Sensing Properties and Sensitivity Improvement of an Asymmetric Waveguide withDispersive Left-handed Material

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ABSTRACT

Optical sensors supporting resonant phenomena have been extensively employed for characterizing surface effects manifested in the vicinity of a metallic layer and a dielectric of opposite permittivities. To get appreciable sensing performance in terms of detection accuracy and resolution highly required in various applications such as biochemical and gas sensing, various plasmonic materials were proposed in the literature. Importantly, the proper responses of possible arrangements between active layers and dielectric media when stimulated with an external incident light differ on the field profiles, energy distribution and dispersion properties. As to this, owing to their unique properties, black phosphorous, graphene and molybdenum disulfide (MoS2) mediated silver or gold regarded as multilayer sensors, were functionalized and implemented for sensing applications. In this contribution, an asymmetric waveguide including gold (Au), left-handed material (LHM) layers and an outer medium, was designed and numerically investigated, under plane wave irradiation as a function of the incidence angle and of the polarization. The proposed configuration as schematically illustrated in Fig. 1, is a four layered media stacked along z-direction. Gold layer of thickness, d_2 is placed in contact between a sensing environment of refractive index, n_c and a left-handed material (LHM) of thickness, d_1. The above media are coated on the base of a chalcogenide (2S2G) glass-substrate having a RI, n_p. The refractive index of the a left-handed material (LHM) n_{LHM} is given by $n_{LHM} = -\sqrt{\varepsilon_{LHM} \times \mu_{LHM}}$ and we chose the experimental values of the dielectric permittivity and magnetic permeability: $\varepsilon_{LHM} = -33.5$, $\mu_{LHM} = -11$ respectively [1].

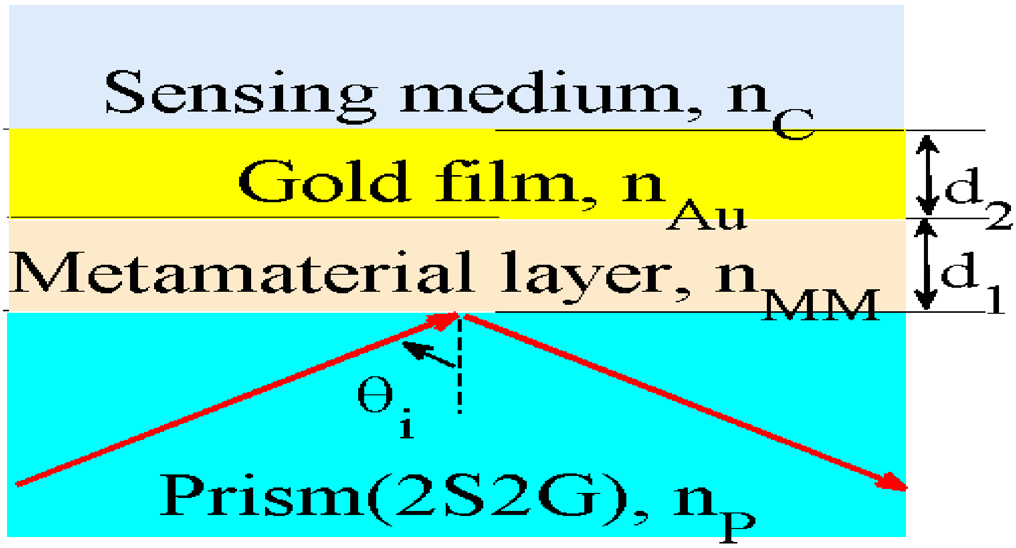

Fig.1: Schematic diagram of proposed SPR

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Furthermore, we also investigate the effect of sensing environment RI, n_c on p-reflectance curve in the previous conditions. As shown in Fig. 2 , when RI increases from 1.32 to 1.34, resonance condition shifts gradually from 36.15° to 36.84°.

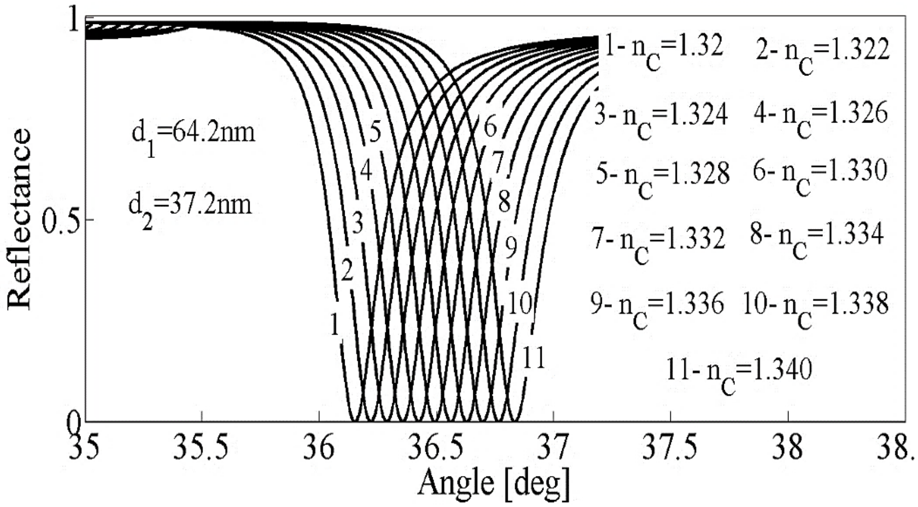

Fig. 2 Change of the reflectance spectra as a function of the incidence angle for the multilayered structure Metamaterial (64.2nm)/Au (37.2nm)/Sensing medium with increasing refractive index of inner gap, n_s from 1.320 to 1.340

As such, a small fluctuation in the RI of sensing environment reflects, how precisely the sensor detects the resonance condition and its shift, this value allows the determination of resulting sensitivity, $S_\theta = \partial\theta_{SPR} / \partial n_S$ [2] and Figure of merit is $FoM = S_\theta / FWHM$ [3]. Angular resonance a linear change between the refractive index of the medium to be sensitive as follows:

$$\theta_{SPR} = 34.364 \times n_S - 9.21 \pm 0.00874$$

According to this significant effect induced on SPR mode, angular sensitivity and figure of merit for the designed sensor can be evaluated as $S_\theta = 34.364$ and $FoM = 137.46$ respectively. It is matter in fact that, if the approach is used for sensing aqueous solution whose RI is close to the one of water, the closest accuracy value could be within thousandths of the reference index, hence rendering it a highly sensitive optical sensor.

Keywords: Asymmetric Waveguide, Biosensing, Left-Handed Material, Sensitivity, Sensing Characteristics.

References

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