Charge transport and optimization for Dye-sensitized nano-porous TiO_2 solar cells

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Dye-sensitized solar cells (DSC) are made of wide band-gap semiconductor of nano-porous films, which provides large surface area for dye adsorption against projected area.[1] This structure allows large light absorption in a thin film with simple fabrication process, which is desirable for low-cost high-efficiency solar cells. The highest efficiency achieved at this moment is about 10%.

To increase the efficiency and reliability with lowering cost, further understanding of charge transport mechanism in DSC is required. Electron transport in the nano-porous films has been studied by several groups, showing that slow electron diffusion coefficients which are more than a few orders of magnitude lower than that in a bulk TiO_2. In DSC using an electrolyte containing redox couples, charge recombination lifetimes are long so that the diffusion lengths are about the thickness of the films.[2] However, using electrolyte may not be suitable in view of long time reliability. On the other hand, when the electrolyte is replaced with solid state hole conductor, recombination lifetimes would become shorter, resulting shorter diffusion lengths and lower charge collection efficiency. Here, increasing electron transport properties remains an important issue as well as increasing recombination lifetime.

Electron transport in nano-porous films depends on several parameters. In DSC, electrons in the film are surrounded by larger number of cations in nano-scale range. Hence, the electron transport has been described mainly with diffusion.[2-4] Measurements of electron diffusion coefficients were performed by several methods, showing light intensity dependence. Figure 1 shows the current transients from the same DSC induced by a laser pulse (Nd:YAG, λ=532nm, 7ns) under continuos light irradiation of different intensities from a HeNe laser. Time constants of the current transient decays increased as the light intensity of the HeNe laser decreased, indicating that the electrons take longer time to travel the same distance under lower electron densities in the film.

Parameters to affect electron transport are not only light intensity but also TiO_2 nano-particle preparation methods, film annealing temperature, particle size, species of cations in an electrolyte, and density and diffusion coefficients of cations in the electrolyte.[5,6] Figure 2 shows the measured electron diffusion coefficients in DSC prepared from different sizes of TiO_2 nano-particles prepared by a same method (Home made), TiO_2 by different preparation method (Nanoxide-T), and different hole conductors (solution and gel) under various light intensities. All shows the increase with the light intensities but orders are varied. In view of particle size, as increase the particle size, the electron diffusion coefficients increased.

With the results of charge recombination lifetime measurements, diffusion lengths can be estimated. Based on the results from the different TiO_2 nano-porous films, only increasing diffusion coefficients is not enough to increase the diffusion length. Furthermore, effective light absorption coefficients should be taken into account to optimize the charge collection efficiency. Parameters for optimization of DSC will be discussed in view of TiO_2 film properties.

References

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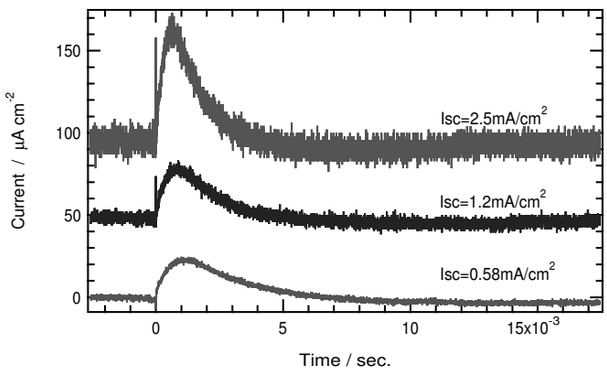

Figure 1. Current transients induced by a pulse laser under continuous irradiation to DSC.

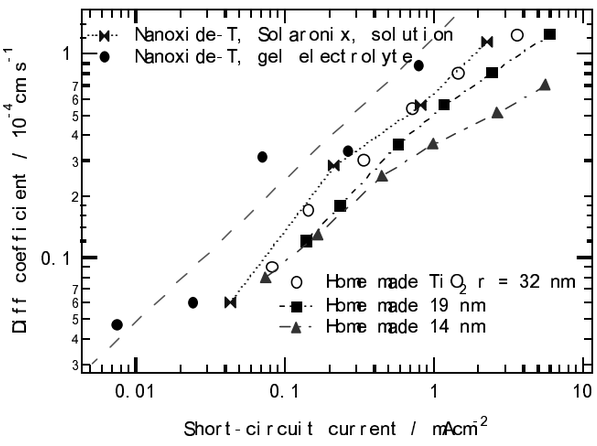

Figure 2. Electron diffusion coefficients in DSC, prepared from various TiO_2 particles under various light intensities.