Plasmon Enhanced Dye-Sensitized Solar Cells

Nastasia Allred[1], William R. Erwin[2], and Rizia Bardhan[2]

[1]Department of Chemical & Biomolecular Engineering, Tennessee Technological University, Cookeville, TN, 38505
[2]Department of Chemical & Biomolecular Engineering, Vanderbilt University, Nashville, TN, 37235

VANDERBILT

VANDERBILT School of Engineering

Introduction

Tandem DSSCs

- Dye-sensitized solar cells (DSSCs) utilize a light absorbing dye adsorbed to mesoporous TiO_2 to capture light and convert it into electrical energy.
- A tandem DSSC is made by connecting two DSSCs in parallel, and lining up the footprint of the two cells.
  - Each tandem DSSC is composed of a cell using N719 (red) dye and a cell using N749 (black) dye.
  - The black dye "*catches*" the light that doesn't get absorbed by the red dye further increasing the light harvesting capabilities.

Plasmons

- Broad resonance Au@Ag bimetallic nanoparticles are incorporated into the mesoporous semiconductor.
  - Light scattering is increased, thereby increasing the overall photocurrent of the device.

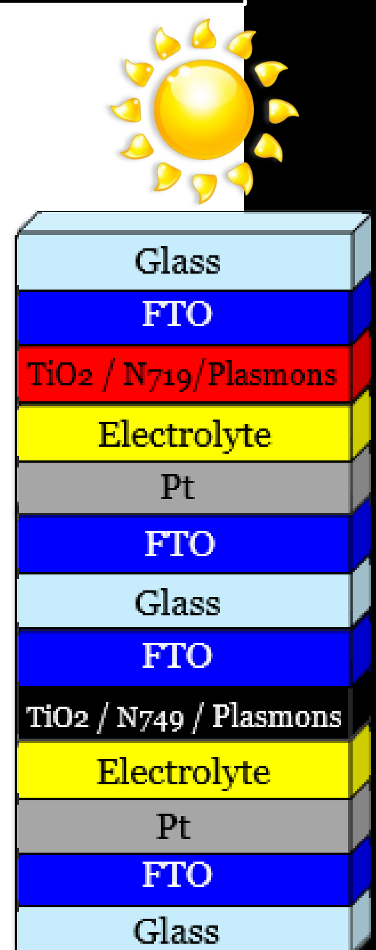


Figure 1: Tandem DSSC Structure.

Materials & Methods

Prep — FTO coated glass is cut into ½" by 1" rectangles and cleaned.

TiCl4 — The cleaned glass is taped off and undergoes a TiCl4 treatment.

TiO2 — A doctor-blading method is used to apply mesoporous TiO2 & plasmons.

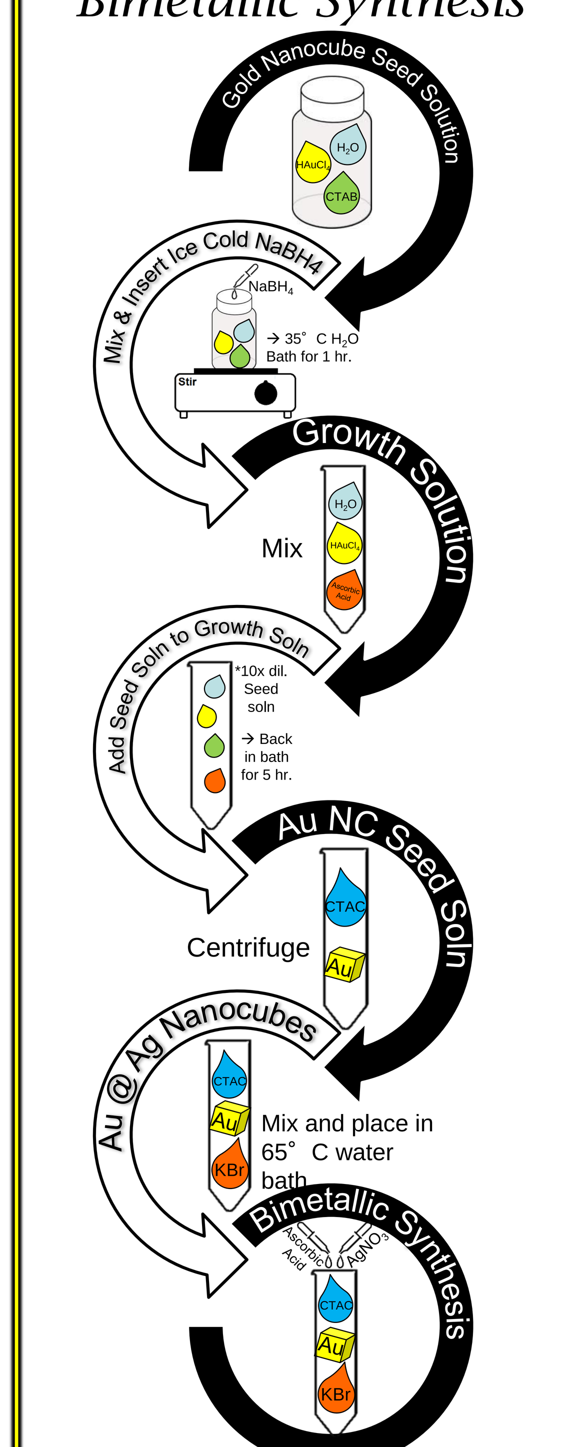
TiCl4 — A second TiCl4 treatment is performed.

