

NDnano Summer Undergraduate Research 2016 Project Summary

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Adjustable Photonics of SiO₂-Au Core-Shell Nanoparticles

Briefly describe any new skills you acquired during your summer research:

My summer research has introduced me to the rewards and frustrations of working in a bioengineering lab. In Dr. Roeder's lab, I studied the relationship between the physical and optical properties of a specific type of nanoparticles (NPs). Dr. Nallathamby taught me novel methods of synthesizing silica-gold core-shell NPs, and I gained experience in characterizing these nanoparticles. I learned how to characterize their size in the solution phase using dynamic light scattering (DLS) and in the dry phase using transmission electron microscopy (TEM), and I also learned how to characterize their optical and plasmonic properties using UV-Visible spectroscopic measurements (UV-Vis).

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

The size-dependent properties of silica-gold core-shell NPs have unique applications in therapeutics, biomedical imaging, and optics because these NPs can be tuned to resonate at desirable wavelengths of light. In my research, I have executed a systematic and reproducible study that examines the effect of the size of silica-gold core-shell NPs on their optical properties. I correlated the surface properties of these NPs to the size and concentration of nanoparticles in their homogeneous and heterogeneous systems.

Project Summary:

For my research project, I studied the relationship between the physical properties of silica-gold core-shell NPs and their resulting photonics. The nanoscale dimensions of these NPs confer unique size-dependent properties at the interphase of the bulk and atom phase, and I focused on studying how the geometry of these NPs influences the way in which they interact with light. Gold NPs, in particular, exhibit localized surface plasmon resonance spectra (LSPRS) in the visible to near-infrared spectrum, and the resonant wavelength of the nanoparticles can be changed by altering the dimensions of the NPs.

I examined how the optical properties of gold NPs change as a result of (a) tuning the gold NP diameter from 3 nm to 15 nm and (b) using 500 nm or 50 nm diameter silica cores on which the gold nanoparticles are electrostatically adsorbed. The size of synthesized silica-gold core-shell NPs was characterized in the solution phase using DLS and in the dry phase using TEM. Optical properties due to LSPRS were characterized using UV-Vis.

DLS measurements (Figure 1) demonstrated that the gold NPs were adsorbed to 500 nm silica cores with a diameter of 599.7 ± 101.9 nm. TEM data (Figure 2) indicated that the 3 nm gold NPs surface density on the silica nanoparticles was higher by a factor of approximately 10 in comparison with the surface density of 15 nm gold NPs on silica NPs. Respective UV-Vis spectra (Figure 3) revealed that silica-gold (15 nm) core-shell NPs had a LSPRS peak occurring at 560 nm, which was more redshifted in comparison with the silica-gold (3 nm) core-shell NPs that had a LSPRS peak at 520 nm. This indicated that changing the dimensions of gold NPs influences the LSPRS wavelength. This same trend was observed for smaller silica-gold core-shell NPs that utilized a 50 nm silica core (Figure 4).

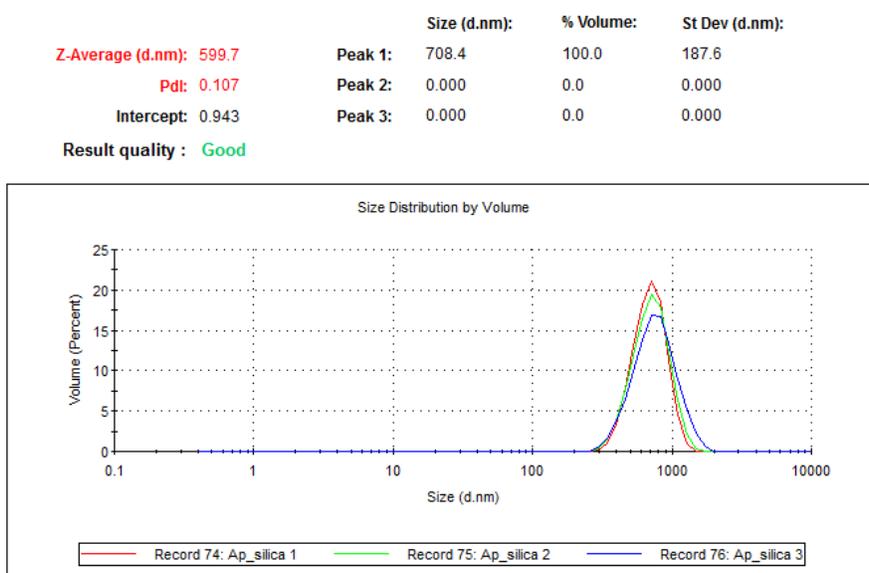


Figure 1: Size measurement of large silica in solution

A silica NP suspension solution was used to roughly measure the size of the NPs. DLS shows the silica cores to have a diameter of about 600 nm. This measurement is larger than expected due to the hydrodynamic radius of silica in water.

