Highly Sensitive Plasmonic Silver Nanorods

Arpad Jakab, Christina Rosman, Yuriy Khalavka, Jan Becker, Andreas Trugler, Ulrich Hohenester, and Carsten Sonnichsen *

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†MAINZ Graduate School of Excellence and Institute of Physical Chemistry, University of Mainz, Jakob-Welder-Weg 11, 55128 Mainz, Germany, and ‡Institute of Physics, Karl-Franzens University Graz, Universitätsplatz 5, 8010 Graz, Austria

Indranath Chakraborty
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In this paper

- Single-particle sensors can have a higher sensitivity than propagating surface plasmon based sensors.

- The spectral position of the localized surface plasmon is highly dependent on dielectric properties of the surrounding medium.

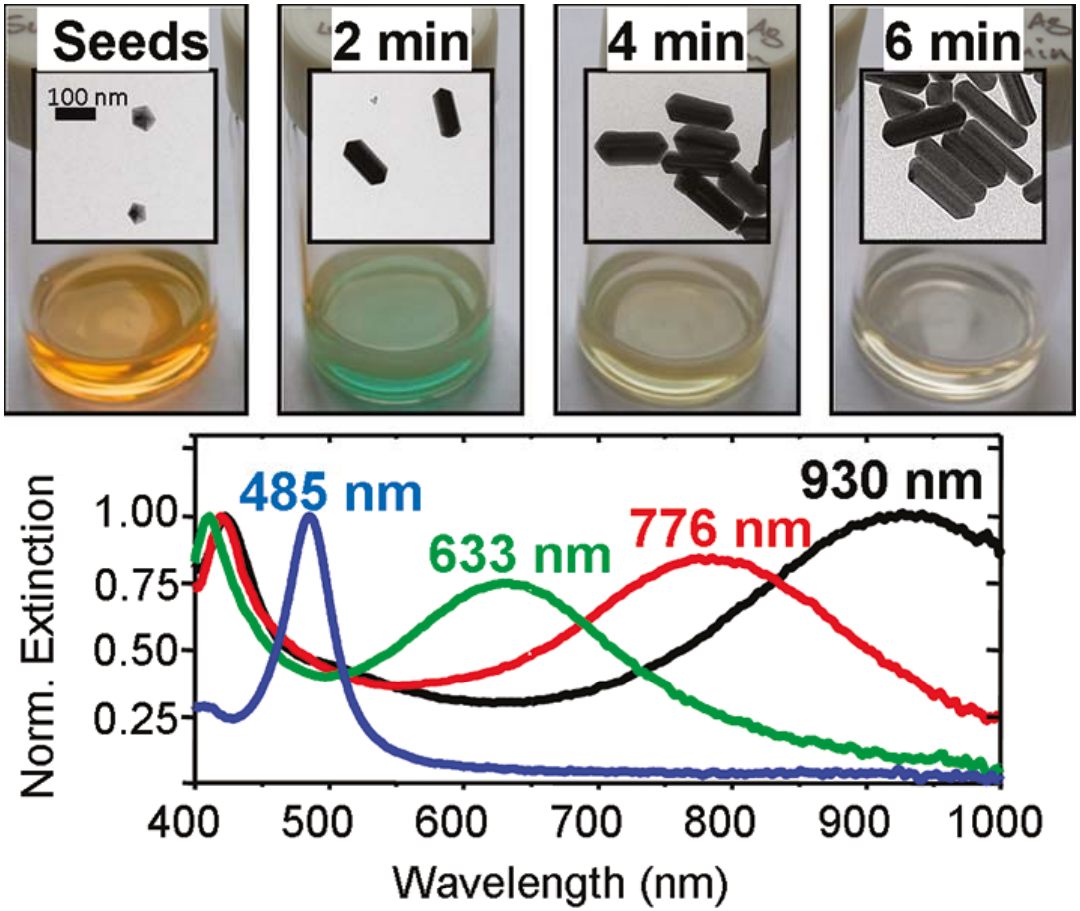
- Silver nanorods have a higher sensitivity than gold nanorods at the same resonance wavelength.

- The background polarizability of the d-band electrons strongly influences the sensitivity.

