Considering the Origin of Surface Plasmon Polaritons for a Surface Plasmon Sensor with 1D Metal Grating Structure and Characterization of Sensitivity

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1. Introduction

Surface plasmon resonance (SPR) is widely used in applications such as the detection of infinitesimal materials and high-efficiency photoelectric conversion. For a target medium with a high refractive index (n > 1.5), total reflection generally becomes impossible owing to a limitation in the incidence angle of light; therefore, such a medium cannot be detected. For this problem, we focused on a method that uses a diffraction grating as the structure of the sensor. With this method, a metal diffraction grating is used instead of a thin metal film, and the resonance is caused by the diffraction of light. Because the diffraction grating method does not use total reflection, the limitation on the incidence angle is relaxed. An additional advantage of this method is the flexibility it enables in changing the detection range and excitation angle by modifying the period and duty ratio of the grating. We experimentally demonstrated the detection of a high refractive index medium (n = 1.546–1.700) using surface plasmon sensors for the first time [1].

In this study, theoretical consideration was done using transmittance mapping calculated by the rigorous coupled-wave analysis (RCWA) method and our experimental data. In addition, we considered the applicability to the sensor and estimated figure of merit (FOM) experimentally.

2. Simulation and Experiments

Simulation and experimental results of the transmittance

The dependence of transmittance and reflectance on the incidence angle was characterized using a red-light laser (λ = 635 nm). The simulation was performed through the RCWA method. In the simulation, the angle spectra of transmittance and reflectance as well as a transmittance mapping for the incident angle and period were created. We attempted to detect a mixed solution of 1-iodonaphthalene and sulfur (n = 1.700). Figure 1 shows the incidence angle spectra of transmittance for a medium with periods of 500 and 300 nm. In the 500-nm case with sulfur, transmittance peaks occurred in the angular spectrum at 7.15° and 17.35°. For a medium, the angle corresponding to a dip in reflectance is the same as that cor responding to a peak in transmittance. In the 300-nm case with sulfur, the peaks occur at 16.60° and 27.35°. The two types of transmittance peaks in these spectra are assumed to occur because there are two different modes for exciting SPPs. The similar results are obtained by the experiment. From the distribution of the magnetic field and transmittance mapping, one is excited at the interface between Au and medium and the other is excited at the interface between Au and air.

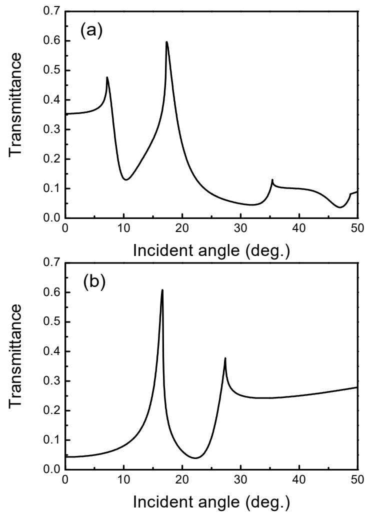

Figure 1 Simulation results for transmittance as a function of incidence angle for a mixed solution of 1-iodonaphthalene and sulfur. Grid periods of (a) 500 nm and (b) 300 nm.

The sensitivity and figure of merit for the sensor

We calculated the sensitivity and FOM, which is an index of sensor performance. The experimental results obtained over a period of 300 nm displayed a sensitivity of 47.77 °/RIU and an FOM of 36.89 /RIU.

3. Conclusions

Theoretical consideration was performed using transmittance mapping calculated via the RCWA method and our experimental data. In addition, we considered the applicability of this technique to the sensor and estimated the FOM. The SPPs are excited to two types of interfaces, such as Au-glass substrate and Au-medium. The sensor properties were characterized. The sensor was found to have a considerably high FOM value (~40) when the period of of the 1D metal grating was 300nm.

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References

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