Adhesion of Gold Nanoparticles to a Silicon Substrate

Karsten Poulsen
Undergraduate

Dana Dement
Graduate Student Advisor

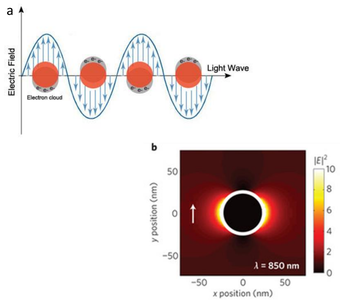
Dr. Vivian Ferry
CEMS Professor

BACKGROUND & MOTIVATION

Plasmonic Resonance

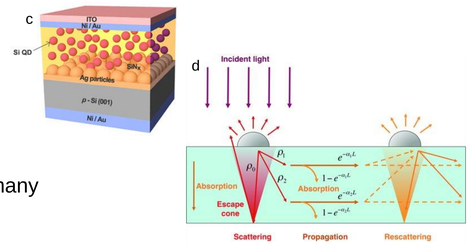
A surface plasmon is a collection of oscillating electrons on a metal. These are useful because they:

- Increase scattering cross section of light
- Increase absorption of light into surrounding materials
- Cause near field enhancement which focuses light
- Depend on the size of particles and spacing between these metallic particles



Applications

- Light Emitting Diodes
- Photovoltaics
- Enhanced sensors for many biological applications



a) "Gold Nanoparticle Properties." *Cytodiagnostics*. Web. 12 Apr. 2015.
b) H. Shen, P. Bienstman, and B. Maes, "Plasmonic absorption enhancement in organic solar cells with thin active layers," J. Appl. Phys. **106**(7), 073109 (2009).
c) Kim, B.-H. "Silicon Quantum Dots: Getting the Light out." *Nature.com*. Nature Publishing Group, 19 Aug. 2009. Web. 12 Apr. 2015.
d)Ferry, Vivian, Munday, J., and Atwater, H. "Design Consideration for Plasmonic Photovoltaics." Advanced Materials. 2010, Vol. 22, 4794.

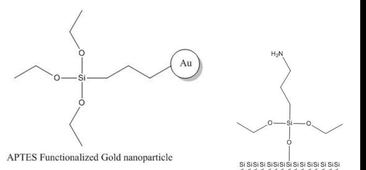
METHODOLOGY

1) RCA Clean:

The method used for cleaning the silicon substrates which was done by soaking silicon substrates in, methanol, acetone and a mixture of hydrogen peroxide, water, and ammonium hydroxide. In between each of the soaks the slides were dried under a stream of air.

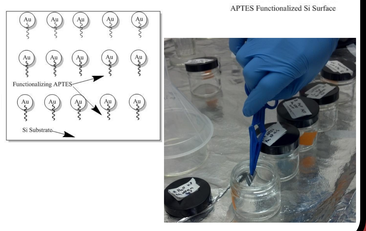
2) Functionalization of Substrates:

The substrates were functionalized by letting them sit in an APTES solution in dark room conditions for twenty-four hours. After this they were rinsed with Isopropyl-alcohol and deionized water.



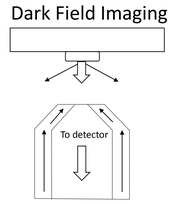
3) Dip-coating substrates:

The slides were coated with 100 nm gold octahedral nanoparticles by immersing them in an aqueous gold nanoparticle solution for varying times between 30 minutes and 90 minutes



RESULTS

All of the images were found using dark field imaging which was done through the use of the inverted optical microscope. Dark field microscopy is a method of microscopy which excludes the unscattered beam which allows only the light scattered by the specimen to be seen.