Experimental Section

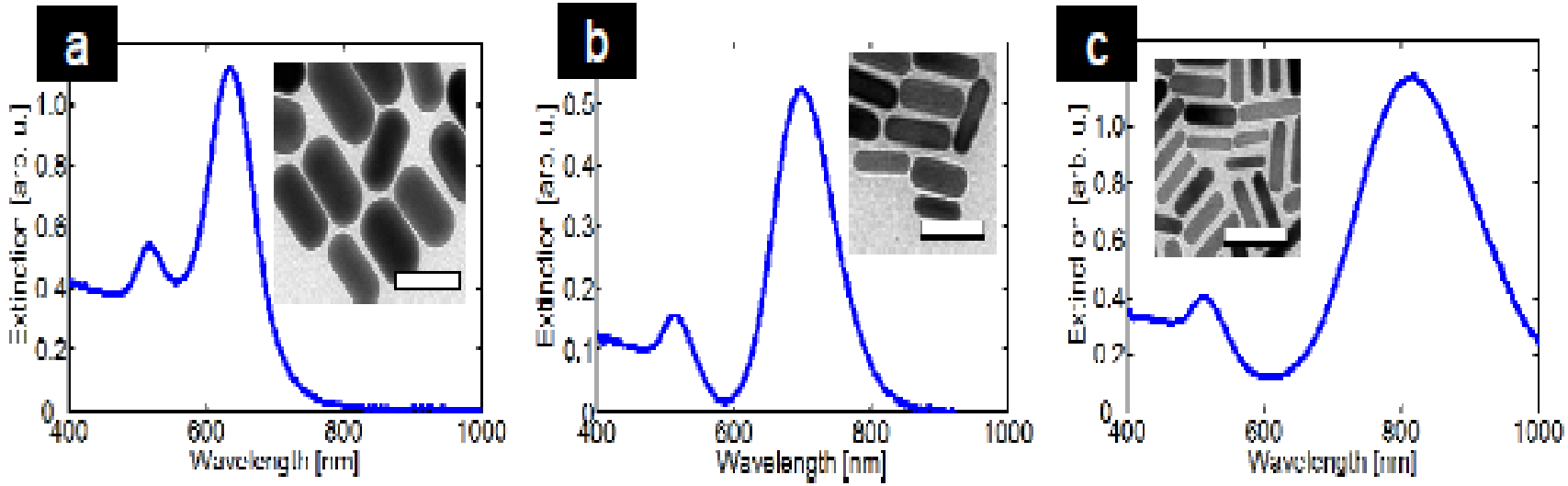
- Silver nanorod was synthesized using two step seeded growth approach.
- In the first step silver seed's are produced under light illumination and heating with the help of blue LED lamp.
- In the second step the seed's are added to a growth solution where they develop into silver nanorods.
- Then it was pre-heated for 1 min, followed by addition of $AgNO_3$, again placed into microwave for heating between 2 and 6 min resulting in rods with increase in aspect ratio.

Results



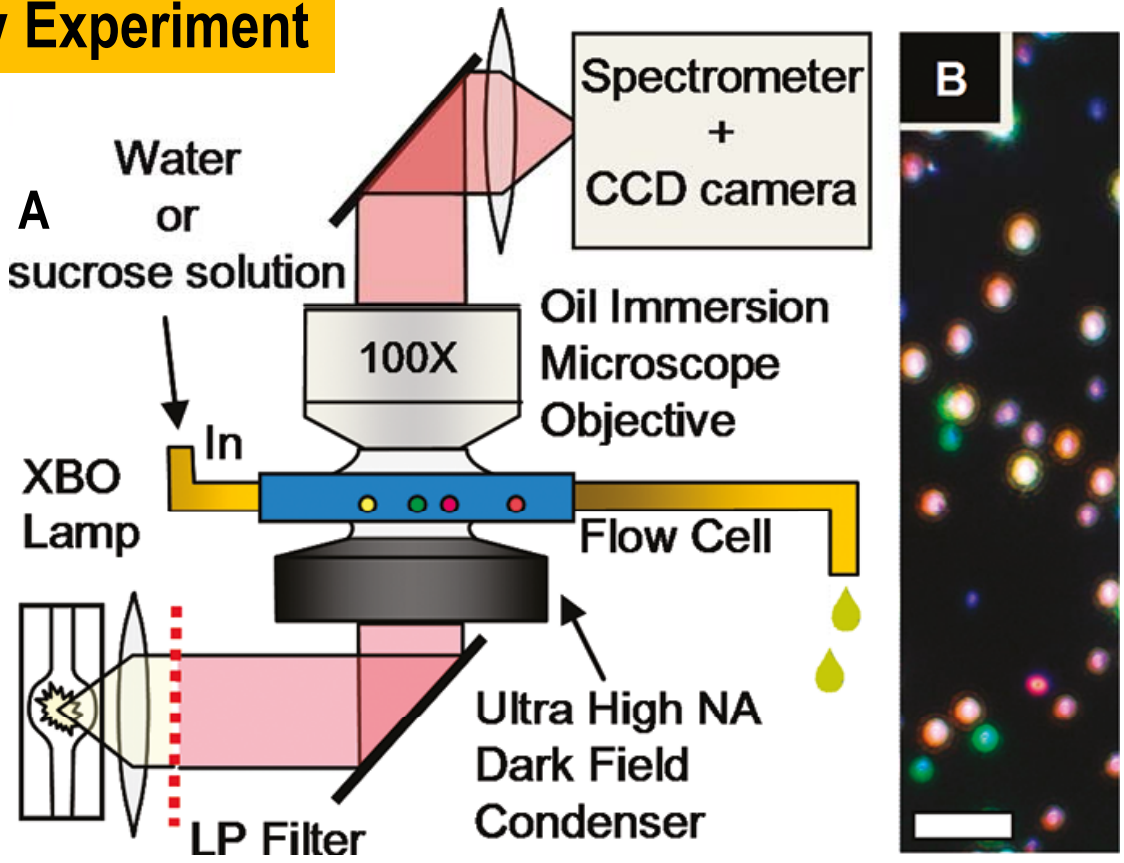
Representative silver nanorod samples are shown as photographs and TEM images together with the corresponding ensemble extinction spectra (bottom). The samples correspond to Ag-seeds and Ag-nanorods grown with 2, 4, and 6 min of heating time (from left to right). Their plasmon peak increases from 485 to 633, 776, and 930 nm.