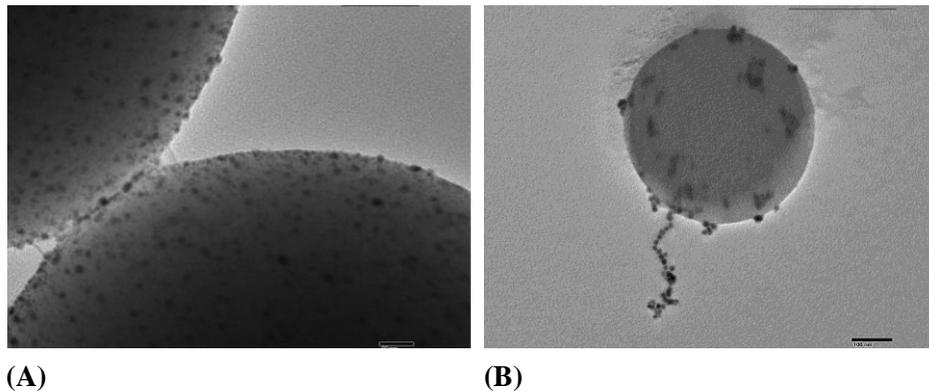


Figure 2: Differing surface densities between silica with different sized gold
 Either ~3 nm or ~15 nm gold NPs were adsorbed to ~500 nm silica. Silica was functionalized using APTES, giving them a positive charge, and the gold NPs were functionalized using THPC, giving them a negative charge. The ~15 nm gold NPs formed larger colloids due to the presence of a citrate group.
(A) ~500 nm silica NPs with ~3 nm gold NPs. The gold NP seeds on the silica are small and uniformly dispersed. **(B)** ~500 nm silica NPs with ~15 nm gold NPs. The gold NP seeds are large and sparse.

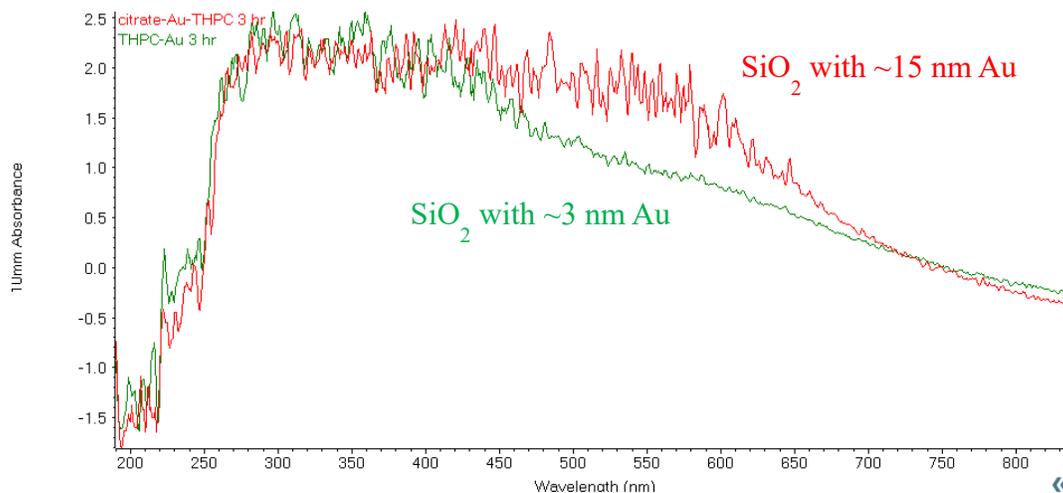


Figure 3: Larger gold seeds lead to redshift

UV-Visible light spectroscopy was used to measure the plasmon resonant peak of the silica-gold core-shell NPs in solution. The ~500 nm silica with the larger gold seeds is represented by the peak corresponding with the longer, redshifted wavelength. The ~500 nm silica with the smaller gold is represented by the peak corresponding with the smaller, blueshifted wavelength.

Note that there is “noise” in the spectra due to the large particle size, which exceeds the diffraction limit

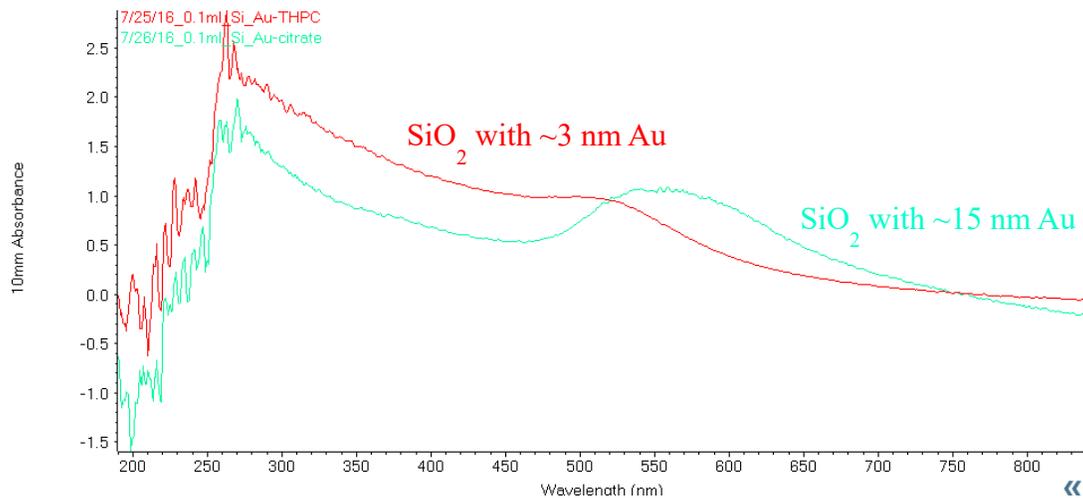


Figure 4: Larger gold seeds on smaller silica core lead to redshift

UV-Visible light spectroscopy was used to measure the plasmon resonant peak of the smaller silica-gold core-shell NPs in solution. The ~50 nm silica with the larger gold seeds is, again, represented by the peak corresponding with the longer, redshifted wavelength. The ~50 nm silica with the smaller gold is, again, represented by the peak corresponding with the smaller, blueshifted wavelength. Note the absence of “noise” in the spectra due to the smaller particle size, which does not exceed the diffraction limit

From my research, I systematically executed a study correlating the geometry of the silica-gold core-shell NPs with their photonic properties. I was able to tune the resonant wavelengths of silica-gold core-shell NPs by adjusting factors like gold size, gold seed density, and NP size. I believe this lays the foundation for tuning the optical properties of other core-shell NPs by manipulating size, shape, and elemental composition (silver or gold-silver alloy).