FABRICATION OF GaAs NANOWIRES FOR SOLAR CELL DEVICES

Erin Sanehira[1,2], M. Yoshimura[2], S. Soundeswaran[2], K. Hiruma[2], and T. Fukui[2]

1. NanoJapan Program, Rice University and Department of Electrical & Computer Engineering, University of Rochester
2. Research Center for Integrated Quantum Electronics, Hokkaido University, Sapporo, Japan

While solar cell efficiencies have been improved by adding multiple junctions and cladding layers to enhance optical absorption, these devices are limited by their planar structure. Unlike conventional, planar solar cells, semiconducting nanowires can be fabricated with a core-shell, i.e. radial pn junction, structure that can enhance carrier collection[1] and increase the depletion region area. Periodically aligned nanowire arrays can also reduce surface reflection and increase optical absorption.[2] In this experiment, we fabricated single junction GaAs nanowires using selective-area metal-organic vapor-phase epitaxy. Coaxial p-GaAs/n-GaAs/n^+-AlGaAs/n^+-GaAs nanowires were grown on a p-type GaAs (111) B substrate. Micro-photoluminescence and scanning electron microscopy (SEM) were used to assess crystal quality of the nanowires. SEM images show that the grown GaAs nanowires measured about 250 nm in diameter and 1.4 µm in length. The periodically aligned array was arranged in a triangular lattice with a pitch of 400 nm. These dimensions resulted in a nanowire filling ratio of 0.29 and a light absorption ratio of 0.75, using 10^4 cm^{-1} as the absorption coefficient for GaAs. A photovoltaic device will be fabricated and then tested by analyzing I-V characteristics under Air Mass 1.5 Global (AM 1.5G) standard illumination. The development of the single junction GaAs nanowire photovoltaic device suggests that semiconducting nanowires are a promising technology for improving solar cell efficiencies.

[1] B.M. Kayes, H.A. Atwater, and N.S. Lewis: J. Appl. Phys. 97 (2005) 114302.
[2] L. Hu and G. Chen: Nano Lett. 7 (2007) 3249.

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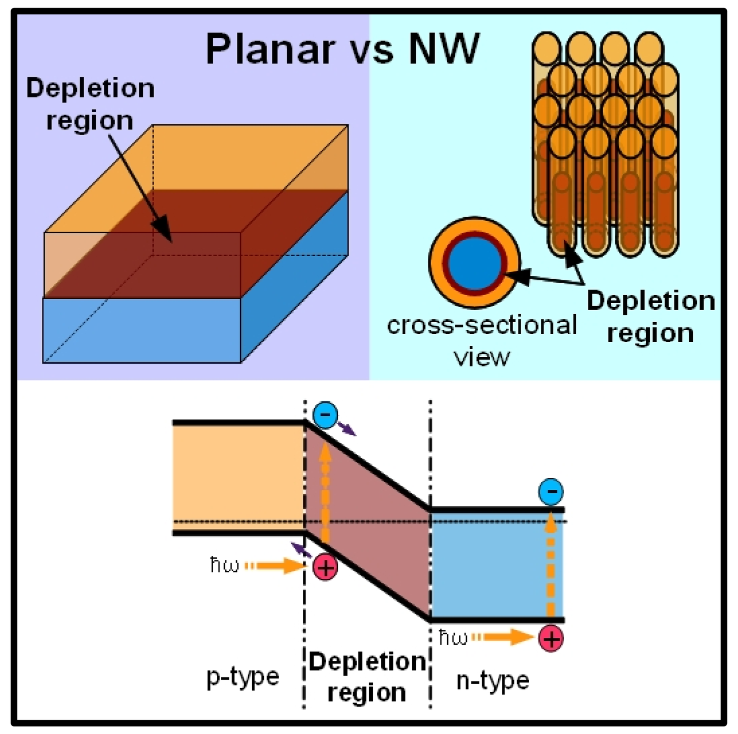
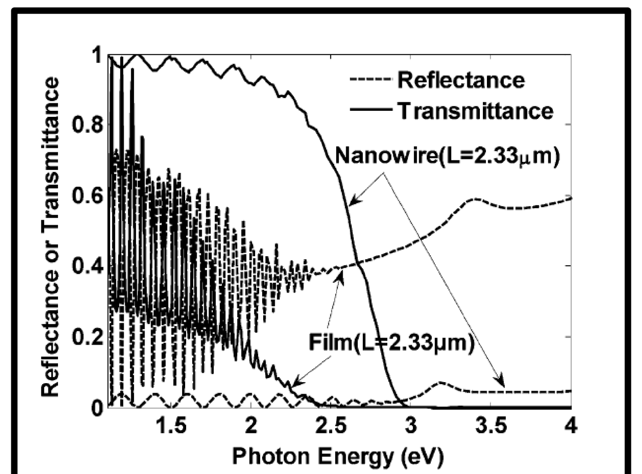
Introduction