Results



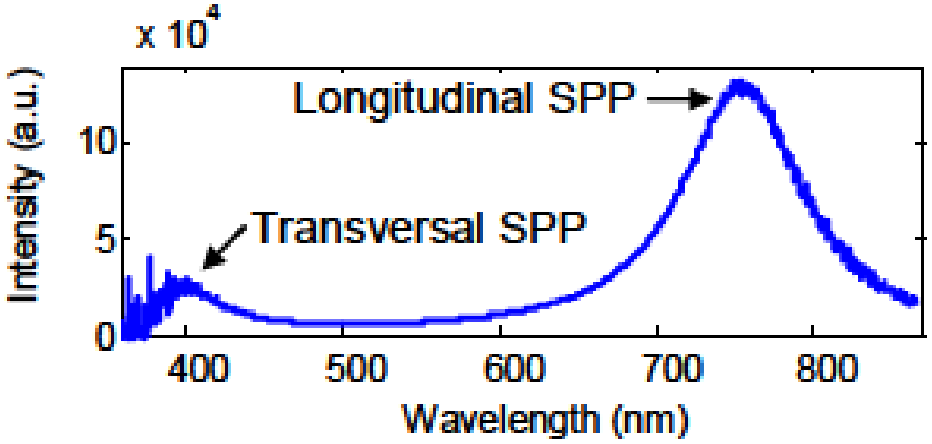
TEM images and ensemble absorption spectra of the small gold NRs used to measure the sensitivity. The longitudinal ensemble peak is at (a) 630nm, (b) 702 nm and (c) 816 nm. The gold NRs have spherical or slightly flattened endcaps. The scale bars are 50 nm.

Sensitivity Experiment

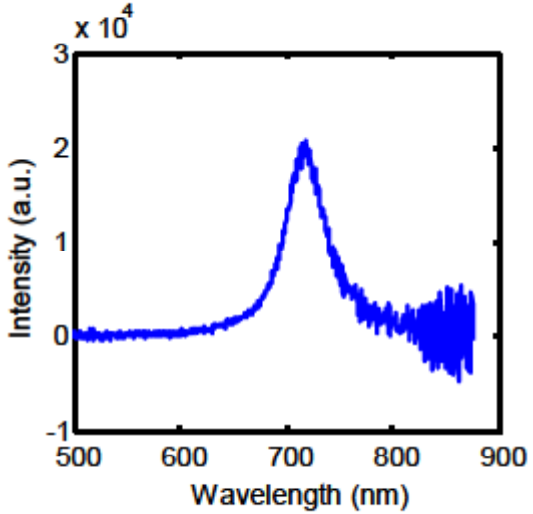


(A) Experimental wet environment dark-field setup designed for single nanoparticle spectroscopy in various surrounding media. (B) Typical dark-field image of the nanoparticles; the scale bar is 10 μm.

