Design & Analysis of Quantum Dot/Plasmonic Enhanced Solar Cells

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Introduction:

- Solar Cell efficiency can be increased by increasing the light absorption coefficient, tunability to a broader range of the solar spectrum, and novel effects such as multiple carrier generations
- Quantum dots (or nanoparticles of semiconductors) have light focusing properties and can be embedded into solar cells to increase efficiency
- Challenge: lack of a nanoparticle fabrication technique suitable for light absorption/carrier extraction
- Nevada Nanotechnology Center at UNLV has developed a proprietary technique ideally suited for quantum dot and plasmonic enhanced solar cells

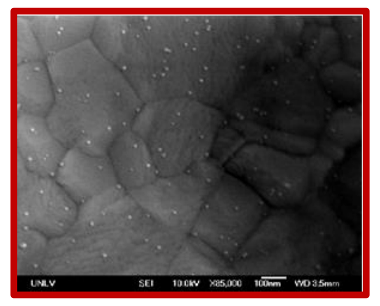

Figure 1: Quantum Dots deposited by the UNLV technique

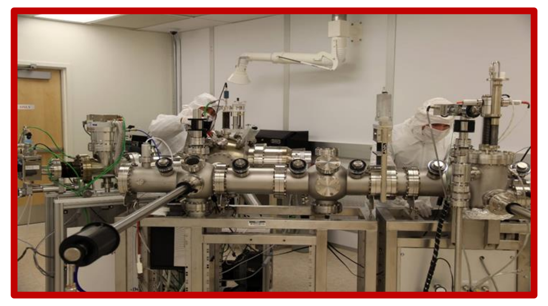

Figure 2: UNLV Tool for Nanoparticle fabrication

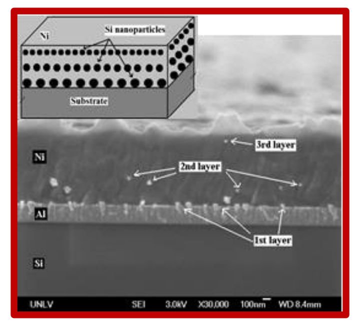

Figure 3: Complex multilayered structure fabricated by UNLV technique

Purpose:

The objective of this project is to design, analyze and optimize a high efficiency solar cell structure enabled by the UNLV fabrication technique.

Methods:

The project objective will be accomplished through the completion of the following tasks :

- Study UNLV fabrication technique to identify features and limitations relevant for solar cell implementation
- Identify appropriate solar sell structure and material
- Select nanoparticle material and dimensions
- Investigate and determine analysis tools appropriate for quantum dot and plasmonic properties of nanoparticles and solar cells
- Design solar cell structure incorporating quantum dots and plasmonic nanoparticles
- Analyze solar cell structure and optimize for maximum efficiency

Results:

- The UNLV fabrication technique can create nanoparticles of any semiconductor or metal material ranging between 2 and 60 nm with flexible placement
- A single junction solar cell with and without layers of 20 nm Germanium nanoparticles were simulated
- Using JCMsuite (https://jcmwave.com/) and MATLAB (http://mathworks.com/) software, a 2D simulation of absorption vs wavelength was created
- This technique produced quantitative results which showed that the plasmonic solar cell had a higher absorption averaged across the tested wavelengths
- The absorption was increased by adding layers of nanoparticles to the solar cell

