NANOMATERIALS INNOVATION FOR EFFICIENTLY HARVESTING SOLAR ENERGY

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Introduction

Photoelectrodes of sensitized solar cells are nanostructured by nature for effectively ferrying electrons and holes. The rapid advance of nanomaterials and nanotechnology in recent years is therefore propitious in promoting their delopment. The nanoscale engineering of new photoelectrode architectures should not only enhance our understanding of the inherent working of such solar cells but also help to improve the cell performance, especially in the emerging frontiers such as flexible and solid-state solar cells. In this context, we have recently engaged in the bottom-up fabrication and assembly of nanostructures that can be used as photoelectrodes to efficiently harvest solar energy in the form of dye-sensitized solar cells (DSSC) and quantum-dot sensitized solar cells (QDSSC).

Results and Discussion

For the sensitized solar cells, we studied ZnO nanotetrapods, TiO_2 nanospindles, and mesoporous TiO_2 microspheres developed in our laboratory as photoanodes and exploited their advantages for their good electron transport and light scattering property. By infiltrating SnO_2 nanoparticles into the ZnO nanotetrapods photoanodes, we have achieved a 6.31% DSSC efficiency. An ultrathin layer of ZnO was found to spontaneously shell on SnO_2 nanoparticles, primarily responsible for enhancing V_{oc} by lifting the band edges rather than by suppressing recombination.

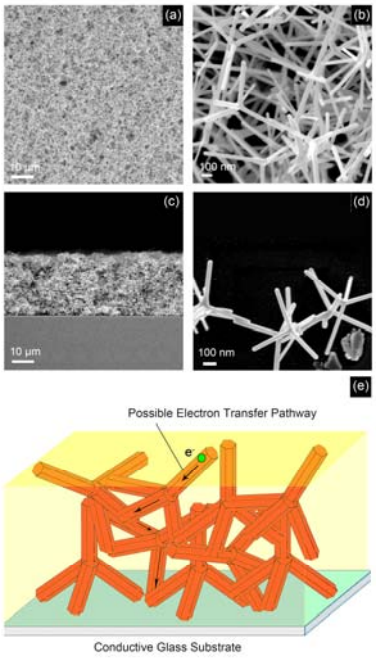

Figure 1. Structural characteristics of a ZnO nanotetrapods film. (a-d) SEM images viewed from top (a), at high resolution (b), in cross-section (c), and at the detailed inter-tetrapod connections (d). (e) Schematic showing a possible electron transport pathway across the ZnO nanotetrapod film.

The good network forming ability of the ZnO nanotetrapods has allowed us to extend their use in to flexible DSSCs. Specifically, we applied the composite photoanodes of SnO_2 nanoparticles/ZnO nanotetrapods to flexible DSSCs by an effective low temperature technique of "acetic acid gelation–mechanical press–ammonia activation". A 4.91% efficiency has been achieved on ITO–coated polyethylenenaphtalate substrate.

For the TiO_2 nanostructures developed in our laboratory, we tested a double-layer photoanode architecture for DSSC, and achieved nearly 9% energy conversion efficiencies. In addition, we elaborated the mesoporous TiO_2 microspheres for developing photoanodes of quasi-solid DSSCs.

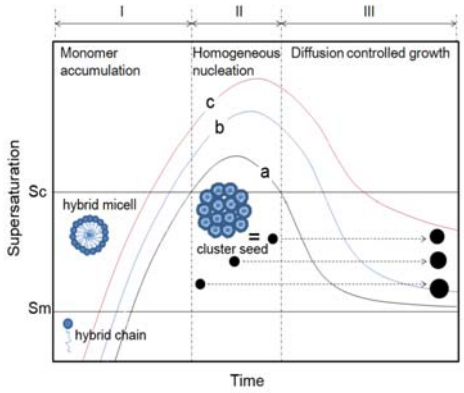

Figure 2. Schematic showing the formation and size variation of the mesoporous TiO_2 microspheres. (a–c) Supersaturation profiles versus time, based on the LaMer model, with the source materials' concentrations changing from low to high. The microsphere growth is roughly divided into 3 periods separated by the vertical dashed lines: "Period I" for monomer accumulation; "Period II" for homogenous nucleation, and "Period III" for diffusion controlled growth.

Finally, we used such mesoporous TiO_2 microspheres for the development of quasi-solid QDSSCs with a newly developed linker-seeding approach, and significantly improved the efficiency and stability of the solar cells.

Conclusions

Our results have shown that there is still plenty of room for improving the performance of the sensitized solar cells not only in terms of efficiency but also in terms of stability and multifunctionality by exploiting novel nanostructures. This can be taken a step further by combining the materials innovation in molecular materials such as new light absorbers, new electrolytes and new charge transport materials.

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