Determining Optical Properties of Gold-Embedded Electrosprayed Materials

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GET UP Green Energy Technology Undergraduate Program

(Research Thrust: Nanotechnology and Materials for Energy Storage and Conversion)

Background

A Brief Overview of ESD

Electrospray deposition (ESD) is a micro/nano - manufacturing process, in which extremely thin and uniform coatings can be created through the electrical atomization of a solution. [1]

Advantages of ESD include:

-Smaller and more uniform droplet size

-Self-repulsion prevents coagulation of droplets

-Size of droplets and layer thickness can be manipulated through parameters such as flow rate and input voltage [1]

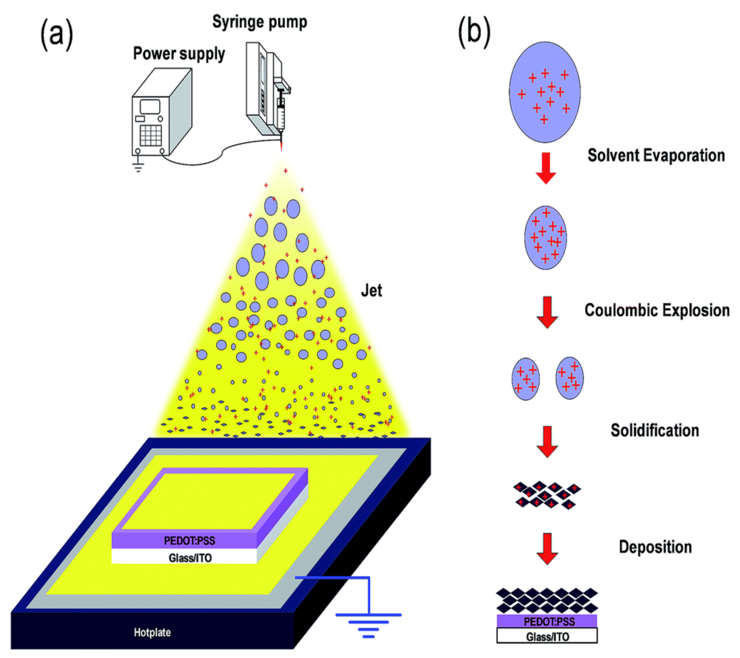


Fig I. **Standard ESD Experimental Set-Up**

Rutgers HMNL

At Rutgers University, Dr. Singer and his team have further enhanced the understanding of ESD technology, leading to the development of "SLED", or Self-Limiting Electrospray Deposition.

-Prevents charge from dissipating, allowing for even thinner coating of more complex materials [2]

Continued Importance

Embedding gold and silver nanoparticles into solar cells has been found to increase the overall absorption and efficiency. [3]

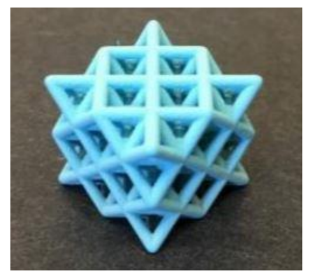
-Due to a light-scattering effect

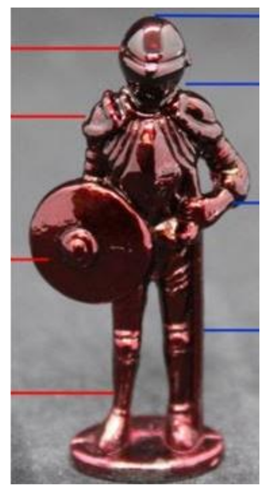
-The Rutgers HMNL team has seen similar increases in reflectivity with gold-embedded nanowire forests. [4]

Further research can help improve the efficiency of solar cells.