Solar Cell Geometries

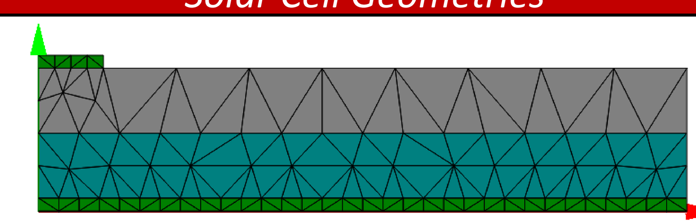

Figure 4: No Layers of Nanoparticles

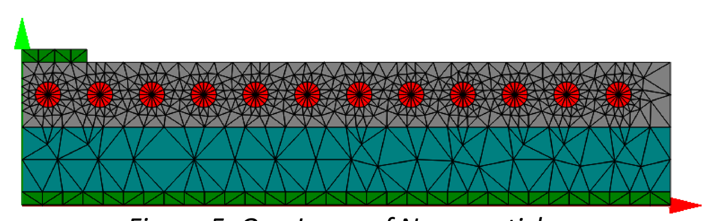

Figure 5: One Layer of Nanoparticles

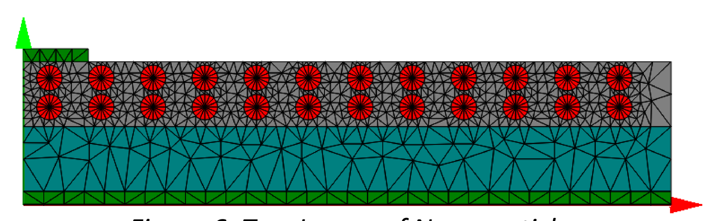

Figure 6: Two Layers of Nanoparticles

Absorption vs Wavelengths Plots

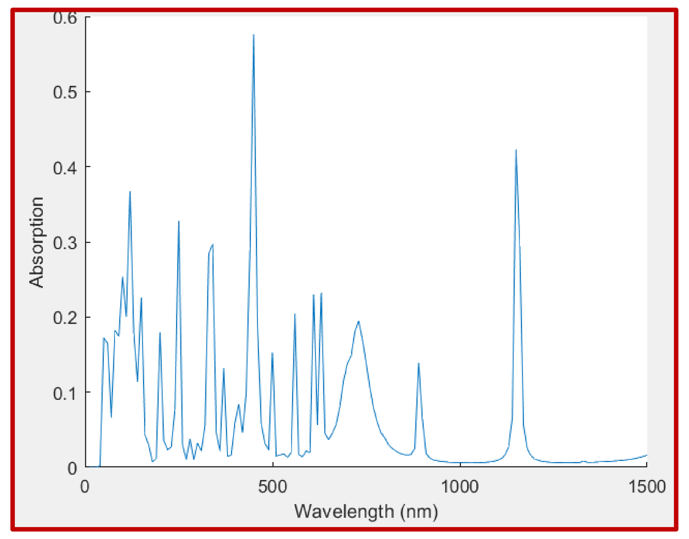

Figure 7: No Layers of Nanoparticles

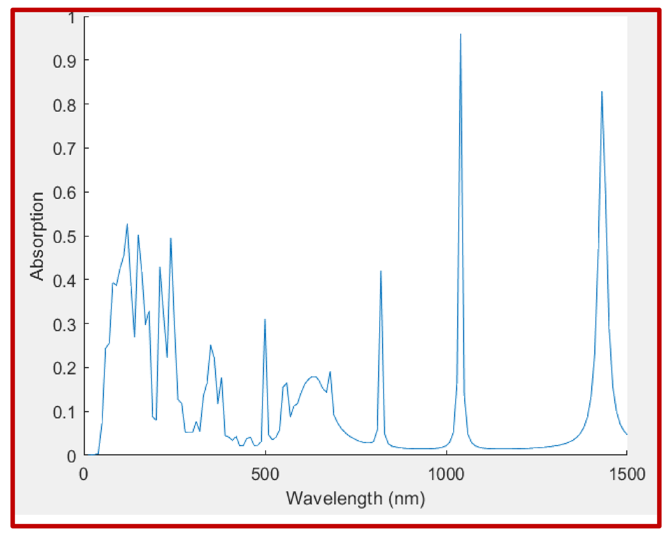

Figure 8: One Layer of Nanoparticles

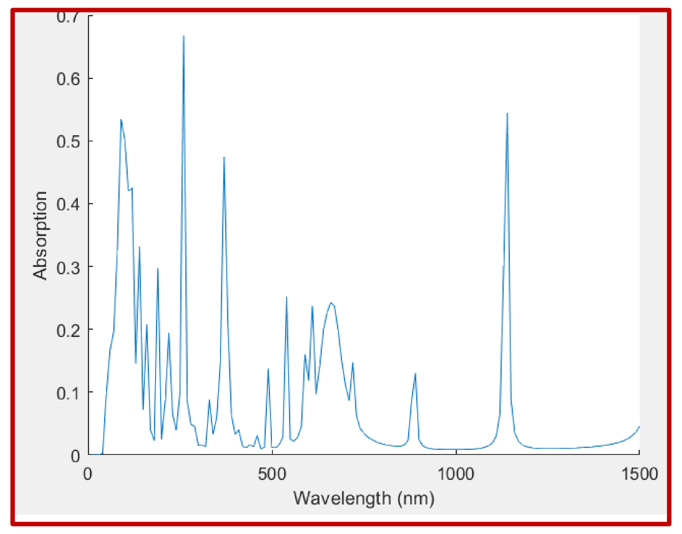

Figure 9: Two Layers of Nanoparticles

Results:

- This project explored and confirmed the suitability of the UNLV fabrication technique for implementation of quantum dots and plasmonics in the fabrication of high efficiency solar cells
- Based on computed simulations, quantum dots and plasmonics will increase the absorption of the solar spectrum in a solar cell, leading to an increased efficiency of the solar cell
- Computed results also suggest the range of wavelengths absorbed will increase with placement of nanoparticles.
- Achieved identification and acquisition of software tool JCMsuite which was found to be computationally intensive and had computational limitation with 3D structures

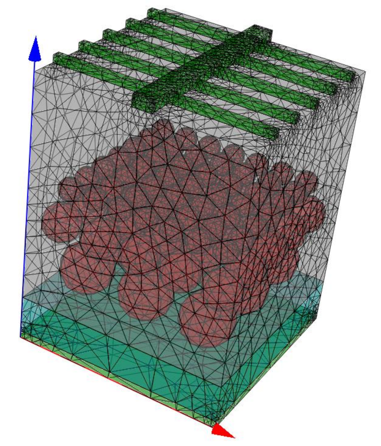

Figure 10: 3D Plasmonic Solar Cell Geometry

Future Research:

Since this project created results which supported the use of nanoparticles for implementing quantum dots and plasmonics to create high efficiency solar cells, the following future work is recommended for the successful implementation of a complete solar cell structure:

- Install JCMsuite on a high speed server to increase simulation speed and capability
- Investigate single junction solar cell structure varying the location of the nanoparticle payers
- Investigate the effect of nanoparticle size and density
- Investigate the effect of multiple layers of nanoparticles
- Study the effect of variable size nanoparticles in the same structure
- Investigate potential multijunction solar cell structures

Acknowledgements:

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