Wire Array Solar Cells:

Fabrication and Photoelectrochemical Studies

Thesis by

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Abstract

Despite demand for clean energy to reduce our addiction to fossil fuels, the price of these technologies relative to oil and coal has prevented their widespread implementation. Solar energy has enormous potential as a carbon-free resource but is several times the cost of coal-produced electricity, largely because photovoltaics of practical efficiency require high-quality, pure semiconductor materials. To produce current in a planar junction solar cell, an electron or hole generated deep within the material must travel all the way to the junction without recombining. Radial junction, wire array solar cells, however, have the potential to decouple the directions of light absorption and charge-carrier collection so that a semiconductor with a minority-carrier diffusion length shorter than its absorption depth (i.e., a lower quality, potentially cheaper material) can effectively produce current. The axial dimension of the wires is long enough for sufficient optical absorption while the charge-carriers are collected along the shorter radial dimension in a massively parallel array. This thesis explores the wire array solar cell design by developing potentially low-cost fabrication methods and investigating the energy-conversion properties of the arrays in photoelectrochemical cells.

The concept was initially investigated with Cd(Se, Te) rod arrays; however, Si was the primary focus of wire array research because its semiconductor properties make low-quality Si an ideal candidate for improvement in a radial geometry. Fabrication routes for Si wire arrays were explored, including the vapor-liquid-solid growth of wires using $SiCl_4$. Uniform, vertically aligned Si wires were demonstrated in a process that permits control of the wire radius, length, and spacing. A technique was developed to transfer

these wire arrays into a low-cost, flexible polymer film, and grow multiple subsequent arrays using a single Si(111) substrate. Photoelectrochemical measurements on Si wire array/polymer composite films showed that their energy-conversion properties were comparable to those of an array attached to the growth substrate. High quantum efficiencies were observed relative to the packing density of the wires, particularly with illumination at high angles of incidence. The results indicate that an inexpensive, solid-state Si wire array solar cell is possible, and a plan is presented to develop one.

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List of Publications

Portions of this thesis have been drawn from the following publications:

Spurgeon, J. M., Boettcher, S. W., Kelzenberg, M. D., Brunschwig, B. S., Atwater, H. A., and Lewis, N. S., Photoelectrodes from arrays of crystalline Si wires embedded in a flexible polymer. Submitted, (2009).

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