Urchin-inspired zinc oxide as building blocks for nanostructured solar cells

Laetitia Philippe, *Jamil Elias,* Mikhael Bechelany, Ivo Utke, Rolf Erni, Davood Hosseini, Johann Michler*

[*] Dr. J. Elias, Dr. I. Utke, Dr. J. Michler, Dr. L. Philippe
Laboratory for Mechanics of Materials and Nanostructures, EMPA Materials Science & Technology, Feuerwerkstrasse 39, 3602 Thun, Switzerland
Dr. M. Bechelany
Institut Européen des Membranes (UMR CNRS 5635), Université Montpellier 2, Place Eugène Bataillon, 34095 Montpellier, France.
Dr. R. Erni
Electron Microscopy Center, EMPA Materials Science & Technology, Ueberlandstrasse 129, 8600 Duebendorf, Switzerland
D. Hosseini
Laboratory for Thin Films and Photovoltaics, EMPA, Materials Science & Technology, Ueberlandstr. 129, CHD-8600 Dübendorf, Switzerland

Contact@E-mail laetitia philippe@empa.ch

Abstract

According to recent studies on the global power plant market, the installed capacity of solar power grew faster than that of any other power technology. Last generation nanostructured photovoltaic devices include dye sensitized (photoelectrochemical, quasi-solid, and solidstate) solar-cells and their hybrid and fully inorganic variants as extremely thin absorber (ETA) solar-cells. They appear to have a big light harvesting potential compared to planar thin film photovoltaic devices due to their "built-in" large surface area architecture involving an n-type semiconductor material covered by a light absorber (dye, organic or inorganic films) for collecting photons. After charge separation, electrons are collected by a photoanode for electricity generation.

TiO2 and ZnO were agreed to be the most promising materials as wide band gap n-type semiconductors with a preference for ZnO due to its better electronic transport properties and its comparatively easy controllable growth as single-crystal nanowire arrays Better control of light-scattering and electronic transport through this n-type semiconductor is essential for improving the solar efficiency.Among numerous studied architectures, nanoparticles and nanowires are the most employed building-blocks because they either provide high surface areas (nanoparticles) or direct electron transport (nanowires). In direct comparison, single-crystal nanowire arrays offer shorter electron collection paths, thus avoiding charge recombination; but solar cells based on nanoparticles still have a higher solar efficiency due to their larger surface area. Hence, increasing the surface area of planar nanowire carpets by increasing the diameter and length of the individual nanowire has been proposed in many research reports to enhance the solar light harvesting. As a commonly acquired result, such an increase of the surface area in nanowire carpets leads to an augmentation of charge recombination being detrimental for solar cell efficiency. Therefore, future nanostructured solar-cell architectures need to improve multiple light-scattering while keeping reasonable surface areas with a short electron collection path; in other words, improving the solar light absorption and reducing the electron-hole recombination. To tackle this challenge we have recently developed urchin-like nanostructures by electrodeposition of ZnO nanowires onto surface activated polymer spheres. This structure showed a twofold improvement of light scattering compared to nanowire arrays. However, these nanostructures had a limited mechanical stability and their interspacing could not be varied which prohibited further optimized use in applications. In the present paper, we report on a novel architecture – based on a self-stabilized hollow urchin-like ZnO nanowire building-blocks using a novel low-costand scalable synthesis route which allows for controlled building-block interspace and tunable nanowire dimensions. We show that the light diffusion and absorption as well as solar cell efficiency can be elegantly controlled and enhanced by engineering the dimensions of such building-blocks.

References

J. Elias, C. Levy-Clement, M. Bechelany, J. Michler, G. Y. Wang, Z. Wang, L. Philippe *Adv. Mater.* **2010**, *22*, 1607.

