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Synthesis and Characterization of Nanotube TiO_2 and the Utilization as the Electrode of Dye-Sensitized Solar Cells

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Porous, nanostructured TiO_2 materials have received special attention because of their potential applications in environmental purification, photocatalysts, gas sensors, and photovoltaic cells [1]. TiO_2 nanotubes with high photocatalytic activity had been report [2]. However, the reports on dye-sensitized solar cells made of titanium nanotubes are limited [3]. In this study, we describe synthesis and characterization of nanotubes TiO_2 by the hydrothermal process [4] as well as the utilization as the electrode of dye-sensitized solar cells.

TiO_2 nanotubes were prepared using the hydrothermal process. In a typical process, 1 g of TiO_2 (ST-01) powder and an aqueous solution of NaOH (5-15 M, 200 ml) were placed into a Teflon container. The mixture was vigorously stirred in an oil-bath at 80 ~ 150°C for 12 ~ 168 h. The white suspension was filtrated, washed and dried. The products were characterized by XRD, TEM, SEM, N_2 adsorption-desorption and laser Raman.

The mixture of nanotubes TiO_2 powder, ethyl cellulose (10 wt%), and α-terpineol was dispersed sufficiently with a homogenizer to obtain a homogeneous paste. The paste was printed on a conduction glass plates (F-doped SnO_2) using screen printing machine and then calcined at 525 °C for 2 h in air, and a nanotube TiO_2 thin film electrode was obtained. The nanotubes TiO_2 films were immersed into the dye solution (N719) and then kept at 25 °C for 7 days, so that the dye could be adsorbed onto the surface of the TiO_2 electrodes.

The dye-sensitized TiO_2 electrode was incorporated into a thin-layer, sandwiched solar cell. The counterelectrode was a Pt sputtered on a transparent conducting glass using an ion coater. The photovoltaic performance of the solar cells was measured with a source meter.

Fig. 1 shows TEM images of samples synthesized at 100 °C for 120 h. The hollow nature of the nanotube with an opening end is clearly visible. This nanotube TiO_2 had an average wall thickness of 4 nm and an inner diameter of 15 nm.

Effect of reaction time on product was also investigated. It was found that no any tubular structure was observed when the reaction time was less than 48 h, only nanosheets TiO_2 with rolling edge was obtained. With increasing time, more and more tubular structure was formed. From these results, we suggest that the nanosheets with rolled edge prepared at short time are an intermediate product. This is also agreement with the formation mechanism of TiO_2 nanotubes proposed by Wang et al [5].

The results of laser Raman spectra show that the peaks of the nanotubes TiO_2 is significantly different from that of the raw TiO_2, new peaks were observed, indicating that the phase was varied after reaction.

The photocurrent-voltage (IV) characteristic of cells made of the nanotube TiO_2 and raw TiO_2 are depicted in Fig. 2. The cell size of them was 0.5 × 0.5 cm. It is clear that the short-circuit photocurrent of cell made of nanotube TiO_2 is higher than those of raw TiO_2. This might be contributed to the fact that the surface area of nanotube TiO_2 is lager than that of raw TiO_2, and the adsorbed amount of dye for the former is more than the latter. On the other hand, the intercrystalline contacts of TiO_2 can be highly decreased by using nanotube TiO_2 as the electrode of solar cells [3].

We have successfully synthesized nanotubes TiO_2 by the hydrothermal process. Nanotubes TiO_2 was used as an electrode material for dye-sensitized solar cells. It was found that the conversion efficiency of solar cells made of nanotube TiO_2 is higher than those of raw TiO_2.

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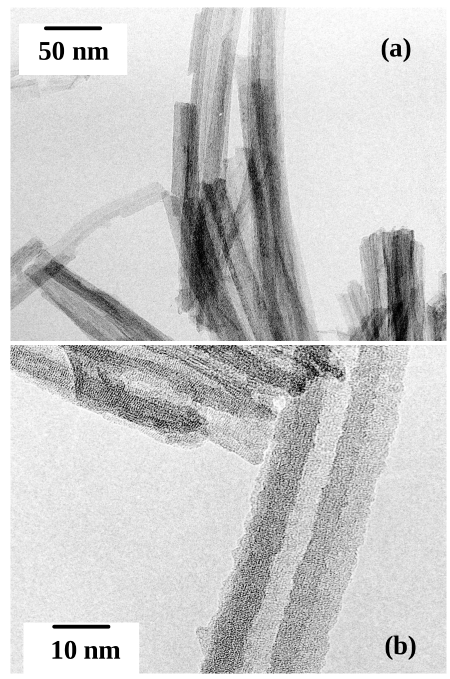

Fig. 1 TEM images of nanotube TiO_2 (a) low magnification and (b) high magnifaction.

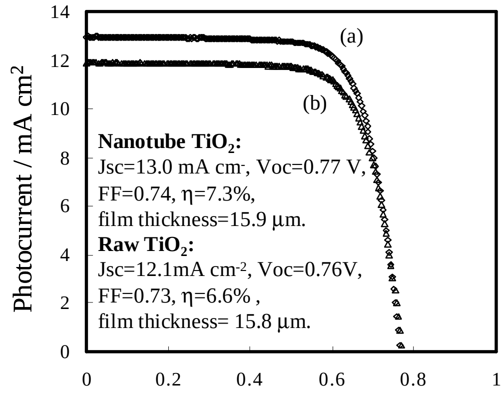

Fig. 2 I-V curves for the dye-sensitized solar cells made of (a) nanotube TiO_2 and (b) raw TiO_2.