Supporting Information

Ultrasensitive Fano Resonance Biosensor Using Two Dimensional Hexagonal Boron Nitride Nanosheets: Theoretical Analysis

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Determination of Reflectance and Sensitivity

In this study, we proposed a sensitive FR biosensor designed by phase modulation. The differential phase between p-polarized and s-polarized light can be given as,

$$\phi_d = \left|\phi_p - \phi_s\right| \tag{1}$$

In addition, the phase (ϕ_p) of p-polarized light can be obtained as,

$$\phi_p = \arg\left(r_p\right) \tag{2}$$

Where r_p is the reflection coefficient, and it can be determined by Fresnel's equation and Snell's law,

$$r_p = \frac{E_{rp}}{E_{ip}} = \frac{n_t \cos\theta_i - n_i \cos\theta_t}{n_t \cos\theta_i + n_i \cos\theta_t}, n_i \sin\theta_i = n_t \sin\theta_t \tag{3}$$

where n_i and n_t are the refractive index of different mediums at the interface.

Next, we employed the transfer matrix method to study the phase and reflectivity changes in our proposed configuration. All the layers are assumed to stack alone in the z-direction, and each layer is considered to be optically isotropic and non-magnetic. The first boundary of tangential electromagnetic fields was set as $Z = Z_1 = 0$, and the relation of tangential filed between the first boundary and the final boundary $Z = Z_{N-1}$ can be given as,[1-3]

$$\begin{bmatrix} U_1 \\ V_1 \end{bmatrix} = M \begin{bmatrix} U_{N-1} \\ V_{N-1} \end{bmatrix} \tag{4}$$

where U and V are the tangential components of the electric and magnetic fields respectively.

To calculate the total coefficient r_p, the matrix M was defined in equation (5), and k denotes the k-th layer in a Nth layered structure.

$$M = \prod_{k=2}^{N-1} M_k = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} \tag{5}$$

with

$$M_k = \begin{bmatrix} \cos\beta_k & -i\sin\beta_k / q_k \\ -iq_k \sin\beta_k & \cos\beta_k \end{bmatrix} \tag{6}$$

where

$$q_k = \frac{\left(\varepsilon_k - n_{SF11}^2 \sin^2\theta_1\right)^{1/2}}{\varepsilon_k} \tag{7}$$

and

$$\beta_k = \frac{2\pi d_k}{\lambda}\left(\varepsilon_k - n_{SF11}^2 \sin^2\theta_1\right)^{1/2} \tag{8}$$

Here, θ_1 is the incident angle in the first layer, and the λ is the incident wavelength. d_k and ε_k are the thickness of the k-th layer and the dielectric constant, respectively.

Then, the total complex reflection coefficient of the N layer for p-polarized light can be described as follows：

$$r_p = \frac{\left(M_{11} + M_{12}q_N\right)q_1 - \left(M_{21} + M_{22}q_N\right)}{\left(M_{11} + M_{12}q_N\right)q_1 + \left(M_{21} + M_{22}q_N\right)} \tag{9}$$

where q_1 and q_N denote the corresponding relations for the first layer (SF11 prism) and N-th layer. Finally, the reflectivity of the p-polarized light at incident angle θ can be expressed as:

$$R_P = \left|r_p\right|^2 \tag{10}$$

Here, all the above equations are applicable except

$$q_k = \left(\frac{\varepsilon_k}{\mu_k}\right)^{1/2} \cos\theta_k = \left(\varepsilon_k - n_1^2 \sin^2\theta_1\right)^{1/2}$$

For our proposed configuration, the intensity sensitivity can be described as,

$$S_I = \frac{\Delta R_P}{\Delta n} \tag{11}$$

where Δn is the variation in refractive index of sensing interface due to the molecular adsorption behavior Also, the phase sensitivity is defined as:

$$S_p = \frac{\Delta\phi_d}{\Delta n} \tag{12}$$

Similarly, EF of phase detection sensitivity with h-BN-SiO_2-Ag hybrid structure versus that of the SiO_2-Ag hybrid structure can be expressed as,

$$EF = \frac{S_{h-BN-SiO_2-Ag}}{S_{SiO_2-Ag}} \tag{13}$$

References

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