Optical and Electrical Simulations of Amorphous Silicon Nanorods Solar Cells

Daren Davoux, Research Assistant, South Dakota State University

Dr David Galipeau, major advisor

Dr Mahdi Barroughi, thesis advisor

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Background

- High absorption results in high efficiency
  - Absorption increases with thickness
- Minimizing recombination losses increases efficiency.
  - Recombination increases with thickness
- Beer-Lambert law is traditionally used to determine photoabsorption

Motivation

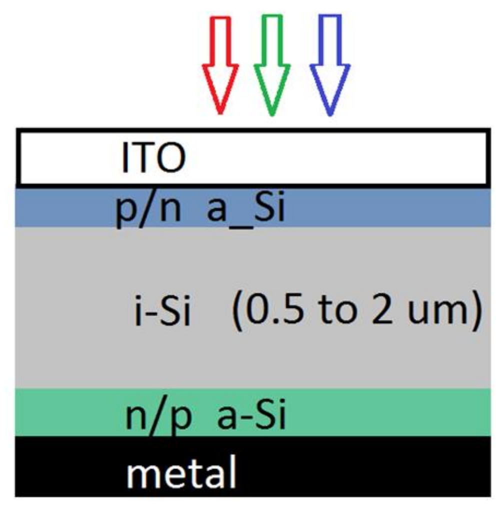
- Need to optimize thickness to maximize efficiency

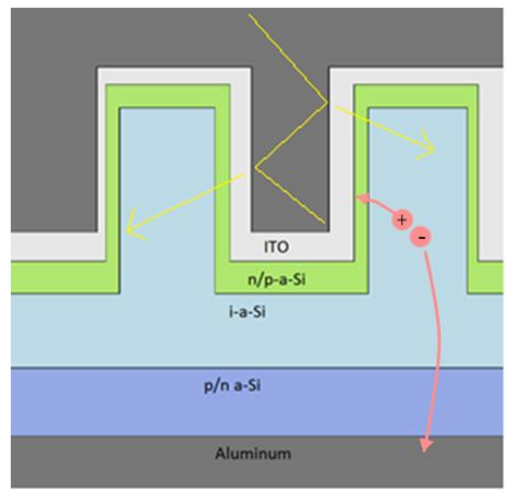
Objective

- Use nanorod structured solar cells to maximize absorption while minimizing recombination

Proposed Design

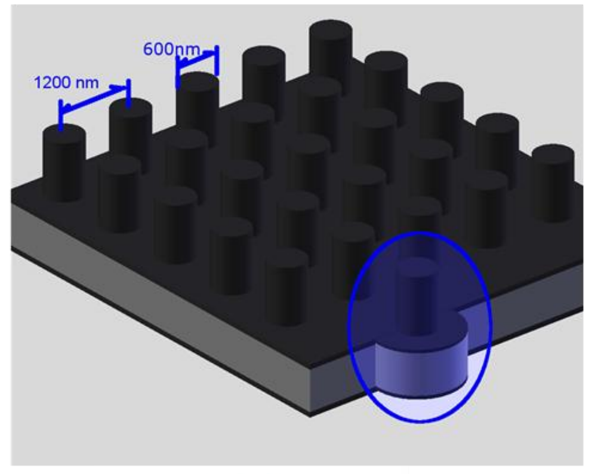
- Upper figure shows the typical thin film design
  - Typically between 500 nm and 2 um thick
  - Bulk material is intrinsic a-Si, doped Si has a high recombination rate
- The lower figure shows the proposed design
  - Total height/ nanorod to be optimized for absorption (shown in yellow) vs minimized charge transport path (shown in red)
  - Adding nanorods may allow total device thickness to be significantly reduced, allowing very shortened hole transfer paths

