Silicon Based Materials For Hybrid Solar Cells and Photoelectrochemical Cells

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Abstract

Solar energy is thought to be the only renewable energy source to have potential to provide alone the 10 – 20 TW carbon-neutral energy needed in 2050 in order to avoid the likely most serious consequences of global climate change.[1] In the past decades, vast research efforts have been devoted to developing highly efficient and low cost solar energy harvesting devices including solar cells (for solar-electrical energy conversion) and photoelectrochemical cells (PECs, for solar fuel production). Among the various materials investigated so far, silicon (Si) is still one of the most promising semiconducting materials for use in both solar cells and PECs because it is earth-abundant and has a broad-band adsorption. In this talk, two types of energy harvesting devices based on planar Si and Si nanostructures will be presented, namely, 1) Si/PEDOT:PSS hybrid solar cells and 2) ordered Si nanobelt array based PECs for solar hydrogen generation.

Usually, the Si/PEDOT:PSS solar cells only exhibit low power conversion efficiency in case hydrogen-terminated Si (Si:H) is used. We recently found that by intercalating a layer of platinum nanoparticles (Pt NPs) between Si:H and the PEDOT:PSS layer, the cell's photovoltaic (PV) performance can be markedly improved.[2] In addition to the current-voltage (J-V) characteristics and photocurrent action spectrum (IPCE) characterization, unconventional techniques such as impedance spectroscopy, Mott-Schottky analysis and intensity modulated photocurrent/photovoltage spectroscopy were also used to clarify the underlying mechanism responsible for the PV performance enhancement. The results show that a Pt NP interlayer intercalated between the Si:H and PEDOT:PSS is able to reduce the series resistance and charge transfer resistance giving rise to an increased short circuit current density, to raise the built-in voltage at the space charge region facilitating charge separation, and to effectively suppress p-n interface recombination, thereby improving the cell's overall PV performance.

Besides, well-ordered tilted Si nanobelt arrays were fabricated over a large area by cost-effective metal assisted chemical etching of pre-patterned Si substrates.[3] Compared with planar Si of the same type, the tilted Si nanobelt arrays exhibit markedly enhanced photocurrent density for hydrogen evolution and much faster charge transfer kinetics at the electrode/electrolyte interface, which can be attributed to the unique structural feature of the array which allows more incident light to be absorbed and the remarkably increased surface area, respectively. The stability of the Si nanobelt array photocathodes was investigated as well.

References

[1] N.S. Lewis, MRS Bull., **32** (2007) 808.
[2] X.Q. Bao, L.F. Liu, submitted
[3] X.Q. Bao, R. Ferreira, E. Paz, D.C. Leitao, A. Silva, S. Cardoso, P.P. Freitas and L.F. Liu, Nanoscale, Accepted

Figures

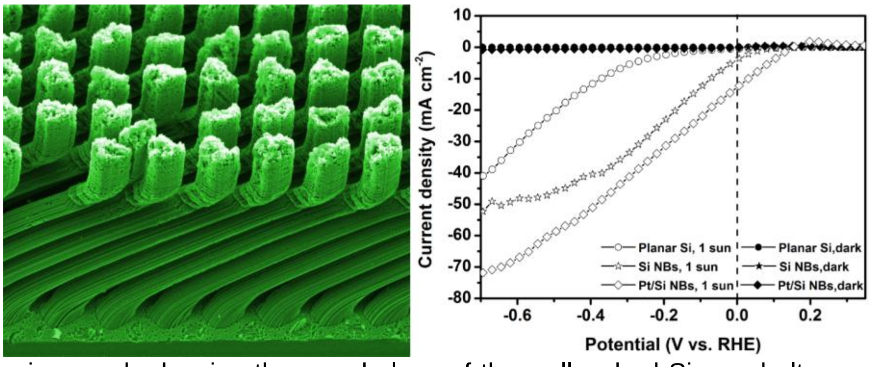

Figure 1. SEM micrograph showing the morphology of the well-orderd Si nanobelt arrays (left) and J-V characteristics of the Si nanobelt array photocathode for solar hydrogen evolution.