Surface Plasmon Resonance Based Sensors

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Abstract

Surface plasmons which we know as quanta of collective charge density oscillations in free delocalized electrons throughout to dielectric-metallic interface, offer wide range developments in photonics and nanoscience such as sensing, detecting, optical storage, subwavelength applications and lithography in nano scale.
In this project, theoretical background of surface plasmons and SPR-based sensors has been deeply covered.Also, essential performance characteristics of SPR Sensors have been investigated with numerical simulation in python.

Introduction

Exciting surface plasmon needs to delocalized electron which consist in solid metals.Oscillation of electrons generate electromagnetic surface wave in surfaces.Due to propagating along the metal-dielectric interface,exiting Surface plasmons can be studied according to solution of p-polarized wave with Maxwell's Equations[1].

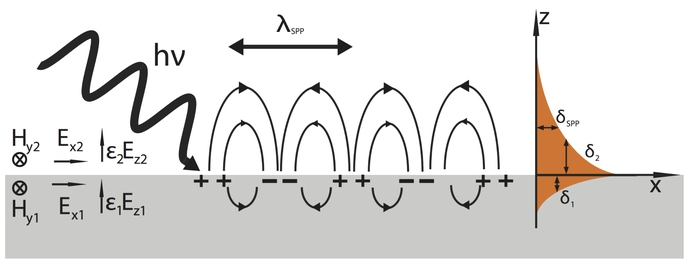

Figure 1: Schematic Representation Surface Plasmon Polariton

To excite SP,frequency and momentum of incident photon and SP must be match.For exciting mainly two different methods used: Prism Coupling and Grating Coupling.
Surface Plasmon Resonance occurs the when these fully match and also depends on the some characteristics of materials like thickness, dielectricity etc. that changes the refractive index.[2] The main principle of SPR based sensors construct on this changing.

7. References

[1] J M Pitarke, V M Silkin, E V Chulkov, and P M Echenique. Theory of surface plasmons and surface-plasmon polaritons. *Reports on Progress in Physics*, 70(1):1–87, 2006.

[2] Jirí Homola. *Surface Plasmon Resonance Based Sensors*. Springer, 2008.

[3] Elton B. Costa, Eloise P. Rodrigues, and Helder A. Pereira. Sim-SPR: an Open-Source Surface Plasmon Resonance Simulator for Academic and Industrial Purposes. *Plasmonics*, 14(6):1699–1709, 2019.

[4] Sookyoung Roh, Taerin Chung, and Byoungho Lee. Overview of the Characteristics of Micro- and Nano-Structured Surface Plasmon Resonance Sensors. *Sensors*, 11(2):1565–1588, 2011.

Methods

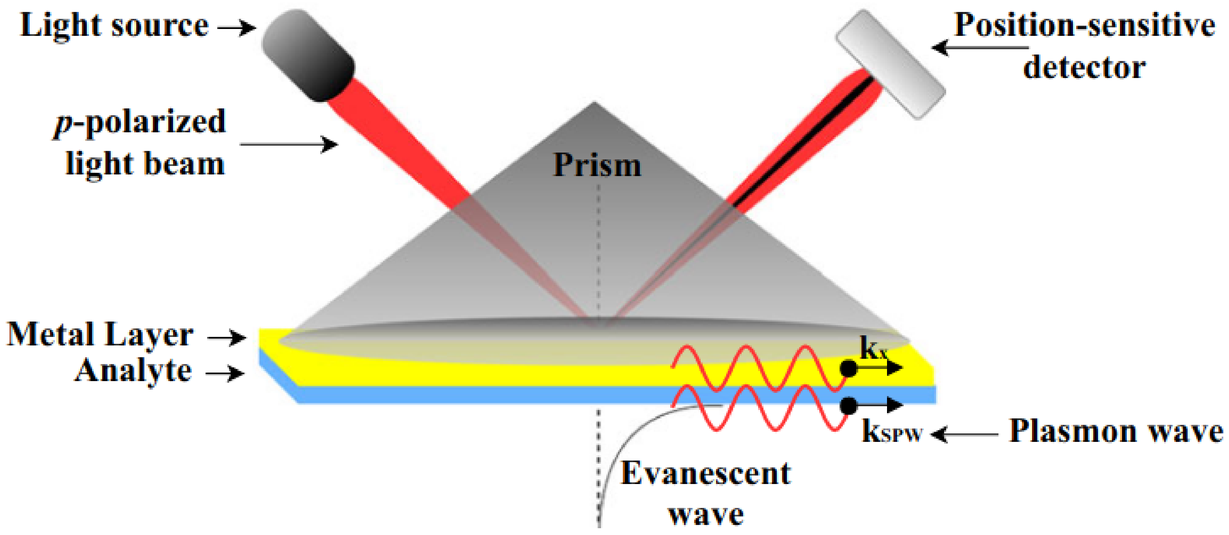

Figure 2: Schematic Representation Kretschmann Configuration(Prism Coupling)[3]

$$k_{spw} = (\frac{\omega}{c})\sqrt{\frac{\varepsilon_m(\omega)\varepsilon_d}{\varepsilon_m(\omega)+\varepsilon_d}} \tag{1}$$

