Optimization of Dye-sensitized Solar Cells by Spray Pyrolysis Deposition (SPD) Technique

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1. Introduction

A dye-sensitized solar cell has been a hot topic during the decade due to its scientific and technological importance. In order to fabricate the solar cell in a practical use, a novel industrial electrode production technique should be developed. Among many thin film processing techniques, spray pyrolysis deposition (SPD) is one of the most promising ones, since the film formation is carried out in air by a simple apparatus. However, the photovoltaic property of the cell produced by this technique was relatively lower than that fabricated by the conventional ways. We report here an optimization of the surface morphology of SnO_2:F transparent conducting film to improve the cell performance.

2. Experimental

Transparent conducting SnO_2:F (FTO) films were prepared from di-*n*-butyltin(IV) diacetate ethanol solution with ammonium fluoride as an additive [1]. The source solution was sprayed by a compressed air onto the heated glass substrate (Corning 1737; 25 x 25 x 1 mm^3 in size). The mist pyrolized on the substrate to form FTO film in air. Since the mist cooled down the substrate, the spray was not carried out continuously but intermittently. Tetrabutyltin(IV) ethanol solution was further sprayed in order to control the surface morphology of FTO film [2]. Porous TiO_2 film was then deposited on the FTO film in the same way that mentioned above from the mixture of aqueous amorphous and anatase TiO_2-sols (TKC-01 and -02, respectively, TAYCA Co., Ltd.). Ruthenium(II) *cis*-di(thiocyano)bis(2,2'-bipyridyl-4,4'-dicarboxylic acid) dye was adsorbed on the surface of TiO_2 film by refluxing electrodes in the ethanol solution. An anhydrous electrolyte containing I^-/I_3^- was sandwiched between the dye-adsorbed TiO_2 electrode and platinum coated glass to construct a dye-sensitized solar cell [3, 4]. The photovoltaic properties were measured under the illumination of quasi-sunlight of AM-1.5 and 100 mW/cm^2.

3. Results

FTO film produced in Asahi Glass Co., Ltd., is utilized in general in the field of dye-sensitized solar cells. The film consists of large SnO_2:F particles with a grain size of 100-200 nm to revealed a coarse surface. On the other hand, the surface morphology of FTO film deposited from di-*n*-butyltin(IV) diacetate by SPD technique was smooth, while the grain size was almost same to the commercial one. Since the electrical and optical properties are almost comparable between the film, a superior cell performance reported in other research groups is supposed to be attributed to the coarse surface of FTO film. In order to enhance the surface roughness of the film by SPD, tetrabutyltin(IV) ethanol solution was further sprayed on the FTO film. The surface morphology of the film became porous with 80-100 nm-sized FTO particles after the surface modification. Although the particle size was smaller than that of commercial ones, we succeeded in controlling the surface roughness of FTO film by SPD technique.

Dye-sensitized solar cells were fabricated with the FTO films. The conversion efficiency was effectively enhanced up to 6.8% due to a significant increase of the short circuit current density, I_{SC}, after the surface modification. We suppose the improvement of the cell performance is derived from a light confinement attributed to a scattering within the film to increase the light absorption as well as from the enhancement of the electrical contact between FTO and TiO_2 film to reduce the recombination of photo generated electrons.

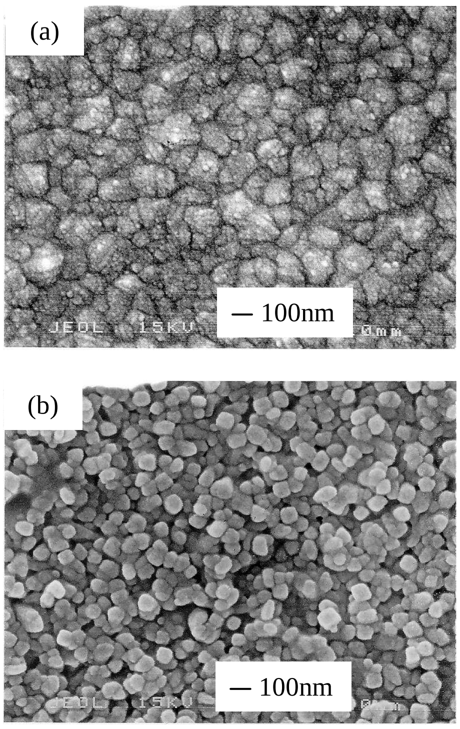

Fig. 1 Surface morphology of FTO films before (a) and after (b) the surface modification by SPD technique.

Table 1 Photovoltaic properties of dye-sensitized solar cells prepared from FTO film before and after the surface modification by SPD technique.

	V_{OC} (V)	I_{SC} (mA/cm^2)	FF	η (%)
Before	0.63	11.6	0.70	5.1
After	0.66	14.4	0.72	6.8

References

[1] K. Murakami, I. Yagi and S. Kaneko, *J. Am. Ceram. Soc.*, **79** (1996) 2557.

[2] M. Okuya, S. Kaneko, K. Hiroshima, I. Yagi and K. Murakami, *J. Euro. Ceram. Soc.*, **21** (2001) 2099.

[3] M. Okuya, K. Nakade and S. Kaneko, *Sol. Ener. Mater. Sol. Cells*, **70** (2002) 425.

[4] M. Okuya, K. Nakade, D. Osa, T. Nakano, G.R.A. Kumara and S. Kaneko, *Photochem. Photobiol., A Chem.*, **164** (2004) 167.