Advantages to periodically-aligned, core-shell nanowire (NW) arrays for solar cells:

•Increased optical absorption by reducing surface reflection and increasing absorption at high frequencies[1]

•Enhanced carrier collection due to an increase in depletion region area



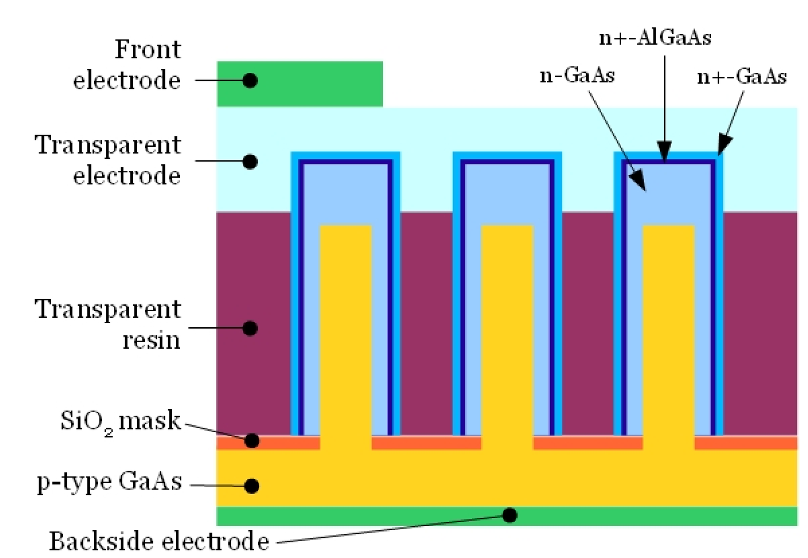


Device physics modeling[1] by Hu *et al.* shows the NW surface reflectance reduces dramatically at higher photon energy levels.

[1] L. Hu and G. Chen: Lett. 7 (2007) 3249

Experimental Objective

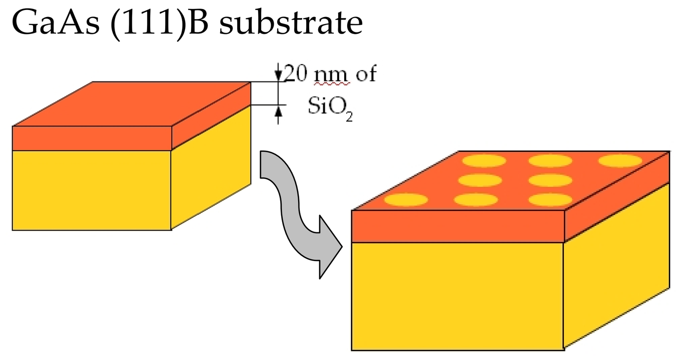
In this experiment, we use selective-area metal-organic vapor-phase epitaxy (SA-MOVPE) to grow core-shell p-GaAs/n-GaAs/n+-AlGaAs/n+-GaAs nanowires. We fabricate a photovoltaic device from the periodically aligned nanowire array and test device performance under Air Mass 1.5 Global (AM1.5G) standard illumination.



