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Comparison of dye-sensitized photo electrochemical cell and solid-state cell: Studies of charge transport and carrier lifetime

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Dye-sensitized solar cell is a low cost alternative to the silicon base solar cell, which draws much attention during the past decades. It composes of a nanocraytalline mesoporous metal oxide semiconductor film deposited on conducting tin oxide (CTO) glass, which is coated with a dye. The charge transport media at the dye interface is generally an electrolyte, which causes many technological problems such as liquid evaporation, sealing problems etc. Scientists search for solutions to these problems replacing the electrolyte with a p-type semiconductor, which they thought would solve all these problems. But, because of the lack of a strong charge inversion layer, recombination is crucial at the dye semiconductor interface of the solid state cell. Therefore the expected efficiency could not be achieved with the dye sensitized solid state solar cell comparable to the photoelectrochemical solar cell. In this study we have calculated the carrier lifetime and the diffusion coefficient of electrons in the two types of solar cells for comparison using intensity modulated photovoltage spectroscopy (IMVS) and intensity modulated photocurrent spectroscopy (IMPS) respectively.

The techniques of depositing the TiO_2 films on the CTO glass are different for the two types of solar cells. TiO_2 film for the dye-sensitized electrochemical solar cell is made by coating a TiO_2 past by doctor blade technique on CTO glass which was made grinding Degussa powder with acetic acid and distill water and then sintering at 500 °C in a furnace. The TiO_2 film for solid-state cell is made by spreading a colloidal solution prepared by hydrolysis of titanium isopropoxide in propanol several times on CTO glass and sintering after the each coating at 500 °C. Both the films were coated with ruthenium bypiridyl dye by immersing the films in dye solutions. The fabrication of the electrochemical cell is done by placing a Pt coated CTO glass on the dye coated surface of the film and filling the capillary space with an electrolyte with I^-/I^{3-} redox couple. Solid-state dye-sensitized solar cell is fabricated by coating copper iodide on the dye coated film by dissolving CuI in acetonitrile and applying the solution with a dropper and allowing to dry. IMVS and IMPS measurements were carried out using a blue light emitting diode (λ_{max}= 470 nm) driven by a frequency response analyzer. The LED provided both the dc and ac components of the illumination. The intensity of the LED was measured using a lux meter.

The electron lifetime calculated with the IMVS measurements were always large values for photoelectrochemical solar cell. The reason could understand as the low recombination of photo generated electrons in dye sensitized electro chemical solar cell compared to the solid state cell. But when the diffusion coefficient is calculated from the MIPS measurements the diffusion rate is high in the solid state dye-sensitized solar cell. The interfaces of the dye is different in two types of solar cells where a p-type semiconductor in solid state cell and electrolyte in the electrochemical cell. We cannot totally reject the presence of depletion layer in the dye-sensitized solid state solar cell similar to the photoelectrochemical cell. That is because of the observed rectification action in solid state cell. Therefore this build in electric field would force the electrons to diffuse faster in the dye-sensitized solar cell. This kind of electron kinetic studies will help to understand the operation of the dye-sensitized solid state solar cell intensively that help to develop it as a viable device.

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