Silver Nanoparticles for Enhanced Efficiency in Solar Applications

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Introduction

Solar energy is plentiful, powerful, and easily converted into different forms. The challenge for energy engineers is in how to collect solar energy most effectively, safely, and efficiently. The manufacturing process for the most commonly used solar cells emits greenhouse gases such as sulfur hexafluoride, and the materials used in these cells are often exotic. Alternative materials, such as quantum dots and porphyrins, are being aggressively researched, but they often do not have the light-harvesting efficiency of older, more established technologies. Wavelengths of light "leak" through these novel films, reducing the power density of the material.

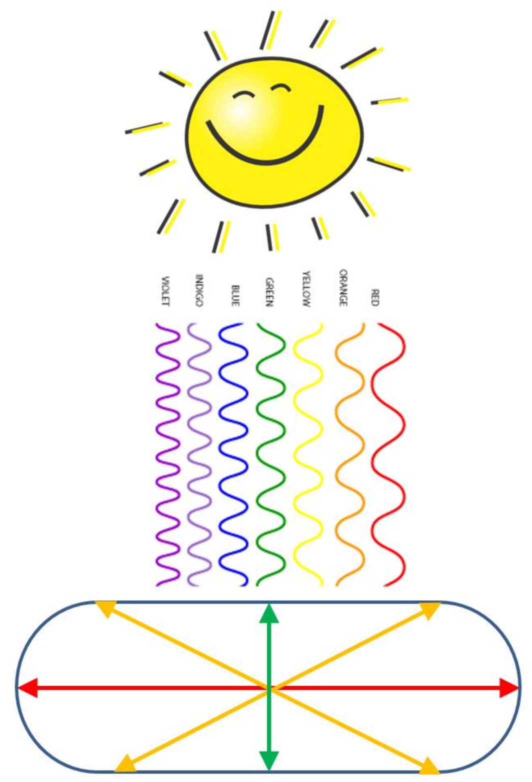
An underlying film of metal nanorods is a potential method for capturing these pesky, leaked wavelengths and redirecting them to the primary fluorophores. This is analogous to maximizing skin exposure to sunlight by using a reflector to bounce light back toward the face that otherwise would pass down toward the ground.

Silver is a metal known for its excellent conducting and scattering properties. This superior conductivity is due to the ability of free electrons on groups of silver atoms to move together and oscillate. A group of oscillating electrons is known as a surface plasmon. Groups of silver atoms from 1-100 nm in size are considered "nanoparticles". The ability of a silver nanoparticle to generate surface plasmons of different wavelengths, and hence scatter different wavelengths of light for solar harvest, is dependent on its shape and diameter. Silver nanospheres would be able to scatter just one wavelength of light, due to the equal diameters across all possible great circles.

A rod has different diameters within the same particle, and therefore is able to scatter various wavelengths of light. The longer the rod, the greater the possible number of wavelengths. Since the goal of using a nano film is to enhance the amount of light directed to the primary organic film, nanorods are a good choice. More wavelengths scattered translates to more wavelengths bounced back to the organic Film to be converted into electricity.

The goal of this work is to develop a method of growing Silver nanorods and applying them to a film to be used in conjunction with quantum dot technology for the harvest of solar energy.

Figure 1: A nanorod has many different diameters along which it can scatter light.



Methods

I. Glass Film Substrate Preparation

Glass microscope slides were cut to size and thoroughly cleaned with a piranha bath protocol. Films were then treated with a silane protocol in anticipation of nanorod attachment.

II. Ag Nano-Rod (AgNR) Synthesis

A. Seed solution preparation: silver nitrate was combined with trisodium citrate to cap and stabilize the product, and reduced with sodium borohydride to obtain silver seeds (see figure 2a). UV-Vis was taken for the seed solution (figure 3).

B. Nanorod Growth: Seven solutions were prepared using the seed solution and various concentrations of silver nitrate, then reduced with ascorbic acid to promote aggregation of silver onto the seeds to form rods. CTAC was supplied to act as a ligand for later in the protocol. UV-Vis was taken for each solution (figure 3).

III. Ligand Exchange: Ligand exchange from CTAC to citrate was performed in preparation for attachment of AgNRs to silanized films

IV. Applying Ag Nano-Rods to Films: Silanized films were soaked in the nanorod solutions for 24 hrs for film formation

Results

The absorption of all solutions and final films was measured with Ultraviolet-Visible spectroscopy (UV-Vis). Absorption of all solutions peaked in the 424-428 nm range, which is expected for silver particles. A prominent "shoulder" appears at ~519 nm for solution 5.1, an indicator that there are silver nanorods (AgNR) present in the solution. Once films were prepared from the solutions, UV-Vis was measured again. Film absorbances peaked in the 411-422 nm range, with film 5.1 showing a shoulder at 468 nm (Fig. 3). Once films were prepared, the topography of the films was measured with atomic force microscopy (AFM) to evaluate AgNR coverage and rod length (Figs. 4&5). Some films were unusable, but AFM showed rods ranging from 7.5 to 12 nm in length on films 5.1, 6.1 and 7.1.