-Particularly appealing for organic solar cells (OSCs) due to the numerous practical and environmental benefits

Fig II. **Pewter Statue (right) and Lattice Structure Coated Using SLED**





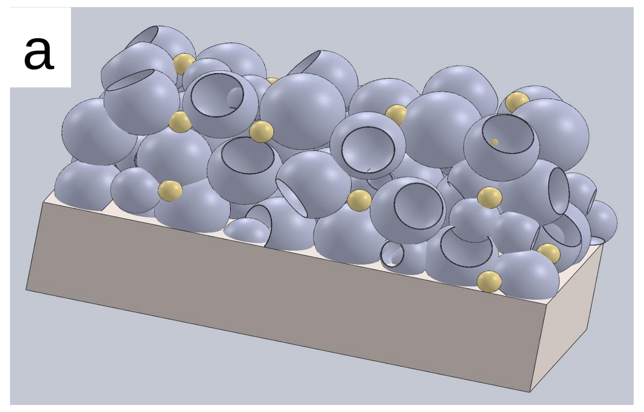
Methods

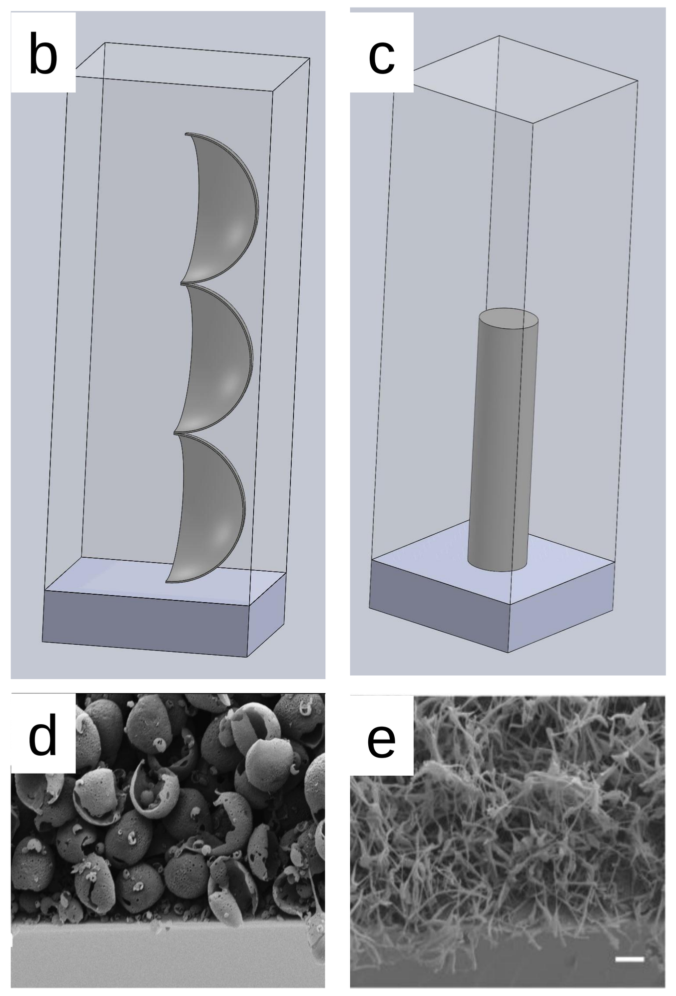
SOLIDWORKS Modeling

Simplified models of both nanoshell and nanowire SLED formations were created using Solidworks modeling software.

Fig III. (a) Large-Scale Solidworks Model of Nanoshell Formation with Embedded Gold Nanoparticles.

Solidworks Models and Experimental Images of (b, d) Nanoshell and (c, e) Nanowire Formations





Methods

COMSOL Optical Simulations

Figures 3b and 3c were then uploaded into COMSOL to perform optical simulations. Gold nanospheres (radius = 100 nm) were added within COMSOL.

-Two gold nanospheres were embedded within the nanowire model.

-One nanosphere was embedded in the nanoshell model due to mesh complexity.

-Simulations were run to calculate total power absorbed by the nanospheres, with wavelengths varying from 450 – 800 nm.

