NANO-STRUCTURED PLASMONIC SENSORS AND DEVICES

Nano-structured plasmonic metals have been extensively researched for advances in plasmonic sensors and various optical devices. Nano-structured plasmonic metals enable the excitation of hybrid surface plasmons, which consist of both localized as well as propagation surface plasmons. Localized surface plasmon based devices can be used to detect a local change in the surrounding medium. Nano-structured plasmonic metals enable us to use the coupling technologies of the propagating surface plasmon polariton as well as detection capabilities of the localized surface plasmons.

A surface plasmon resonance sensing and imaging platform based on plasmonic non-uniform nano-gratings with narrow groove is presented. When the localized refractive index of the medium around the gold layer present in these nano-gratings is changed, theoretical analysis is used to numerically compute reflectance and differential reflectance signals. The binding of biomolecules to the gold layer will cause a change in the localized refractive index. Finite difference time domain modeling is used to investigate plasmonic non-uniform nano-gratings. These plasmonic non-uniform nano-gratings provide very high differential reflectance amplitude values.

We also present a theoretical study of the various nano-structured plasmonic sensor chips investigated utilizing the Kretschmann configuration for highly sensitive localized sensing with high tunability from visible to infrared wavelengths. The proposed nano-structured sensor chips are analyzed, and their sensing capability is compared using the rigorous coupled-wave analysis method. The sensitivity parameters are defined to focus on the detection of a thin layer of biomolecules on the surface of nano-structures. Shifts in the reflectivity minima are determined to obtain information on perturbations in localized (local binding analyte layer sensing) and bulk refractive index (bulk medium sensing) on the sensor surface. The dimensions of the nano-structures and the incident angle shift the plasmon resonance wavelengths and can be used to tune the operating wavelength. The nano-structured films create local regions of high electric fields, which results in enhanced sensitivity of the proposed structures. We have then introduced a spacer between the nano-structures and thin film to further enhance the localized sensitivity. The proposed sensors do not require any sophisticated optical set-ups and can be implemented on the optical setups used for the conventional Kretschmann configuration-based sensors. The proposed sensor design could easily be fabricated using the state-of-the-art top-down nanofabrication approaches and could be employed for developing highly sensitive biosensing platforms. The proposed sensors can be used in surface plasmon resonance imaging (SPRi) to detect multiple biomolecules in a single measurement.

The capability of plasmonic nano-structures to detect localized changes in the surrounding medium is also utilized to design a plasmonic switch. We present plasmonic switches — based on gold nanoparticles (Au NPs) embedded between layers of VO_2 films. Vanadium dioxide (VO_2) undergoes a reversible phase change, from semiconducting to metallic, with a change in temperature. The operating wavelength of the switching device can be tuned between 650 nm and 1000 nm using the localized surface plasmon resonance (LSPR) properties of the Au NPs. We also demonstrate experimentally and theoretically a higher switchability — i.e. a higher extinction ratio upon phase transition of VO_2 — than what has been shown earlier in the spectral regions less than 1000 nm. All the device layers were grown at the same substrate temperature and laser intensity in a single vacuum PLD process, leading to a simplified large-area fabrication process.