Hybrid responsive polymer-metal materials for plasmonics and biosensor applications

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Aims

This interdisciplinary project aims at development of new nanomaterials with actively tunable plasmonic characteristics. Particularly, responsive hydrogel materials will be combined with metallic nanoparticles by using nanopen and nanoimprint lithography. The optical characteristics of prepared materials (spectrum of surface plasmon resonances, profile of surface plasmon-enhanced electromagnetic field intensity) will be tuned by controlled swelling / collapsing of hydrogel component which will be observed by various spectroscopies. Different trigger mechanisms, including rapid temperature modulation for thermo-responsive hydrogels, will be considered. The hydrogel component will be functionalized by biomolecular recognition elements for specific capture of target analyte in the structure. The implementation of developed materials to biosensor applications for sensitive detection of molecular analytes will be carried out based on plasmon-enhanced fluorescence and surface-enhanced Raman spectroscopy methods. These methods will be applied for the analysis of trace amounts of low molecular weight analytes (e.g. hormones or drugs) or medium size molecules (e.g. detection of methylated DNA) that are relevant to medical diagnostics where new tools for the ultrasensitive and rapid molecular analysis are urgently needed.

Background

Plasmonics represents a rapidly growing research field having an increasing impact in numerous fields embracing life sciences [1], analytical technologies [2, 3], photovoltaics [4] and signal processing [5]. It takes advantages of highly confined and intense electromagnetic field of surface plasmons that originate from charge density oscillations at surfaces of metallic surfaces. Particularly, plasmonics plays an important role in the development of rapid biosensors for detection of biological and chemical analytes by using direct (label-free) surface plasmon resonance (SPR) [2, 3], plasmon-enhanced fluorescence (PEF) [6] and surface-enhanced Raman spectroscopy (SERS). These research fields are driven by the needs in important areas such as medical diagnostics and food safety for advancing the sensitivity and speed of currently sued analytical technologies [6, 7].

For the analysis of molecular analytes, target molecules contained in a liquid sample are brought in contact with biomolecular recognition elements (such as antibodies) that are tethered to a metallic surface. The specific capture of the analyte on the surface is probed by resonantly excited surface plasmons and detected from binding induced refractive index changes (SPR), by measuring of fluorescence light (PEF) or from the Raman spectrum (SERS). PEF schemes allow i) enhancing the fluorescence signal through the excitation and emission via strongly confined plasmon fields [8] and ii) improving the photo-stability of fluorophores through decreasing the fluorophore lifetime [9]. PEF was exploited by using propagating SPs in a method referred to as surface plasmon fluorescence spectroscopy (SPFS). This method was a subject to extensive research in Dostalek group at AIT laboratory where it was implemented in biosensors for detection of analytes at as low as femto- molar concentrations [10, 11]. SERS benefits from strong enhancement of electromagnetic field intensity that is accompanied by the excitation of localized surface plasmons on metallic nanostructures and it is among core topics of Li's at NTU [12].

In majority of applications, plasmonic devices are based on a design with fixed characteristics (passive components). In addition, slow diffusion-driven mass transfer of analyte to the sensor surface is employed on virtually all plasmonic detection schemes. In this project, this limitation will be addressed by hybrid plasmonic materials composed of metallic (nano)structures supporting LSPs and responsive hydrogel materials functionalized with catcher molecules. This schemes will be employed for rapid actuating of surface plasmon resonance (e.g. for tuning the surface plasmon resonance and associate field enhancement profiles) and for active analyte collecting on the metallic surface that is subsequently probed with intense surface plasmon fields.

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