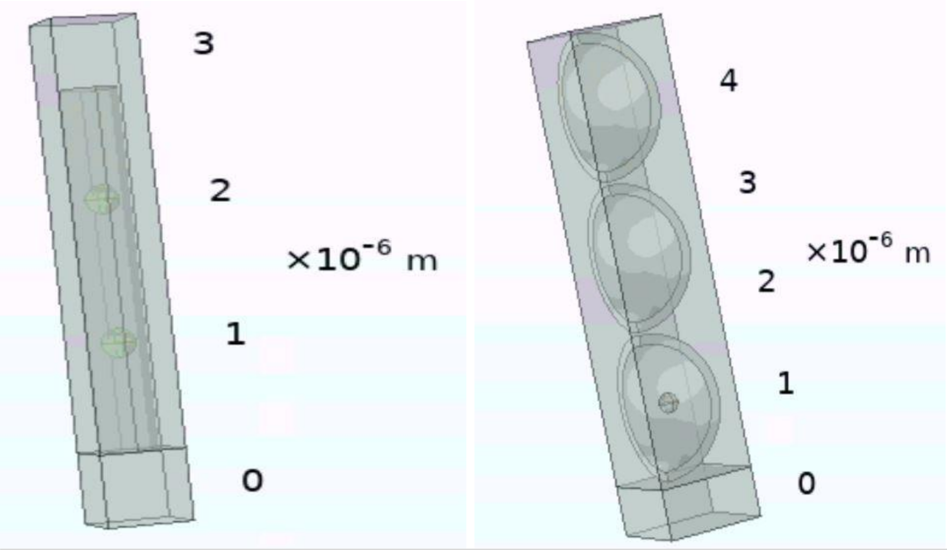


Fig IV. **COMSOL Renderings of Nanowire (left) and Nanoshell (right) Solidworks Models, with Embedded Gold Nanospheres (Radius = 100 nm)**

Results

Electric Field Renderings

Computer-generated electric fields were analyzed to determine interactions occurring around nanospheres.

-Higher levels of light interaction with nanospheres results in higher likelihood of increased absorption levels.