Results

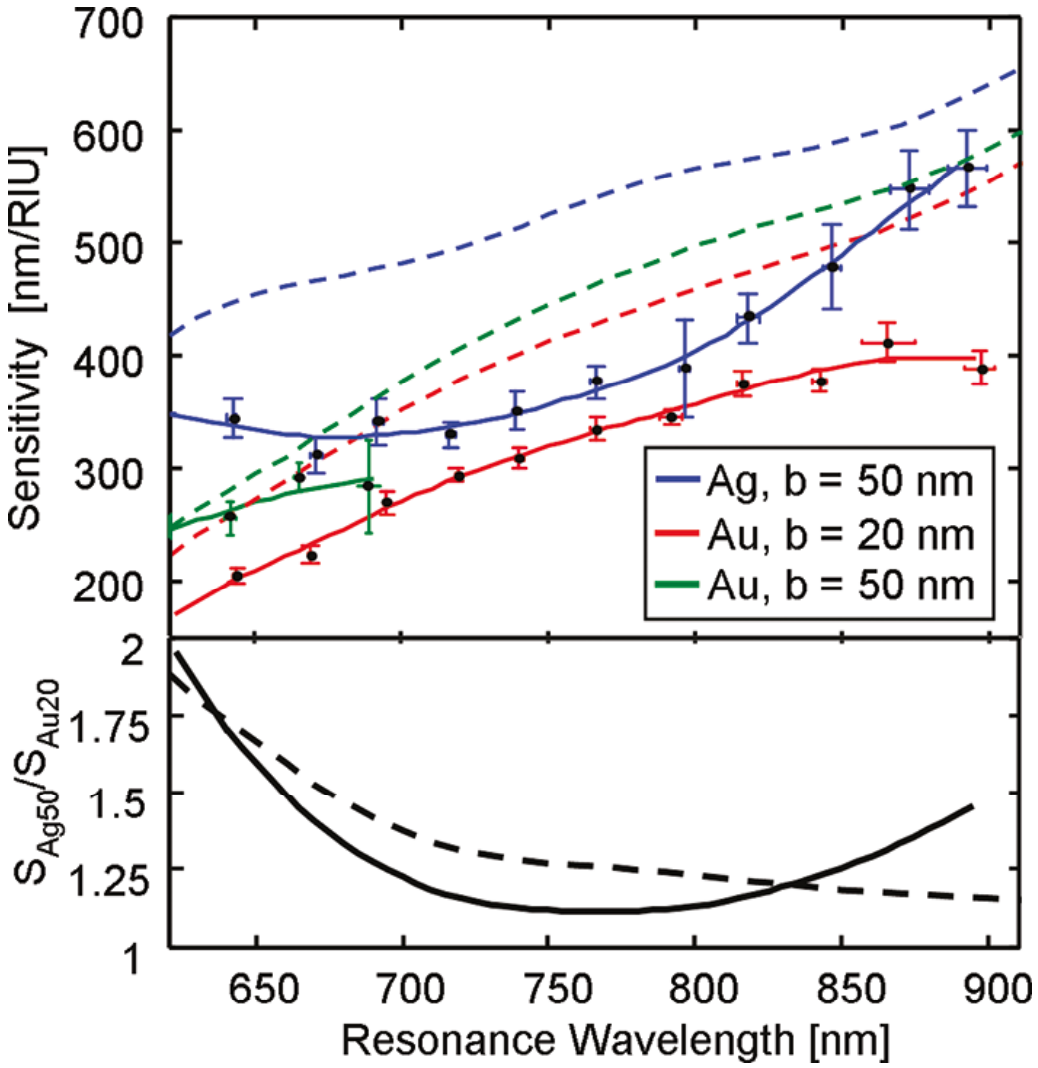


Example of a white light scattering spectrum of a single silver nanorod. For unpolarized excitation, both the long axis (or longitudinal) and the short axis (or transversal) plasmon resonances are visible.



Example of the scattering spectrum of a single gold nanorod from the batch with 702nm ensemble peak. For unpolarized excitation only the long axis (or longitudinal) plasmon resonances is visible, the short axis (or transversal) plasmon resonance is very weak at widths of 18 nm.

Results



(Top) Experimental results (continuous lines) and
BEM-simulation without substrate (dashed lines) of singleparticle sensitivity of silver (blue line), 20 nm thick (red line), and 50 nm thick (green line) nanorods. The error bars indicate the uncertainty of the mean in a range of 25 nm. (Bottom) The experimentally obtained (continuous line) and BEM-simulated (dashed line) sensitivity enhancement (SAg/SAu) of silver nanorods with 50 nm thickness in relation to gold nanorods with 20 nm thickness.

Theory Behind the Experiment

- The sensitivity S at a given resonance wavelength λ is given by

$$S(\lambda) = \frac{\lambda}{n}\left(1 - \frac{\lambda_p^2}{\lambda^2} n_\infty^2\right)$$

- Bulk plasmon wavelength : $\lambda_p = 2\pi c_0/\omega_p$

$\lambda_p = 136$ nm for gold and silver

- Background refractive index: $n_\infty = (\varepsilon_\infty)^{1/2}$ $n_{\infty,Au} = 3.1$ $n_{\infty,Ag} = 1.9$

- Background dielectric constant $\varepsilon_{\infty,Au} = 9.84$ $\varepsilon_{\infty,Ag} = 3.7$

Conclusion

- Experimental results of silver nanorod sensitivity and a comparative study with GNR is presented.

- Width of nanorod and the material of nanorod is the two factor influencing the sensitivity. That is also supported by MLWA calculations and BEM simulation.

- From simple theoretical arguments (Drude's model and QSA) they developed an expression for sensitivity.


ThankYou