Modelling Nanowire Photovoltaic Devices

D. Paige Wilson[1], Ray R. LaPierre[1]
1. Department of Engineering Physics, McMaster University, Hamilton, ON, Canada

Introduction

Nanowires (NW) are thin columns of light absorbing material with such a small footprint that they can be grown epitaxially on lattice mismatched substrates. Previous work has shown that straight NWs act as evanescent waveguides and are coupled to specific frequencies [1]. Straight, cylindrical NWs can be optimized for the solar spectrum by tuning their diameter [2]. Tapered NWs present an additional advantage because they can remain thin at the interface but widen to absorb more light.

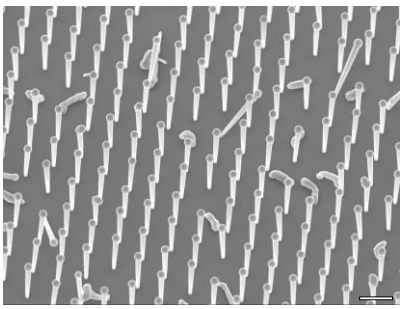

Figure 1: An SEM image of a GaAs NW array on a Si substrate. Scale bar is 1 µm. Tilt is 30˚

Model

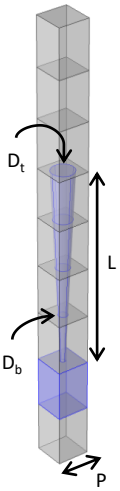

Figure 2: Model geometry produced in COMSOL. The tapered GaAs NW and its Si substrate have been highlighted.

P	Array pitch
L	NW length
D_t	Top diameter
D_b	Base diameter

We use the COMSOL RF module to model arrays of NWs. Figure 2 shows the geometry. A single nanowire is given periodic boundary conditions in the x and y directions to simulate a square array of nanowires. Perfectly matched layers are placed at the top and bottom of the geometry.

Acknowledgements

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References

[1] K. M. Azizur-Rahman and R. R. LaPierre, "Wavelegth-selective absorptance in GaAs, InP and InAs nanowire arrays," *Nanotechnology*, 2015.

[2] Y. Hu, R. R. LaPierre, M. Li, K. Chen and J. J. He, "Optical characteristics of GaAs nanowire solar cells," *Journal of Applied Physics*, 2012.

Results

We have solved for the electric fields of several tapered NWs with varying top diameters. We determine the absorptance in each section of the NW by finding the difference in transmittance between the top and bottom of each section. Weighting the incident power to the AM1.5D solar spectrum allows for the generation rates of each NW geometry to be calculated.

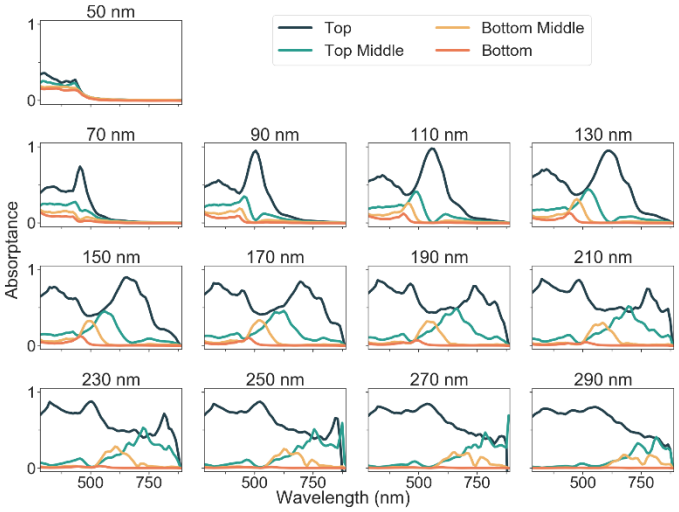

Figure 3: The absorptance in 500 nm thick sections of a 2000 nm long NW. The top diameter of each NW is given as the plot title. Each NW had a base diameter of 50 nm and a pitch of 320 nm.

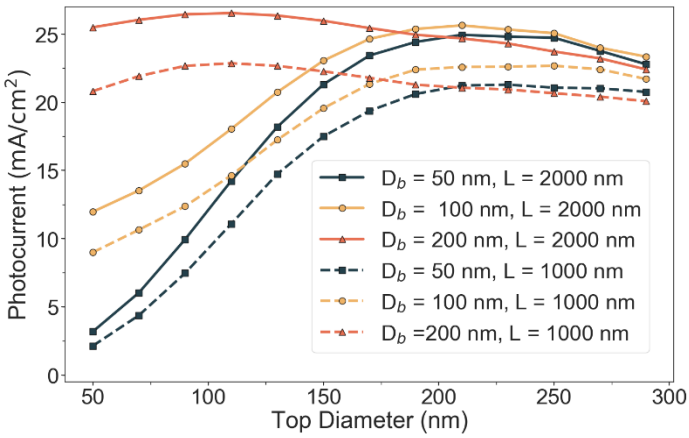

Figure 4: Total photocurrent generated within a NW under the AM1.5D spectrum.

Conclusion

The absorption peak corresponding to the NW segment will shift to longer wavelengths for wider diameters and to shorter wavelengths for smaller diameters. The optimal choice of NW geometry is constrained by the base diameter which can be achieved experimentally but is improved greatly by an appropriate choice of top diameter and length.