Pt — Holes are drilled into another piece of glass which is then cleaned and coated with platinum.

Assembly — Once the anode (TiO2) and cathode (Pt) are complete, they are assembled using surlyn and a heat sealer. Electrolyte is then inserted into the holes which are then covered with surlyn.

Testing — The cells are then tested individually and in tandem using a solar simulator to obtain IV data. A supercontinuum laser in conjunction with an acousto-optic tunable filter for parsing light into narrow spectral bands was used to determine the incident photon to charge carrier efficiency (IPCE).

Bimetallic Synthesis



Objective

To build and fully characterize a tandem DSSC with optimal concentrations of bimetallic nanoparticles.

Results

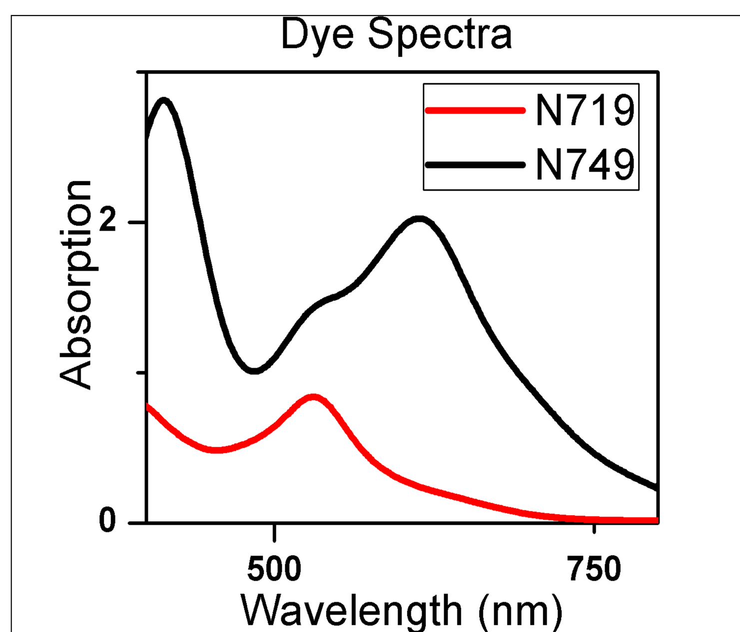
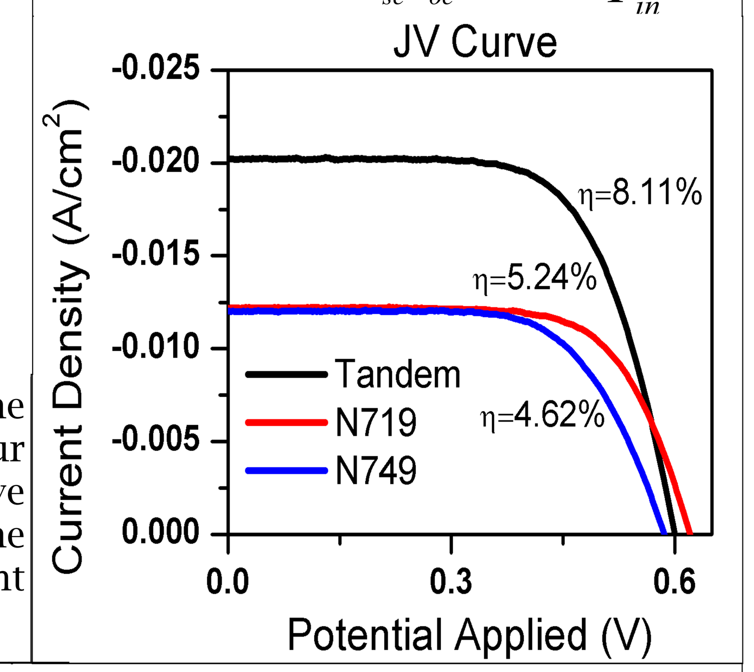


