Fabrication of Dye-Sensitised Solar Cell Utilizing PELID (Patterning with Electrostatically-Injected Droplet) Method

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Abstract

Solar cell is one of the key technologies in this century because this has possibility to clear energy problems. In this paper, we tried to pattern TiO_2 layer of dye-sensitised solar cell (DSC) utilizing PELID method. The PELID method is an inkjet fabrication method. The PELID method has good merit; that is ability to eject highly viscous liquid. We applied the merit for patterning TiO_2 paste on FTO (Fluorine-doped Tin Oxide) glass. The thickness of TiO_2 layer was controlled by the time to print. DSC is composed of electrolyte that is sandwiched between FTO glass and Pt electrode. TiO_2 and N3 are patterned on FTO glass. The efficiency is not so high. The main purpose of the study is to improve the efficiency. The fabrication process of the DSC was simple. TiO_2 paste was patterned on FTO glass utilizing doctor blade. The patterned paste was dried and sintered. The thickness of the layer was controlled by the spacer between the doctor blade and the glass. In the former study, the thickness was not changed, however it is essential to determine the thickness to achieve the highest efficiency. Because best thickness will be changed by the chemical characteristics of TiO_2, new fabrication method that can change the thickness easily should be developed. We developed the PELID method. When the strong electric field was applied to a nozzle, small droplets were ejected by the electrostatic force.

In this paper, we applied the PELID method to pattern TiO_2 on FTO glass. In this experiment, the viscosity of the TiO_2 paste was from several 10 to 700 mPa・s. In spite that the viscosity is high, the paste was patterned on FTO glass utilizing the PELID method. When the time to pattern was increased, TiO_2 layer was thick. The efficiency was investigated when the TiO_2 patterned glass was sintered. The efficiency of the fabricated DSC was 2 %~5 % in this experiment.

Introduction

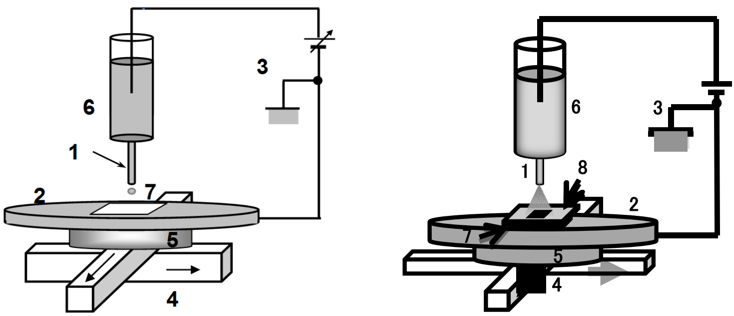
Solar cell [1-3] is highly focused because this is able to generate energy without carbon. Many kinds of solar cell were suggested and produced. Silicon type and compound type are excellent in efficiency. However there are some difficulties in fabrication; those are high cost, complex process and high vacuum condition. Many researchers are engaged on dye-sensitised solar cell (DSC) to clear the problems. DSC is composed of electrolyte that is sandwiched between FTO glass and Pt electrode. TiO_2 and N3 are patterned on the FTO glass. Light passes through the FTO electrode into the dye that is covered on the TiO_2 particles. Light excites electrons that flow into the TiO_2. The electrons flow toward the FTO electrode. Through the external circuit, electrons are back to the Pt electrode of the cell. The electrolyte transports the electrons back to the dye. The mechanism of power generation of the DSC is similar to the photosynthesis of leaf. The efficiency of the DSC is not so high. The main purpose of the study on the DSC is to improve the efficiency. Former studies were focused on the shape and chemical characteristics of TiO_2 and pigments, the efficiency was relatively increased [4, 5].

The fabrication process was simple. TiO_2 paste was patterned on FTO glass utilizing doctor blade. The patterned paste was dried and sintered. The thickness of the layer was controlled by the spacer between the doctor blade and the glass. In the former study, the thickness was not changed, however it is essential to determine the thickness to achieve the highest efficiency. Because best thickness will depend on kind of TiO_2 paste, fabrication method that can change the thickness easily should be developed.

We developed new inkjet technology that name was PELID method. When the strong electric field was applied to a nozzle, small droplets were ejected by the electrostatic force. Modes of droplet ejection were classified into several modes [6]. In this paper, we applied the droplet mode and spray mode to pattern TiO_2 layer on FTO glass.

Experimental Set-up

We studied inkjet technology for printing, circuit printing and bio-applications [6-8]. Experimental set-up of PELID method was shown in Fig. 1. Small droplets were ejected by electrostatic force when high voltage was applied between nozzle that was



(a) droplet mode (b) spray mode

Fig. 1 Experimental set-up. (1: nozzle mounted at the bottom of syringe, 2: plate electrode, 3: high voltage applier, 4, 5: xyz linear stage, 6: syringe, 7: target, 8: mask)

filled with conductive liquid and plate electrode. The electrostatic field was controlled by the amplitude of applied voltage and the air gap between the electrodes. Print samples were patterned by the control of voltage application and xy linear stage. We already reported the fundamental characteristics of this inkjet technology. The merits of the inkjet technology were high resolution and ability to eject highly viscous liquid [6]. Inkjet technology is suitable to find best thickness of TiO_2 layer because the thickness is determined by the time to print. TiO_2 paste in this experiment was made as follows. TiO_2 particles (1.85 g) and water (1.0 g) was mixed. Acetylacetone (0.2 ml), Triton-X (1.0 ml) and polyethyleneglycol (0.185 g) were mixed into the paste. TiO_2 was patterned on FTO electrode because FTO electrode was transmissive.

Results

TiO_2 paste was patterned on FTO electrode utilizing droplet mode. Figure 2 shows the samples of patterned TiO_2 on FTO electrode when the applied voltage was changed. Figure 2 indicated that the width of patterned TiO_2 line was wide in case that the applied voltage was high and the air gap was large. The efficiency of the fabricated DSC was 1 %~2 %. The efficiency was not high. However this mode was suitable for spot printing of TiO_2.

In general, area of solar cell was large. Spray mode was suitable to print large area. Figure 3 shows the print sample utilizing spray mode. This picture was demonstration that the spray mode was suitable to print large area. The efficiency was

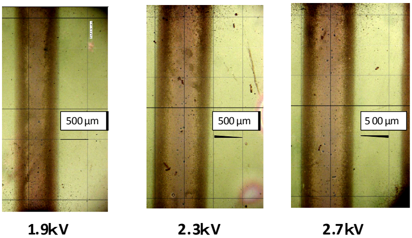


Fig. 2 Patterned TiO_2 (droplet mode).

Fig. 3 Patterned TiO_2 (spray-mode).

investigated by solar simulator (PEC-S20, Peccell inc.). The patterned area was controlled with mask shown in Fig. 3. The specifications were as follows. The thickness of the patterned TiO_2 was about 100 μm. J_{sc} was 8.23 mA/cm^2. V_{oc} was 0.685 *V*. *ff* was 0.47. The efficiency was 2.6 % in this case. When the time to pattern was changed, the thickness of the patterned TiO_2 and the efficiency were changed.

Conclusions

Our inkjet technology, PELID method, was applied to pattern TiO_2 paste on FTO electrode. In spite that the viscosity of the paste was high, the paste was ejected by the PELID method. Droplet mode was suitable for spot printing. Spray mode was suitable to pattern large area. The patterned area was controlled utilizing the mask on FTO glass. It was possible to control the thickness of TiO_2 layer when the time to pattern was changed. The efficiency of the fabricated DSC was 2 %~5 %.

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