Immobilization and Protection of Silver Nanocubes with SiO_2 for Use on S.A.W. Devices

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Abstract

Silver nanoparticles with a slight predominance of cubic geometries were synthesized using a scaled up polyol synthesis and then deposited on a quartz substrate SAW device using single wafer spin coating to achieve a more uniform distribution. An approximately 5nm thin film of silicon dioxide was then deposited onto the surface of the SAW device and the silver nanoparticles through chemical vapor deposition. The ability of the silicon dioxide coated silver nanoparticles to survive a surface acoustic wave powered at 10mW was then investigated by measurement of metal enhanced fluorescence.

Background

Surface plasmon resonance is the phenomena whereby the frequency of incident photons hitting the surface of the material resonate with the frequency of the delocalized electrons on the surface, known as plasmons. In nanometals, this resonance leads to deep absorption bands in the UV and near UV spectrum, as well as a unique scattering phenomena resembling fluorescence. Because of this scattering phenomenon, metal nanoparticles can be used to greatly enhance the fluorescence of fluorophores when the scattering frequency coincides with the excitation frequency of the fluorophore. This phenomena has potential applications in the field of immunofluorescent assays by greatly enhancing the sensitivity of such tests, and eliminating the problem of photobleaching of the fluorophore.

Immunofluorescent assays rely on the fluorescing of fluorophore tagged antibodies when they attach to suspect corresponding antigens. Because metal enhanced fluorescence (MEF) so greatly increases the sensitivity of this technique, it also leads to an unacceptable level of increased noise resulting from overlapping fluorescence of nonspecifically bound proteins. It has been previously shown that nonspecifically bound proteins can be removed by using a surface acoustic wave (SAW) device on a quartz substrate.[1] If such a device can work with the addition of metal nanoparticles on it's surface, then a suitable scheme for the creation of an immunofluorescent biosensor using MEF and SAW becomes a possibility.

Objectives

- Synthesize silver nanocubes of sufficient size for use in metal enhanced fluorescence of Alexa-488 tagged fluorophores.
- Achieve uniform distribution of cubes on a quartz surface using single wafer spin coating.
- Immobilize and protect the cubes onto the surface of a quartz wafer through chemical vapor deposition of SiO_2
- Assess the survivability of the cubes when subjected to surface acoustic waves.

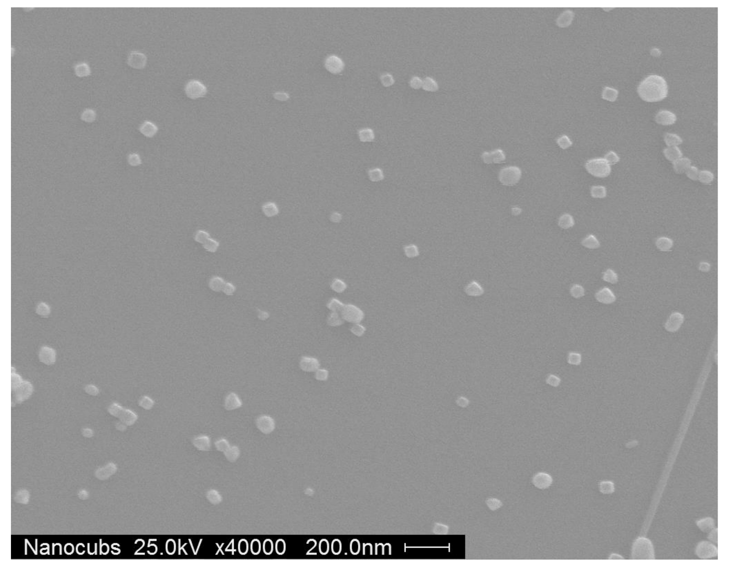
Approach

Silver nanocubes were chosen as the enhancing metal for investigation because for several reasons:

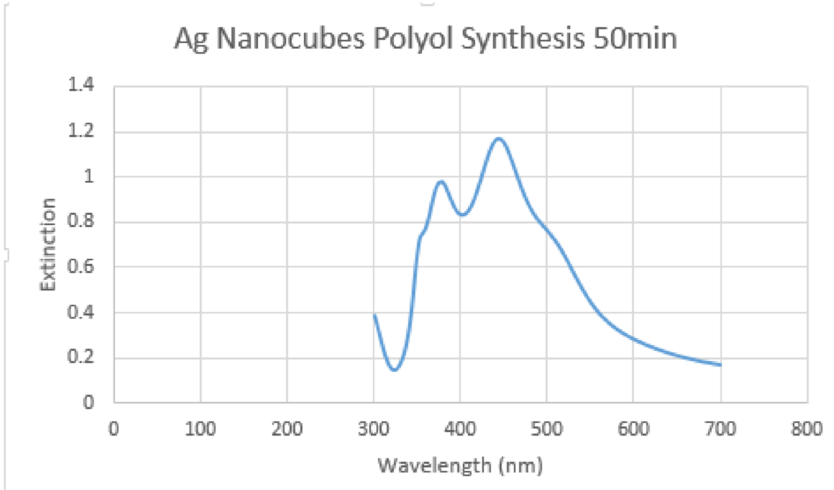
1. Previous research into metal enhanced florescence for immunofluorescent assays have used silver nanocubes.[1]
2. Sufficiently robust, scalable, and controllable synthesis' have been demonstrated to enable the production of silver nanocubes with relative ease.
3. Scattering wavelengths for silver nanocubes occur in the range of commonly used fluorophores for protein tagging.
4. Scattering wavelengths for silver nanocubes can be precisely tuned by altering the synthesis time and thereby altering the edge length of the cubes.[3]

Silver nanocubes were synthesized using the polyol method outlined by Zhang et. al.[3] and scaled up x3. Edge length of cubes were assessed using UV-Vis extinction spectra and verified by scanning electron microscopy to be around an average of 55nm.