Figure 2: Dye Absorption Spectra. The spectra depicts the reasoning behind our choice of organic dyes. The black dye absorbs in the near infrared, where the red dye is unable to, increasing the light absorption of the tandem system.

Figure 3: JV curve which is used to obtain V_{OC}, J_{SC}, V_{MP}, and J_{MP} which are then used to calculate efficiency and fill factor.

$$FF = \frac{J_{mp}V_{mp}}{J_{sc}V_{oc}} \qquad \eta = \frac{P_{out}}{P_{in}}$$



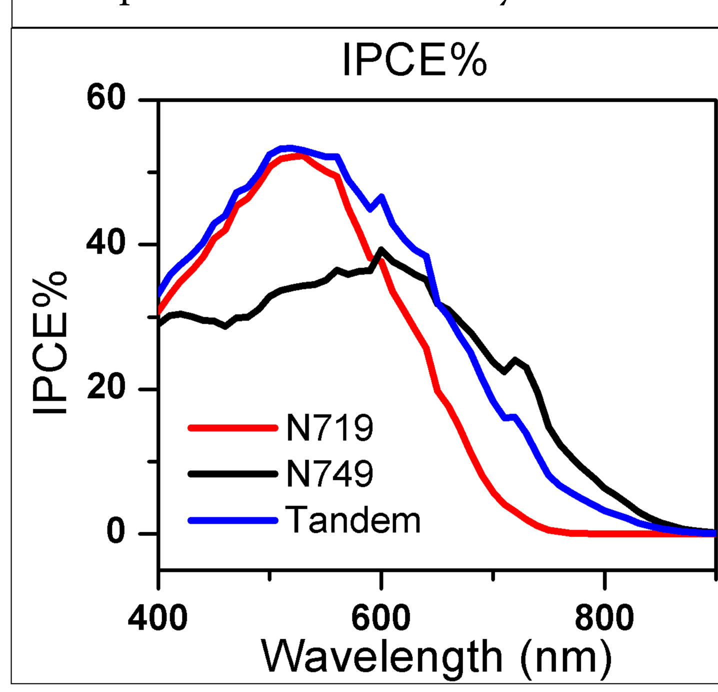


Figure 4: Incident photon to charge carrier efficiency plot that tells us how efficiently the device converts the incident light into electrical energy at a given wavelength.[1]

