Seed-mediated synthesis and application of gold nanorods in organic solar

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Introduction

* Gold nanorods (AuNR) are rod-shaped plasmonic nanostructures with tunable size-dependent optical responses and unique optical properties [1-3]
* These plasmonic nanorods can confine resonant photons to induce localized surface plasmon oscillations of the conduction band electrons [4]
* Through plasmonic confinement the amplitude of the light wave is increased substantially which in turn increases light intensity, since intensity is proportional to the square of the wave's amplitude [4]
* This effectively focuses resonantly coupled light consequently enhancing optical properties such as light absorption [4]
* In the presence of an oscillating electromagnetic (EM) field of light, the conduction band electrons of a metal nanoparticle undergo a collective coherent oscillation in resonance with the frequency of light, often referred to as surface plasmon resonance (SPR) [5-7].
* Electron oscillation can occur in one of two directions depending on the polarization of the incident light.
* The excitation of surface plasmon oscillations along the short axis induces an absorption band in the visible region (referred to as the transverse band), and its excitation along the long axis induces an absorption band in the infrared region (referred to as the longitudinal band) [4]

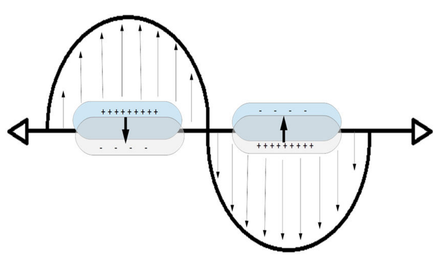

Figure 1. Transverse surface plasmon resonance

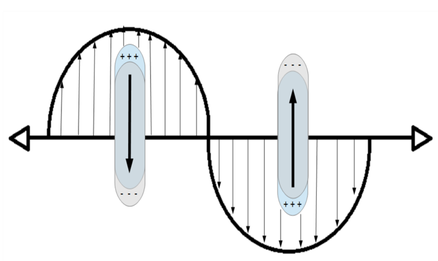

Figure 2. Longitudinal surface plasmon resonance

* This study reports the growth of AuNR with lengths ranging from 10 to 12 nm, widths from 3.5 to 4.0 nm, and an aspect ratio of 2.9. The absorption spectrum showed two bands: the transverse band at 524 nm and longitudinal band at 761 nm. Their sizes and double region absorption spectrum are desirable properties for light absorption enhancement in OSCs.

Materials and Experimental Procedure

Cetyltrimethylammonium bromide (CTAB), Hydrogen tetrachloroaurate (III) trihydrate ($HAuCl_4.3H_2O$), sodium borohydride ($NaBH_4$), silver nitrate ($AgNO_3$), deionized water and ascorbic acid.

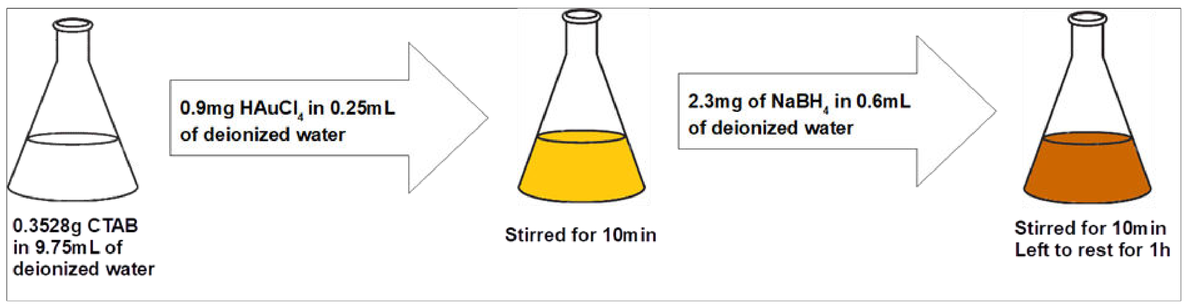

Figure 3. Synthesis of Au-seed solution

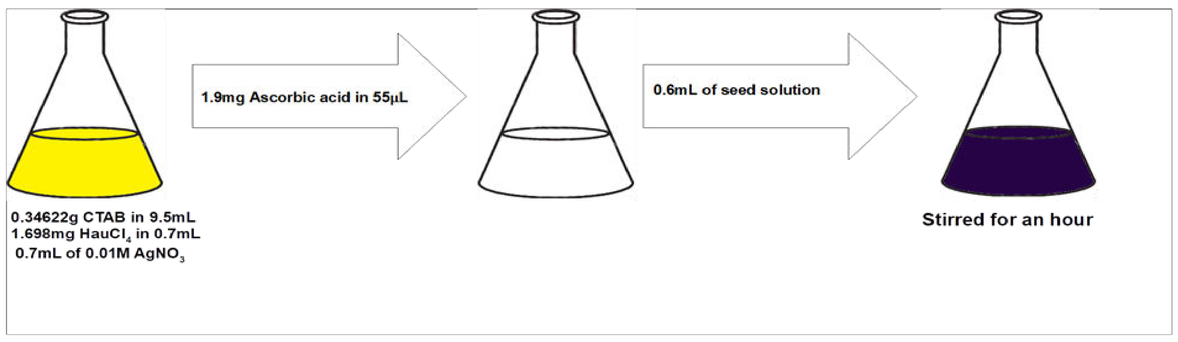

Figure 4. Synthesis of AuNR

Characterization

* The absorption spectrum was obtained using Agilent Cary 60 UV-Vis spectroscopy for wavelengths ranging from 200 to 800 nm.
* The size and shape of the nanorods were viewed using JOEL JEM 2100F Field Emission Transmission Electron Microscope (FEG-TEM)
* The crystalline nature and structural properties of the nanorods were analysed using a Bruker D2 phaser X-ray diffractometer (XRD)