In prism-metal-air layers systems (Kretschmann configurations) we can calculate Reflectivity in SPR with deriving Fresnell's Equations :

$$R_{p12} = \left|r^p_{p12}\right|^2 = \frac{r_{p1} + r_{12}e^{2ik_z d_1}}{1 + r_{p1}r_{12}e^{2ik_z d_1}} \tag{2}$$

$$r_{ik} = \frac{(\tilde{\varepsilon_i} - n_p^2 sin^2\theta)^{1/2}/\tilde{\varepsilon_i} - (\tilde{\varepsilon_k} - n_p^2 sin^2\theta)^{1/2}/\tilde{\varepsilon_k}}{(\tilde{\varepsilon_i} - n_p^2 sin^2\theta)^{1/2}/\tilde{\varepsilon_i} + (\tilde{\varepsilon_k} - n_p^2 sin^2\theta)^{1/2}/\tilde{\varepsilon_k}} \tag{3}$$

Our code is written in python to get the SPR curve. We also used Sim-SPR and Winspall open source program to analyze the SPR.

Results

Firstly we calculate the numerical reflectance values of configuration for detecting SPR angle
(1) $n_{SF10} = 1.723$, $d_{gold} = 50nm$, $n_{gold} = 0.1726 + i3.4218$,$n_{air} = 1$, $\lambda = 633nm$
(2) $n_{BK7} = 1.51$, $d_{gold} = 50nm$, $n_{gold} = 0.1726 + i3.4218$,$n_{air} = 1$, $\lambda = 633nm$
(3) $n_{SiO} = 1.45$, $d_{gold} = 50nm$, $n_{gold} = 0.1726 + i3.4218$,$n_{air} = 1$, $\lambda = 633nm$

Configuration	θ_{SPR} - Our Simulation
(1)	57.8
(2)	73.09

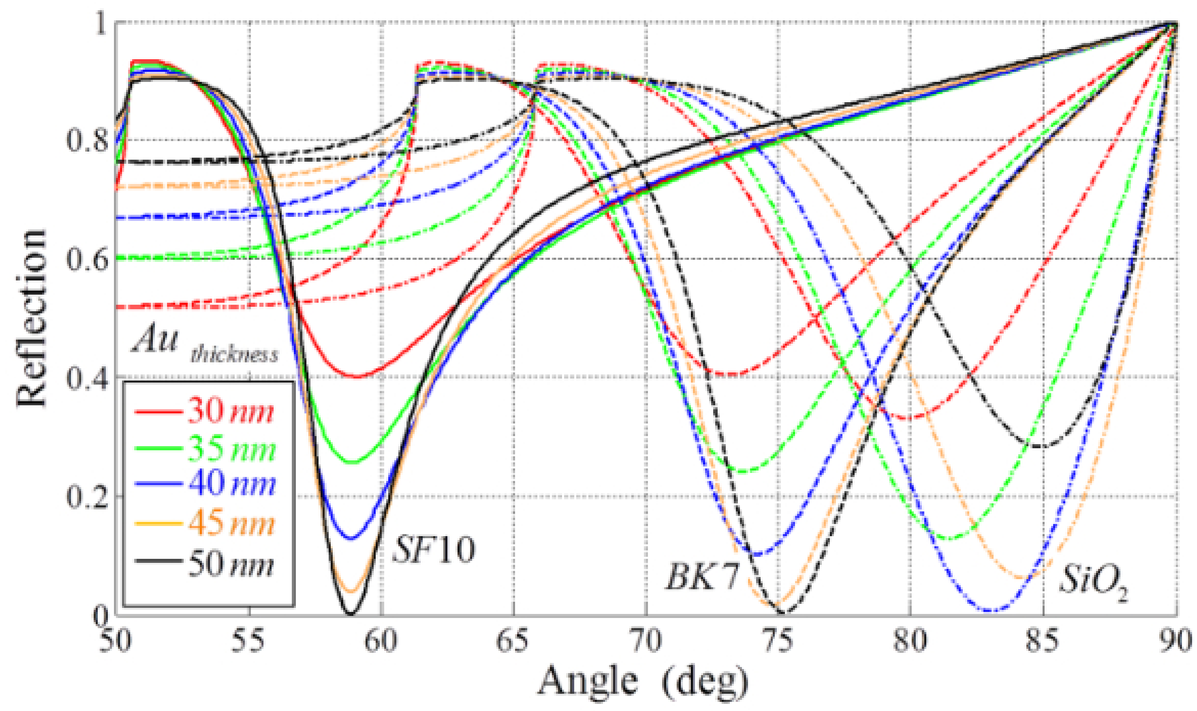

Figure 3: SPR curve with different thickness of the Au metal layer and different prism layers. Retrieved from[4]

6. Conclusions & Discussions

Consequently,in this project we studied the surface plasmons and main characteristics of SPR based sensor.We assume that sensor configuration is depends on thickness of metal,refractive index of prism under the constant wavelength
In future studies, we can use FDTD simulation for comparing to numerical and experimental values and also getting more accurate results.