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High performance SPR biosensor using Cu-Pt bimetallic layers and 2D materials

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In this present paper, we propose a surface plasmon resonance(SPR)sensor having better performance parameters based on Kretschmann configuration. The proposed SPR sensor is a modified Kretschmann configuration comprised of BK7 prism-Cu-Pt-Graphene/BP/WS_2. The bimetallic layer provides consistent enhancement of sensitivity over other SPR structures. Extensive numerical analysis based on transfer matrix theory has been performed to characterize the sensor response considering sensitivity, full width at half maxima (FWHM), detection accuracy(DA), quality factor(QF) with other conventional reported SPR sensor. We have also analyzed the electric field intensity enhancement factor(EFIEF) for the proposed SPR sensor. We have found that maximum sensitivity of 309deg/RIU corresponds to the four layer of BP configuration. We believe that this proposed SPR sensor could find the new platform for the chemical examination, medical diagnosis, gas detection and biological detection.

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*Keywords :*Surface plasmon resonance(SPR), Sensitivity, Electric field intensity enhancement Factor(EFIEF), Detection accuracy(DA), Quality factor(QF)

1. Introduction

Surface plasmons are transverse magnetic (TM)-polarized electromagnetic excitations at the metal-dielectric interface with their fields decaying exponentially in metal as well as in the dielectric medium. The SPR sensing technique utilizes the Kretschmann configuration to excite surface plasmon using an evanescent field of P-Polarized light. The most popular configuration for analyzing the SPR technique is the Kretschmann configuration[1-2]. The SPR sensor has been implemented in various fields such as environmental monitoring, chemical compound detection, food sciences , forensic identification, bio sensing and photonic industry[3-5]. Sensitivity is the essential parameter of a SPR biosensor and to enhance the sensitivity using several method to improve the overall performance of the sensors such as air gap, bimetallic layers, 2D materials etc[6-8]. Recently, research work have been done for enhancing the performance of SPR sensor using bimetallic layer. Dyankov et.al., suggested that using bimetallic layer of silver-gold(Ag-Au) to enhance the sensitivity of the SPR biosensor[9]. Chen & Lin reported a bimetallic SPR sensor chips based on Kretschmann configuration, the results shows low FWHM and high sensitivity than the SPR sensor with single silver layer[10]. B. H. Ong et al. analyzed bimetallic Ag-Au film configuration to enhance the high sensitivity surface plasmon resonance sensing and found a sharp resonance FWHM and evanescent field enhancement [11]. Gao C. et al theoretically investigated the performance of SPR sensor with a enhancing prism and bimetallic Ag-Au alloy nanoparticles which may enable many plasmonic applications with high performance, long lifetime and especially for those involving corrosive species[12]. Zynio et.al., investigated a bimetallic layer of Au-Ag for chemical sensors, bimetallic films shows a high shift in resonance angle on changes of