Results and Discussion

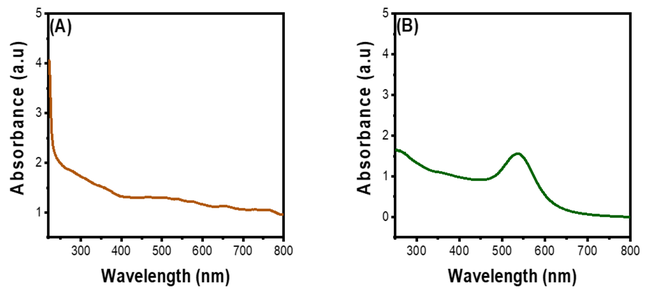

Figure 5. UV-Vis absorption spectrum of Au-seed (A) 12 h after synthesis and (B) after one week

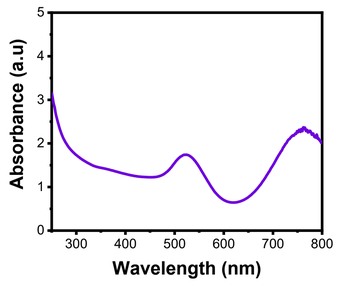

Figure 6. UV-Vis absorption spectrum of gold nanorod

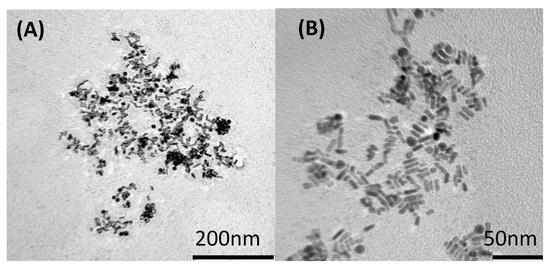

Figure 7. TEM images of gold nanorods

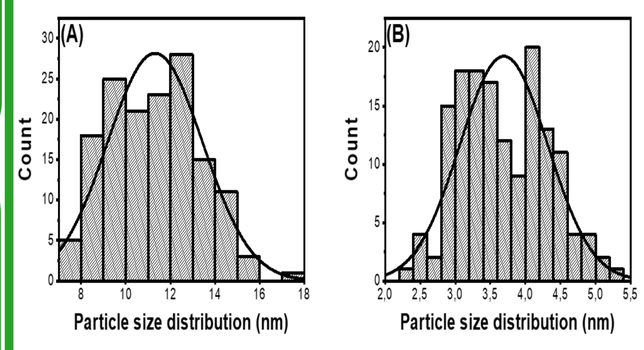

Figure 8.(A) Gold nanorod length distribution

(B) Gold nanorod width distribution

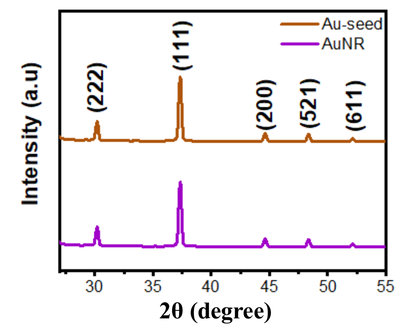

Figure 9. XRD pattern of gold nanorods and gold seed

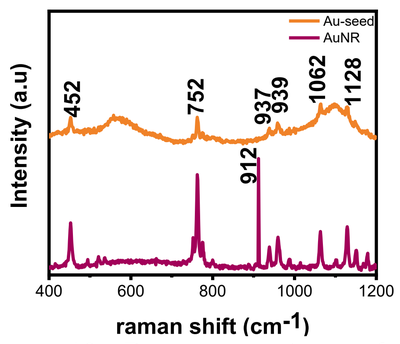

Figure 10. Raman spectrum of gold nanorods and gold seed

* Figure 5 (B) shows a SPR band 536 nm which corresponds to spherical gold nanoparticles (AuNP) [8]. The slow formation of the nanospheres seen in Figure 5 is because reaction kinetics is proportional to temperature[9]
* The absorption spectrum of AuNR is shown in Figure 6 with a peak transverse SPR band of 524nm and a peak longitudinal SPR band of 761nm
* Figure 7 shows TEM images of gold nanorods and Figure 8 shows a histogram size distribution of the gold nanorods. The average length is between 10-12nm, and the average width lies between 3.5-4.0nm. This yields an aspect ratio of 2.9.
* The XRD diffractograms is shown in Figure 9. The peak matching to the (111) plane is the most intense indicating that the predominant growth of the nanorods was in this direction.
* The Raman peaks (Figure 10) for gold nanorods are similar to the gold-seed peaks, but great enhancement is observed. This enhancement can be attributed to the shape of the nanorods [10, 11]

Conclusion

* AuNR were successfully synthesized by mediated seed method
* UV-Vis showed a transverse surface plasmon resonance peak at 524 nm and a longitudinal surface plasmon resonance peak at 761 nm
* TEM showed average lengths between 10-12nm, widths between 3.5-4.0nm and an aspect ratio of 2.9
* XRD confirms a fcc crystal structure of AuNR
* Raman spectroscopy showed sharp peaks for AuNR due to near-field enhancement in the nanorods.

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