Surface-plasmon wave at a planar metal-chiral interface

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Abstract: The theoretical study of a surface-plasmon wave at a planar metal-chiral interface is presented in this communication. It is found that a surface-plasmon wave can be excited at the planar interface of a thin metal film and a structurally dielectric chiral medium, if the exciting plane wave is P-polarized.

Surface-plasmon polariton (SPP), which is a quantum of collective electron oscillations resonantly excited by the light[1] at metal-dielectric interface, has been extensively studied for many years. The fields are strong at the interface and die off exponentially as evanescent fields on either side. It is one of the promising optical techniques that find several applications in optical devices, chemical and biological sensors, surface enhance spectroscopies, subwavelength lithography, optoelectronic devices, etc[2]. The coupling of light to the surface-plasmon mode is often done via the evanescent wave generated by the total internal reflection from a high index medium or by scattering using a structured surface.

Chiral sculptured thin films (CSTFs), made of helicoidally shaped nanowires oriented perpendicular to the surface of the film, are optically anisotropy, porous, and nonhomogeneous in the thickness direction. Glancing angle deposition (GLAD), an advanced technique for fabricating designed microstructures at nanometer scale, is used to fabricate the CSTFs. The porosity of the CSTF may offer a medium in which to embed analyte and/or recognition molecules to which the analyte may bind. Because of its porosity and the ability to engineer the microstructures of the dielectric material, the metal-chiral interface may be more attractive than traditional methods of producing SPPs.

The theoretical study and numerical calculations are performed based on a modified Kretschmann configuration which is first proposed by A. Lakhtakia[3]. In this configuration, the bulk metal is in the form of a thin film of uniform thickness, bounded by dielectric mediums on both sides, one medium is being optically denser than the other. A plane wave of P-polarized is lunched in the optically denser dielectric medium towards the metal film, in order to excite a surface-plasmon wave at the interface of the metal with the optically rarer dielectric medium. All numerical calculations of reflectances, transmittances, and absorbances at the free space wavelength $\lambda_0 = 633$ nm are completed as functions of incident angle, θ. The following parameters of structurally chiral medium are used: $\varepsilon_a = 2.7$, $\varepsilon_b = 3.0$, $\varepsilon_c = 2.72$, $\chi = 30°$, $\Omega = 200$ nm, and $h = +1$. The relative permittivity of the incident medium is chosen to be $\varepsilon_l = 5$ and that of the silver as $\varepsilon_{ag} = -16.40+i0.5427$.

Fig. 1 shows the reflectances, tranmittances, and absorbance as function of the incident angle, θ with 1 period thickness of chiral medium. The incident plane wave is P-polarized light and the thickness of the silver film is 0 nm, 40 nm, 50 nm, and 60 nm. A rapid increase in the absorbance indicates the excitation of a surface-plasmon wave. The maximum absorbance value is found 0.802 at an angle of 54°, when the silver film thickness is 50 nm.

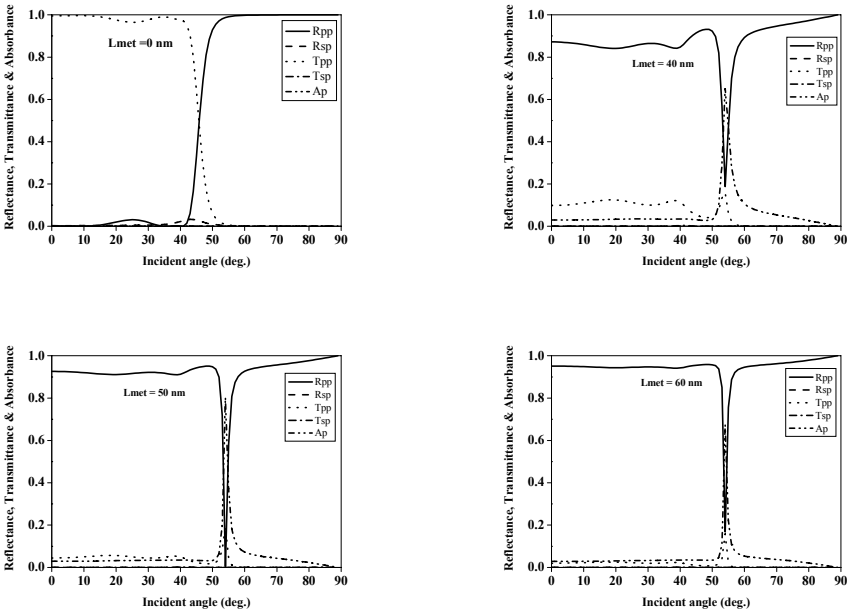

Fig. 1. Reflectances, Transmittances, and Absorbance as a function of incident angle, θ. The incident plane wave is P-polarized.

The variations of the reflectances, transmittances, and the absorbance with the incident angle, θ for the incident plane wave of S-polarized are illustrated in fig.2. In this calculation, the structurally chiral medium is also 1 period thick and that of the silver film is 50 nm. It is clear that the excitation of a surface-plasmon wave is absent from this figure.

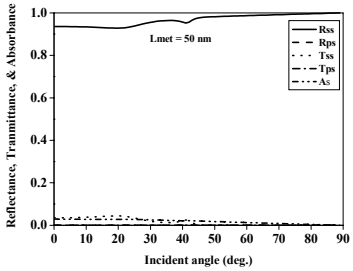

Fig. 2. Reflectances, Transmittances, and Absorbance as a function of incident angle, θ. The incident plane wave is S-polarized.

Therefore, the solution of a boundary value problem formulated for a modified Kretschmann configuration shows that a surface-plasmon wave can be excited at the planar interface of a silver thin film and a non-dissipative structurally chiral medium, if the incident plane wave is P-polarized.

References

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2. P. L. Rochon and L. Levesque, Optics express, 14 (2006) 13051.
3. A. Lakhtakia, Optics commun, 279 (2007) 291.