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ambient refraction index and providing a higher signal / noise ratio that enhances the sensitivity of the sensors [13]. Dmitry et al analyzed sensitivity of the SPR sensor that utilizes different double layers of Cr/Au, Ag/Au, Ti/Au, Cu/Au and Al/ Au combinations [14]. Pal et.al reported that implementation of 2D materials such as $Batio_3$ with bi metallic silver layer, the enhanced sensitivity obtained as 280deg/RIU[15]. P. K. Maharana et.al., reported the that optimized bimetallic configuration of (6nm Au and 29nm Al) along with chalcogenide prism, induces the electric field enhancement at the interface of metal-analyte and it is more than 15 times greater and its probing depth is more than 300% longer than that of the gold based BK7 configuration [16]. In the proposed configuration Cu-Pt bimetallic layer is used as active plasmonic metals. Copper posses superior sensitivity and is a considerably less expensive metal than both gold(Au) and silver(Ag) because it can produce a very sharp resonance curve and it has the ability to absorb light due to inter-band transition as gold. Cu oxidizes much easily, lacks its attraction as a plasmonic material [17-18]. Recently S. Singh et al. suggested that the oxidization problem of Cu can be avoided by suitable oxide coatings such as TiO_2, SiO_2 and SnO_2 [19].Sharma et al. reported that utilizing a thin layer of Platinum (Pt) over copper can reduce the oxidation problem and enhance the sensitivity of the SPR sensor [20]. Recently, Rifat et al. suggested that coating of graphene on Cu prevents oxidation and enhances its durability [21]. Platinum(Pt) is widely involved metal in various research areas because of its high reflecting property, inert, chemically stable with high melting point, and prolonged stability. [22]. Shukla et al. theoretically reported the performance of the SPR sensor coated with Platinum layer on optical fiber. They observed that the sensitivity of the sensor enhances linearly with the increase in the refractive index of the sensing medium for all thickness of platinum layer and for a given refractive index of the sensing medium [23] Recently, the 2D materials were introduced in order to increase the absorbance and sensitivity. The sensitivity of the traditional SPR sensor is not much high because of metal layer is unable to absorb enough light energy for higher excitation. The large real part of the dielectric constant of TMDC's materials which produces stronger excitation, allow them to absorb more light energy and coating of TMDC's materials over metal which improving the sensors stability. In the recent years the various 2D materials such as graphene, BP and TMDCs (Mos_2, WS_2 and $MoSe_2$) have been discovered and used in many fields, especially in the biosensor[24-25]. It attracts the significant interest due to the physical structure and the optical, electrical properties. These 2D materials are atomically thin, honey comb lattice, and have direct band gap [26]. Due to these properties it absorbs the biomolecules well. In our present work, we have done a comparative study on the performance of SPR biosensor using graphene, BP and WS_2. The boundless research has been going on this field of 2D materials by many nanotechnology research teams in the world. In the case of graphene it shows strong coupling induced at the interface between metal-graphene films, because of effective charge transfer due to high charge carrier mobility of the graphene[27].L. Wu et.al., reported a highly sensitive SPR biosensor by increasing graphene layer to enhance the sensitivity caused by the optical properties of the graphene [28]. R. Verma et. al. analyzed a SPR-based prism using silicon and graphene layers for the detection of biomolecules [29]. A phosphorus allotrope known as BP is composed of several layers with two-dimensional structures that are kept together by Van der Waals forces. The BP is an excellent alternative for chemical applications with great performance potential since it also has attractive physical, mechanical and chemical anisotropic properties[22,30]. Recently Almawgani, A.H.M et.al., reported that a surface plasmon resonance (SPR) biosensor based on a black phosphor (BP) layer to improve the sensor performance[31]. Recently, the emerging two-dimensional (2D) Transition Metal Dichalcogenides (TMDCs) have been widely used in many fields such as transistors and photo detectors due to the worthy of attention in electrical and optical properties. Monolayer of MX_2 contains tri atomic layers and each layer is stacked via van der Waals forces[32]. In WS_2, a single layer of tungsten atoms with six-fold coordinate symmetry are bonded between two sulphide atoms in trigonal geometry, resembling materials from graphene. It is a promising material for biosensing applications due to its wide surface to volume ratio, tailored band gap from the visible to NIR spectrum, strong photoluminescence, etc[33]. Hao Wang et.al., reported that the WS_2nanosheet over layer is able to show additional advantages, such as protection of metal film from oxidation, tunability of the resonance wavelength region, biocompatibility, capability of vapor and gas sensing[34].Biswajit Dey reported that WS_2/ metal/WS_2/graphene heterostructure based SPR sensor exhibits improved performances and the well optimized structure of the developed sensor exhibits the highest sensitivity around 208 deg/RIU[35].

In the present theoretical work, numerically analysis the performance of a novel structure comprised of Cu-Pt bimetallic layer on BK7 prism. Based on TMM matrix method various performance such as sensitivity, FWHM, Detection Accuracy(DA) , Quality Factor(QF), phase angle and EFIEF are analyzed and optimized for superior performance. The effect of various 2D materials such as graphene, BP and WS_2 on the bimetallic layer is also analyzed and optimized for further enhancement of sensitivity.

2. Theory and design consideration

The proposed SPR sensor has six different layers based on the Kretschmann configuration as shown in fig.1.

