Fabrication of GaAs nanowires for solar cell devices

Y. Lai[1,2], E. Nakai[2], K. Hiruma[2], and T. Fukui[2]

1. *NanoJapan Program, Rice University and Department of Electrical & Computer Engineering, Massachusetts Institute of Technology*

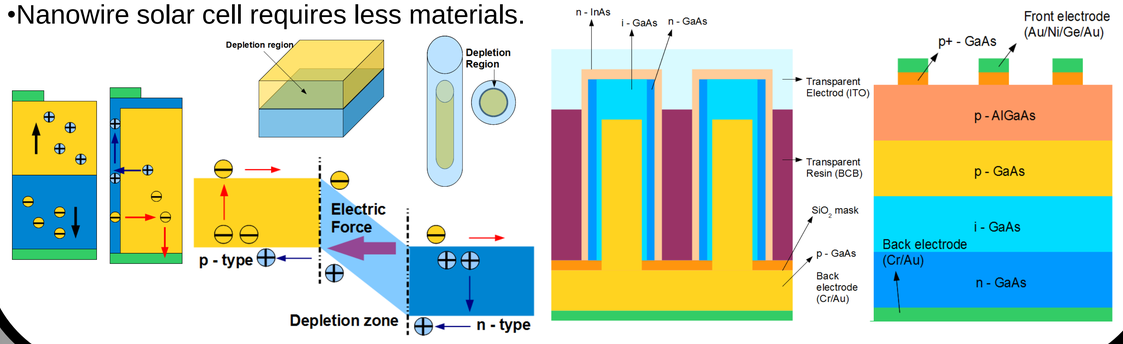
2. *Research Center for Integrated Quantum Electronics, Hokkaido University, Sapporo, Japan*

Introduction

In this experiment, we will use selective-area metal-organic vapor-phase epitaxy (MOVPE) to fabricate planar and nanowire solar cells. We will further test the I-V Characteristics under Air Mass 1.5 Global (AM1.5G) standard illumination and the reflectances of the devices and compare their performances.

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

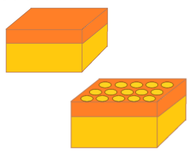
- The nanowire is long in the direction of incident light, improving the light absorption; but then short in the other dimension, allowing for effective carrier collection.
- Shell structure of the nanowire increases the depletion region area, enhancing carrier collection.
- The nanowire structure reduces the reflection, and increases the absorption at high frequency.
- Nanowire solar cell requires less materials.



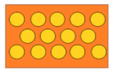
Methods

Mask Pattern Development

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

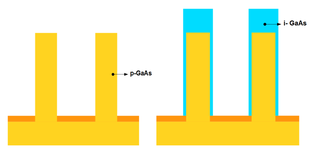


- Develop hexagonal lattice mask pattern using electron beam (EB) lithography and wet chemistry

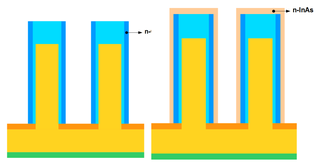


SA-MOVPE Growth

(1) T_G = 750°C (2) T_G = 750°C

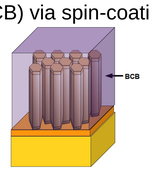


(3) T_G = 680°C (4)T_G = 680 °C

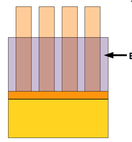


Device Fabrication

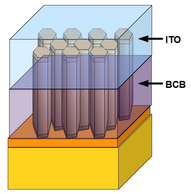
(1) Insulate NWs with resin (BCB) via spin-coating



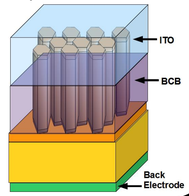
(2) Expose NW tips via reactive ion etching (RIE)



(3) Deposit transparent electrode (ITO) via sputtering

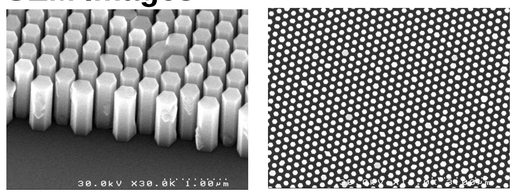


(4) Deposit the back electrode (Cr/Au) using Electron Beam Evaporation method

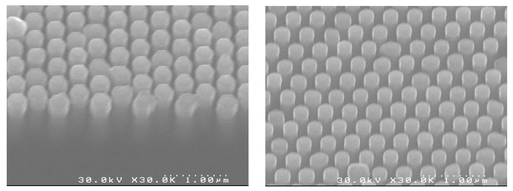


Results

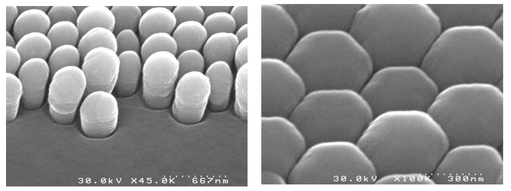
SEM Images



Core-shell Nanowires



Nanowires with BCB

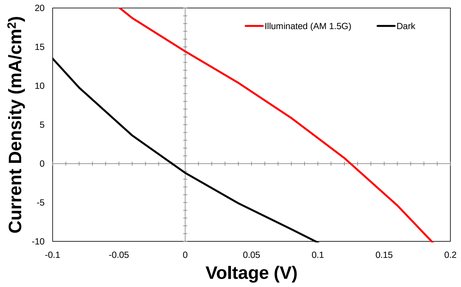


Nanowires with BCB and ITO

Grown NW Observations

Height = 1.1μm
Diameter = 80 nm
Pitch = 400 nm

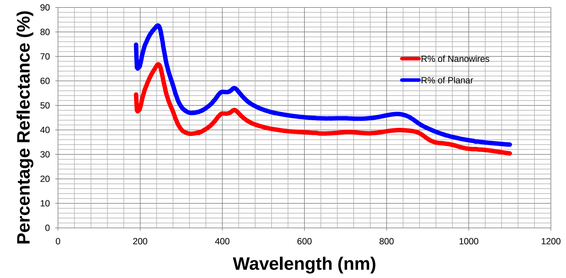
I-V Characteristics of Nanowire Solar Cell

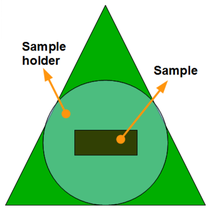


ISC = 14.4286 (mA/cm^2)
VOC = 0.124688 (V)
Imax = 7.806 (mA/cm^2)
Vmax = 0.064 (V)

FF = 0.27769
η = 0.49958%

The Reflectance of Nanowire and Planar Solar Cells





Machine Condition:

The diameter of the sample holder is 5mm, and the dimension of the sample is 3mm x 1mm. Due to the hole of the sample holder is bigger than the sample of NW solar cell, the reflectance of NW solar cell is lower than the reality. For example, according to the data, the reflectance of planar solar cell is 45% and the NW solar cell is 40%; while in the reality the reflectance of NW solar cell is 10~11%.

Conclusions and Future Works

- Successfully fabricate planar solar cell and core-shell nanowire solar cell using MOVPE and developed fabrication process for 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
- The quantum efficiency of solar cell can also be improved by adding buffer layers in the nanowires to more effectively separate the electrons

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. OISE-0530220. http://nanojapan.rice.edu