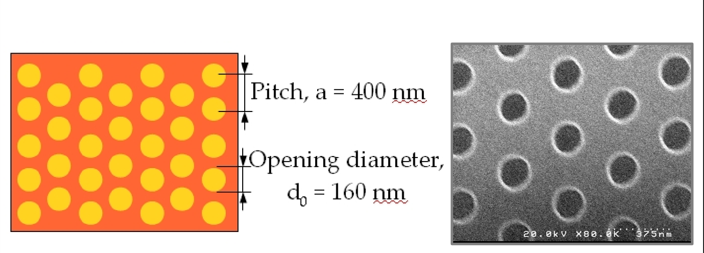
Method

Mask pattern development

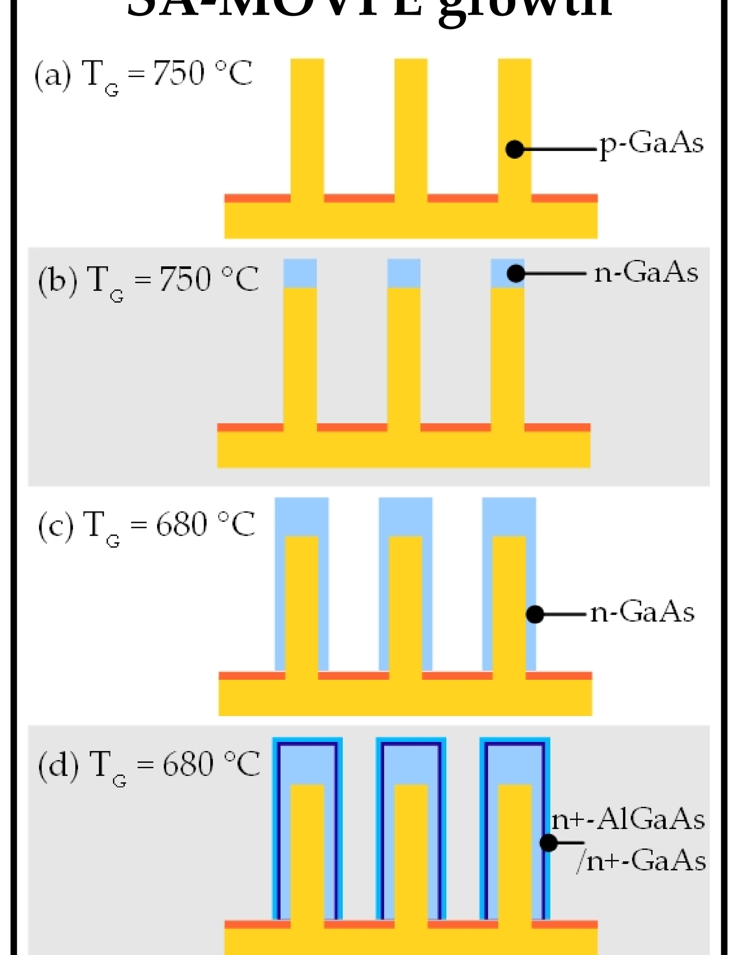
(a) Sputter SiO_2 on p-type GaAs (111)B substrate



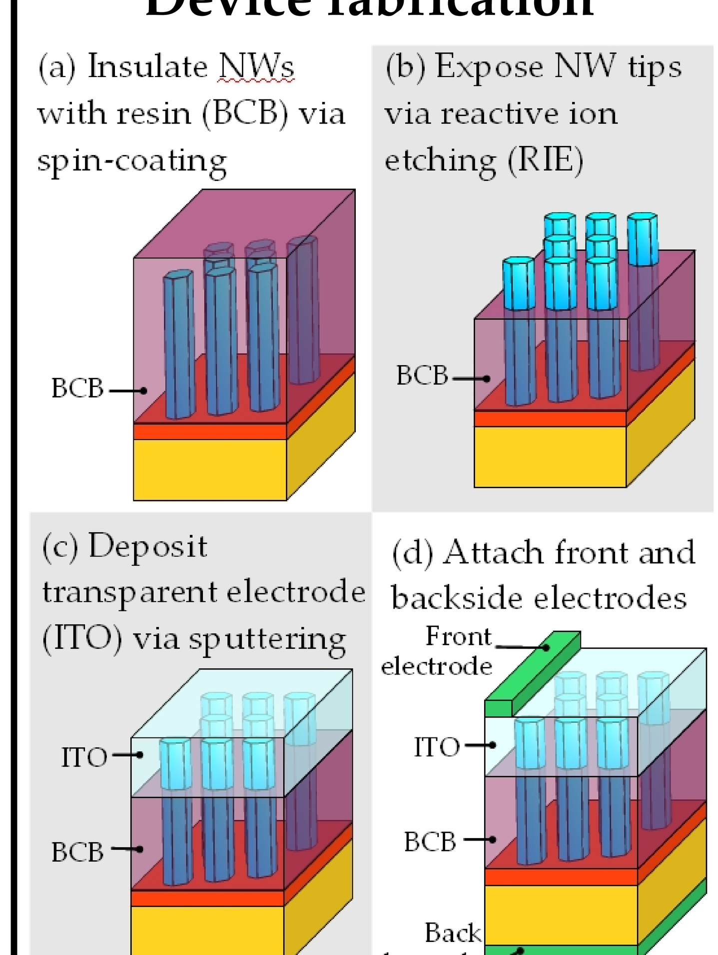
(b) Develop triangular lattice mask pattern using electron beam (EB) lithography and wet chemistry