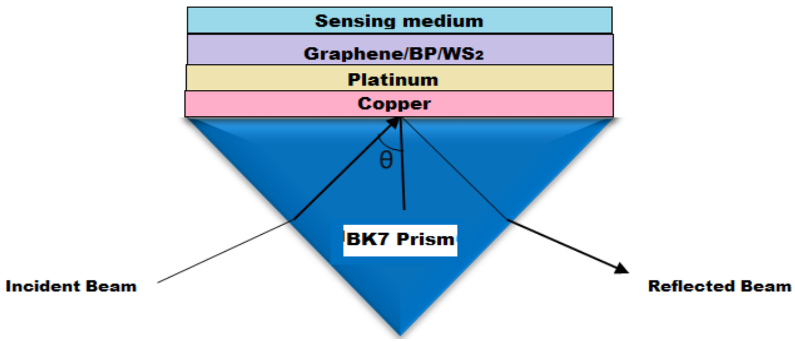

Fig. 1. Schematic diagram of proposed SPR biosensor.

Here we assumed the excitation of SPs with 633nm wavelength laser source. The first layer is BK7 prism and its refractive index is n1= 1.5151 [36]. The second and third layers are Cu and Pt metal films. Here we fixed the thickness of Cu film d_2 as 45nm and the Pt film d_3 as 10nm. The complex refractive indexes of the Cu and Pt films are calculated according to the Drude formula as [3]

$$\varepsilon(\lambda) = \varepsilon_r + i\varepsilon_r = 1 - \frac{\lambda^2 \lambda_c}{\lambda_p^2(\lambda_c + i\lambda)} \tag{1}$$

where, λc and λp defines the collision and the plasma wavelengths of the given materials, the optical parameters of Cu and Pt are [22,37]

$$Cu \Rightarrow \lambda_c = 4.0853 \times 10^{-5} m, \lambda_p = 1.3617 \times 10^{-7} m.$$

$$Pt \Rightarrow \lambda_c = 1.795 \times 10^{-5} m, \lambda_p = 2.415 \times 10^{-7} m.$$

The fourth layer we considered is graphene/BP/WS_2. The thickness and refractive index of 2D materials are tabulated in table1 as given below[36,22]

Thickness of 2D materials	BP	Graphene	WS_2
Thickness(nm) and RI of monolayer	0.53 3.5+0.01*I*	0.34 3.0+1.1491*I*	0.8 4.9+0.3124*I*

The last layer we consider is the bimolecular analyte whose refractive index is starting from 1.330 to 1.350.

The change in reflectivity of the proposed scheme is analyzed using matrix method for N layer model which is more efficient and does not considered any approximation. By applying the boundary condition, the tangential field at $Z=Z_1=0$ are presented in terms of tangential field at $Z=Z_{N-1}$ as follows [4],

$$\begin{bmatrix} U_1 \\ V_1 \end{bmatrix} = M \begin{bmatrix} U_{N-1} \\ V_{N-1} \end{bmatrix} \tag{2}$$

where, V_1, V_{N-1} and U_1, U_{N-1} are the tangential components of magnetic and electric fields of the first and N^{th} layer. M is the characteristic matrix for the combined structure which is obtained by the following equation,

$$M = \prod_{k=2}^{N} M_k = \begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} \tag{3}$$

$$M_k = \begin{pmatrix} \cos\beta_k & -i\sin\beta_k / q_k \\ -iq_k \sin\beta_k & \cos\beta_k \end{pmatrix} \tag{4}$$

Here β_k and q_k are

$$q_k = \frac{(\varepsilon_k - n_1^2 \sin^2\theta_1)^{1/2}}{\varepsilon_k}$$

$$\beta_k = (2\pi d_k / \lambda)(\varepsilon_k - n_1^2 \sin^2\theta_1)^{1/2}$$

where λ and Θ_1 are the wavelength and incident angle of the incident light, d_k and ε_k are the thickness and dielectric constant of the k^{th} layer.

