Microspectroscopy of single noble-metal nanoparticles

F. Hallermann, RWTH Aachen, Germany (July 2010)

Application Note

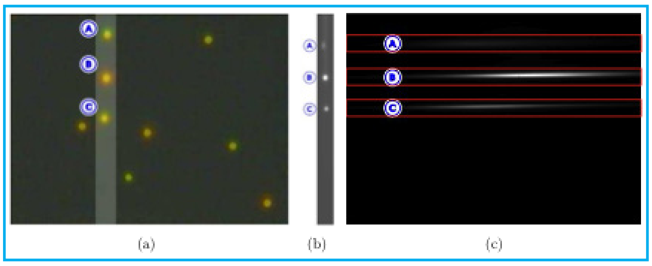

Figure 1:
(a) Dark-field microscope image of gold nanoparticles.
(b) Image of the three marked nanoparticles on the CCD detector.
(c) Image of dispersed light scattered by the three marked particles

Introduction

We investigate the optical properties of metal nanoparticles. These particles, with typical sizes between 40 nm and 80 nm, have interesting optical properties which differ from those of the corresponding bulk metals. The optical properties are dominated by the plasmon resonance which is a resonant, collective, oscillation of the conduction electrons in the metal particle [1,2]. This oscillation leads to an enhanced absorption and scattering of the incident light and to a strong enhancement of the optical fields near to the particle. This field enhancement effect can be used for surface-enhanced Raman scattering or fluorescence enhancement. The spectral position of the plasmon peak and the linewidth depend on the material, size, shape and dielectric surroundings of the particle.

Experimental Set-up

Due to their small sizes, the shapes of the nanoparticles cannot be resolved with a conventional optical microscope. However, one can detect light which is scattered by the particle. Figure 1a shows a dark-field microscope image of gold nanospheres with different diameters. For the larger spheres, the plasmon resonance wavelength is larger. Therefore they appear more yellow than the smaller particles which mainly scatter green light.

We use an Olympus BX51 dark-field microscope. The dark-field configuration means that only light which is scattered by the nanoparticles can enter the objective. This scattered light is then coupled into a spectrograph (Andor Shamrock SR-303i-B). The spectrograph is equipped with 150 l/mm and 1200 l/mm gratings. These gratings are mounted on a turret and can be selected using the Andor Solis software. The light is detected with an Open Electrode CCD detector (Andor DU420-OE). The grating with 150 l/mm allows us to measure a large spectrum with one single measurement whereas the grating with 1200l/mm provides an approximately eight times better resolution at the expense of a reduced spectral range.

The imaging mode of the spectrograph lets us see an image of the sample with the CCD detector. In figure 1b, the same particles as marked in the microscope image (figure 1a) can be seen on the CCD detector as well. Thus, we can identify the nanoparticles on the sample surface, select single nanoparticles which lie in a row, move their images to the center of the CCD detector and close the entrance slit of the spectrograph. In this way, we ensure that only light which is scattered by these selected nanoparticles reaches the CCD detector. If the concentration of nanoparticles on the sample is low enough, it is possible to position the sample in a way that only the light scattered by one single nanoparticle enters the spectrograph. After turning the grating turret, the dispersed light appears on the CCD detector and the scattering spectrum of the nanoparticle can be recorded. In figure 1c, one can see the dispersed light of the three marked particles (cf. figure 1a).

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Results

The blue line in figure 2 shows the measured scattering spectrum of a single gold nanosphere with a diameter of 80 nm in an aqueous environment. The light was dispersed by a 150 l/mm grating, measured for 30 s and corrected for the spectrum of the white light lamp of the microscope. A normalized scattering cross-section of the particle is shown in red. This spectrum was calculated using Mie theory, which is an analytical theory for the calculation of the optical properties of spherical nanoparticles [3].

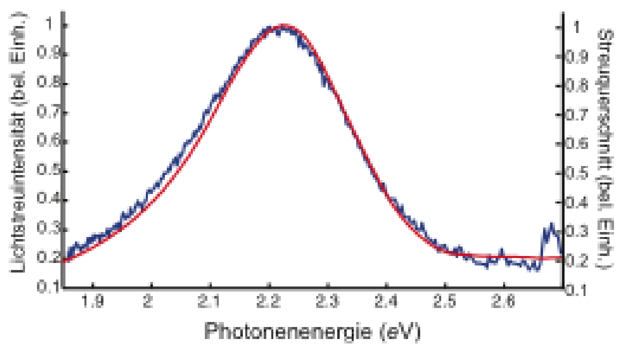

Figure 2: Scattering spectrum of single gold nanoparticle with 80 nm diameter (blue line). Calculated scattering cross section is shown in red.

References

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[2] C. Dahmen, G von Plessen. Optical effects of metallic nanoparticles. Aust. J. Chem., 60:447-456, 2007

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