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Biosensors Based on Plasmonics

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Abstract

Because of the sensitivity to refractive index changes, plasmonics nanostructures have been investigated broadly for the bio-molecules detection through the excitations of the propagating surface plasmon resonance (PSPR) or localized surface plasmon resonance (LSPR). PSPR sensors can detect sub-monolayer quantities of bio-molecules at the gold film surface and provide real-time data through continuous optical measurements. LSPR sensors could be more sensitive to local refractive index changes and the factors of nanoparticle material, shape and size are all interrelated and contribute to the refractive index sensitivities.

Keywords: PSPR sensors; LSPR sensors; Refractive index sensitivities; Bio-molecules detection

Introduction

Noble metal nanostructures display specific optical properties that arise from the coupling of incident light to the collective oscillation of the conduction electrons. The propagating surface plasmon resonance (PSPR) on a noble metal plate and localized surface plasmon resonance (LSPR) of a noble metal nanoparticle can be used for ultra-sensitive biosensors because changes in the refractive index near the metal surface cause a pronounced shift of the resonance wavelength [1]. Therefore, the modification (concentration) or absorption (species) of biological molecules on the metal nanostructures surface can be detected in a label-free manner using PSPR or LSPR spectra shifts.

PSPR sensors usually induce SPR on the noble metal surface through an optical prism. Meanwhile, SPR is a powerful surface analytical technique because it can detect sub-monolayer quantities of bio-molecules at the gold film surface and provide real-time data through continuous optical measurements [2]. Over the past years, a myriad of new structures with ever increasing sensitivities have been developed. The circular aperture–groove nanostructures patterned on a gold film can detect multiple binding events, which improves the sensing accuracy and high-throughput applications [3]. The sensitivity of the SPR based biosensor coated by a layer of graphene can be enhanced greatly compared to the conventional SPR biosensors [4]. In addition, PSPR shows a strong dependence on the angles of the incident light, which indicates that we can realize the concrete detection by scanning angles at a certain wavelength. Angular SPR sensors are also the most commonly used because of their wide linear ranges and high refractive index resolution. But for SPR sensors, there is one drawback of lacking a localized sensing volume.

In general, PSPR sensors are more sensitive than LSPR sensors to the changes in the bulk refractive index, i.e. the refractive index of the overall background medium, and LSPR sensors are more sensitive to local (the region near the nanoparticles) refractive index changes just in the vicinity of the nanoparticle because of an enormous enhancement of the optical local field in nanoscale [5]. Thus, LSPR sensors are suitable for bio-molecules, medical, cell research and environmental detection. For instance, if plasmonic nanoparticles are modified or adsorbed with small and subtle antibody molecules, they can work as immunosensors effectively. In addition, LSPR sensors save cost and are suitable for miniaturization, integrated with chips and rapid detection, because they require only a small volume and a simple optical configuration [6]. However, a relatively low sensitivity of LSPR sensors is a main reason to restrict the applications in sensing. It is known to that the sensitivity can be improved by a series of methods.

The vast majority of LSPR sensors have been carried out based on the Au or Ag nanoparticles. Gold is often chosen because of its chemical stability. The Ag particles are more desirable because they have sharper resonances and higher refractive index sensitivity [7]. Especially, in our previous work, we incorporated a suitable amount of gain material in core layer to improve the sensitivity of the gold-shell silica–core nanoparticle for bio-molecular sensors [8]. The gain-assisted sensors have the powerful ability to detect a subtle change in the concentration of its background medium. The particle shape also plays an important role in determining the sensitivity. In particular, it has been shown experimentally and in electromagnetic simulations that particles with sharp features or tips exhibit much higher refractive index sensitivities than that with smooth features [9,10]. For instance, the sensitivity of the nanorods could reach to 262 nm/RIU (refractive index unit), which was a significant improvement compared with that of the nanosphere [11]. And the Au star could obtain as high as 665 nm/RIU for the sensitivity of refractive index [12]. Meanwhile, the sharp tips could be used to increase the sensitivities further by producing a red shift in the plasmon resonance, and the sharp tips would also show an additional advantage for molecular detection at the microscopic level because a sharp tip creates an enormous enhancement of the optical local field. For metal nanoparticles with a given material and shape, the LSPR can be tailored by control of metal size in nanoscale, because the particle size has an important effect on the plasmon resonance wavelength, strength of the scattering cross-section and absorption and line width [13].

In conclusion, PSPR and LSPR sensors play a critical role in chemical and biological sensing technology. PSPR sensors can detect sub-monolayer quantities of analytes at the gold film surface. LSPR sensors could be more sensitive to local refractive index changes and are suitable for miniaturization, integrated with chips and rapid detection.

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