NDnano
Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research
2023 Project Summary

1. Student name & home university: **John Howe, Notre Dame**

2. ND faculty name & department: **Svetlana Neretina, Aerospace and Mechanical Engineering**

3. Summer project title: **Synthesizing Gold Hexagonal Nanoplates under Different Lighting Conditions**

4. Briefly describe new skills you acquired during your summer research:
   - **Spectroscopy**
   - **Colloidal Synthesis of Nanoplates**
   - **3D Printing**
   - **Digital Circuit Design**
   - **LED Lighting Systems**

5. Briefly share a practical application/end use of your research:
   - **Sensors and Medical Imaging**
   - **Catalysis**
   - **Spectroscopy**

1. 50- to 75-word abstract of your project:

Controllable nanostructure formation shows promising applications in sensing and nanoelectronics. Gold hexagonal nanoplates are among some of the structures that show great promise in these evolving fields. Recent developments in the Neretina Lab have allowed for further control over the growth process. While interactions with basic LED room lights have been observed, little is known about how monochromatic light in different intensities may affect the growth process.

We demonstrate two possible competing growth mechanisms are present when arrays of nanostructures are subjected to monochromatic irradiation at a controlled duration and intensity. These growth mechanisms shed light on the photochemical reactions occurring during the synthesis of gold nanoplates.

2. References for papers, posters, or presentations of your research:

- Demille TB et al., 2021. Epitaxially aligned single-crystal gold nanoplates formed in large-area arrays at high yield. Nano Research. 15(1):296–303.

- Neal RD et al., 2021. Substrate-immobilized noble metal nanoplates: a review of their synthesis, assembly, and application. Journal of Materials Chemistry C. 9(38):12974–13012.

- Zhang H et al., Fabrication of Single-Nanocrystal Arrays. Adv. Mater. 2020, 32, 1904551.

- Spencer D. Golz et al., Nano Letters 2019 19 (8), 5653-5660.Plasmon-Mediated Synthesis of Periodic Arrays of Gold Nanoplates Using Substrate-Immobilized Seeds Lined with Planar Defects.

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One-page project summary that describes problem, project goal and your activities / results:

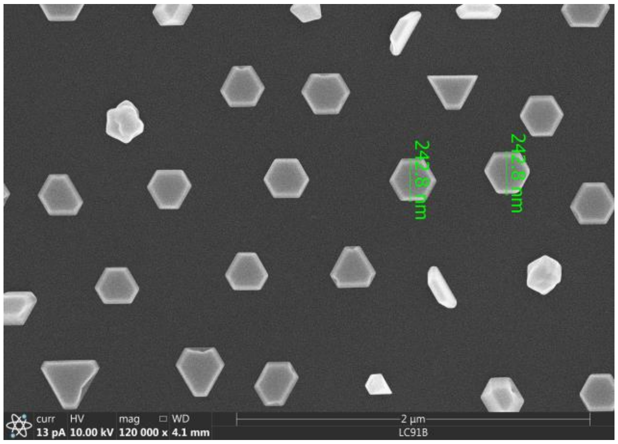

Figure1. SEM Image of a sample array that was placed in the standard growth solution and irradiated with 1 Watt/m² of 465 nm peak blue light for 1.5hrs

Tunable and controllable nanostructure formation has applications in sensing, photovoltaics, and spectroscopy. Previous developments in the Neretina Lab have created a standardized growth process in which "seed" arrays of gold crystalline structures fabricated via Nanoimprint Lithography (NIL) are then placed in a solution of Brij-700 copolymer and aqueous gold salt and then stirred for several hours. These seed arrays then grow two dimensionally, eventually forming plates with sharp hexagonal or triangular geometries. While this process has been shown to be affected by a variety of parameters such as pH and temperature, little is known about how light may interact with the solution. While the growth rate of these hexagonal plates is shown to accelerate in the presence of room light, preliminary evidence suggests that different colors or wavelengths of light change the growth rate and may alter the nanostructures that are formed. Our goal, then, was to maintain similar growth procedures but under the presence of different types of monochromatic light in order to find out more about how light may be interacting with the gold hexagonal nanoplate formation process.

In order to create optimal conditions for irradiating the arrays and growth solutions, we designed and built an isolated reaction chamber with reflective inner linings of aluminum. Inside the reaction chamber, the growth process was carried out while being subjected to uniform LED irradiation with different colors/wavelengths (UV, Blue, Green, Yellow, and Red) with a controlled energy output. At regular intervals, arrays and growth solutions were analyzed using UV/Vis (UV/Visible Spectrum) Spectroscopy. After the growth process, arrays were imaged via SEM (Scanning Electron Microscopy). Additionally, using fiber optics, spectrums of both the room light and light irradiated from various color LEDs used in experimentation were measured. SEM images of arrays were analyzed to find the average plate length and plate area, while UV/Vis spectroscopy data was analyzed to find the redshift of the plasmon resonance of samples as well as the possible growth of unwanted or undesirable structures.

We demonstrated that there were two possible competing growth mechanisms present, each one due to irradiation with certain types of light. Wavelengths of light greater than 500nm, such as green, yellow, and red, influenced growth based on plasmon resonance, with the growth rate of the arrays increasing as the plasmonic peak approached the peak wavelength of the irradiated light, and then decreasing once the peak plasmon moved beyond the peak wavelength of the irradiated light. However, for wavelengths of light below 500nm, the growth rate followed a different pattern that was continuously exponential. Ultimately, the absorption spectrum of the growth solution indicates that the growth solution is absorbing wavelengths below 500nm, which indicates that a possible intermediate solution is being formed due to photochemical reactions of the growth solution under more energetic wavelengths. While both possible growth mechanisms can induce significant nanoplate growth, the intermediate solution created with irradiation of light below 500nm induced significantly more growth than wavelengths above 500nm. This correlated with larger, more defined plates being created. Additionally, growth induced via plasmon resonance yielded more triangular nanoplates while growth induced via the intermediate solution yielded more hexagonal nanoplates. Going forward, more work is needed to understand the exact composition of the intermediate solution and how the intermediate solution induces growth different than the currently used growth solution.