The r_p is total reflection coefficient of the p-polarized light, which is derived as follows

$$r_p = \frac{(M_{11} + M_{12}\chi_N)\chi_1 - (M_{21} + M_{22}\chi_N)}{(M_{11} + M_{12}\chi_N)\chi_1 + (M_{21} + M_{22}\chi_N)} \tag{5}$$

The reflectivity of the given multilayer configuration is given by

$$R_p = \left| r_p \right|^2 \tag{6}$$

Sensitivity of the SPR biosensor is measured as the small change in the refractive index(Δn_s) of the analyte with the change in resonance condition in the reflectance curve($\Delta\theta_{res}$); therefore the sensitivity is given by,

$$S = \frac{\Delta\theta_{res}}{\Delta n_s} \tag{7}$$

The other prominance parameters of the SPR sensors are Quality Factor (Q), and Detection Accuracy(DA) these parameters should be high for the good sensors.DA is defined as the ratio of resonance angle shift ($\Delta\theta_{res}$) and the full width at half maxima (FWHM)($\Delta\theta_{0.5}$) of the reflectance curve,

$$DA = \frac{\Delta\theta_{res}}{\Delta\theta_{0.5}} \tag{8}$$

The quality factor (Q) is given by,

$$Q = \frac{S}{\Delta\theta_{0.5}} \tag{9}$$

where,
S(θ) - Sensitivity of the SPR biosensor
$\Delta\theta_{0.5}$ - FWHM of the SPR curve

The electrical field intensity enhancement factor is defined that the square of the electric field at last layer (graphene-sensing medium) to the first layer interface(prism-Cu) is given by[38]

$$\left|\frac{E\left(\frac{N}{N-1}\right)}{E\left(\frac{1}{2}\right)}\right|^2 = \frac{\varepsilon_1}{\varepsilon_N}\left|\frac{H\left(\frac{N}{N-1}\right)}{H\left(\frac{1}{2}\right)}\right|^2 = \frac{\varepsilon_1}{\varepsilon_N}|t|^2 \tag{10}$$

Phase angle change(ϕ) is a parameter to characterize the sensor. The phase angle change in reflected light occurs at the resonance angle, which corresponds to the reflectivity minima and theoretically defined as

$$\phi = \arg(r) \tag{11}$$

3. Results and discussions

We have numerically simulated the behavior of the proposed configuration using Fresnel transfer matrix method at 633nm. Fig.1 shows the 2D materials graphene, BP and WS_2 separately coated over on bimetallic layer(Cu-Pt). The analyte present in the sensing medium attached with these 2D materials directly, due to the label free binding capability of these materials. Pure water is considered as sensing medium and for the theoretical analysis of our proposed work as we increase the concentration of biomolecules in water its refractive index is assumed to change from 1.330 to 1.350. In the initial phase of optimization, the thickness of Cu-Pt bimetallic layers are fixed as 45nm and 10nm respectively. The addition of 2D materials such as graphene, BP and WS2 above the Cu-Pt bimetallic is analyzed and optimized for superior performance of the sensor.

In the first phase of our work, the monolayer of graphene on BK7-Cu-Pt layer is considered. The reflection intensity versus incident angle plot is shown in Fig. 2(a). Here, adsorption of biomolecules in water the corresponding RI is 1.330. It is observed that for the mentioned configuration, resonance angle θ_{res} is found to be 73.03°. As we increase concentration of biomolecules, due to the adsorption of biomolecules over graphene layer, resonance angle appears at 73.89°, 74.80°, 75.72° and 76.75° corresponding to the change of RI of sensing medium as 1.335,1.340,1.345 and 1.350 respectively. It is also clear from reflectance plot of graphene, when the RI of sensing medium increase from 1.330 to 1.350 the minimum reflectance changes from 0.046 to 0.068 as shown in fig.2(a).The condition of R_{min} close to zero ensures coupling of the maximum energy of incident Transverse Magnetic (TM) polarised light with the surface plasmon, which is essential for the design of any SPR sensor to have higher sensitivity and resolution[22]. In the similar way, we have plotted reflectance plot for monolayer of BP and WS_2. In case of monolayer BP, it is found that resonance angle shift from 73.605° to 77.44° and R_{min} decreases from 0.001 to 0.0001 corresponding to the change of RI of sensing medium 1.330 to 1.350 and are shown in fig.2(b). Similar analysis is done for monolayer of WS_2 configuration shows and that resonance angle shifts from 75.38° to 80.02° and minimum reflectance also increases from 0.0485 to 0.098 as shown in fig. 2(c).