Figures

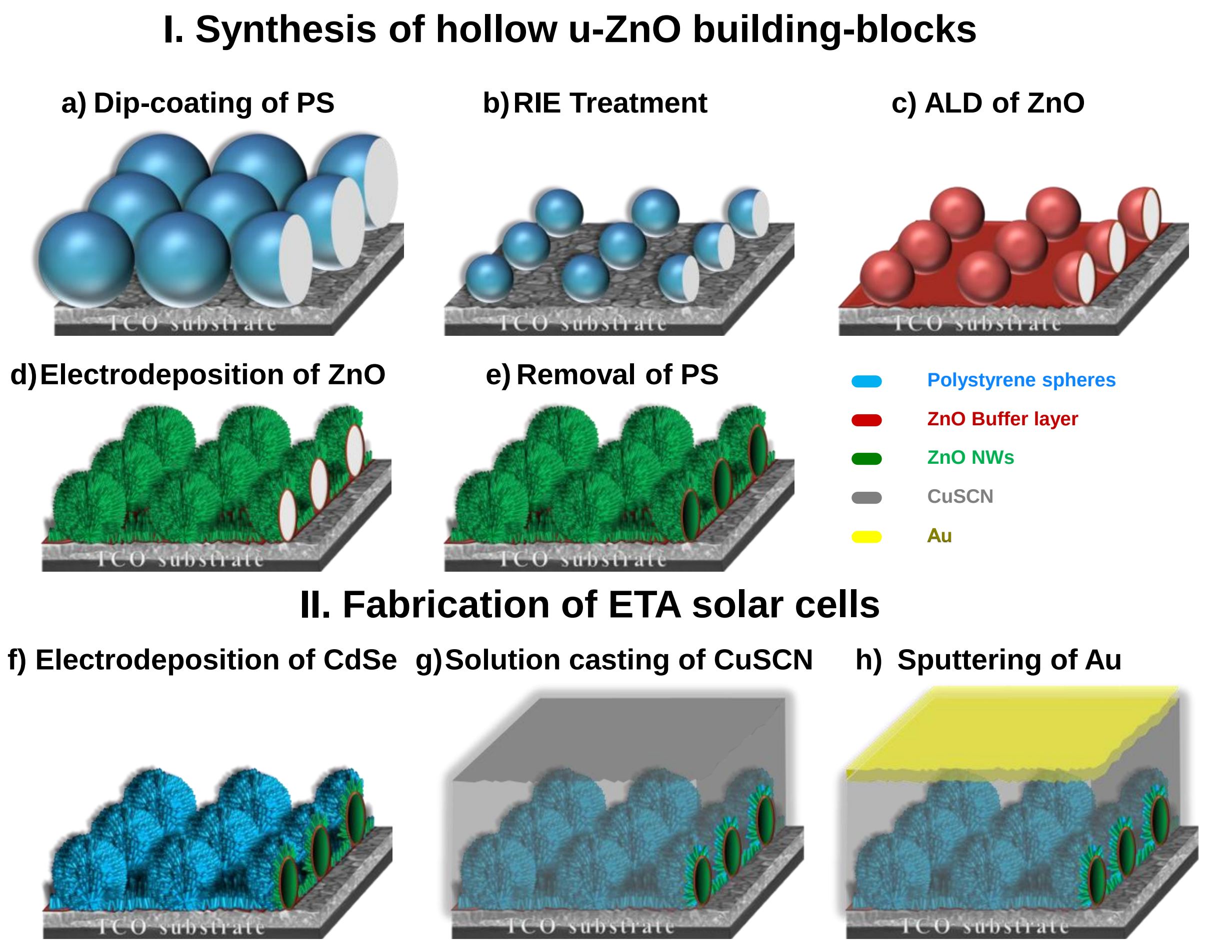

Figure 1. Schematic view of synthesis route for (I) self-stabilized hollow urchin-like ZnO nanowire building blocks and (II) successive fabrication steps for the ETA solar-cell: a) Dip coating for the deposition of an ordered monolayer of polystyrene microspheres onto an FTO covered glass substrate; b) Size reduction of spheres using plasma etching with oxygen plasma.; c) Deposition of a uniform conformal thin layer of about 20 nm of ZnO by ALD; d) Electrodeposition of n-type ZnO NWs with controlled length and diameter; e) Formation of hollow u-ZnO by dissolving the polystyrene spheres in toluene; f) Coating of NWs with an absorber film of CdSe by electrodeposition; g) Covering with p-type CuSCN by chemical impregnation, and h) Deposition of a gold thin film electrode by physical vapor deposition.

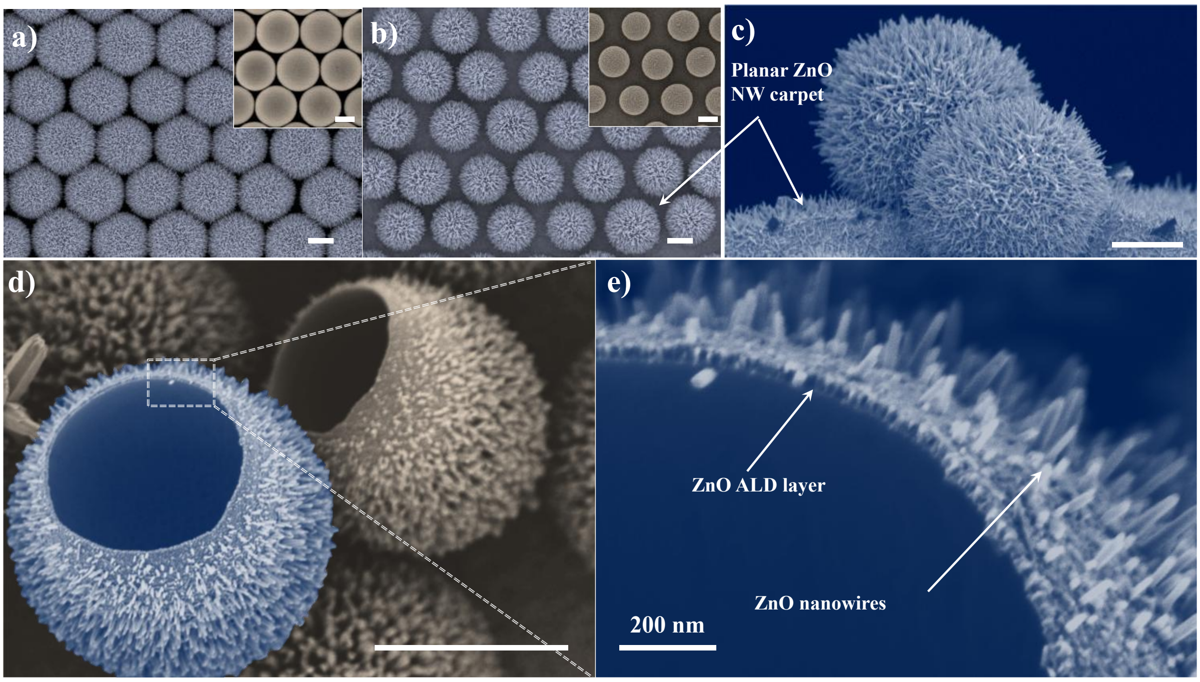

Figure 2. SEM images of ZnO urchin-like structures after dissolution of the polystyrene sphere monolayers a) without PE and b) with 20 min PE treatment. The insets of a) and b) are the SEM images of the ordered PS before electrodepostion coated with 20 nm of ZnO by ALD. c) Side view of individual u-ZnO structures. Note: the planar NW-carpet between the u-ZnO. d and e) are views of individual hollow u-ZnO structures from a scratched part of the sample where the structures were reversed upside down. All the scale bars in the figure (except (e)) are 2 μm.