

## Enhanced Light Harvesting by Fast Charge Collection Using the ITO Nanowire Arrays in Solid State Dye-sensitized Solar Cells

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Dye-sensitized solar cells (DSSCs) have generated a strong interest in the development of solid-state devices owing to their low cost and simple preparation procedures. Effort has been devoted to the study of electrolytes that allow light-to-electrical power conversion for DSSC applications. Several attempts have been made to substitute the liquid electrolyte in the original solar cells by using (2,2',7,7'-tetrakis (N,N-di-p-methoxyphenylamine)-9-9'-spirobi-fluorene (spiro-OMeTAD) that act as hole conductor [1]. Although efficiencies above 3% have been reached by several groups, here the major challenging is limited photoelectrode thickness (2  $\mu\text{m}$ ), which is very low due to electron diffusion length ( $L_n$ ) for spiro-OMeTAD (4.4  $\mu\text{m}$ ) [2]. In principle, the  $\text{TiO}_2$  layer can be thicker than had been thought previously. This has important implications for the design of high-efficiency solid-state DSSCs. In the present study, we have fabricated 3-D Transparent Conducting Oxide (TCO) by growing tin-doped indium oxide (ITO) nanowire (NWs) arrays via a vapor transport method [3] and mesoporous  $\text{TiO}_2$  nanoparticle (NP)-based photoelectrodes were prepared using doctor blade method. Finally optimized light-harvesting solid-state DSSCs is made using 3-D TCO where electron life time is controlled the recombination rate through fast charge collection and also ITO NWs length can be controlled in the range of over 2  $\mu\text{m}$  and has been characterized using field emission scanning electron microscopy (FE-SEM). Structural analyses by high-resolution transmission electron microscopy (HRTEM) and X-Ray diffraction (XRD) results reveal that the ITO NWs formed single crystal oriented [100] direction. Also to compare the charge collection properties of conventional NPs based solid-state DSSCs with ITO NWs based solid-state DSSCs, we have studied intensity modulated photovoltage spectroscopy (IMVS), intensity modulated photocurrent spectroscopy (IMPS) and transient open circuit voltages. As a result, above 4  $\mu\text{m}$  thick ITO NWs based photoelectrodes with Z907 dye shown the best performing device, exhibiting a short-circuit current density of 7.21  $\text{mA cm}^{-2}$  under simulated solar emission of 100  $\text{mW cm}^{-2}$  associated with an overall power conversion efficiency of 2.80 %. Finally, we achieved the efficiency of 7.5% by applying a  $\text{CH}_3\text{NH}_3\text{PbI}_3$  perovskite sensitizer.

### References

- [1] Francisco Fabregat-Santiago, Juan Bisquert, Le Cevey, Peter Chen, Mingkui Wang, Shaik M. Zakeeruddin, Michael Gratzel, J. AM. CHEM. SOC. 2009, 131, 558-556
- [2] J. R. Jennings, L. M. Peter, The Journal of Physical Chemistry C. 2007, 111, 16100-16104
- [3] Jun Hong Noh, Hyun Soo Han, Sangwook Lee, Jin Young Kim, Kug Sun Hong, Gil-Sang Han, Hyunjung Shin, Hyun Suk Jung, Advanced Energy Materials, 2011, 1, 5, 829-835

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