$$IPCE\% = \frac{I_{SC}(A)}{P(W)} * \frac{1240}{\lambda(nm)} * 100$$

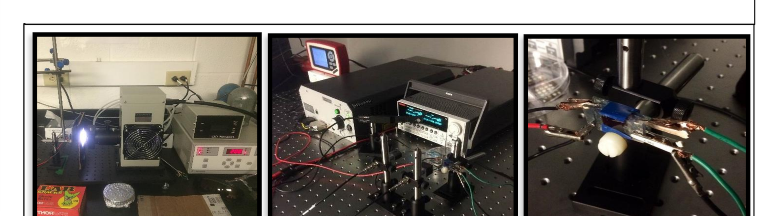


Figure 5: i) JV testing setup ii) tandem wiring iii) IPCE% setup

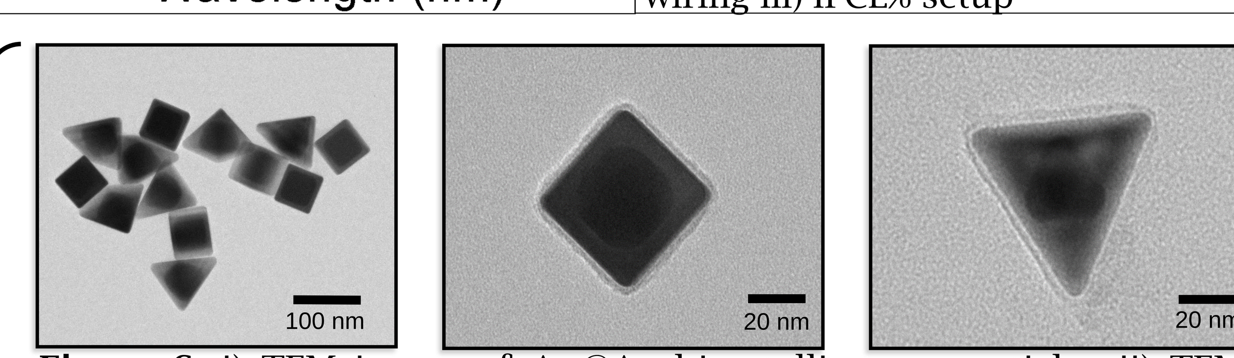


Figure 6: i) TEM image of Au@Ag bimetallic nanoparticles ii) TEM image of cube geometry iii) TEM image of pyramidal geometry

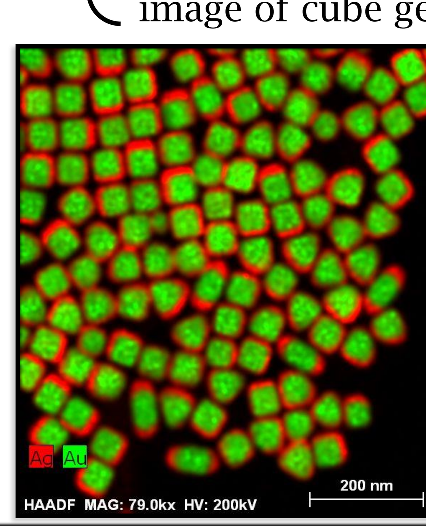
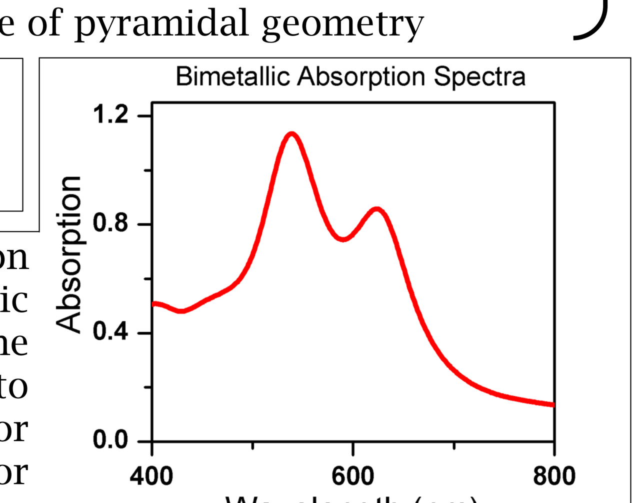


Figure 7: SEM image of Au@Ag nanoparticles

Figure 8: Absorption spectra of bimetallic nanoparticles. The particles give rise to two peaks, one for gold and one for silver.



