2-4-3. Surface Plasmon Resonance Sensor

Outline

Surface Plasmon Resonance (SPR) is formed by coupling between the incident light and plasmon polariton on the thin metal film and the metal nanoparticle under the resonance condition, which changes by the refractive index (dielectric constant) or the film thickness of materials adsorbed on the metal surface. Therefore, by measuring the resonance wavelength and resonance angle, SPR can quantitatively detect the binding molecules as a non-labeled solid/liquid interface sensor. Furthermore, using the property that the SPR field corresponds to the enhanced electric field, SPR has been developed to the surface enhanced Raman spectroscopy, the surface enhanced fluorescence spectroscopy, and so on. Recently, SPR is applied to the detection of chiral molecules and the control of the excited state or the chemical reaction by the plasmon-electronic strong coupling, and further development is expected.

Current Status and Frontiers

SPR was discovered as an interface phenomena for metal nanoparticles or thin metal films in early 20 century, and the studies in physics were developed.[1] In the late 1990s, Biacore as the solid/liquid interface sensor for detecting biomolecules was expanded to the fields of biology and chemistry. Biacore is based on the propagated SPR, and the resonance condition of plasmon polaritons on the thin metal film depends on the refractive index (dielectric constant) or film thickness of materials adsorbed to the metal surface. By measuring the resonance wavelength and resonance angle, SPR can quantitatively detect the binding molecules. SPR is one of the popular methods as non-labeled detection method, but the enhanced electric field of SPR-field was applied to the surface enhanced Raman spectroscopy (SERS) and surface enhanced fluorescence spectroscopy (SPF).

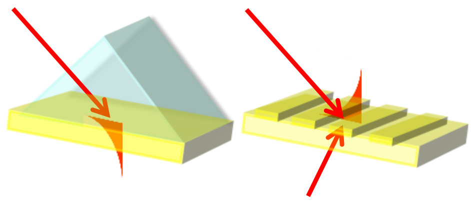

Figure 1. SPR sensor: (a) prism-coupling method, (b) grating-coupled method.

SPR is classified to the propagated SPR on the thin metal film and the localized SPR (LSPR) on the nanoparticles. In the point of the enhanced electric field intensity, LSPR has large advantages.[2] More than10^4-fold electric field formed in the nano-gap less than 1 nm between the metal nanoparticles was applied to SERS and molecules were sensitively detected. On the other hand, due to the quench of fluorescence by Főrster energy transfer to a metal surface, a metal surface with the most enhanced intensity cannot be utilized for fluorescence detection and therefore, the propagated SPR with 200 nm-decay length is advantageous. Representative optical system of SPF using this propagated-SPR is prism coupling,[3] grating coupling,[1,4] and fiber coupling methods. They are based on the evanescent wave at the bottom surface, the diffraction light on the wavelength-sized grating, and the evanescent light at total reflection in the fiber. The grating pattern in the grating-coupled SPR was developed to the concentric circle called Bull's eye as shown in Fig. 2. In the center of Bull's eye, significantly large electric field is formed.[5] Plasmonic device of Bull's eye pattern shows a powerful effect with optical microscope, e.g., extracellular vesicle with 100 nm-diameter secreted from cells was sensitively detected as a single exosome.[6] Further antenna effect in the Bull's eye is considered as an optical device.

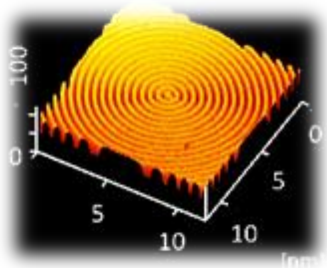

Figure 2. AFM image of a Bull's eye pattern.

Recently, SPR is applied to the detection of chiral molecules and the control of the excited state or the chemical reaction by the plasmon-electronic strong coupling, and further development is expected.

References

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Future Perspectives and Directions

Key challenges to be addressed within the next decade include: Single molecule detection device including highly sensitive optical device utilizing antenna effect, Control of the chemical reaction by the plasmon-electronic super-strong coupling and the clarification of its mechanism.

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