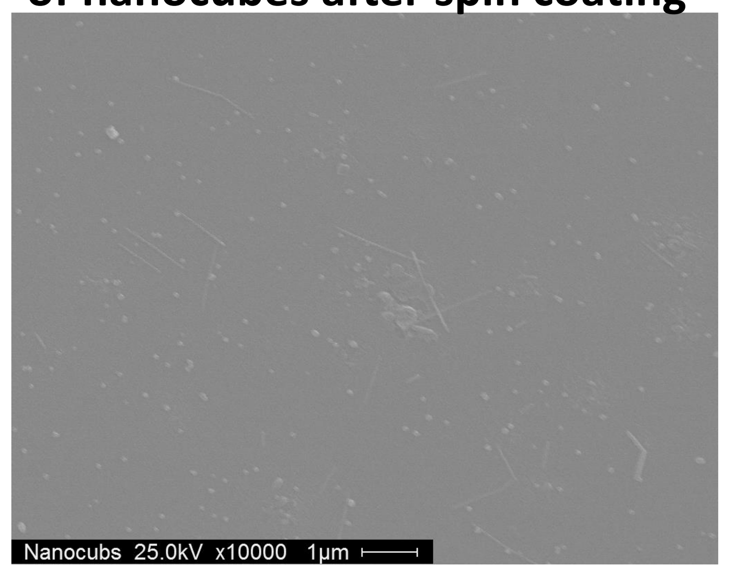
SEM image of silver nanocubes



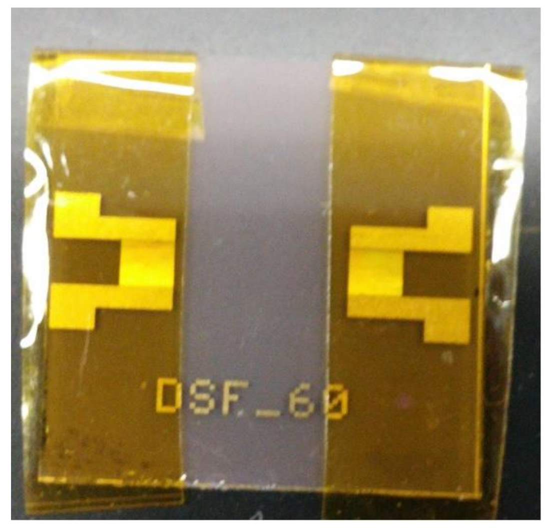
Extinction spectra showing 55nm cubes



SEM image showing distribution of nanocubes after spin coating



SAW device with IDT electrodes covered



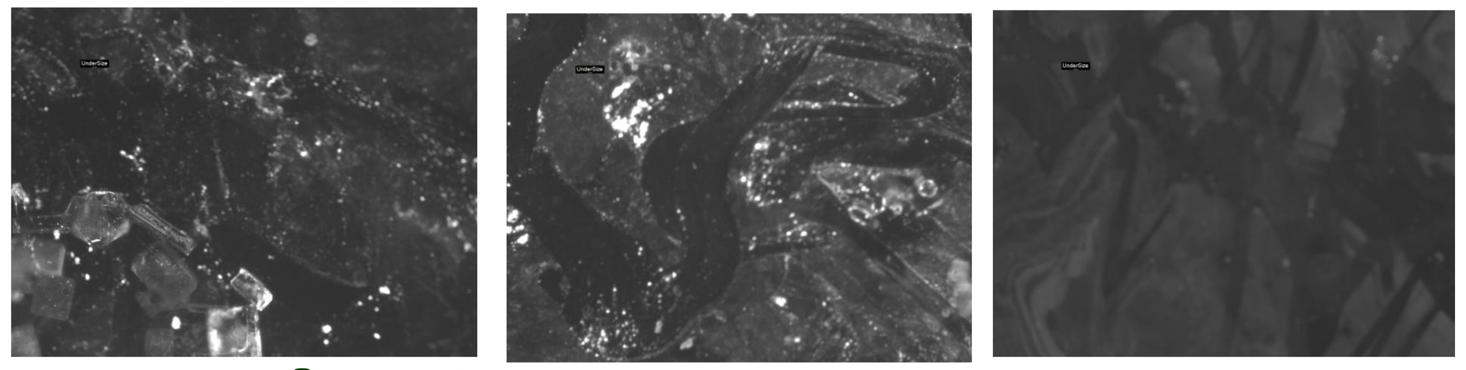
In order to obtain an even distribution of cubes on the surface of the quartz substrate SAW device, single wafer spin coating was utilized. Prior research suggested that the optimal rotation speed for such work would be 3000rpm for 35 seconds.[2]

The SAW device and nanocubes were then coated with a 5nm thin layer of SiO_2 on the delay path using chemical vapor deposition, and powered on at 10mW for 60 seconds.. Devices were then silanized with 3-GPDMS to facilitate attachment to the fluorophore. IDT electrodes on the saw device were protected from spin coating, SiO_2 deposition, and silanization using kapton tape.

Nanocubes on quartz, covered with SiO_2 and silane

After silanization, IgG goat anti-mouse, tagged with alexa-488, was attached to the silane layer. The SAW device was then washed and placed on an inverted fluorescence microscope to observe fluorescent intensity and verify nanoparticle persistence after SAW.

With cubes, before SAW | **With cubes, after SAW** | **No cubes, after SAW**



Conclusions

Fluorescence study indicated that deposition of silicon dioxide onto the surface of a quartz SAW device appears to be a viable means for persistent nanoparticle immobilization capable of surviving SAW processing. Nanoparticles provided substantial fluorescence enhancement even after deposition of silicon dioxide and silane layers to their surface.

Kapton tape proved sufficient for protecting IDT electrodes during spin coating and SiO_2 deposition processes, but failed during silanization because of solvation of the adhesive on the tape. This led to artifacts on fluorescence microscopy.

Future Work

Some areas for future study include:

1. Determination of the survivability of SiO_2 coated nanocubes against oxidation over time.
2. Further refinement of nanocube synthesis techniques to yield more reliably uniform shape distributions.
3. Optimization of the use of SAW devices to detach nonspecifically bound species, keeping specifically bound ones in tact.
4. Investigation of more effective protection techniques for IDT electrodes.
5. Development of cleaning techniques for the recycling and reuse of MEF-SAW devices

Referenced Resources

1.) Morrill S. (2014) Combined Metal-Enhanced Fluorescence-Surface Acoustic Wave (MEF-SAW) Biosensor. Unpublished master's thesis. University of South Florida

2.) Bhethanabotla V. (2014) Single Wafer Spin Coating to Achieve Uniform Distribution of Nanocubes on a Quartz Surface. Unpublished. University of South Florida.

3.) Zhang, Q., Li, W., Wen, L., Chen, J., & Xia, Y. (n.d). Facile Synthesis of Ag Nanocubes of 30 to 70 nm in Edge Length with CF3COOAg as a Precursor. *Chemistry-A European Journal*, *16*(33), 10234-10239.

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