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# Fabrication of high-efficiency dye-sensitized plastic photocells by low-temperature electrode preparation using a binder-free nanocrystalline $TiO_2$ coating paste

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Low-temperature preparation of mesoporous semiconductor electrodes for dye sensitization has been a subject of recent intense study for realizing full-plastic thin flexible photocells. We have devised high-efficiency plastic photocells by two approaches, electrophoretic deposition of $TiO_2$ nanocrystalls[1-3] and preparation of binder-free viscous $TiO_2$ paste for doctor blade coating. Both methods need completion of inter-particle binding (necking) that enables efficient diffusion of conduction-band electrons through particles. In this paper binder-free pastes for doctor-blade coating were prepared by using $TiO_2$ precursor sol, which causes efficient chemical necking at temperatures below 200℃. We could achieve energy conversion efficiency of 4.6-5.4%, which is comparable with the top efficiency obtained by electrophoretic technique combined with post chemical treatments and with the efficiency obtained by high-temperature sintering of the same $TiO_2$ particle on a glass electrode.

Nanocrystalline $TiO_2$ (Showa Denko F-5, average size, 20 nm) was mixed with light-scattering large $TiO_2$ particle (G2, 500 nm) and acidic $TiO_2$ precursor sol in a mixture solvent of *tert*-butanol and ethanol to give a viscous paste free of binder materials. The viscosity of the paste was variable and was controlled by the composition of solvents. The paste ($TiO_2$ content, 14wt%) was coated on a transparent ITO-PET or ITO-PEN film (10-15 ohm/□) by the doctor blade method, dried, and heat-treated at 150-200℃ for 5 min to form a mesoporous $TiO_2$ layer. $TiO_2$-coated films showed high adhesion strength for $TiO_2$ layer (about 10 μm thick) against bending (see Fig. 1). The film electrode was dye-sensitized with a Ru complex (N719) and made into a thin cell (effective electrode area, 8 × 8 mm) with Pt-coated counterelectrode and methoxyacetonitrile-based $I^-/I_3^-$ electrolyte composition.

Figure 2 shows I-V characteristics for the $TiO_2$ layer according to the present method and a reference layer prepared by high-temperature sintering at 550℃ on glass electrodes. Photocurrent density ($J_{sc}$) proved to reach the same level as that of sintered electrode. Open-circuit voltage ($V_{oc}$) was lower than the sintered one suggesting that there is a wide distribution in conduction-band potential of $TiO_2$ layer as a result of low temperature preparation process. By optimization of the large particle (G2) content and thickness of $TiO_2$ layer, energy conversion efficiency under 100 $mW/cm^2$ reached around 4.6% at 11-12g $TiO_2/m^2$ and G2 content of 30 wt%, as shown in Fig. 3. Non-volatile molten salt (imidazolium iodide) was also used as electrolyte, with which efficiency level was decreased to 3-3.5%. With this method, we are fabricating large-size full plastic photocells (>50 $cm^2$) by introducing metal grid pattern electrodes on the ITO surface for current collection.

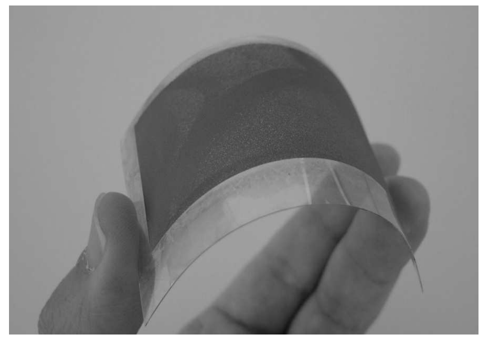

Fig. 1 Flexible plastic film photoelectrode bearing dye-sensitized mesoporous $TiO_2$ layer

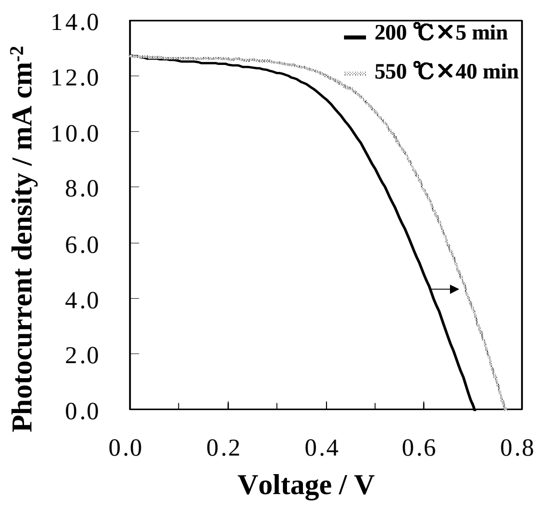


Fig. 2 Photocurrent-voltage characteristics of the low-temperature $TiO_2$ coating in comparison the same coating having been treated by high-temperature sintering at 550℃

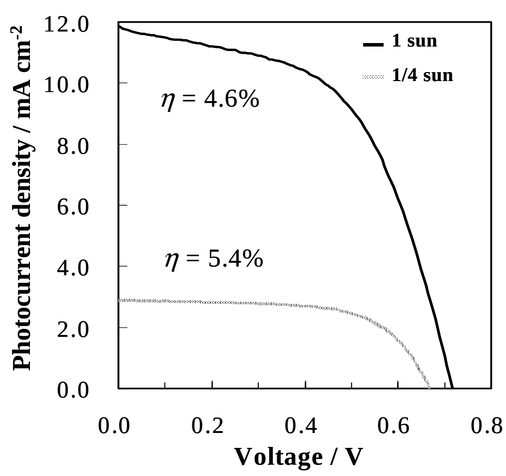


Fig. 3 Photocurrent-voltage characteristics of the low-temperature coated binder-free $TiO_2$ layer at incident intensities of 1 sun (100 $mW/cm^2$) and 1/4 sun.

References

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