Nanostructured ZnO Photoelectrode grown on Seedless Flexible Substrate

Md. Faruk Hossain¹, Shigeki Naka, and Hiroyuki Okada² (University of Toyama) E-mail: ¹ faruk94_ruet@yahoo.com , and ² okada@eng.u-toyama.ac.jp

[Introduction] Recently, ZnO nanostructures have been a growing interest for their potential applications infabricating electronic, and electrochemical devices, such as, solar cell, sensor, light-emitting diode, nanogenerator, ultraviolet laser, and piezoelectronic devices [1]. Because, ZnO is an important and versatile n-type semiconductor with wide bandgap (3.37 eV), high electron mobility ($115-155 \text{ cm}^2 \text{V}^{-1} \text{s}^{-1}$) and a very large exciton binding energy (60 meV) at room temperature [2]. The various methods have been reported for the synthesis of ZnO nanostructures, such as, catalytically vapor-liquid-solid process and catalyst-free metal-organic chemical vapor deposition [3]. These methods produce high crystalline ZnO nanostructures. However, the strict requirement of the high crystallinity of seed layer on the substrate and the high deposition temperature seriously limit the compatibility of these methods for the applications in flexible electronics. Compare to above mentioned methods, hydrothermal synthesis is an attractive, alternative and cost-effective method because it could be carried out at a relatively low temperature around 50-90°C, and could allow for polycrystalline/ amorphous substrates.

[Experimental] At first, the PET (polyethylene terephtalate)/ITO (indium tin oxide) substrates were cleaned by the ultrasonic system in acetone, then distilled water, and then dried in pure N₂ steam flow. The ZnO nanostructures were fabricated by simple and inexpensive unocovered hydrothermal method [4] at different temperature of 55, 65, 75, and 85°C. A 50 mM of zinc nitrate hexahydrate was dissolved in 50 ml of deionized water (Millipore Milli-Q Plus purification system, 18.2 M-Q-cm) water, and then 50 mM of HMTA was dripped under constant stirring at room temperature to ensure well dispersion of the reactant. After completion of deposition process, the ZnO nanostructures coated flexible-substrates were removed from the solution, then immediately rinsed with deionized water to remove any residual salt from the surface, and dried at 150°C in air for 30 min. The structural, optical, and surface morphological properties of ZnO films were investigated.

[Results and discussions] Figures 1 (a)-(d) show the field emission scanning electron microscope (FE-SEM) images of ZnO films with deposition temperatures of 55, 65, 75, and 85°C, respectively. The nanoparticles are found on the surface of ZnO films with 55°C. The hexagonal nanorods-like structures are observed with 65°C of ZnO sample. The 20-30 nm width of nanoflakes has been showed on the surface of ZnO films prepared with 75 and 85°C. Figure 1 (a) shows the x-ray diffraction (XRD) pattern of ZnO photoelectrode. Several sharp peaks are observed, which are in agreement with the typical wurtzite structure of ZnO films. The sharp peaks especially (100) and (101) peaks of the aligned ZnO films indicate good crystallinity.



Fig. 1 FE-SEM images of ZnO photoelectrode prepared with (a) 55° C, (b) 65° C, (c) 75° C, (d) 85° C; (e) XRD pattern for ZnO prepared with different temperatures

[Conclusions] Nanostructured ZnO photoelectrodes were successfully prepared on seedless flexible PET/ ITO substrate by simple and inexpensive hydrothermal method with different deposition temperatures of 55-85°C. This prepared ZnO films can be used as photoelectrode for the application of perovskite solar cell.

[Acknowledgement] An author, Md. Faruk Hossain would like to thank the Japanese Society for Promotion of Science for his fellowship and financial supports (MEXT/JSPS KAKENHI Grant Number: JP16F16372).

[References]

- [1].S. Zhang, Y. Shen, H. Fang, S. Xu, J. Song, Z. L. Wang, J. Mater. Chem. 20, 110606 (2010).
- [2].L. Pan, G. Q. Shen, J. W. Zhang, X. C. Wei, L. Wang, J. J. Zou, X. Zhang, Ind. Eng. Chem. Res. 54, 7226 (2015).

[3].J. B. Cui, C. P. Daghlian, U. J. Gibson, R. Pusche, P. Geithner, L. Ley, J. Appl. Phys. 97, 044315 (2005).

[4].M. F. Hossain, and T. Takahashi, IEEE Trans. Nanotechnol. 13, 755 (2014).