Design of radial p-i-n Si nanowires for high performance solar cells

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BIOGRAPHY

Binh-Minh Nguyen: Binh-Minh Nguyen received an engineer degree from Ecole Polytechnique, France and a doctoral degree from Northwestern University, USA in 2005 and 2010 respectively. Prior to joining Los Alamos National Lab as a Director’s Postdoctoral Fellow in 2012, he was a Research Assistant Professor at the Center for Quantum Devices, Northwestern University.

His research interests include band structure modeling, epitaxial growth and device physics of semiconductor optoelectronic/electronic devices. Currently, he is working on exploring transport mechanisms in one-dimensional Si/Ge core/shell nanowire structures, and developing novel electronic/optoelectronic devices based on this material system.

He is the author/co-author for five book chapters and has more than 50 scientific papers published in refereed journals and international proceedings. He serves as a frequent reviewer for many journals of the Institute of Physics, the American Institute of Physics, the Optical Society of America and Elsevier. Nguyen is recipient of a SPIE Educational Scholarship in Optical Science and Engineering in 2009 and 2010; an IEEE Photonics Society 2010 Graduate Student Fellowship and the Edward G. Weston 2010 Summer Fellowship from the Electro Chemical Society (ECS).

TECHNICAL ABSTRACT

The quantum efficiency of solar cells, like of any photon detector, is dictated by the ability to absorb photons to create conducting carriers, and the efficiency to drive such carriers to electrodes for collection. Having a medium that enables full photon absorption in a short length, together with a long carrier lifetime that allows photo-generated carriers to reach...
electrodes before recombining are ideal, but are not always realistic. For example, silicon photovoltaics, despite being a major player in the solar cell market, suffer from the low absorption coefficient, thus requiring a thick absorbing layer which impairs the efficiency with which photogenerated carriers are collected. Radial silicon nanowires have been proposed as a candidate for reducing the optical absorption length and required processing purity in Si based solar cells’ without compromising their quantum efficiency and yet reducing the overall cell cost. On the one hand, incident light propagates along the axial dimension of the wires, and thus has a greater chance of being absorbed when the wire length extends beyond 10\( \mu \)m due to inter-array light scattering effects. On the other hand, the core/shell p-i-n structure leads electrical current flow along sub-micron radii, which enables rapid collection of most photogenerated carriers as the transport length is typically less than the diffusion lengths of minority carriers.

In this work, we perform Finite Difference Time Domain (FDTD) simulation to investigate the absorption process in arrayed radial nanowires. Effects of light scattering and fill factor at different wire spacings will be discussed. Evolution of absorption with wire length, particularly in the long wavelength range (700nm-1100nm) will be shown to illustrate the advantages of nanowires as opposed to conventional planar structures. In addition, actual wire geometries after shell overgrowth using chemical vapor deposition (CVD) for different wire lengths and spacings have been studied. Results exhibit good agreement between the simulations and absorption measurements for nanowire array devices.

**Fig 2:** Simulation results showing effect of scattering with different array pitches. Smaller pitch facilitates stronger light scattering, light intensity in air spacing between wires decreases, thus stronger absorption.

**Keywords:** Solar cell, high absorption efficiency, Si, Ge, nanowires.

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