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Control of Titania Layer of Dye-Sensitized Solar Cell (DSC)

Yuki Nakamura(1), Kengo Takamori(2), Yoshihito Kunugi(3), Satoru Iwamori(1), Shinjiro Umezu(4),*; (1)Dept. of Mech. Eng., Tokai University (Japan), (2) Graduate School of CSE, Waseda University (Japan), (3) Dept. of Chemical Eng., (4) School of CSE, Waseda University (Japan); * Okubo, Shinjuku, Tokyo, Japan

Abstract

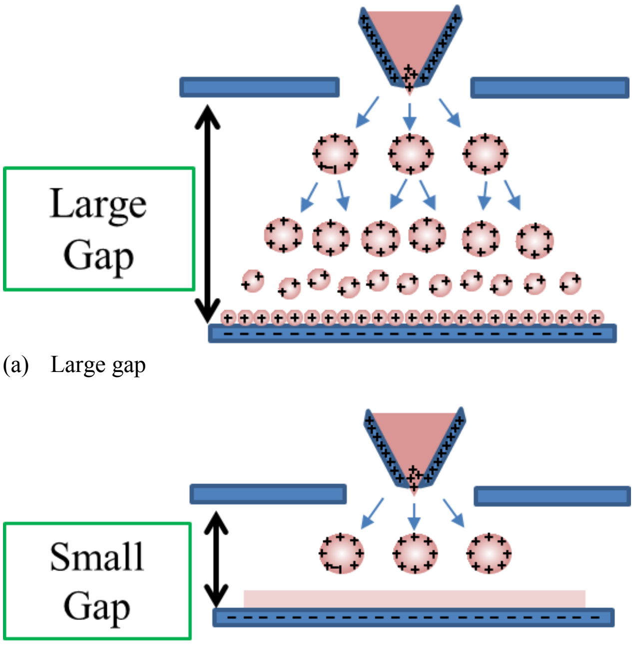
In recent days, green technology that is based on solar cell is highly focused for sustainable society. So, the efficiency of Si type of solar cell is drastically improved. On the other hand, dye-sensitized solar cell (DSC) is also highly focused because of flexibility and design in spite of low efficiency. To clear the low efficiency problem, many studies on the development of dye and titania were carried out. Because the dye was developed, then the absorbed wavelength became broad and the absorption ratio on each wavelength was increased. Due to the study on titania, unique shapes of titania were suggested and the absorption characteristics were improved. In spite that many studies on chemical view were carried out, few studies on fabrication process were carried out. So, we focused on fabrication of titania layer of DSC. Usually, the titania layer was fabricated by the doctor blade method or the screen print method. The inside of the fabricated titania layer utilizing the ordinary method had little porous. In the case that the porous titania layer was formed, then the flow of electricity was increased due to the increased surface of titania layer. We applied the electrostatic inkjet method for fabrication of the titania layer because the porous layer was formed due to evaporation effect utilizing the electrostatice inkjet method. We already formed porous titania layer and achieved the efficiency improvement. In this paper, we investigated the fundamental characteristics on fabrication of porous titania layer utilizing the evaporation effect. The experimental set-up to investigate the characteristics was shown as follows. Titania paste was filled with the ink tank. Nozzle was installed at the end of the tank. FTO glass electrode was set on the XY linear stage and the rotation stage. When the high voltage was applied between the nozzle and the glass electrode, small droplets were ejected because the electrostatic inkjet method was took place. Formation and ejection of the small droplets were observed with a high-speed camera and a light. The evaluation of the porous titania layer was carried out with the SEM and XRR. We investigated the characteristics of the porous titania layer in case that the rotation speed was changed.

Introduction

Solar power that is clearn and sustainable energy is highly expected. Si type of solar cell that is high efficiency dominates a market. However, the manufacturing cost is high. So, recently dye-sensitized solar cell (DSC) [1] that conservation efficiency is low is highly focused by many researchers to improve efficiency [2-8]. DSC does not require expensive materials and manufacturing apparatus. Large-scale DSC is fabricated utilizing the printing process. However, the conservation efficiency is low. So, many studies those are development on the DSC material, dye, titania, electrolyte are carried out to improve the efficiency. In spite that the titania thickness is important on the efficiency, a few studies on the process of titania printing [9,10] are carried out. The authors printed porous titania layer that efficiency was relatively higher utilizing electrostatic inkjet [11-15]. In this paper, the authors print titania layers those porous ratio is changed at each level.