Conclusions

- It was shown that a *successful* tandem DSSC was able to be constructed and the resulting efficiency was **higher** than that of the individual DSSCs.
- Broad resonance Au@Ag bimetallic nanoparticles of two different geometries (cubes&pyramids) can be synthesized.
  - These different geometries arise from the different crystal faces of the gold nanoparticles and the affinity of KBr for those faces.[2]

Future Work

- The main goal for future work is to now **incorporate** the Au@Ag bimetallic nanoparticles into the tandem DSSC in order to hopefully achieve *even higher* efficiencies.
  - The bimetallic nanoparticles will be mixed with the TiO_2 paste with the rest of the process carried out as usual.
- Before these particles can be incorporated, they must be silica coated. Silica coating helps the particles in a few ways:
  - Enhances stability of the particles
  - Protects the particles from the corrosive electrolyte
  - Prevents electron scavenging

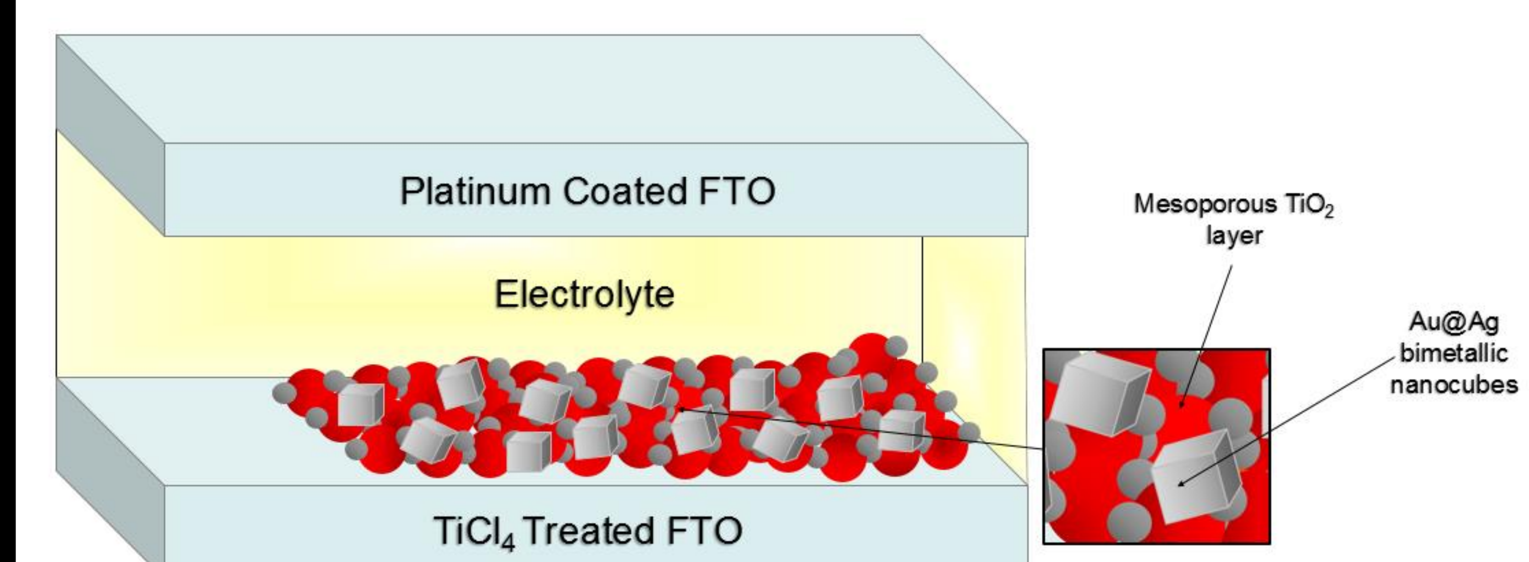


Figure 8: Device incorporated with silica-coated Au@Ag bimetallic nanoparticles.

Acknowledgments

This work was supported by TNSCORE through the National Science Foundation: Research for Undergraduates, grant NSF EPS-1004083.

References:

[1]Gevorgyan, Suren. "Incident photon-to-current efficiency (IPCE)." *IPCE*. DTU Energy Conversion, n.d. Web. 22 July 2014. <http://plasticphotovoltaics.org/lc/characterization/lc-advanced-c/lc-ipce.html>.

[2]Zarick, Holly F. et al. "Morphological Modulation of Bimetallic Nanostructures for Accelerated Catalysis." *Journal of Materials Chemistry A* 2.19 (2014): 7088–7098.