Synthesis and Properties of Gold Nanoparticle Solution and Nanoparticle Necklace Networks (N^3)

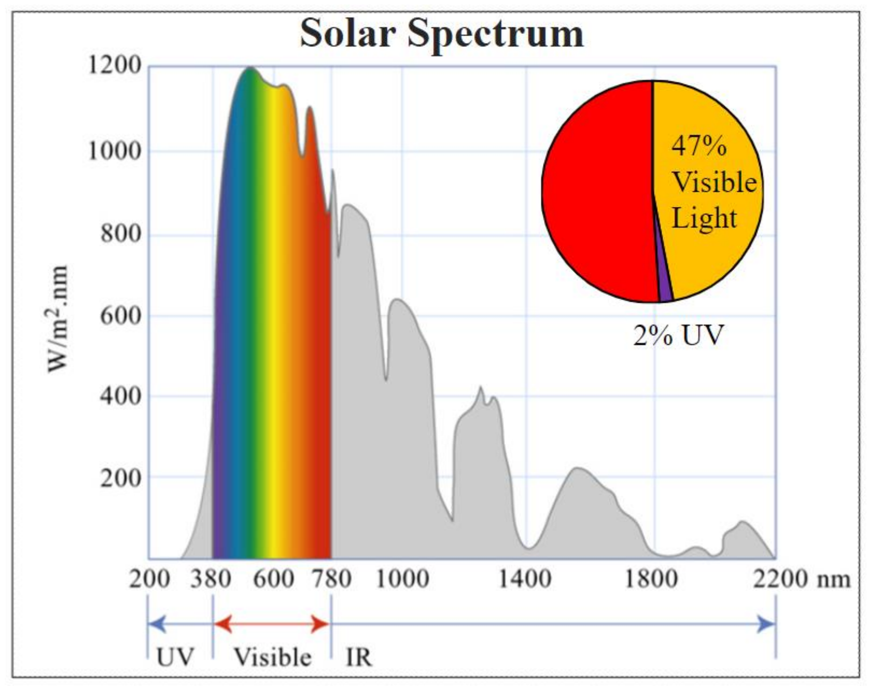
Joiner Pfister[1], Jay Min Lim[2], Md Khirul Alam Titu[3], and Ravi Saraf[3]

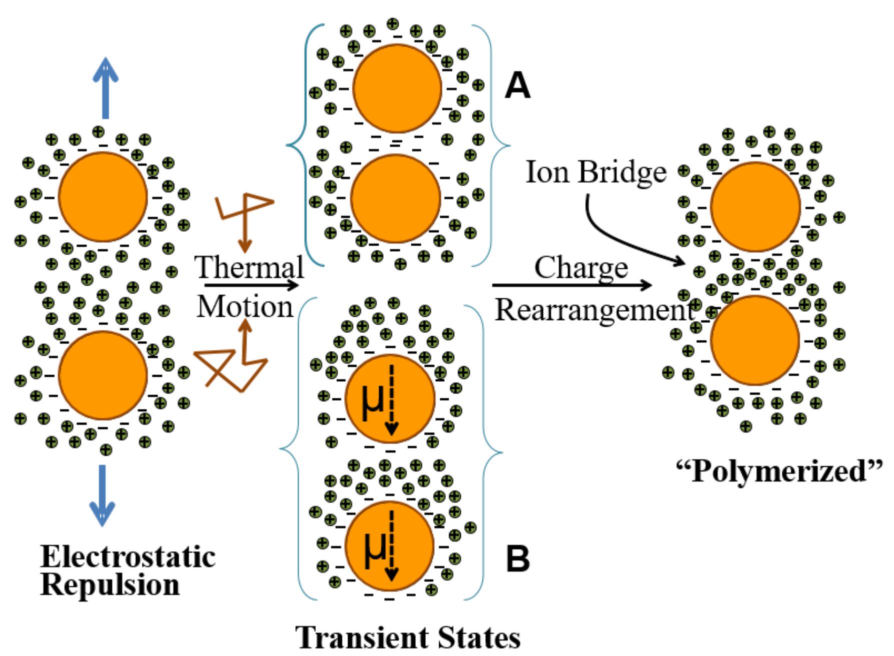
[1]Chemistry, [2]Mechanical Engineering, [3]Chemical Engineering, University of Nebraska – Lincoln