Mechanism of Nano Porous Titania Layer

Fig. 1 shows the mechanism of nano porous titania layer utilizing electrostatic inkjet phenomena. Evaporation process of the electrostatic inkjet is applied for fabrication of nano porous titania layer. When the gap2, the distance between the plate electrode and the target, is large, then titania paste are hardly dried before the paste are attached on the target, and titania layer which has much nano porous will be formed. On the other hand, when the gap2 is small, wet titania paste are attached on the target, and mat titania layer will be formed. We already printed porous titania layer with the evaporation process. Because of the porous titania layer, the efficiency of the DSC is increased. However, the pore ratio of the titania layer is not optimized.



(a) Large gap

(b) Small gap

Fig. 1 Evaporation mechanism utilizing electrostatic inkjet. Small particles are dispersed from the nozzle. When the gap is large, then the droplets are dried by the evaporation process.

Experiment

Fig. 2 shows the experimental set-up of the electrostatic inkjet. The detail of the titania paste is already reported in the former papers [9, 10]. The paste tank that tip has small nozzle is set above the plate electrode. When the high voltage is applied between the tank and the plate electrode, then the electrostatic inkjet phenomena is observed. FTO electrode with mask is set on the plate electrode. When the ring electrode is inserted

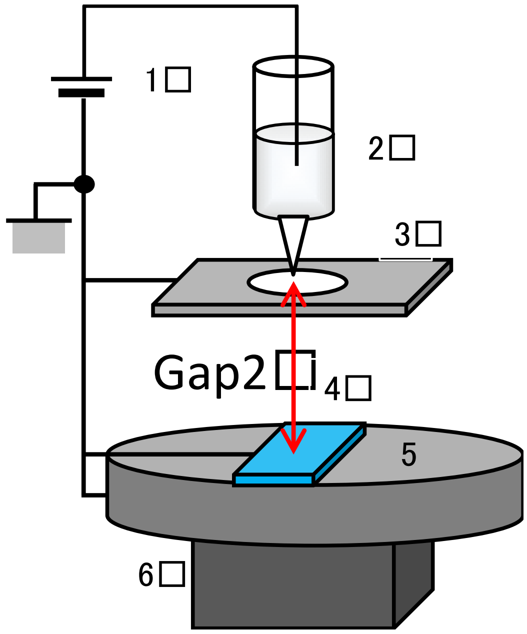


Fig. 2 Experimental set-up of electrostatic inkjet. (1: High voltage supply, 2: Ink tank filled with titania paste, 3: Plate electrode with a hole, 4: FTO plate electrode, 5: Plate electrode, 6: Spin coater)

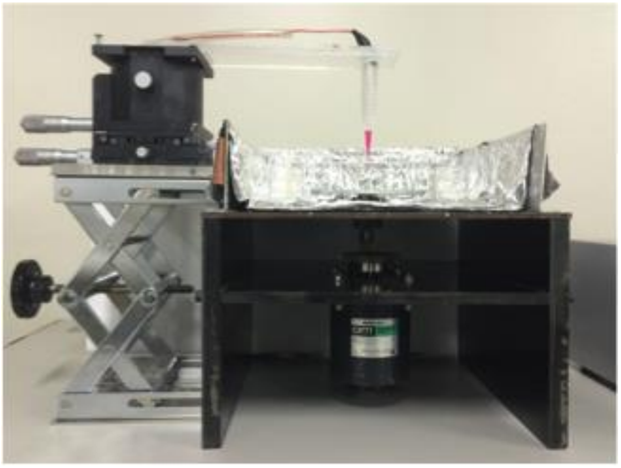
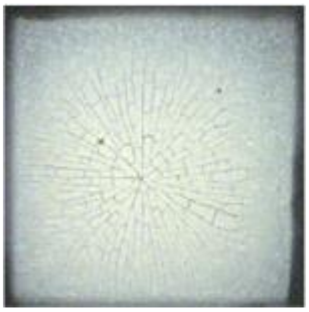