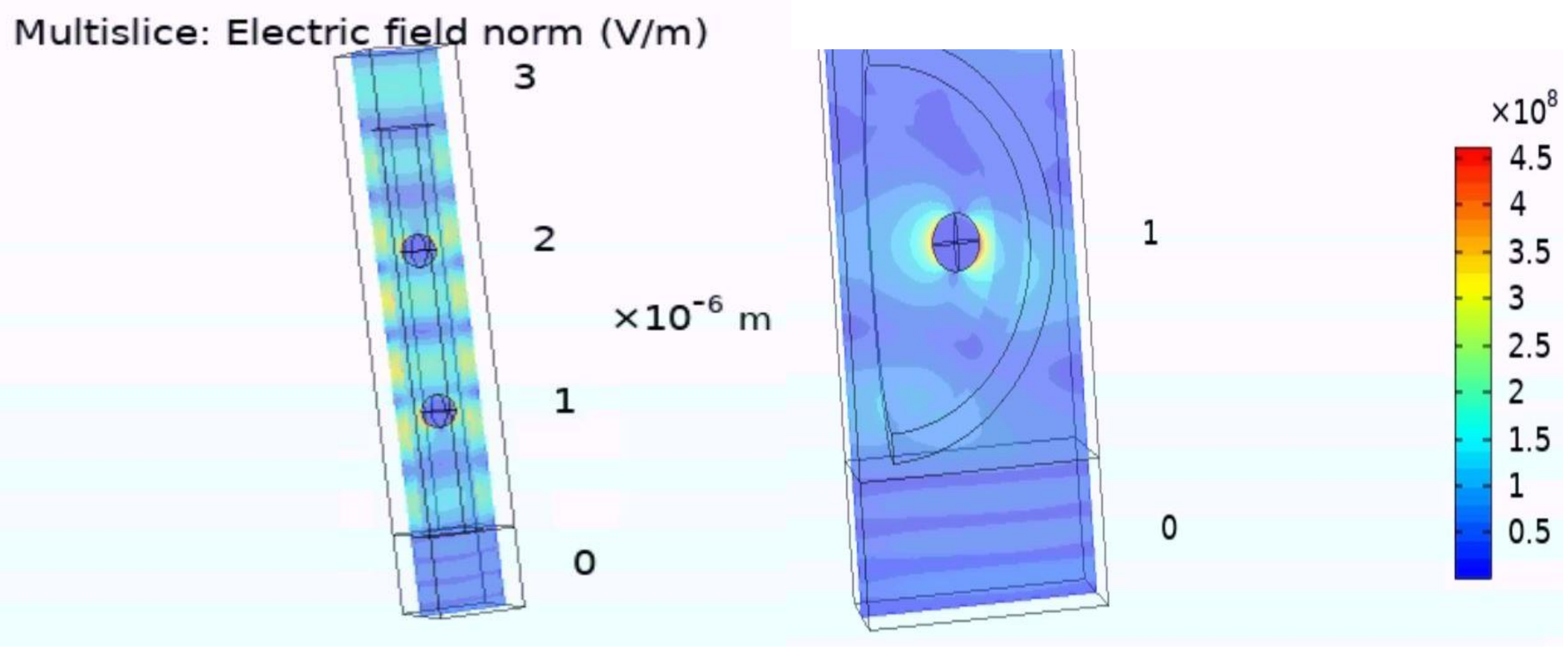


Fig V. **Electric Fields for Nanowire (left) and Nanoshell (right) COMSOL Renderings Generated at a Wavelength of 450 nm.**

Higher activity levels are clearly noted around and in-between the locations of the nanospheres.

Total Power Absorption

The total power absorbed by the gold nanospheres was calculated for each respective wavelength.

-Reference models were created to determine the amount of power absorbed by the gold particles without any SLED geometry present.

-Open models with one and two nanospheres were created to compare to the nanoshell and nanowire results, respectively.

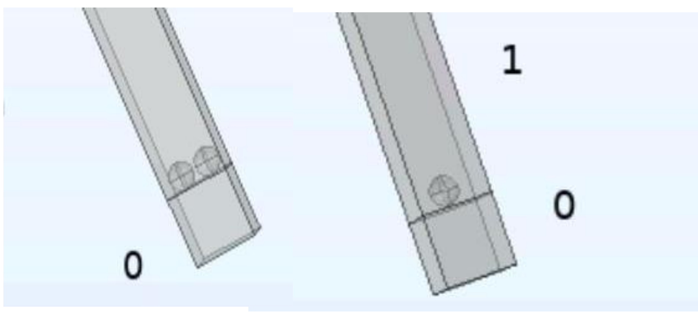


Fig VI. **Reference Models with One (right) and Two (left) Gold Nanospheres (Radius = 100 nm)**

Results

-One Watt of Power was applied to each model.

-Both the nanoshell and nanowire formations absorbed significantly more power than their respective reference models.