Results *(continued)*

Figure 2: Transmission Electron Images of a) a Silver Seed before growth and b) Nanorod after

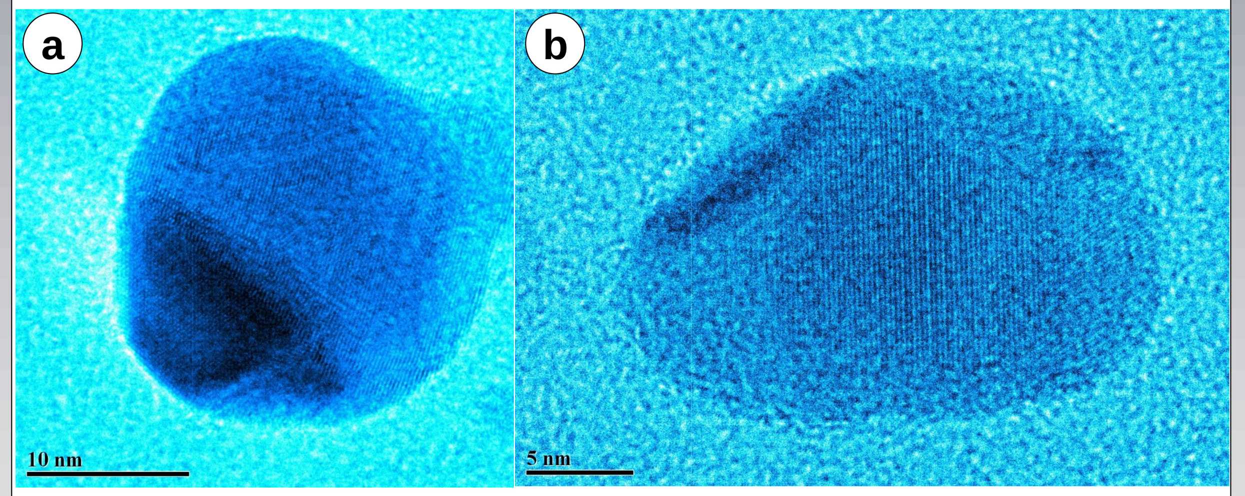


Figure 3: Results of Ultraviolet-Visible Spectroscopy

Normalized absorbance of nanorod suspensions prepared with different concentrations of $AgNO_3$ added to a silver seed suspension. Solution 5.1 decidedly exhibits two peaks, which is indicative of rod-shaped particles.

