NDnano
Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research 2022 Project Summary

1. Student name & home university:

Ana Corcoran
Saint Mary's College

2. ND faculty name & department:

Dr. Svetlana Neretina, Department of Aerospace and Mechanical Engineering

3. Summer project title:

Squeezing Light into Small Volumes using Gold Nanoparticles

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

This research experience improved my chemistry skills by preparing solutions of desired concentrations required in order to complete reactions. I also learned tactile skills when handling small substrates with tweezers and small volumes with a micropipette. Lastly, I developed intuition, problem solving skills, and decision-making in a lab setting when there are multiple paths that can be taken.

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

Nanoparticle dimers are utilized in both sensing and catalysis by offering an increased signal due to the nanogap that is present when the dimers are formed. This includes surface enhanced Raman spectroscopy and ultraviolet-visible spectroscopy.

6. 50- to 75-word abstract of your project:

Gold nanoparticles (AuNPs) exhibit size-dependent properties that have applications in catalysis and sensing. This is due to the nanogap that is formed when the distance between two AuNPs decreases. The nanogaps were produced using two types of AuNPs, substrate-immobilized and colloidal. It was found that as the size of the colloidal AuNPs grew past 15 nm, it became more difficult to attach them to the substrate-immobilized AuNPs via the linkers used.

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

NDnano
Notre Dame Nanoscience and Technology

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

Gold nanoparticles (AuNPs) demonstrate size-dependent physiochemical properties that make them useful for a wide variety of applications such as catalysis and sensing. As the distance between two AuNPs decreases to < 5 nm, the electrons in the AuNPs begin to couple with one another when exposed to light such that the localized surface plasmon resonance of the AuNPs now oscillate in unison. This coupling effect leads to a dramatic increase in the electric field within the space between the AuNPs, called a nanogap, leading to a greater electric field enhancement effect when compared to a standalone plasmonic nanoparticle.

Nanogaps were produced using two types of AuNPs (i) substrate-immobilized AuNPs and (ii) colloidal AuNPs. The substrate-immobilized AuNPs were fabricated through a solid-state dewetting process whereby a 11.5 nm Au film was deposited on a (0001)-oriented sapphire substrate and heated to 1000 ˚C in a tube furnace. The colloidal AuNPs were synthesized using trisodium citrate (NaCA) as a capping agent. These structures were formed using a synthesis that was a variation of the Turkevich method which entailed the addition of a NaCA solution to a hydrogen tetrachoroaurate ($HAuCl_4$) solution upon boiling. Sequential growths are then used to increase the AuNPs size using a syringe pump to ensure the slow and controlled addition of NaCA and $HAuCl_4$. The nanogaps were formed by submerging the substrate-immobilized AuNPs into a 0.1 mM solution of 1,8-octanedithiol followed by submerging the substrate-immobilized AuNPs into a suspension of AuNPs. This process produced a large substrate-immobilized AuNPs with smaller AuNPs attached across the nanostructure.

Results showed that as the size of the colloidal AuNPs grew, it became more difficult to attach them to the substrate-immobilized AuNPs. Further work is needed to attach AuNPs that are larger than ~15 nm. This can be achieved by using different capping agents such as hexadecyl trimethyl-ammonium bromide or hexadecyl trimethyl-ammonium chloride since these new capping agents provide a positive surface charge to the AuNPs whereas the NaCA provides a negative charge.