Funding Source: NCESR

Background

- Climate change has spurred global research efforts toward improvements in renewable energy.
- Solar energy provides 3.9% of the United States' power but requires a large amount of land to operate, as the leading semiconductor materials absorb light only in the UV range.
- Gold nanoparticles harvest light throughout the visible spectrum, generating a free energy gradient by localized surface plasmon resonance (LSPR).
- LSPR absorption is increased further by assembling gold nanoparticle necklace networks (N^3).
- LSPR is shown to catalyze water splitting, allowing for integrated solar-fueled hydrogen energy.
- Hydrogen is unique in its versatility as a chemical energy carrier, with applications in fuel and manufacturing.

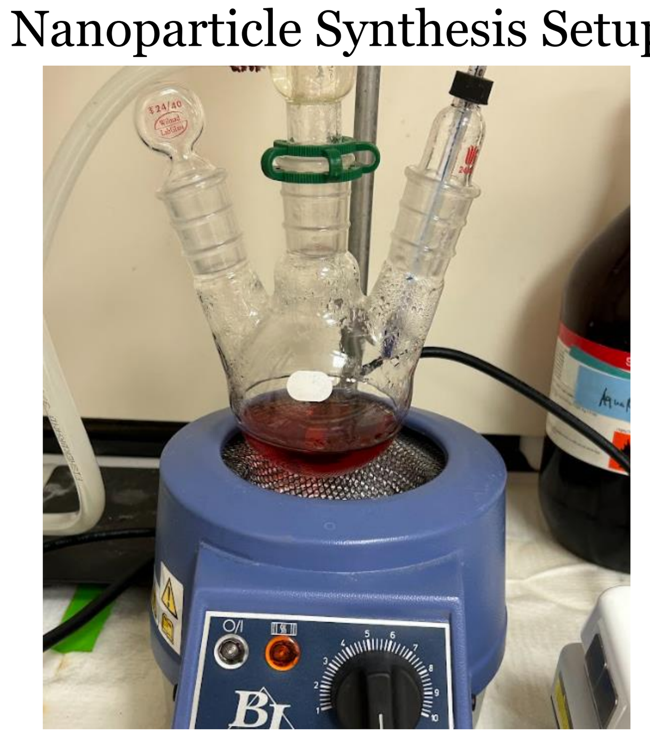




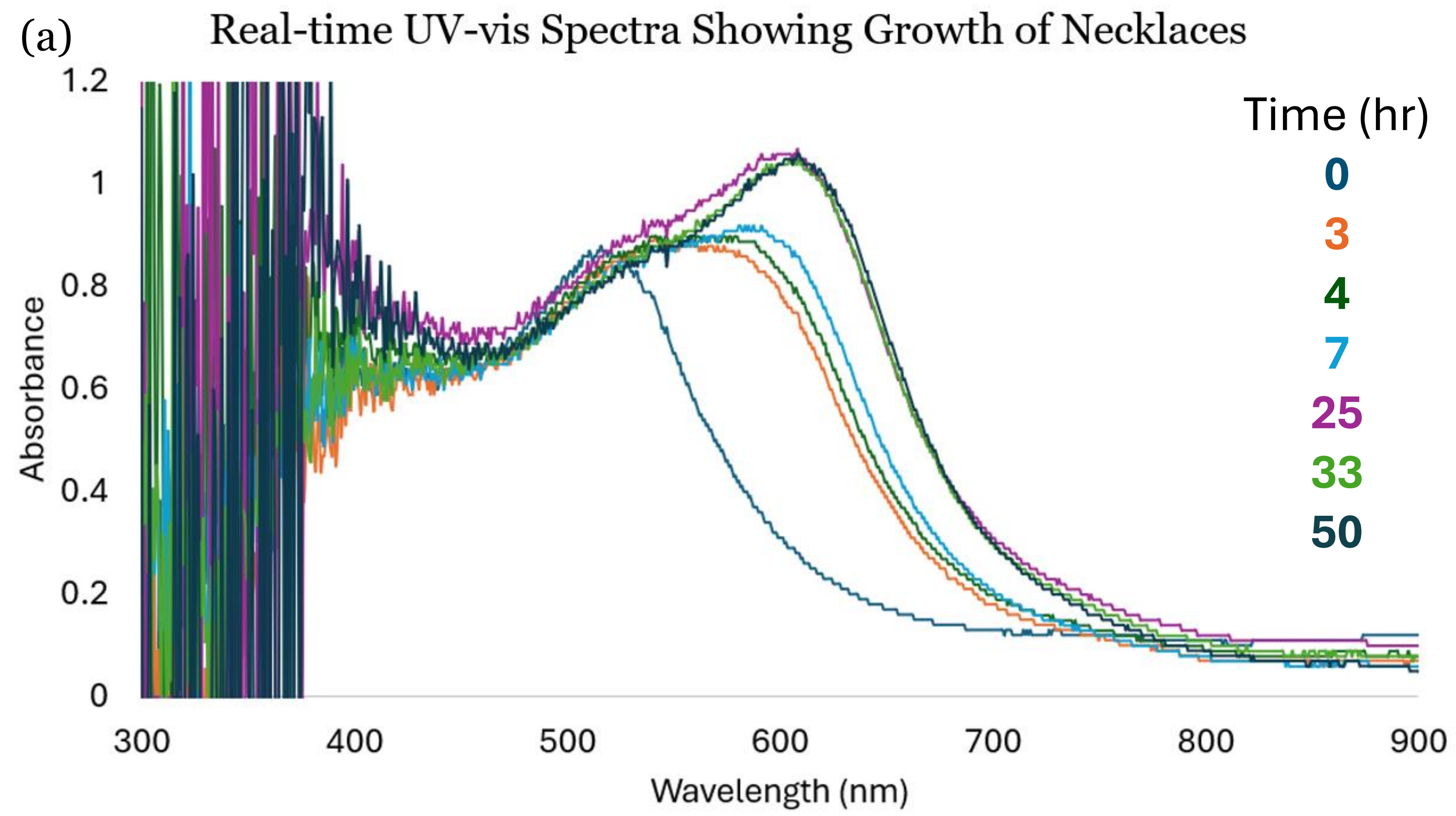