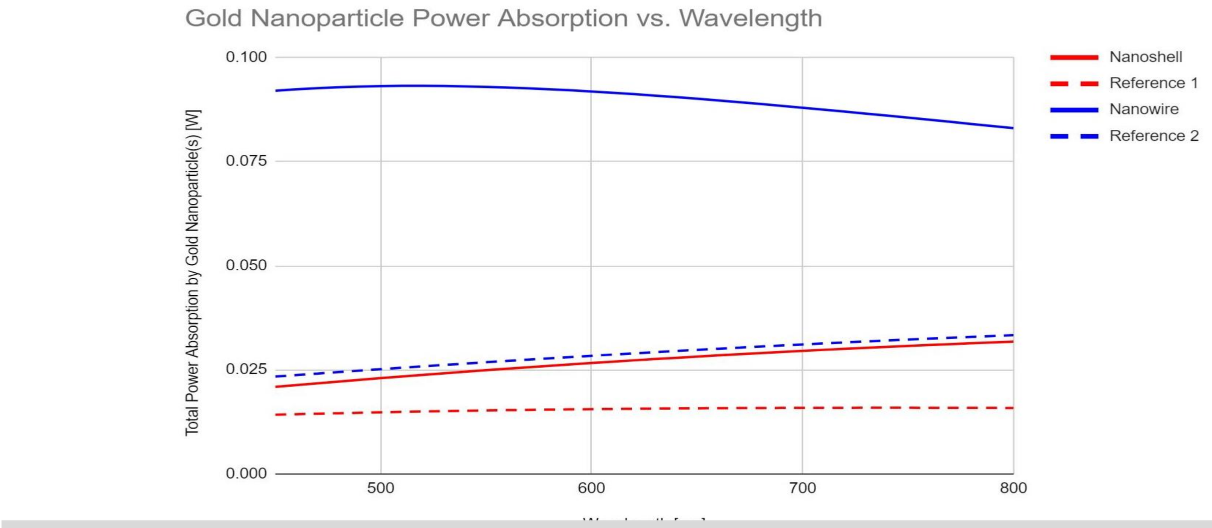


Fig VII. **Gold Nanoparticle Power Absorption vs. Wavelength for Nanoshell, Nanowire, and their Respective Reference Models**

-Simulations were also run to determine the effects of nanowire thickness on total power absorption.

-Keeping the gold nanosphere at a radius of 100 nm, it was observed that both too thick and too thin of a nanowire limited power absorption.

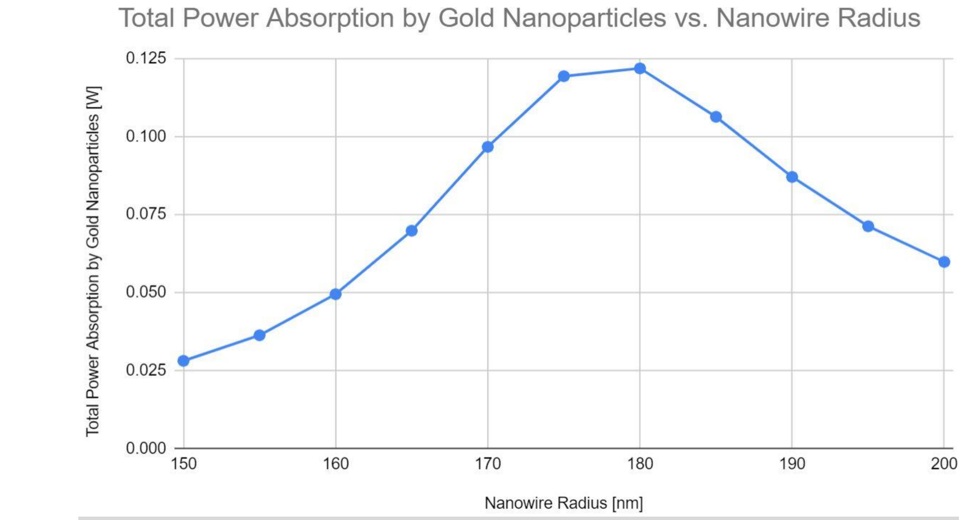


Fig VIII. **Gold Nanoparticle Power Absorption vs. Nanowire Radius**

Conclusions & Future Work

Conclusions

-The presence of SLED formations provides a light scattering effect that enhances the power absorption of the gold nanospheres.

-The ratio of SLED formation thickness to the radius of the gold nanospheres has a noticeable effect on overall power absorption.

-The results of these simulations encourage laboratory implementation of this experiment.

-SLED optical experiments continuing to show successful absorption enhancement offer promising solutions to increasing the efficiency of solar cells.

References

[1] A. Jaworek and A. T. Sobczyk, "Electrospraying route to nanotechnology: An overview," *J. Electrostat.*, vol. 66, no. 3–4, pp. 197–219, 2008, doi: 10.1016/j.elstat.2007.10.001.

[2] L. Lei *et al.*, "Obtaining Thickness-Limited Electrospray Deposition for 3D Coating," *ACS Appl. Mater. Interfaces*, vol. 10, no. 13, pp. 11175–11188, 2018, doi: 10.1021/acsami.7b19812.

[3] S. W. Baek *et al.*, "Au@Ag core-shell nanocubes for efficient plasmonic light scattering effect in low bandgap organic solar cells," *ACS Nano*, vol. 8, no. 4, pp. 3302–3312, 2014, doi: 10.1021/nn500222q.

[4] Electrospray and Electrospinning Homogeneous Gelation Leads to Nanowire Forests in the Transition Between Electrospray and Electrospinning," 2020, doi: 10.26434/chemrxiv.11954910.v2.

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