Protein-Membrane Interaction Probed by Single Plasmonic Nanoparticles

Jan Becker – Ultrafast Nanooptics (Bad Honnef 2008)
Outlook

- Introduction to plasmonic particles
- Darkfield-Microscopy and the novel fastSPS setup
- Protein-Membrane interaction
- Conclusions
Plasmons scatter light strongly

Matrix

collective oscillation of the conduction electrons

Light

same light scattering efficiency

1.1 µm SiO₂

= 60 nm Au

![Image of test tubes with colored liquids]
Resonance Wavelength depends on:

- **Material**: Scattering efficiency is shown for gold and silver nano-spheres.
- **Shape**: The Q_sca graph shows different shapes with peak positions at 400 nm and 700 nm.
- **Interparticle spacing**: Not explicitly shown in the image.
- **Surrounding refractive index**: The graph shows a linear relationship between refractive index and resonance wavelength with values ranging from 1.30 to 1.50.

The graph includes a plot of scattering efficiency against light energy, with distinct peaks for gold and silver nano-spheres.
Transmitted vs. Scattered Light

Transmitted light

(Back)-Scattered light

Transmitted light has complementary color to scattered light
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Darkfield Microscopy

- Objective
- Direct light
- DF condenser
- Scattered light
- Entrance slit/pinhole
- CCD
- Spectrometer
- Grating

Real color image: 10 µm

TEM: 100 nm
Conventional Method to Measure Single-Particle Spectra

Select one particle

Disperse light

Capture the spectrum

serial process ➔ very slow!
The Scanning Method

Entrance Slit

wavelength

➡️ still slow!
The fastSPS Method

fastSPS: fast Single Particle Spectroscopy

many particles automatically observable in parallel

Nano Lett (2007), 7, 1664
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Au rods as Biosensor for Protein Binding

Au rods coated with a biotinated lipid bilayer

H₂O (n=1.33)

H₂O (n=1.5)

glass

➢ Membrane and protein binding can be detected by shift in resonance wavelength

Theoretical Calculations

Scattering spectra calculated using quasi-static approximation

1. Shell of 4 nm thick layer with $n=1.5$ (membrane) leads to: $\Delta = 15\,\text{nm}$

2. Second shell (2.3 nm thickness, $n=1.5$ streptavidin) leads to: $\Delta = 5.8\,\text{nm}$

Difference to measured value:
- In experiment only half of the rod is coated
- In experiment a small water layer is between membrane and goldrod

<table>
<thead>
<tr>
<th></th>
<th>Membrane</th>
<th>Streptavidin</th>
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<tbody>
<tr>
<td>$\Delta$</td>
<td>3.6 nm</td>
<td>2.9 nm</td>
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Different Types of Lipid Bilayer

Shift due to streptavidin binding:

- Incl. biotin: $\Delta = 5.3 \pm 3.1 \text{nm}$
- Incl. spacer $\Delta = 2.4 \pm 2.1 \text{nm}$
- No biotin $\Delta = 1.2 \pm 1.0 \text{nm}$

- Attaching Streptavidin via a spacer results in a smaller spectral shift
- Membrane coating suppress unwanted nonspecific interactions

Conclusions

- fastSPS allows continuous observation of many (up to 30) nano-particles in parallel.

- Membrane and protein binding can be detected by shift in resonance wavelength of single nanorods.

- Due to high functionalizability of membranes (plenty with different headgroups available) this is an ideal characterization tool for biomolecules.

- Membrane coating suppress unwanted nonspecific interactions.
Acknowledgement

Carsten Sönnichsen  Andreas Janshoff

I. Ament  L. Carbone  A. Henkel  A. Jakab  Y. Khalavka  S. Pierrat  C. Rosman  I. Zins

More information:
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Financial Support
Carl-Zeiss-Foundation

ZEISS
SCHOTT

Deutsche Forschungsgemeinschaft
nanobiotechnology
Physical Chemistry group