Dye-sensitized Solar Cells with enhanced performance using modified ZnO vertically aligned nanorods

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Abstract

Solar energy is an attractive energy source since it is available and abundant. For that reason the research on photovoltaic devices has been rising over the last few years. Excitonic Solar Cells, XCSs (Organic, Hybrid and Dye sensitized Solar Cells) are promising devices for the achievement of the three main criteria that would lead to large scale commercialization: high efficiency, low cost and the possibility to apply simple and scalable fabrication techniques.[1] Hybrid and Dye sensitized Solar cells have a combination of organic materials and inorganic semiconductors in the active layer that one acts as a hole conductor and the other one as the transport electron material.[2] Our research work focuses on the improvement of Hybrid and Dye sensitized Solar Cells (DSCs) by the optimization of the active interfaces between semiconductor oxides and organic compounds. In order to optimize the interfaces we use vertically aligned nanostructures of ZnO as semiconductor transport material, which increase the interfacial active area, avoid grain boundary resistances and increase charge carrier mobility.[3] ZnO is a promising material since is similar to TiO_2 (the most successful semiconductor for DSCs) and has other advantages such as higher electron mobility, longer electron lifetimes and easy to be synthesized in a wide variety of nanoforms applying many different techniques.[1-6] Up to date, encouraging efficiencies of 5-6% were obtained using hierarchical ZnO aggregates.[7] However, DSC ZnO nanorods (NRs) have still low power conversion efficiencies not higher than 2.4%.[8] For this reason, an effort to modify the ZnO NR is being developed in our group in order to understand the factors that limit the power conversion efficiency of DSC.

We present here our latest results with vertically aligned ZnO nanorods (NRs). An improvement on DSCs performances was observed using a modification on the hydrothermal synthesis method of the ZnO NRs and also a new ZnO nanostructure was obtained, ZnO Nanotrees. The comparison between the standard hydrothermal synthesis (A) and the modified synthesis (B) will be showed. The hydrothermal technique is an attractive method for their low cost since it needs low temperatures and aqueous solutions. Characterization by SEM and TEM microscopes of ZnO electrodes prepared by both synthesis methods revealed shorter ZnO NRs for synthesis B using the same NR growth time and they allowed higher solar cells efficiencies. The use of Photoluminiscence (PL) and free exciton lifetime studies explained the reasons of the DSCs enhanced performances of ZnO NRs electrodes B. The ratio of visible and near-band-edge (NBE) PL peaks measured for A and B electrodes showed a different behavior. Electrodes A have a visible PL band with higher intensity compared to electrodes B which means they have higher recombination due to higher quantity of electron traps on their surface states and thus lower efficiencies. Besides, shorter free exciton lifetimes on the surface of electrodes A were observed that confirms the higher recombination effect. The application of electrodes A and B in DSCs allowed efficiencies as high as 1.01% A (length 5.0 µm), 1.24% B (length 1.0 µm) and 1.53% NTs B (length 3.0 µm). Our latest results on the modified synthesis highlight the importance of the ZnO surface energy states which influences directly on the solar cells performances.

References

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