Fig. 3 Photograph of experimental set-up.

between the nozzle and the target, then the small droplets are dispersed from the nozzle because the electrostatic field around the nozzle is high. The gap1, the vertical distance between the nozzle and the ring electrode is positive, some dispersed droplets attaches on the edge of the ring electrode. So, gap1 is set as 0. The gap2, the vertical distance between the ring electrode and the target, is changed. In the case that the gap2 is small, the wet droplets are attached on the target and the attached area is normally distributed. When the spin coater is used, the normally distributed area will be flat because of the centrifugal force. The rotation speed is 1000 rpm. When the rotation speed is slow, the area is not flat because of weak centrifugal force. When the rotation speed is high, the attached titania paste is blown away. On the other hand, in the case that the gap2 is large, the dried titania particles by the evaporation effect are attached on the target and the attached area is relatively flat because of long distance for the ejected droplets.

Results

Fig. 4 and 5 show the overall photograph and cross-sectional SEM photograph of the printed titania layer when the gap2 is changed. In the case that the gap2 is 10 mm, wet titania droplets are attached on the FTO electrode, and spread with the centrifugal force by the spin coater. After the spread, the titania paste is dried and the alligatoring is generated. Inside of the cross section of the titania layer is mat. On the other hand, in the case that the gap2 is over 30 mm, then the dried titania particles are attached on the FTO electrode. So, alligatoring is not observed and porous

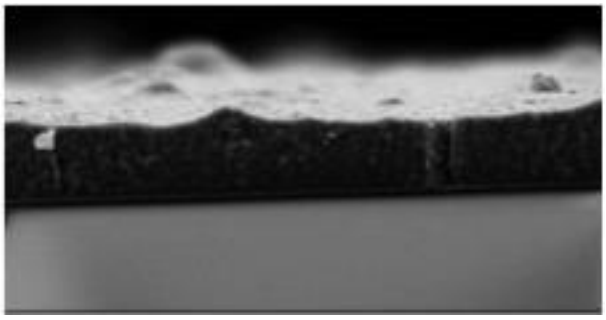


(a) gap2 is 10 mm

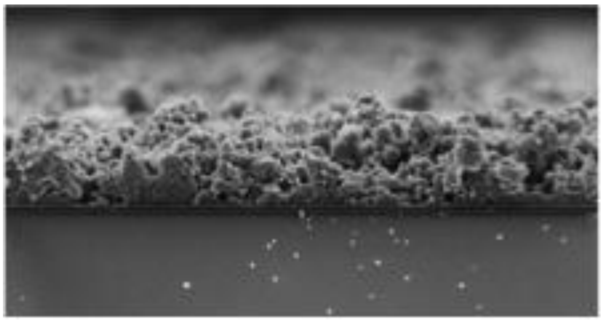
(b) gap2 is 30 mm

(c) gap2 is 50 mm

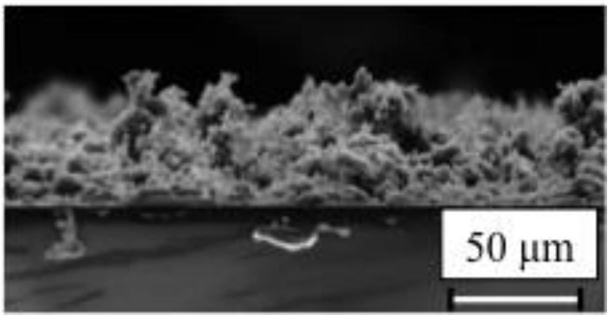
Fig. 4 Overall photograph of the printed titania layer when the gap2 is changed.



(a) gap2 is 10 mm



(b) gap2 is 30 mm



(c) gap2 is 50 mm
Fig. 5 Cross-sectional SEM photograph of the printed titania layer when the gap2 is changed.

