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Surface plasmons resonance detection based on the attenuated total reflection geometry

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Abstract

The conventional surface plasmons resonance (SPR) detection and the improved SPR detection were investigated, which were both based on the attenuated total reflection (ATR) geometry. The conventional detection system on Kretschmann configuration, can detect the dielectric constant changes of the medium near a metal film's surface by measuring the intensity changes of the reflected beam. The improved SPR detection in a prism-multilayer configuration, which formed the long-range surface plasmon polaritons (SPPs) mode, provided the substantial improvement of the sensitivity and contrast of the detection over the conventional method that is of great benefit to the applications in various fields.

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Keyword: Surface plasmons resonance (SPR); ATR geometry; long-range surface plasmon polaritons (SPPs)

1. Introduction

SPR detection as a new detection technology has already found diverse applications, and new applications are emerging rapidly in the area of biomolecular detection, biomedicine science, all-optical devices, due to their advantages in high sensitivity, label-free and real-time detection [1-4]. SPR is a surface sensitive spectroscopy technique, which has become a well-accepted analytical method for monitoring interfacial phenomena for many years [5]. In the ATR geometry, SPR occur when a light beam incident a metal film at a resonance angle, whose sensitivities to the variation of the refractive index of the adjacent medium and the film thickness are due to the excitation of SPPs on the metal-dielectric interface. The SPPs are electromagnetic modes that arise from the interaction between light and mobile surface charges, typically the conduction electrons in metals. In the early 1980s, it was first predicted and then demonstrated that in a thin metal film, imbedded between two identical dielectrics, a long-range SPPs mode may appear as a result of a coupling between SPPs from both film interfaces, whose propagation loss decreases with the decrease of the film thickness [6,7]. Their strong surface confinement and near-field enhancement make them attractive and being widely applied in many fields, especially in the detection area

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[8,9]. In the paper, we demonstrate two different SPR detection systems. In conventional one, the dielectric constant changes of the medium is detected by observing the reflected light intensity. The improved SPR detection is based on a prism-multilayer configuration, which excite the long-range SPPs. In comparison with the conventional one, the improved one shows sharper resonance peak, higher sensitivity and narrower half width.

2. The conventional SPR detection

The experimental setup of conventional SPR on Kretschmann configuration is shown in Fig.1. An Au thin film was coated on a BK7 prism ($n = 1.8$). A probe beam of a semiconductor 650nm laser incidented on a prism-metallic film interface, and the reflected beam was monitored by a photodetector as a function of incident angle.

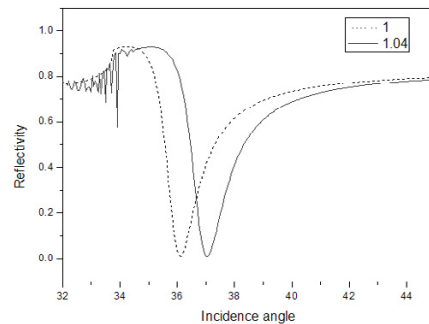
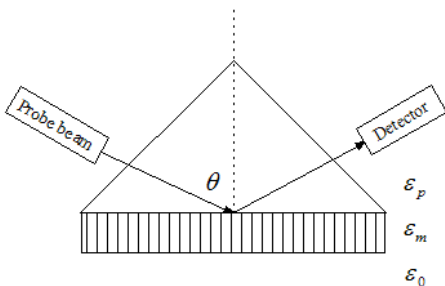


Fig.1 Schematic representation of a conventional SPR detection

Fig.2 Incidence angle dependences of measured reflectance of a BK7 prism with an Au thin film (50nm)

In the ATR geometry, SPR occur when the component of the wave vector of the probe beam parallel to the surface matches the propagation vector of surface plasmon wave (SPW). The angle for SPW modes can be theoretically described as [10,11]:

$$\theta = \sin^{-1} \left[\frac{1}{n_p} \left(\frac{\epsilon_m \epsilon_0}{\epsilon_m + \epsilon_0} \right)^{1/2} \right] \tag{1}$$

Where n_p is the index of the prism, ϵ_m is the the real part of the dielectric constant of the Au layer, and ϵ_0 is the dielectric constant of adjacent medium. When the light beam incident on the metal film at the resonance angle, the light will get coupled into the metal film, giving rise to local minima in the reflectivity curve that is called SPR peak. When all else is kept constant the angle of the resonance phenomenon is dependent on the refractive index of the media close to the metal surface. Changes in this dielectric constant can then be characterized by monitoring the reflected light intensity, which is the operating principle of the conventional SPR detection.