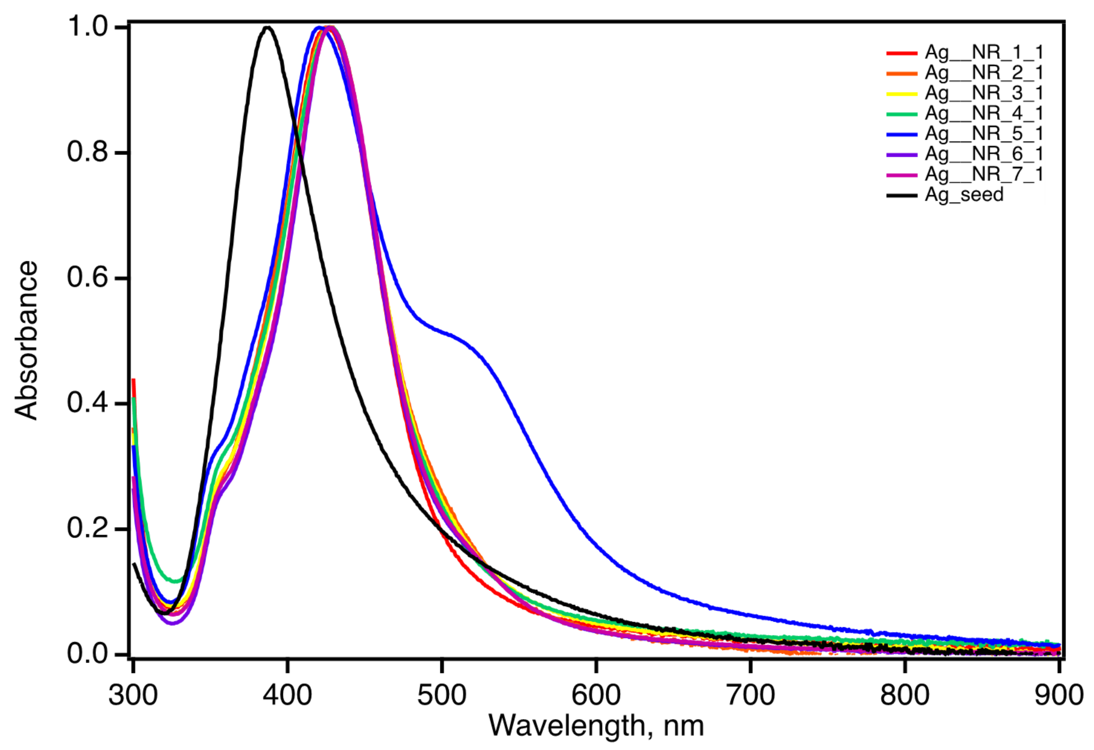


Figure 4: *a) Prepared films for suspensions 5.1, 6.1 & 7.1. The slides should have a green-gold hue b) Atomic Force Microscope (AFM) set-up c) Calibration of AFM in preparation for reading prepared*

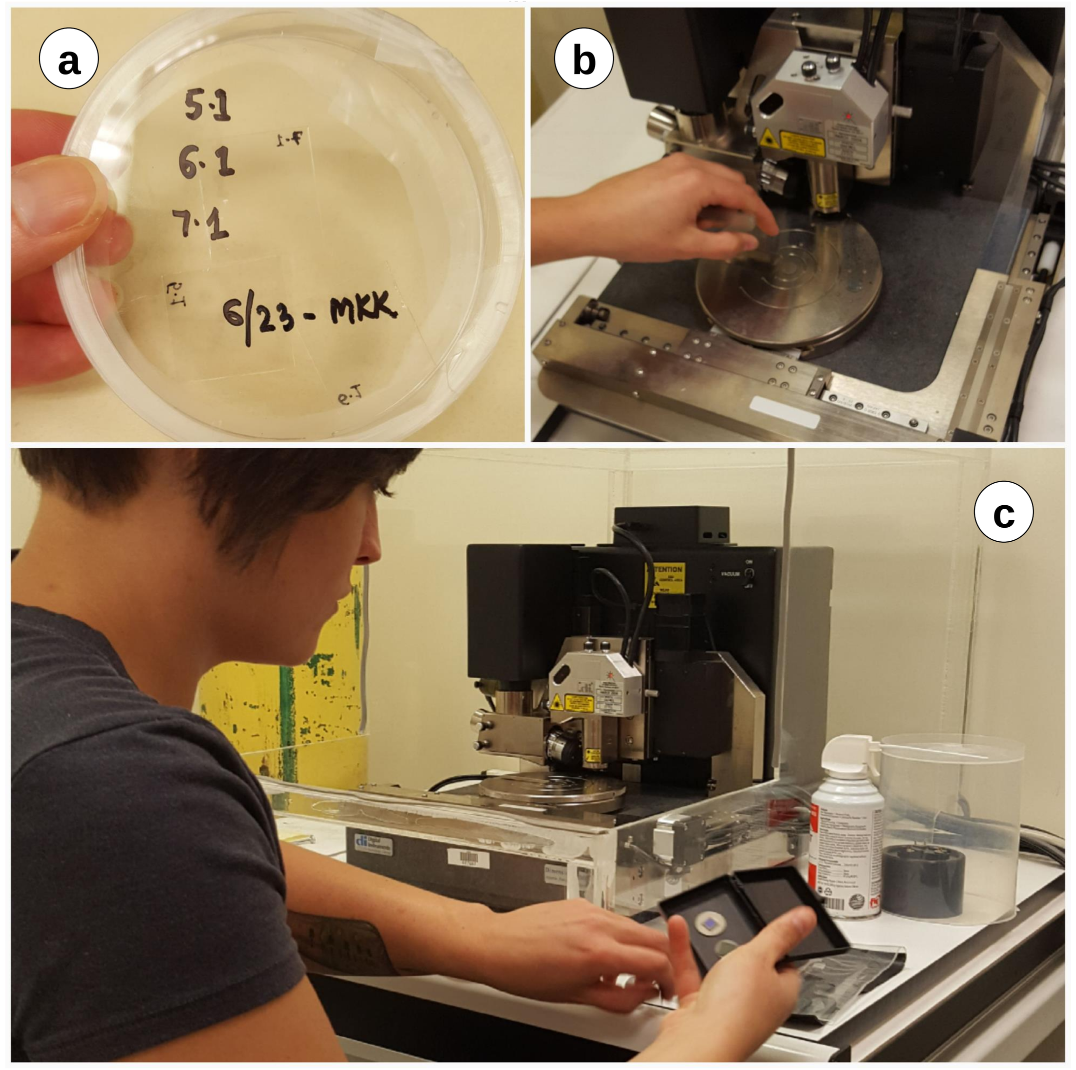
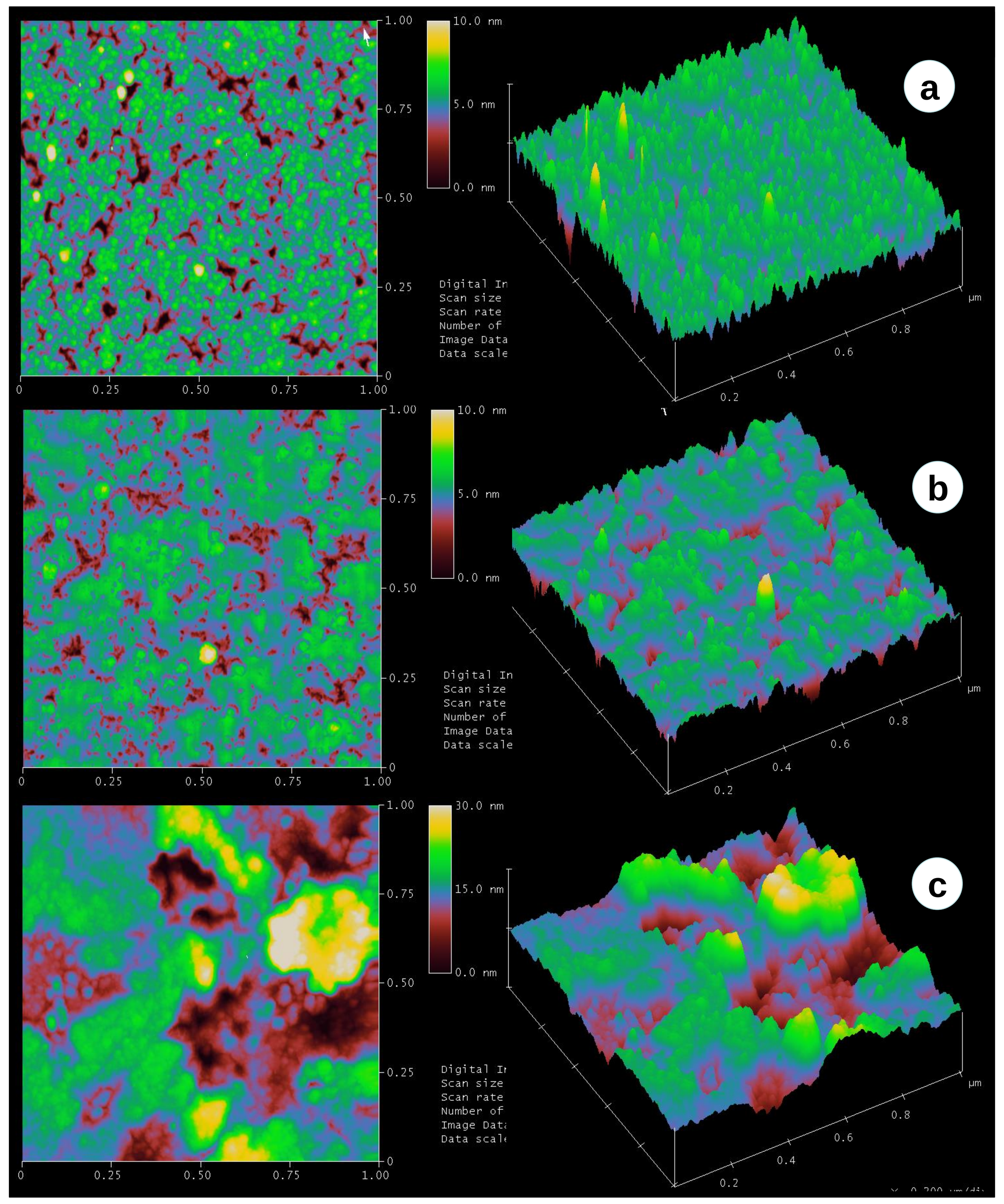


Figure 5: Atomic Force Microscope Imaging

Note Height scale for AFM images. All film areas shown are 1 µm x 1µm a) Film 5.1 This film shows good coverage with silver nano particles. The yellow spots are rods. b) Film 6.1 shows a very large formation in yellow. c) Film 7.1 shows poorer coverage, with large areas of clumped particles.



Conclusions

The goal was to determine if differing concentrations of $AgNO_3$ solution added to a silver seed solution had an appreciable impact on the growth of silver nanorods. Rods grew in all solutions, but solution 5.1 showed the most prominent measureable results. This is exhibited by the prominent double peak it exhibited in both solution and on film when measured with UV-vis, and the good coverage and formations of particles that showed up on the AFM images. This may have been a "Goldilocks" concentration that allowed the excess $AgNO_3$ introduced to the seed solution to reduce in a more orderly manner. Future work will explore a more direct method in which AgNRs will be allowed to aggregate directly on a film.

Bibliography

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