Molecular Plasmonics 2013

23.-25. May 2013, IPHT Jena (Germany)

Summary

Plasmonic effects based on localized (or particle) surface plasmon resonance (LSPR) and directed towards molecules and molecular conjugates represent an emerging field between nanooptics and life sciences with a great potential for applications especially in diagnostics and therapy. This years meeting – in a series of similar symposia aiming at recent developments in molecular plasmonics bi-annually since 2005 (cf. http://molecular-plasmonics.de/) - was focused on recent developments in this field. This includes e.g. phenomenon occurring at molecular components due to local field enhancement effects with a special focus on Raman processes, enhancement of fluorescent dyes, the use of such effects in biomedicine, and the recent developments in detection and characterization technology.

Description of the scientific content and discussion

The meeting started with a session looking at LSPR as well as propagating plasmons (SPR), in order to set the stage for the further meeting. SPR is quite established and is also studying propagation in metal structures. So both the differences as well as joint properties as well as potential applications are of interest. The thematic range was quite broad, from sensitivity comparisons of LSPR with SPR using the same system of molecular layers (Jatschka/IPHT) over spectroscopic approaches using multispectral surface enhancement antennas (Aouani/London), the manipulation of EM waves by plasmonic tools (Huang/Taipeh), the plasmonic optical fiber as a new class in plasmonics (Schmidt/IPHT) and the interaction between molecular excitations and coupled surface plasmons (Toppari/Jyväskylä).

Molecular plasmonics reaches already beyond the purely observation type of experiments, where the response of the system to the incoming light is only measured in the light after interactions such as absorption or scattering. Light can also induce changes in the system such as temperature increase, ablation or even destruction of the plasmonic nanostructure. This interaction depends mainly on laser parameters (such as pulse duration, fluence) as well as the interaction with the particle (resonance wavelength, type of metal), and is usually discussed in quite diverse terms. Luckily (and also due to the financial support by ESF) S. Hashimoto (Tokushima) could give an overview

over this field and tried to order the various applications (ranging from cell destruction to nanoparticle melting) in a systematic way. This approach was further extended by F. Garwe (Jena), covering the full range of non-resonant material manipulation till coupling of energy into plasmonic nanoparticles which transfer this energy into attached molecular wires. The other talks of the sessions were more specialized, addressing the field of nanoparticle cell treatment (Muskens/Southampton) and localized polymerization as tool for visualization the electrical field distribution (Zaarour/Troyes).

The first application of effects based on molecular plasmonic phenomenon are expected in biosensing, where the simple – and often already for the naked eyes visible - color change is promising a low tech approach for molecular detection. Bringing this technology to an array format on substrates and its application in biomedical settings was the subject of the first presentation by P. Baptista (Lisbon). Fluorescent noble metal nanoclusters as an emerging class of novel biolabel looked into novel directions (Le Guevel/Bionand). The phantastic possibilities offered by DNA origami regarding the nanometer-precise control of individual molecular components were then demonstrated (Acuna/Braunschweig). The study of individual particles and their spectroscopic properties as the ultimate limit of detection was presented by M. Orrit (Leiden). Y-C. Chang (Tainan) presented a further development of nanosphere lithography where the spheres are actually used as lenses for subsequent lithographic steps.

Surprisingly, the enhancement of Raman signals at plasmonic nanostructures took a significant part under the submitted abstracts, so a whole oral session was aimed at this interesting effect. Although Raman spectroscopy gives unique fingerprints of molecules and is therefore highly specific but requires no sample preparation, the signal of standard Raman experiments is too low. However, when the electromagnetic field is locally enhanced, as it happens in the case of plasmonic nanostructures, a strong enhancement of the Raman signal is observed (surface-enhanced Raman spectroscopy SERS). F. Hubenthal (Kassel) spoke about fundamentals in SERS, especially the enhancement mechanisms. M. Lamy de la Chapelle (Paris) demonstrated highly sensitive biosensors working on SERS principle. J. Kneipp (Berlin) reported the development of mix-and-match nanoparticle surfaces for SERS applications, and K. Leosson (Reykjavik) demonstrated the combination of lithographic patterning and subsequent self-assembly of gold nanostructures of improved SERS enhancement.

At last but not least, the fluorescent enhancement (based on similar principles as SERS) was discussed. This field offers the rare chance to combine novel applications especially in biosensing with the highly established field of fluorescence markers and labels. B. Barnes (Exeter) discussed the special case of chiral nanostructures. The both sides of he coin - as plasmonic nanostructures can quench but also enhance fluorescent signals - were the subject of studies reported in M. Weerts (ENS Chachan) talk. Other implications for the same effect were the subject of the closing talk of this session, when R. Gill (Wageningen) discussed the effect of particle aggregation both of the fluorescence signal (increased) as well as lifetime decreased).

Assessment of the results and impact of the event on the future direction of the field

Molecular Plasmonics, the field combining the effect of localized surface plasmon resonance with the molecular world, represents a hot field which is expanding and combining with adjacent fields. As the symposium showed again, SERS and fluorescence are the two emerging fields in this area. This probably also due to the fact that both fields are mature in itself, and have therefore an established set of methods as well as theories. Still bioanalytical applications are considered as the most probable (and fastest) possibility to commercialize the studied effects. Therefore, robuste detection and highly defined but also cost-efficient fabrication techniques are required, and will be certainly the subject of growing research in this area.

Jena, 8. July 2013 Dr. Wolfgang Fritzsche