Combining electrochemistry and plasmonics in nanowells – A new biosensor for membrane transport

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The study of membrane permeability and transport rate for different molecules is one of particular importance in biomedical research as it helps to understand cell to cell interactions. Therefore many different attempts and routes are taken in order to investigate this topic.

The basis of our presented sensing device is an array of nanoholes in a multilayer of insulating layers (e.g. niobium oxide) and thin gold in between. This gold film can then be used as working electrode when doing electrochemistry in nanowells. Once molecules enter the nanocavity they get oxidized and reduced at the electrode and thus generate a faradic current. Since the volume inside is relatively tiny, the local concentration changes are large, even for a small amount of molecules.

In addition, these nanodevices are also suitable for plasmonic sensing experiments making it possible to detect changes in the effective refractive index, which occurs for example when molecules bind to the gold film. For this purpose the optical spectrum can also be theoretically calculated: While the expected surface plasmon resonance wavelength of the bonding mode can be estimates with the dispersion relation for a finite film, the contribution to the optical response of the thin film interference can be calculated using Fresnel formulas.

To use these nanodevices as biosensors, in particular for measuring membrane transport, the surface can be covered with a membrane and thus sealing the holes with it. The detected faradic currents will be characteristic for different membranes and molecules as function of their concentration. This dependency will give information about the transport rate and the permeability of the membranes.

The system therefore provides a novel biosensing platform for measuring membrane transport based on electrochemistry in tiny confinement with high sensitivity due to the large sample to volume ration. Above that plasmonic studies can be done as second detection method and so we are not limited to redox active molecules. These two methods can be used individually or even simultaneously, which allows us to do a large variety of biophysical experiments. Besides the investigation of membrane transport or electrochemistry in confinements, studies about the electrode solution interface and binding experiments can be done as well.