Influence of materials properties on the performance of dye-sensitized solar cells

Gerko Oskam

Department of Applied Physics, CINVESTAV-IPN, Mérida, Yucatán 97310, México.
Email: *gerko.oskam@cinvestav.mx*

The performance of dye-sensitized solar cells (DSCs) is governed by an intricate combination of parameters, and a detailed understanding of these is paramount for further improvement. In this presentation, an overview will be given of the research in our group in the Department of Applied Physics at CINVESTAV-Mérida (Yucatán, México) on the application of a variety of ZnO and TiO_2 nanomaterials in DSCs, using novel dyes, various redox couples and a variety of both steady-state and time-dependent characterization techniques, representing results of various collaborative efforts with groups in Spain, USA, Poland, and France.

We have investigated the influence of the nanomaterials properties on the performance of the solar cells, using TiO_2 in both the anatase and brookite form, showing that brookite is an interesting material with efficiencies reaching 5%, and highlighting the importance of surface pH on the dye coverage and optoelectronic properties.

ZnO is an interesting alternative material for DSCs, and recent results on the performance of dye-sensitized solar cells based on ZnO prepared using sol-gel synthesis, electrodeposition and CVD are presented. The morphology and texture influence the performance of the dye solar cell via a variety of effects. For instance, the exposed crystal facets affect the dye coverage, injection efficiency, the electron transfer kinetics to the solution, and the trap state distribution. Using these materials, we have compared the electron transport and recombination properties using small-signal perturbation techniques. We have also addressed the influence of solution additives on the performance of ZnO-based dye-sensitized solar cells and rationalized the results, focusing on the slower electron injection and dye regeneration rates observed for ZnO as compared with TiO_2. A variety of novel dyes have been applied in the ZnO-based solar cell, including perylene mono-imide dyes with an anhydride bonding moiety and benzothidiazole dyes with a classical acrylonitrile bonding group; with the latter dye, an efficiency of 4.8% has been reached, and further optimization is in progress. For electrodeposited ZnO-based cells, using both the $Co(bpy)_3$ and iodide redox couples, SPV measurements show that charge separation and dye regeneration can be achieved using the $Co(bpy)_3$ redox couple, however, small-signal perturbation methods illustrate that electron transfer to the oxidized redox agent is several orders of magnitude faster for the $Co(bpy)_3$ couple, thus limiting the thermodynamically attainable photovoltage.

We are also making progress in the scale-up of the technology, fabricating mini-modules of 24 cm^2 reaching an efficiency of 4.8% for the DSCs based on anatase (in active area), and currently up to 2% for ZnO-based mini-modules, with ZnO nanomaterial prepared using microwave-assisted sol-gel synthesis and subsequent screen printing of the mesoporous films.