

Optimizing light harvesting and charge collection in dye-sensitized solar cells based on ZnO

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Interest in the study of dye-sensitized solar cells (DSSCs) has grown considerably in recent years from both fundamental and applied viewpoints. The most typical DSSC consists of a nanoparticle TiO_2 sensitized photoelectrode and a platinum counter-electrode separated by an iodide-triiodide (I/I_3^-) liquid electrolyte.[1] Zinc oxide has recently emerged as a promising alternative semiconductor material to TiO_2 . The potential advantages of ZnO in DSSCs include a fast charge transfer with an electron mobility several orders of magnitude higher compared to anatase TiO_2 and an impressive variety of nanostructures reported during the last decade. These structures can be assembled to design straightforward pathways for the electrical charge transport from the excited dye to the back contact.

In our work, the light harvesting has been optimized by playing on three different parameters. (i) The absorbance by the dye must be as broad as possible in the visible/near infra-red region. This has been achieved by dye molecular design [2-4] and by the co-adsorption of dyes with complementary spectral responses. The IPCE curves for our optimized conditions are higher than 80% with a large flat plateau.[5] (ii) A large amount of dye must be loaded in the oxide film and this requires films developing a large surface area. This has been obtained, for instance, by using structure directing agents upon the film preparation or by oxide design.[2] (iii) The light pathway in the photoelectrode can be increased leading to larger light collection, by using light diffusing structures and light trapping.[6] We have investigated organized light scattering micro-urchin structures for the enhancement of light absorption by the dye in the red region.[7]

The main parasitic reaction in DSSC is the recombination of electrons in the semiconductor with the redox species. In order to get high charge collection in ZnO photoelectrodes, we have developed and combined different strategies. The uncovered oxide surfaces between the adsorbed dye molecules must be passivated by using a co-adsorbant. The most popular ones are cholic and chenodeoxycholic acids which are rather large molecules. Our approach has been to investigate amphiphilic fatty acid molecules with various alkyl chain lengths.[8] Octanoic acid yield to the best performances. Moreover, this compound has been shown to stabilize the cells against aging.[8] In order to get a high charge collection, the charge transport in the photoelectrode must be as fast as possible. We have prepared various ZnO nanostructures by sol-gel and electrodeposition techniques and combine these structures to increase the specific surface area of the films and have a good crystallinity.[2,9,10] These structures have been designed

to give a straightforward electron pathway between the excited dye and the photoelectrode back-contact. Different structures will be presented. By electrical impedance spectroscopy measurements (EIS) at various applied potentials, we have determined two fundamental parameters of the cells: the charge lifetime (τ_{ct}) and its transport time (τ_{tr}).[10] To get a high collection efficiency (η_{coll}), the former must be much larger than the latter since they are related by : $\eta_{\text{coll}}=1/(1+\tau_{\text{ct}}/\tau_{\text{tr}})$. In the figure we shows the variation of τ_{ct} and τ_{tr} versus the density of states (DOS) in the oxide. They have been plotted for films prepared by ZnO particle paste sintering and for two different films prepared by electrodeposition (types 1 and 2). In every case, τ_{ct} is much higher than τ_{tr} and the collection efficiency is very high, higher than 96% for the best film. We have also checked that the conductivity of ZnO is much larger than the conductivity of nanoparticle TiO_2 films. Further EIS results will be discussed upon the meeting presentation.

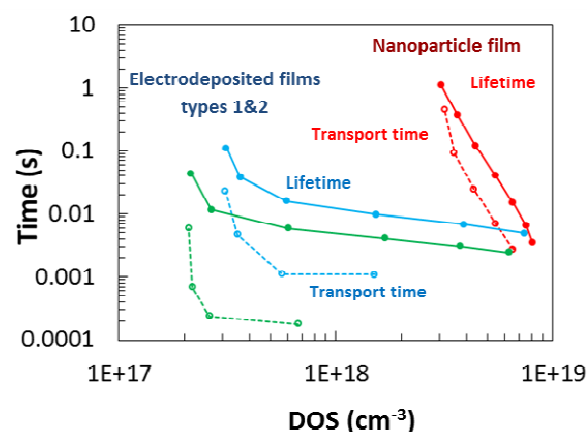


Figure : Electron lifetime and transport time measured by impedance spectroscopy versus DOS (applied voltage) in various ZnO based DSSCs.

References

- [1] C. Magne, F. Dufour, F. Labat, G. Lancel, O. Durupthy, S. Cassaignon, and T. Pauporté, *J. Photochem. Photobiol. A*, **232**, 22-31 (2012).
- [2] V.M. Guérin, C. Magne, T. Pauporté, T. Le Bahers, J. Rathousky, *ACS Appl. Mater. Interfaces*, **2**, (12) 3677–3685 (2010),.
- [3] S.Higashijima, Y. Inoue, M. Matsui et al., *RSC Adv.*, **2**, 2721 (2012)
- [4] R.T.Y. Lin et al., *Chem. Commun.*, **48**, 12071–12073 (2012)
- [5] C. Magne, M. Urien, Th. Pauporté, *RSC Adv.*, **3** (18), 6315-6318 (2013).
- [6] Q. Zhang, T.P. Chou, B. Russo, S.A. Jenekhe, G. Cao, *Angew. Chem. Int. Ed.*, **47**, 2402-2406 (2008).
- [7] V.M. Guérin, J. Elias, T.T. Nguyen, L. Philippe, T. Pauporté, *Phys. Chem. Chem. Phys.*, **14**, 12948–12955 (2012).
- [8] C. Magne, M. Urien, I. Ciofini, T. Tugsuza, Th. Pauporté, *RSC Adv.*, **2**, 11836–11842 (2012).
- [9] V.M. Guérin, T. Pauporté, *Energy Environ. Sci.*, **4**, 2971-2979 (2011).
- [10] C. Magne, T. Moehl, M. Urien, M. Grätzel, Th. Pauporté, *J. Mater. Chem. A*, **1**, (6) 2079-2088 (2013).