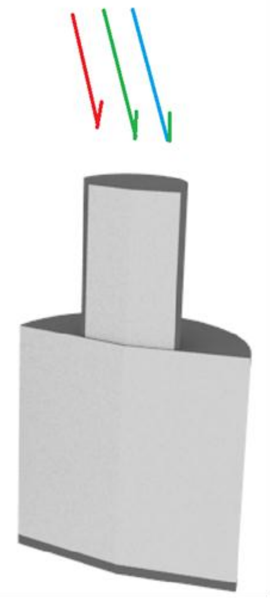




Model Setup

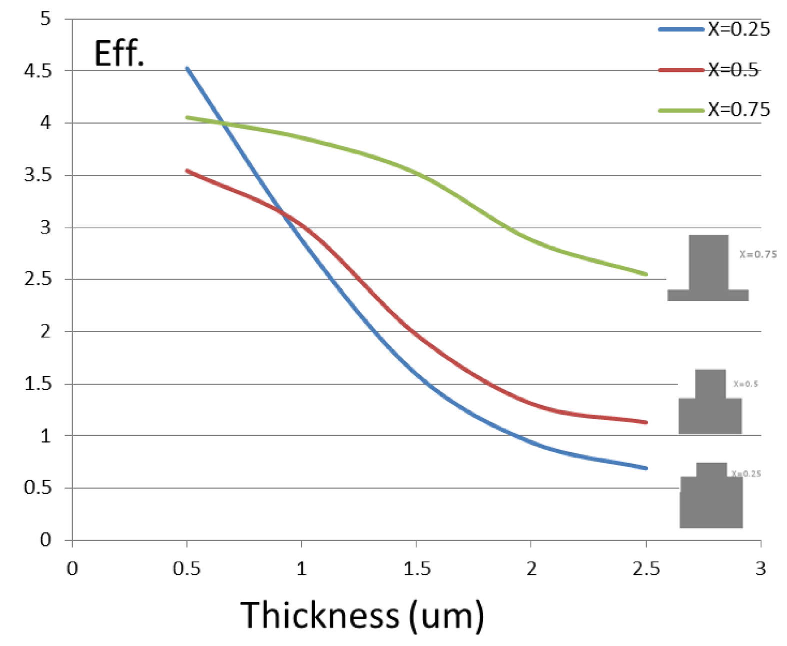
- Top figure shows the design in 3D
  - Nanorod spacing 1200 nm
  - Nanorod diameter was 600 nm
- Lower Figure shows the individual structure
  - Light grey – 50 nm intrinsic Si
  - Dark gray – 50 nm doped Si
- Rod fraction was varied
  - height of the nanopillar divided by total thickness of a-Si





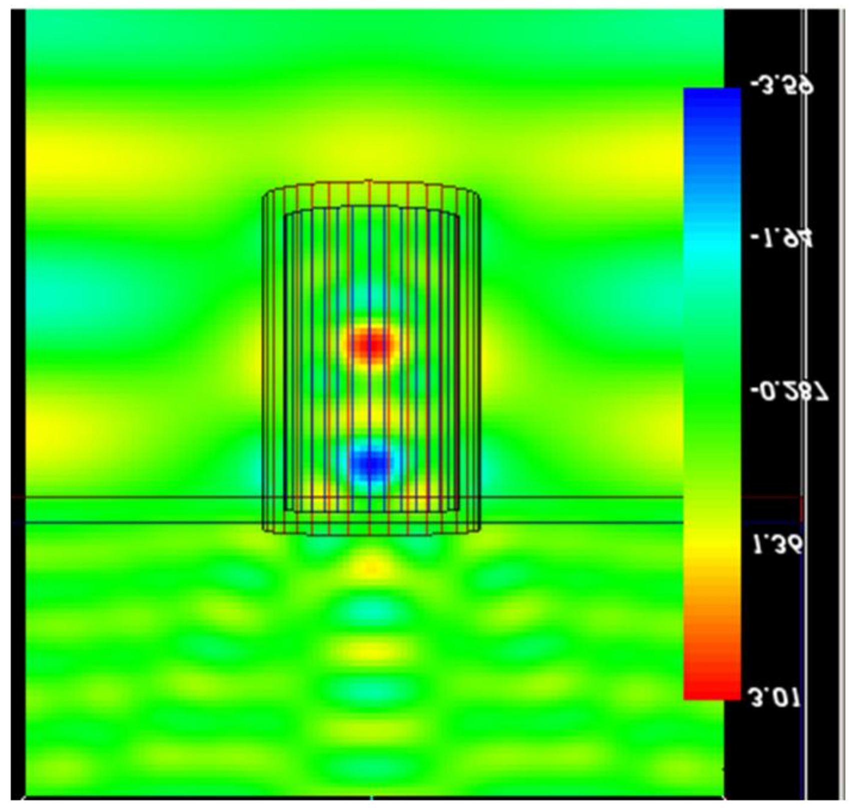
Solar cell efficiency vs Thickness (Beer-Lambert algorithm)

- Efficiency decreased with increasing thickness for all cases
- Efficiency increased with rod length at thicknesses greater than 1 um
- Efficiency was maximum at thicknesses <1um when no nanorods were present
  - Likely due to absorption limit imposed by the algorithm
- Light trapping and electric field enhancement is expected to increase efficiency for the nanopillar case (dashed line)



EM Explorer OPTICAL Simulation of nanostructured a-Si (FTDT algorithm)

- Red indicates 3x increase in photon density
- Blue shows area of no photon density
- Similar results occur at other wavelengths
  - Positions vary.
- This may allow thin nanorod devices to outperform thin flat devices



Conclusions

- Adding Si nanorods to a-Si gives as much as 5x increase in efficiency for thicker films
- Silicon nanorods result in "hotspots" within the silicon structure that can result in enhanced photogeneration

Future Work

- Incorporate EM Exp optical simulation data into electrical simulation model

Acknowledgements

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