Solvents

- Compared water to IPA
- Same immersion time of 1 hour
- water creates a much denser gold coverage

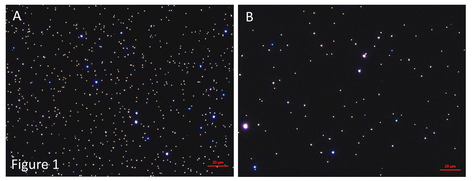


Figure 1 Shows a substrate that was immersed in a gold nanoparticle solution after being functionalized by A) DI water and APTES B) IPA and APTES

Time

- Adhesion time was varied from 30-90 minutes in nanoparticle solution
- These pictures show how as time increases density increases
- E and F are fairly similar densities showing a non-linear relationship between time and density

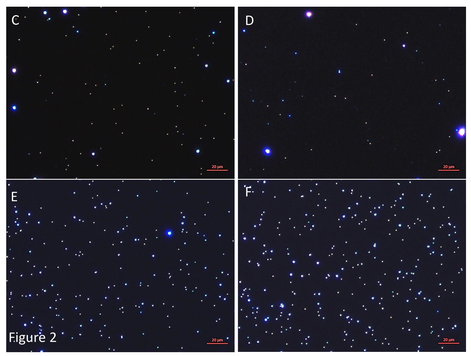


Figure 2 shows substrates that were immersed in gold solution for: C) 30 minutes D) 45 minutes E) 60 minutes F) 90 minutes

Primary Functionalization of Au Nanoparticles

- Nanoparticles were functionalized by mixing the gold nanoparticle solution into a solution of APTES and water or IPA
- Adhesion time of 1 hour
- Densely populated substrate
- Cloudy caused by APTES residue
- Aggregating nanoparticles in IPA

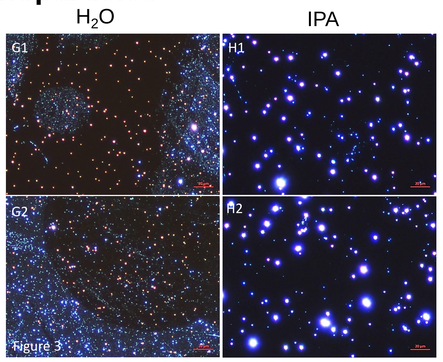


Figure 3 shows that were immersed in a solution with functionalized nanoparticles G1-G2) Immersed in water, APTES, and Gold. H1-H2) Immersed in IPA, APTES, and Gold.

RESULTS

Concentration of Au Nanoparticles

- Concentration was varied between $5.17*10^3$ - $1.12*10^4$ particles/cm^3
- Time held constant at 1 hour
- Higher concentration led to a higher surface density
- Not a linear relationship between concentration and surface density

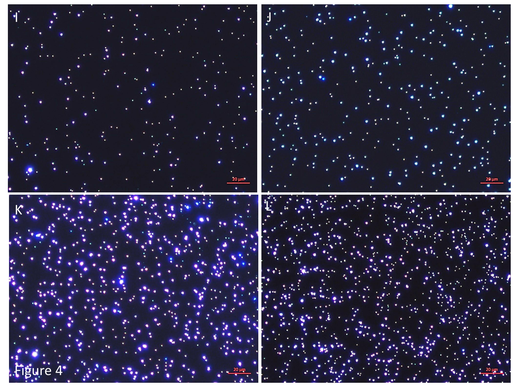


Figure 4 show substrates that have been immersed in different concentrations as follows: I) $5.17*10^3$ J) $6.88*10^3$ K) 9.47 $*10^3$ L) $1.12*10^4$ (particles/mL)

CONCLUSIONS

In this research it was found that the surface density of gold nanoparticles on the silicon substrate depends on the concentration, time in gold solution, and the solvent used. For the purposes of optical devices and light emitters the lower density helps to optimize their efficiency and so their substrates should be functionalized by APTES, immersed in a solution containing IPA and a lower concentration of gold nanoparticles for 30-45 minutes.

FUTURE WORK

To continue this work we plan on delving further into the possibilities of nanoparticle functionalization. Another direction that should be explored now that an adhesion process has been developed is the synthesis of spherical mono-disperse nanoparticles so that they can be easily modeled, tuned, and understood by mathematical equations.

ACKNOWEDGEMENTS

I would like to thank Dana Dement and Professor Ferry as well as the other members of the Ferry Group for assisting me throughout the research. This work was made possible by the Undergraduate Research Opportunities Program (UROP) .

References:

1) A.F. Scarpettini & A. V. Bragas. "Coverage and Aggregation of Gold Nanoparticles on Silanized Glass." *Langmuir* (2010)
2) ChanKyu, Kang, Robwert W. Ashurst, and Changhyun, Roh."Development of uniform density control with self-assembled colloidal gold nanoparticles on a modified silicon substrate." Bioprocess Biosyst Eng (2014).