NDnano
Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research
2021 Project Summary

1. Student name & home university:

Hailey Meyer
Saint Mary's College and the University of Notre Dame

2. ND faculty name & department:

Dr. Svetlana Neretina, Aerospace and Mechanical Engineering

3. Summer project title:

Controlling Gold Nanostructure Dimensions Using an Etching Solution

4. Briefly describe new skills you acquired during your summer research:

My work this summer focused on adapting a colloidal etching solution to etch particles on a sapphire substrate. To do so, I had to constantly adapt methods to address any new problems. In an example of this, the etching solution that most efficiently etched gold nanoparticles produced bubbles. These bubbles, if covering the particles, can protect the gold and encourage an uneven etch. Thus, the solution required sonication. Etching progress was made by constantly analyzing the previous experiment and modifying future experiments to optimize all conditions. In previous work, the optimized conditions had always been provided. I found this process incredibly rewarding and look forward to continuing this process. Working with nanoparticles, I also grew far more coordinated with tweezers!

5. Briefly share a practical application/end use of your research:

Substrate-bound nanostructures are heavily utilized in chemical and biological sensing, often by offering increased sensitivities for spectroscopic analysis. By tuning the shape and size, one can encourage a specific wavelength response from the particle. My work was on changing the particle shape post-synthesis to exhibit greater control on its morphology and on reducing the thickness of the particle to initiate a comparable result with less material.

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

Substrate-bound gold nanostructures provide enhanced chemical and biological sensing, offering increased sensitivity for spectroscopic analysis. The nanostructure morphology can be controlled through an etching solution to exert control on the particles post-synthesis. The etching solution, when applied to seeds, did not destroy the growth potential but encouraged rounded structures when regrown. When the solution was applied to nanoplates, the etch did not remove the gold from a specific side, but evenly across the surface.

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

1) R. D, Neal, R. A. Hughes, A. S. Preston, S. D. Golze, T. B. Demille, and S. Neretina, Substrate-Immobilized Noble Metal Nanoplates: a Review of Their Synthesis, Assembly, and Application, Journal of Materials Chemistry C, 2021, 10.1039/d1tc01494c.

2) S. D. Golze, R. A. Hughes, S. Rouvimov, R. D. Neal, T. B. Demille and S. Neretina, Plasmon-Mediated Synthesis of Periodic Arrays of Gold Nanoplates using Substrate Immobilized Seeds Lined with Planar Defects, Nano Lett., 2019, 19, 5653–5660.

3) X. Cui, F. Qin, Q. Ruan, X. Zhuo and J. Wang, Circular Gold Nanodisks with Synthetically Tunable Diameters and Thicknesses, Adv. Funct. Mater., 2018, 28, 1705516.

4) F. Qin, T. Zhao, R. Jiang, N. Jiang, Q. Ruan, J. Wang, L.-D. Sun, C.-H. Yan and H. Q. Lin, Thickness Control Produces Gold Nanoplates with Their Plasmon in the Visible and Near-Infrared Regions, Adv. Opt. Mater., 2016, 4, 76–85.

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

Gold nanostructures, when bound to a surface, provide for enhanced chemical and biological sensing, offering increased sensitivity for spectroscopic analysis [1]. These substrate-bound nanoparticle structures are synthesized from a small hemisphere of gold, commonly referred to as a "seed". These seeds can be grown into a variety of morphologies, including hexagonal nanoplates. The horizontal growth of the nanoplates is ultimately motivated by stacking faults within the gold, while a capping agent prevents vertical growth. Thus, the final thickness of the nanoplates is determined by the seed thickness, a dimension that is not easily reduced. Here, gold seeds are exposed to an etch aimed at reducing their thickness to synthesize thinner nanoplates. This etch is also applied to gold nanostructures to transform hexagonal nanoplates into disk-like particles bound to a substrate.

Qin et al. have shown that a dilute solution of hydrochloric acid and hydrogen peroxide can etch colloidal hexagonal nanoplates into disk-like particles. However, there is a distinct difference in the synthesis of the colloidal nanoplates and those bound to the substrate.

When a more concentrated solution of hydrochloric acid and hydrogen peroxide was applied to simply dewetted gold particles, obvious etching occurred. Within 90 minutes, the surface was bare of gold particles. When a similar etch was applied to gold seeds and regrown under standard conditions, it was obvious that the etch did not destroy the growth potential. Nanoplates were regrown from the etched seeds, however, without the sharp corners characteristic of the standard growth solution. Currently, work is being done to reduce the growth solution contamination from the etching solution to encourage the sharp corners to form on the hexagonal nanoplates.

A more concentrated etching solution of hydrochloric acid and hydrogen peroxide was also applied to already synthesized hexagonal nanoplates. As the etch continued, the particles become far more irregular in shape and the surface becomes more uneven. Rather than preferentially rounding the corners of the gold nanoplates, the etch occurs on all particle faces. Modifications are required to direct the etch away from the top of the particle and to the sides. Currently, work is being done to introduce different capping agents to the etch to encourage the rounding of the hexagonal corners. Yet, this etching solution allows the dimensions of substrate bound gold nanoparticles to be controlled, and with modifications to the etch, various gold structure geometries are achieved.