SA-MOVPE growth

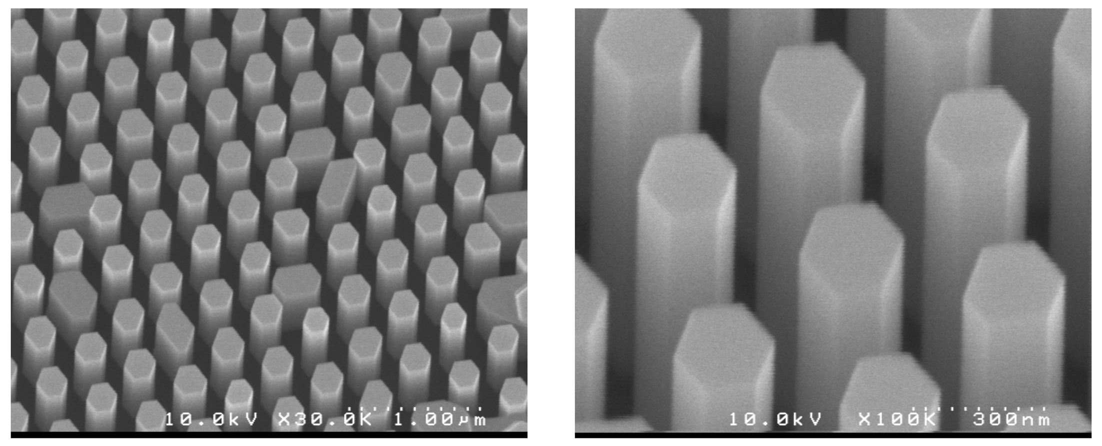


Device fabrication

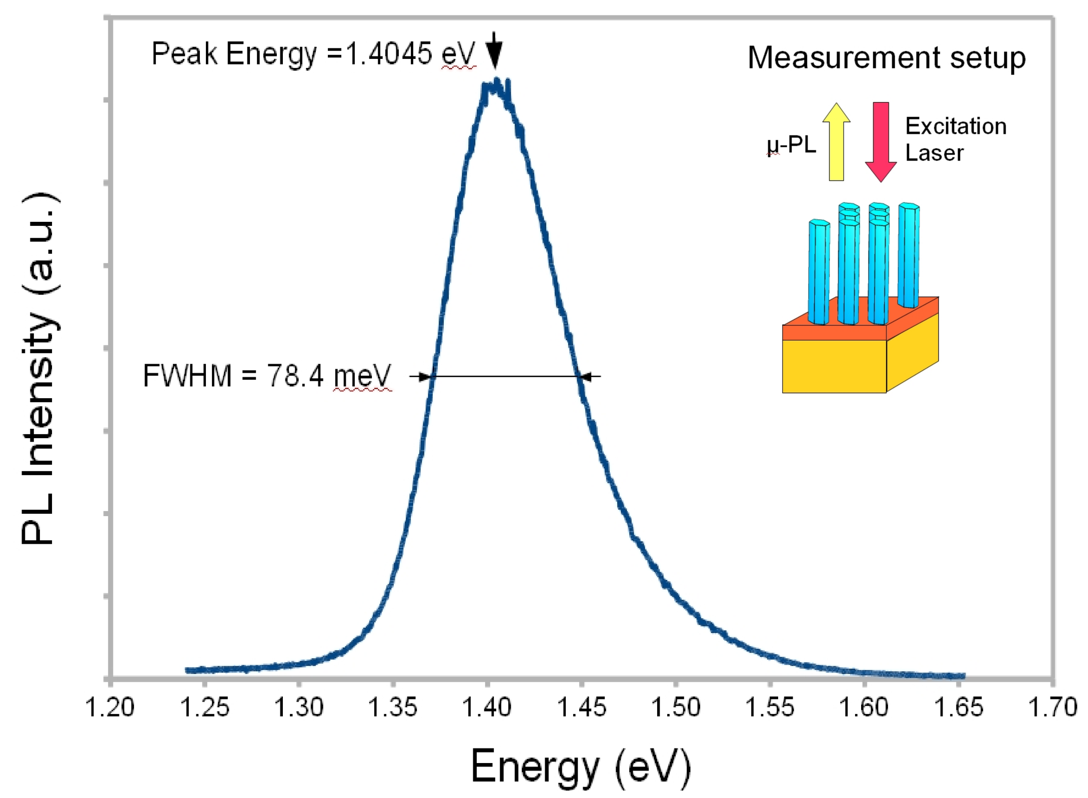


Results

SEM Images



Micro-photoluminescence

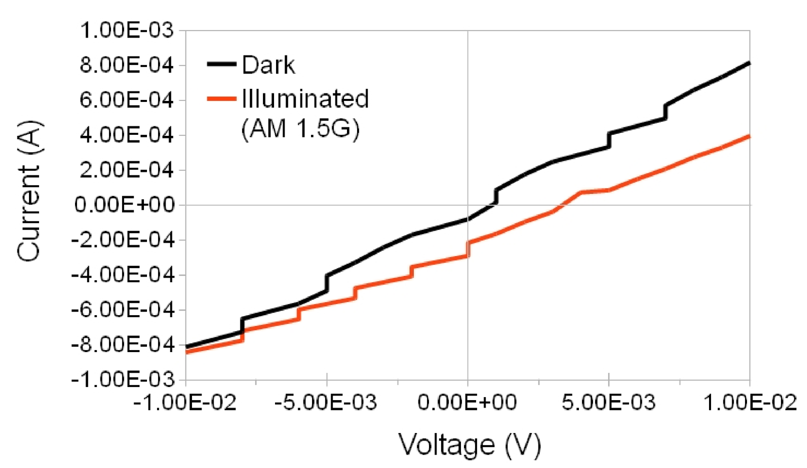


Grown NW observations

Scanning electron microscopy (SEM):
Height = 1.4 μm, Diameter = 250 nm, Pitch = 400 nm
➔ Filling ratio = 0.29

Micro-photoluminescence (μ-PL):
Peak Energy = 1.4045 eV, FWHM = 78.4 eV
➔ Peak energy within 2% of GaAs bandgap energy
➔ Similar to previously grown GaAs NWs[2]

Solar Cell Device I-V Characteristics



I_{SC} = 25 mA/cm^2
V_{OC} =3 mV
I_{max} =15 mA/cm^2
V_{max} =1 mV

FF = 0.2
η = 0.015%

[2] J. Noborisaka, J. Motohisa, S. Hara, and T. Fukui: J. Appl. Phys. 87 (2005) 093109

Conclusions and Future Work

•Successfully grew periodically-aligned NW array of core-shell p-GaAs/n-GaAs/n+-AlGaAs/n+-GaAs NWs using SA-MOVPE
•Developed fabrication process for GaAs NW photovoltaic device
•Measured I-V characteristics for the GaAs NW photovoltaic device

•In the future, the device can be optimized by adjusting geometrical parameters such as array pitch size and NW diameter/length, as well as NW growth conditions.

Acknowledgments

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HOKKAIDO UNIVERSITY RICE ROCHESTER http://nanojapan.rice.edu