irradiation with 100 mW/cm$^2$ white light (1 Sun) with Air Mass (AM) 0 and 1.5 filters as a solar simulator in the presence of a water filter (450 W xenon lamp, Oriel Instruments). Current was measured by using a Keithley 2400 source meter. Electrochemical impedance spectra were recorded with an Impedance Analyzer (COMPACTSTATe: IVIUM Technologies) in a frequency range of 0.01 Hz to 1.5 MHz with 50 mV amplitude. The measurements of EIS were carried out at open circuit potentials under 1 sun AM 1.5 G light illumination. Impedance parameters were determined by fitting impedance spectra using Z-view software.
Fig. S1. Cross-section SEM image of SnO₂ nanowall arrays on FTO showing thickness around 3.2 µm.

Fig. S2. High resolution SEM image of SnO₂ nanowall electrode showing full coverage of TiO₂ nanoneedles.

Fig. S3. SEM image of SnO₂ nanowall electrodes covered with TiO₂ particles.
Fig. S4. EDX pattern of SnO$_2$-TiO$_2$ electrode

Fig. S5. UV-Visible absorption spectra of SnO$_2$ electrodes with various TiCl$_4$ treatment time.

Fig. S6. Equivalent circuit used to fit impedance data.