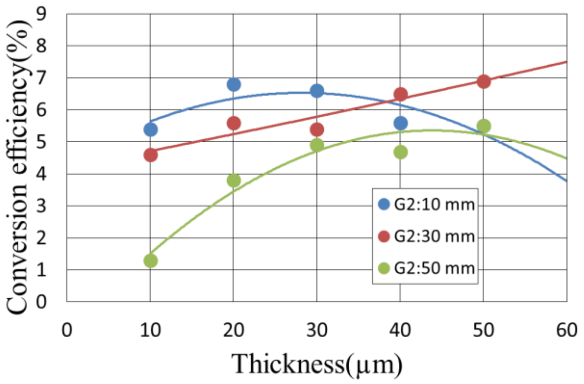
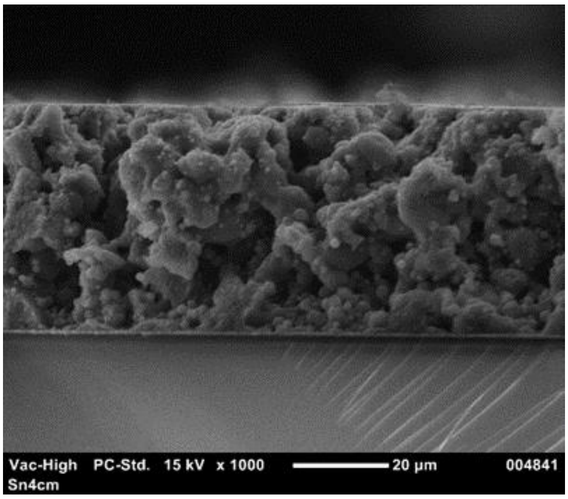


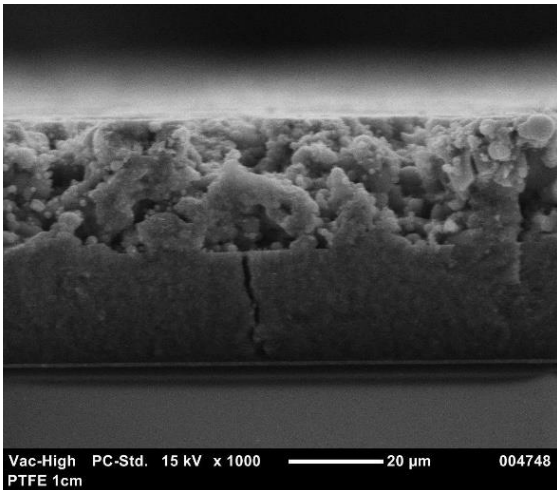
Fig. 6 Conversion efficiency of the DSCs those titania layer is printed in the case that the gap2 is changed.

titania layer is formed. When the gap2 is further large, in this case 50 mm, then the titania paste is exsiccated and the surface of the printed titania layer is not smooth. Fig. 6 shows the conversion efficiency in the case that the gap2 is changed. The trend of the efficiency is changed, however basically the efficiency of the porous titania layer is high according to the former results [9, 10].

Fig. 7 shows the titania layer when the printing condition is changed while printing. After the porous titania layer is printed, wet titania layer is printed over the porous titania layer. It is difficult to recognize the flat and mat titania layer on the porous titania layer because the attached wet titania droplets permeate



(a) Top layer: gap2 is 10 mm, bottom layer: gap2 is 30 mm



(b) Top layer: gap2 is 30 mm, bottom layer: gap2 is 10 mm
Fig. 7 Printed titania layers those porous ratio is changed at each level.

inside of the porous titania layer. However, we are able to print porous titania layer on the mat titania layer because the attached dried titania particles remains on the surface of the titania layer.

Conclusion

The authors printed porous titania layer utilizing electrostatic inkjet. The porous ratio is changed depended on the gap2. The authors print titania layers those porous ratio is changed at each level. These results are suitable for printing optimized titania layer.

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Author Biography

Shinjiro Umezu was a Research Associate, Waseda Univ. (2003). He moved to RIKEN as a Special Postdoctoral Researcher (2007). He moved to Tokai University as an Assistant Professor, Mech. Eng., School of Eng. (2009) and promoted to a Jr. Associate Professor, Mech. Eng. (2012). From 2014, he was an Associate Professor, Modern Mech. Eng., Waseda University.