ABSTRACT

Dye sensitized solar cells are promising alternative to the silicon based solar cells so that interest has been grown to develop them conducting applied and fundamental research. Therefore it opens wide dimensions for researchers to conduct investigations in many directions.

Solar energy conversion based on dye-sensitized solar cells involves conduction of charge carriers only in one band and high band gap nanocrystalline semiconductor material are utilized in the cells. The effort is diverted to improve the efficiency and stability of these devices by understanding the charge transport and carrier recombination mechanisms and resolve the technical problems associated in fabrication.

Basically the cell consists of a thin film of porous nanocrystalline semiconductor coated with a dye to harvest light energy. Photo excitation of the dye leads to inject electrons into the conduction band of the oxide semiconductor. The back reaction of photo-injected electrons with the dye cations and tri-iodide irons present in the electrolyte limits the efficiency of dye-sensitized photo electrochemical solar cell. To avoid this problem, barrier is formed to block the back ward flow of electrons by using composite semiconductor material for the thin film of the dye-sensitized solar cell. One such approach is to use composite semiconductor material consisting of two semiconductors with different band gap energies and particle sizes to separate the electron hole pairs far apart. Another strategy is to cover semiconductor particles with a thin insulating layer that act as a barrier to prevent the direct contact of electrons in the semiconductor with the ions in the electrolyte. As the third method schottky barrier is formed in the semiconductor particles by introducing nanoparticles of noble metal such as gold.

In our studies we have investigated above three systems to find out the mechanisms involve in charge transport and carrier recombination. Intensity modulated photovoltage spectroscopy (IMVS) and intensity modulated photocurrent spectroscopy (IMPS) were used to calculate the electron lifetime (τ_n) and diffusion coefficient (D_n) respectively over a very wide intensity range. Both

electron lifetime, τ_n and electron diffusion coefficient, D_n depend on illumination intensity. When the τ_n and D_n is known we can calculate the electron diffusion length with $L_n = (\tau_n * D_n)^{1/2}$.

ZnO and SnO_2 composite semiconductor films that report high efficiencies were tested with IMVS and IMPS measurement at first. The lifetime of electrons in ZnO cells found to be high compared to SnO_2 cells or SnO_2/ZnO composite. But diffusion coefficient was high in SnO_2 cells. Since the diffusion length is defined as $L_n = (\tau_n * D_n)^{1/2}$, overall performance is good in the composite made of SnO_2 and ZnO.

Secondly semiconductor particles that covered with thin insulating layer to prevent recombination of electrons were measured with IMVS and IMPS measurements. We could find two systems reported under this category. One is the SnO_2 particles covered with thin shell of MgO layer and other one is same semiconductor material covered with thin insulating layer of Al_2O_3.

Calculation of the lifetime and diffusion coefficient of electrons in SnO_2 film and SnO_2/Al_2O_3 film reveals that the electron recombination rate decreases in the SnO_2/Al_2O_3 cell due to the Al_2O_3 barrier layer because the lifetime as well as the diffusion coefficient of electrons in SnO_2/Al_2O_3 composite film has increased. SnO_2/MgO cells also showed similar results.

We have also investigated the SnO_2/Au composite films used to construct dye-sensitized solar cells which comes under the third category. According to our investigation it is clearly seen that the diffusion coefficient and lifetime of electrons increases when gold nano particles are embedded in SnO_2 films of dye-sensitized solar cells.

Finally we also investigated the charge transport and carrier lifetime in dye sensitized solid state solar cell and compare the results with the electrochemical solar cell. We have found that the electron lifetime in dye-sensitized soiled state solar cell is short compared to the photoelectrochemical solar cell in our studies. But the electron diffusion coefficient is higher in the dye sensitized solid-state solar cell, which is an important finding.