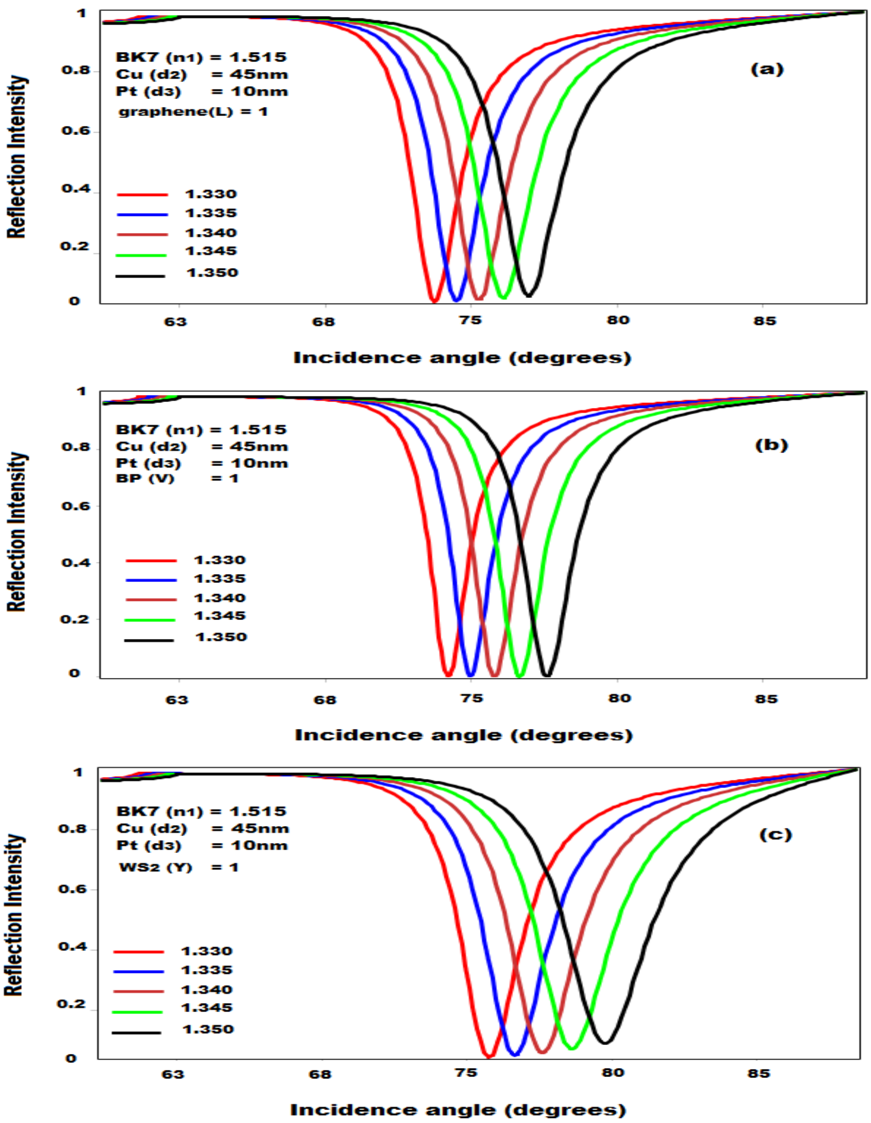

Fig. 2. (a,b,&c): Reflection intensity versus angle of incidence with monolayer of graphene, BP and WS_2.