Highlights

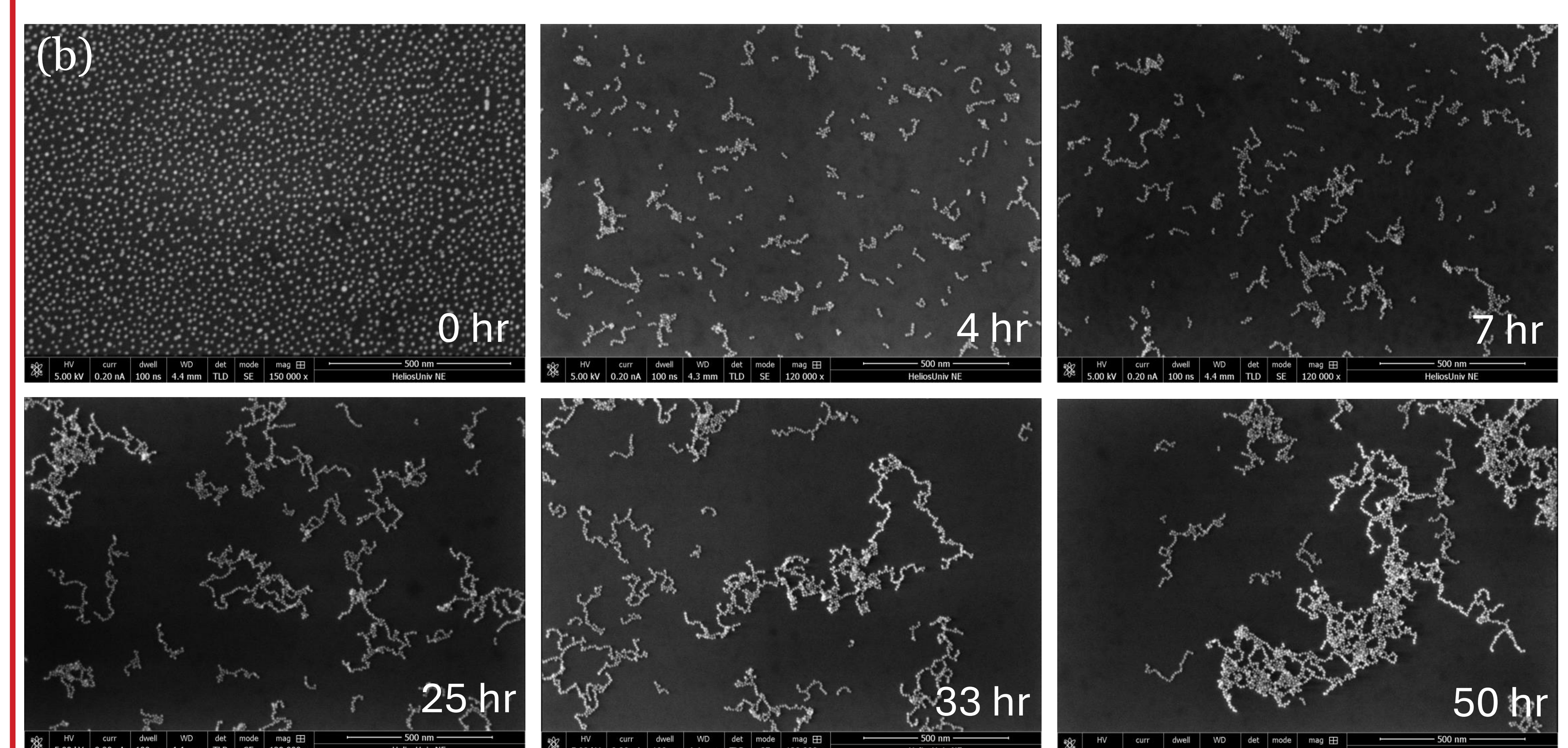
- N^3 can be used as a high-yield photovoltaic device and water electrolysis system.
- Nanoparticle size and monodispersity can be tailored with control over reagent concentration.
- Necklace formation can be monitored in real-time using UV-vis spectra.
- With more development, this technology promises to revolutionize solar and hydrogen energy production.

