Spectroscopic Investigation of the Plasmonic Coupling of a Nanoparticle and a Thin Metallic Film

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Raman spectroscopy is useful for chemosensor and biosensor applications, but signal levels are extremely small, which makes single molecule sensitivity challenging. Interest in surface-enhanced Raman spectroscopy (SERS) has increased based on recent observations of plasmon-enhanced single-molecule detection. Our research aims to provide more sensitive Raman detection using cavity enhancement, which is a nanoparticle spaced by a dielectric over a thin metallic film. Past studies have focused on gold nanoparticles over thin gold films. In this work, we investigate the Raman enhancement of aluminum and silver films coupled with a gold nanoparticle or a gold wire. We used UV-Vis and Raman spectroscopy on these samples to measure the dependence on metal film composition, sizes of nanoparticles, and cavity geometry. Specifically, we intend to develop a thorough understanding of where the film-nanoparticle coupled plasmon peak resides spectrally, as well as optimize SERS conditions for detecting specific molecules.

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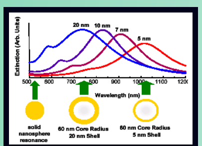
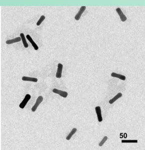
1. Introduction

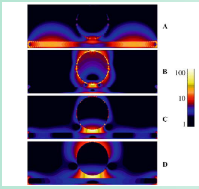
Raman spectroscopy is useful for chemosensor and biosensor applications, but signal levels are extremely small, which makes single molecule sensitivity challenging. Interest in surface-enhanced Raman spectroscopy (SERS) has increased based on recent observations of plasmon-enhanced single-molecule detection. So before now, a great variety of metal shapes and structures were studied. For example, Gold Nanoshells, Gold Nanorods and Gold film-Gold nanoparticle system.



Oldenburg, *et. al.*, Chem. Phys. Lett. **288** 243 (1998)



Liao and Hafner, Chem. Materials **17**,4636 (2005)



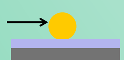
P. Nordlander *et al.*, Appl. Phys. B **84**, 35 (2006)

Objectives

Our research aims to provide more sensitive Raman detection using cavity enhancement, which is a nanoparticle spaced by a dielectric over a thin metallic film. Past studies have focused on gold nanoparticles over thin gold films. In this work, we investigate the Raman enhancement of silver films coupled with a gold nanoparticle.

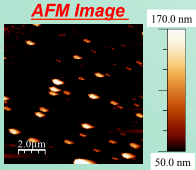
2. Silver films and a Gold nanoparticle

The system of sample consists of gold nanospheres with a diameter 80 nm that is located above a gold surface with a gap distance 3 nm.



SAM: Self-assembled monolayer

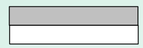
AFM Image



3. Sample fabrication

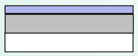
a. EB evaporator

The silver layer were prepared on a 20 nm by electron beam evaporation on glass.



b. SAM layer

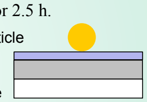
The SAMs were prepared on a 3 nm thick gold film deposited



SAM layer is made by 4-aminothiophenol and ethanol.

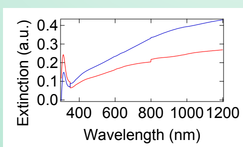
c. Gold nanoparticle

The substrates were immersed in the aqueous solution of the gold nanospheres for 2.5 h.



4. Experimental Results

Optical transmission spectra of the nanoparticle-thin film system are shown. Spectra are taken using a Cary 5000 spectrometer.

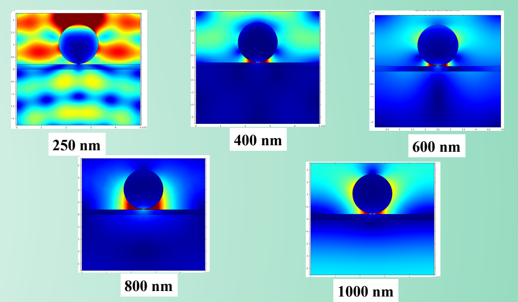


UV-vis-NIR extinction spectra of Au nanoparticles with radious of 80 nm deposited over a silver film of 20 nm thickness with a ~3 nm space layer. 2 graphs are shown because of repeatability.

At wavelength 360, 800 nm we can see the resonances. In next step, we investigate what occur in this system using electromagnetic waves simulation.

5. Simulation Results

Figures A–D are the local field enhancements calculated by Comsol software.
Sizes and materials are similar with the experiment.
The maximum electric field enhancements are 250nm(3.1), 400nm(6.5), 600nm(5.7), 800nm(21.0), 1000nm(5.7).
The incident light is polarized perpendicularly to the slab.



6. Conclusion

- I have made a Au nanoparticles and Silver film system. And I carry out UV-vis-NIR spectroscopy and numerical simulation.
- I can see 2 peaks from experimental spectra.
- The surface enhancement are observed between gold nanoparticle and silver thin film.

Future

Specifically, we intend to develop a thorough understanding of where the film-nanoparticle coupled plasmon peak resides spectrally, as well as optimize SERS conditions for detecting specific molecules. About optimizing for example, thickness, Au particle diameter, many material etc.

Acknowledgments

Research conducted at Rice University, NanoJapan 2011 program sponsored by an NSF-PIRE grant. I appreciate for Prof. Kelly and their Lab. members giving me the opportunity to work in ECE. http://nanojapan.rice.edu/

This material is based upon work supported by the National Science Foundation's Partnerships for International Research & Education Program (OISE-0968405).