From fig.2 (a,b&c), we have calculated sensitivity of proposed biosensor for monolayer of graphene, BP and WS_2 respectively. It is found that for the configuration with monolayer of graphene exhibits maximum sensitivity around 183deg/RIU with detection accuracy about as 1.275deg^{-1} and quality factor around 63.804RIU^{-1} is observed. It is observed for the configuration with mono layer of BP shows sensitivity as 194deg/RIU, detection accuracy as 1.671deg^{-1} and quality factor as 83.613RIU^{-1} is observed. While for configuration with mono layer of WS_2, sensitivity around as 229deg/RIU, detection accuracy as 1.142deg^{-1} and quality factor as 57.13RIU^{-1} is noted and comparison between these three configuration are listed in Table 2. From table 2, the maximum sensitivity is achieved for mono layers of WS_2 compared to configuration with monolayer of BP and graphene while quality factor is found better in case of BP as compared to graphene and WS_2

Table 2. Performance parameter of SPR biosensor for mono layer of 2D materials such graphene, BP and WS_2.

S.No	**2Dmaterials (Mono layer)**	**Sensitivity(deg/RIU)**	**FWHM (deg)**	**Detection Accuracy (DA) (deg^{-1})**	**Quality Factor(QF) (RIU^{-1})**
1.	Graphene	183	2.875	63.804	1.275
2.	BP	194	2.331	83.613	1.671
3.	WS_2	229	4.013	57.13	1.142

Fig. 3 shows the resonance angle in accordance with the RI of sensing medium. It is noted that the resonance angle shifts towards the higher side as we change the RI of sensing medium from 1.330 to 1.350. In case of BP and WS_2 configuration the resonance appears at higher angle as compare to graphene configuration. Fig. 3 exhibits the resonance angle versus RI plots which clearly shows the linear response of the proposed biosensor for different 2D sensing materials particularly graphene, BP and WS_2 corresponding to the dynamic change in the RI from 1.330 to 1.350.

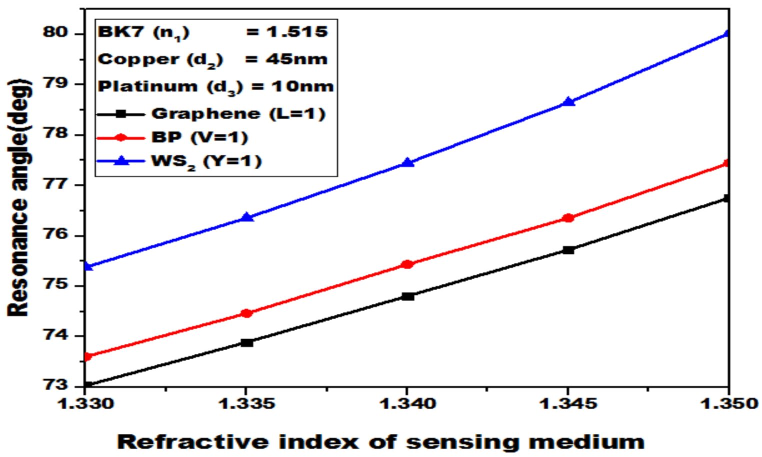

Fig. 3 Resonance angle as a function of change in refractive index of sensing medium.

In the next phase we examines the resonance angle using phase interrogation method. Fig. 4(a,b&c) explained that when the surface plasmon resonance occurs for a particular RI of the sensing medium, the phase between the incidence and reflected light changes suddenly. By increasing the concentration of analyte in the sensing medium, the position of phase change also shifted towards higher angle side. The phase angle increases by increasing the concentration of analyte in the sensing medium. Fig. 2(a,b&c) evidence that phase change occurs at the same resonance angles which supports the findings based on the SPR resonance curve.