Nanoparticle Synthesis Setup



Necklace Growth

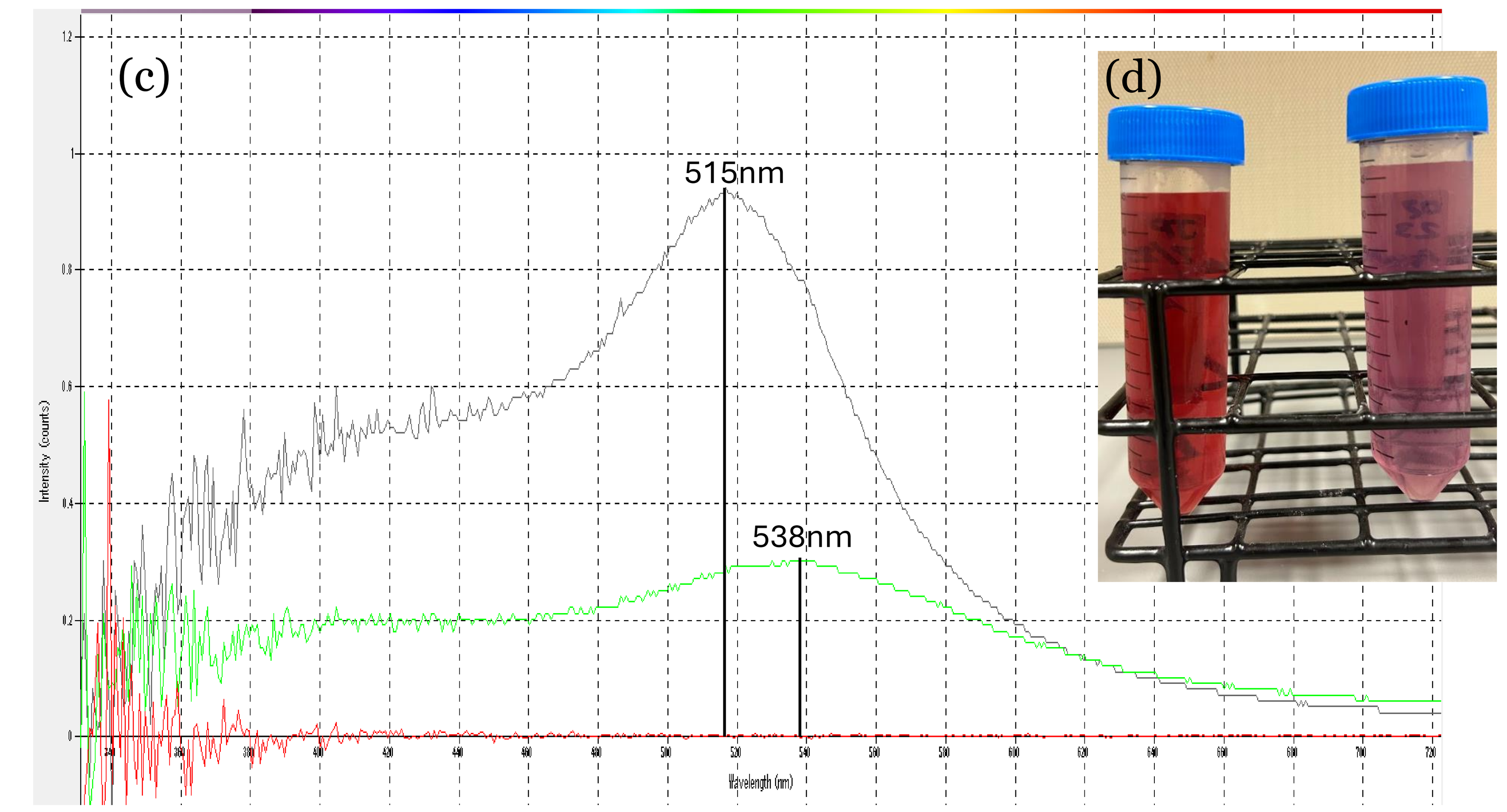




(a) UV-vis spectra showing the growth of N^3 at different time stamps. The original peak forms a "shoulder", which gives rise to a peak shift. (b) Scanning electron microscope (SEM) images of growing necklaces. Over time, islands of necklaces form, which enables their characteristic semiconductor properties.

- N^3 is made by combining gold nanoparticle solution with a volume of salt, 5mM $Zn(NO_3)_2$ in our case.
- Over time, nanoparticles form long chains, eventually reaching a desired coverage.
- Overdevelopment forms gold blankets that have ohmic resistance, not the desired non-ohmic resistance.

Nanoparticle Batch Control



(c) UV-vis spectra showing the absorbance of two batches of gold nanoparticles. The peak at 515nm was synthesized with a [SC]/[Au] of 10, with an estimated nanoparticle diameter of 15nm. The peak at 538nm was made with a [SC]/[Au] of 4, with an estimated diameter of >100nm.
(d) Photograph of both nanoparticle batches, with the 15nm batch on the left and the >100nm batch on the right.

- Sodium citrate (SC) concentration in relation to gold has an obvious impact on nanoparticle size.

Future Research

- Use SEM to measure nanoparticle diameter and monodispersity under a range of reaction conditions.
  - There is a lack of data on using tannic acid in conjunction with the reverse Turkevich method to grow gold nanoparticles.
- Interrogate how nanoparticle size and monodispersity impact necklace formation.

Acknowledgements

This work was supported by the Nebraska Public Power District through the Nebraska Center for Energy Sciences Research at the University of Nebraska-Lincoln.
Special thanks to Saraf group member Joydip Dey for providing instrumentation assistance.

NEBRASKA CENTER FOR ENERGY SCIENCES RESEARCH