Fig 2 shows the reflectance as a function of incidence angle θ . The entire reflectivity curves were analyzed by a theoretical method. Under the condition of adjacent medium $\epsilon_0 = 1$, as the incident angle approaches the SPR angle of 36.08° , the electric field will get coupled into the surface plasmons mode. The reflectance dip shows the SPR spectra, whose half width is about 1.665° . When the dielectric constant of adjacent medium have changes of 0.04 and above, the SPR angle is shifted to 37.07° . Thus at the same incident angle of 36.08° , the reflected intensity monitored by the photodetector is increased from 0.0124 to 0.7843. The detection contrast is 0.857. The conventional SPR detection have some limitation in detection sensitivity and contrast, so the new struction SPR detection as the key of the development of SPR detection has attracted much interest.

3. The improved SPR detection

The improved SPR detection was based on a prism-multilayer configuration. The proposed structure consisted of 1500nm SiO₂ film, 50nm Au thin film and 1500nm SiO₂ film. Long range SPPs modes can be achieved with an Au thin film surrounded by an index-matched SiO₂.

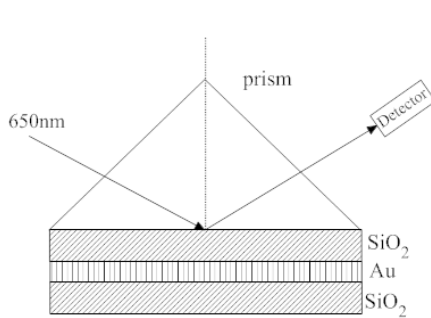


Fig.3 Schematic representation of a conventional SPR detection.

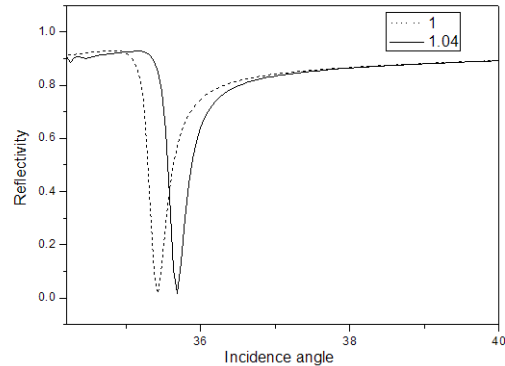


Fig.4 Incident angle dependences of measured reflectance of a BK7 prism-multilayer configuration.

The incident angle is set to the SPR angle 35.432° . A coupling of the surface plasmons mode excited on the upper and lower Au film-SiO₂ interface form the long-range SPPs modes, which have a little loss in the Au thin film, so this structure detection have a higher sensitivity and accuracy than the conventional one. The 0.04 changes in the dielectric constant of the adjacement medium close to the SiO₂ film were kept the same as the one in the conventional detection. The resonance peak is shifted from 35.432° to 35.687° , thus enabling us to monitor the change of reflected intensity from 0.0168 to 0.851. The detection contrast is 0.98 that is about 1.14 times than one of the conventional detection. The half width is 0.32° which is about twenty percent of that of the conventional detection. Therefore, the advantages of the improved SPR detection as opposed of the conventional one are sharper resonance peak, narrower half width and the enhancement of the sensitivity, the contrast, and the efficiency of the detection.

4. Conclusion

Two different SPR detections on the attenuated total reflection(ATR) geometry were demonstrated in detail. The improved SPR detection of a prism-multilayer configuration have some advantages of higher contrast, sensitivity and accuracy in comparison of the conventional detection, which was due to the long-range SPP mode excited. When the dielectric constant of the adjacement medium have 0.04 changes, the improved SPR detection can monitor it by measuring the change of the reflected beam intensity. And the detection contrast was 0.98 which was increased about 1.14 times than one of the conventional detection. The half width of 0.32° was about eighty percent narrower than the one of the conventional detection.

5. Acknowledgments

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