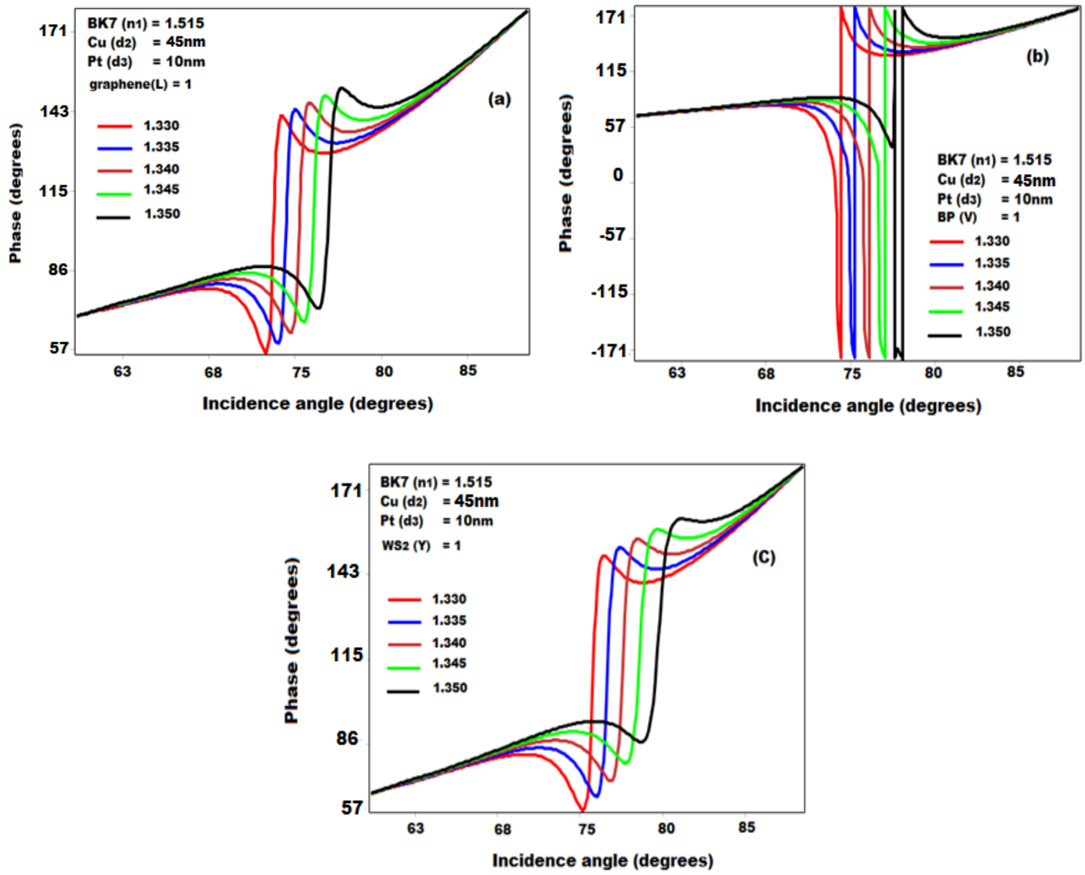

Fig. 4. (a,b&c): Phase angle versus incident angle plot for different 2D materials (graphene, BP and WS_2) with thickness of Cu and Pt as 40nm and 10nm respectively.

The SPR biosensor performance is also influenced by the electric field distribution, which indicates how well the field is concentrated in the interface of the last layer. ie. graphene/BP/WS_2/analyte interface. EFIEF illustrate show the evanescent field interacts with the biomolecules found in the sensing medium. It is noted when the concentration of analyte in the sensing medium, increases, the interaction of the targeted biomolecules with the evanescent field also increases which result in the reduction of EFIEF and are shown in Fig 5(a,b&c). As a result, biomolecules detection becomes more sensitive which means sensitivity increases. The resonance angle is where EFIEF reaches its maximum value because at this angle, surface plasmons receive the most energy from incident light. EFIEF is the ratio of the square of the field at the final interface to the first layer interface in the case of P-polarized light. In our proposed work we have analysis EFIEF in all three structures. For all three configuration ie., for monolayer of graphene, BP and WS_2, the EFIEF versus incident angle plot at different RI of sensing medium as shown in fig.5(a,b&c) respectively. It is clear from fig. 5(a)for monolayer of graphene configuration, EFIEF maxima appeared at the same resonance angle as shown in fig. 2(a). Fig. 5(a) shows that by increasing the concentration of biomolecules, EFIEF maxima decreases which confirm the adsorption of analyte on the surface of graphene layer. The similar behavior can be seen for monolayer BP and WS_2 as shown in fig.5(b &c) respectively. The plot clearly shows that maximum value of EFIEF at different RI of sensing medium occurs at resonance angle which proves that maximum energy of incident light is transferred to SP's at resonance angle. For monolayer of graphene configuration, it is clear that the maximum value of EFIEF decreases from 5.722 to 4.945 as we change RI from 1.330 to 1.350. The same way monolayer of BP and WS_2 configuration the maximum value of EFIEF decreases from 7.288 to 6.310 and 5.121 to4.11 respectively. It can be shown in fig.5(b&c). A comparison of EFIEF maximum for all three configuration the monolayer of graphene, BP and WS_2, the maximum value of EFIEF found for monolayer of BP configuration.

