Tailoring disorder for absorption enhancement in bifacial dye-sensitized solar cells

José M. Miranda-Muñoz, Sol Carretero-Palacios, Alberto Jiménez-Solano, Yuelong Li, Gabriel Lozano, and Hernán Míguez[1]

[1]Multifunctional Optical Materials Group, Institute of Materials Science of Sevilla, Consejo Superior de Investigaciones Científicas – Universidad de Sevilla (CSIC-US), Américo Vespucio 49, 41092, Sevilla, Spain
jm.miranda@csic.es

Great interest is devoted toward the fabrication of photonic devices with enhanced performance, for which the ability to control light transport is highly relevant. Optically disordered media appear as a means for the control of light propagation through interference inside the material. They combine appealing light scattering and characteristic resonance effects with ease of fabrication, which provide them with beneficial features for the integration in dye-sensitized solar cells (DSSCs). Bifacial dye solar cells presenting operation under front and rear illumination have been proposed as an effective means toward cost reduction, as a same area cell is able to harvest a higher amount of light.[1]

In this work, an optically disordered medium offering control over the light scattering has been fabricated and integrated in a bifacial DSSC after theoretical design by means of a model. This yielded an optimized device with enhanced performance without modification of any of the commonly employed components. Such optically random medium comprises a mesoporous TiO_2 matrix, in which monodisperse crystalline TiO_2 nanospheres are dispersed in a random manner. The random distribution of submicron particles of high refractive index in the electrode of DSSCs has been previously proposed as a means toward enhancement of their absorption.[2,3] Due to the effects of multiple scattering, the path length of the light can be effectively enlarged, so that the residence time of the photons can be increased inside the sensitized film and, thus, their probability to interact with a dye molecule. Owing to the features of the scattering centres herein used and the possibility of tailoring disorder, the presented procedure offers unprecedented control over the scattering taking place inside the active film of the device. The optimized design is calculated from a model based on a Monte Carlo approach in which the multiple scattering of the light within the cell is fully accounted for. We identify as key parameter for the control of the angular distribution of the scattered light the spherical shape of the inclusions.

The optically disordered system including scattering centres in diverse conditions has been optically characterized and successfully integrated in bifacial DSSCs after sensitization by a dye. Power conversion efficiencies (PCE) as high as 6.72% and 5.38% have been attained for devices operating under front and rear illumination, respectively. This represents a 25% and a 33% PCE enhancement with respect to an 8 µm-thick standard dye-solar cell using platinum as catalytic material. The remarkable bifacial character our approach grants the devices is proved by the high rear/front efficiency ratio attained, around 80%, which is among the largest reported for this sort of devices.[4]

References

[1] S. Ito *et al.*, Nat. Photonics, **2** (2008), 693.
[2] F. E. Gálvez *et al.*, J. Phys. Chem. C, **116** (2012), 11426.
[3] F. E. Gálvez *et al.*, Energy Environ. Sci., **7** (2013), 689.
[4] J. M. Miranda-Muñoz *et al.*, J. Mater. Chem. A, **4** (2016), 1953.

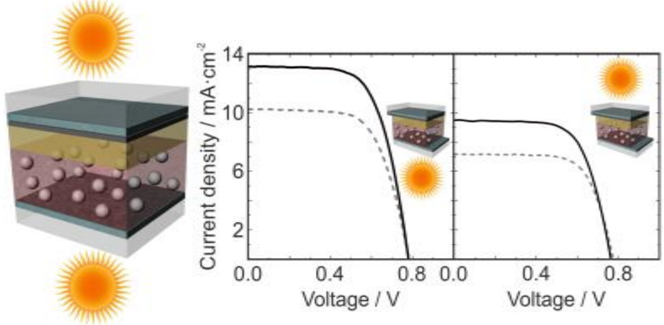

Fig.1: Schematic of the solar cell architecture and Current density/Voltage characteristic for the optimized configuration under front and rear illumination.