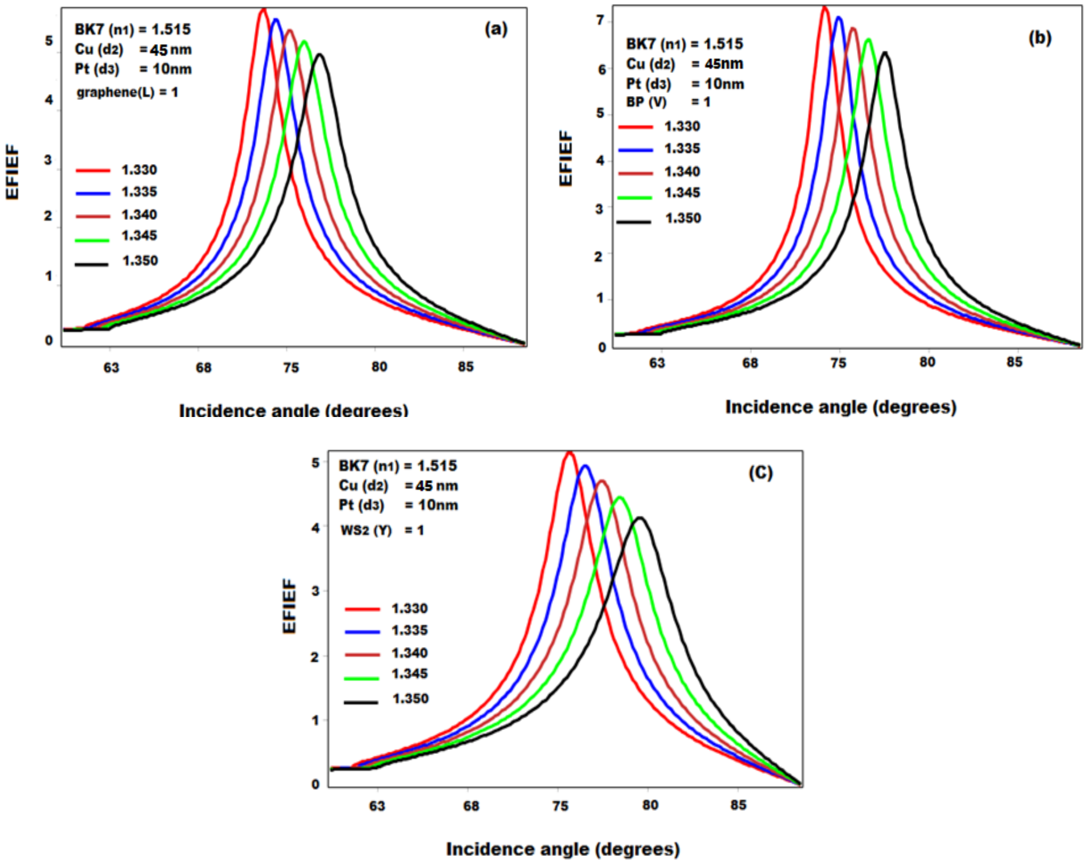

Fig. 5. (a,b,&c): Electric field intensity enhancement factor(EFIEF) versus incident angle plot for different 2D materials(graphene, BP and WS_2) with thickness of Cu and Pt as 40nm and 10nm respectively.

In the next phase of examination a comparative study of performance of SPR for different layer of graphene, BP and WS_2 at optimized thickness of Cu and Pt as 45nm and 10nm are observed. The performance parameters of all these three configurations are calculated which is given in table 3. All the calculations are done for the change of RI of analyte from 1.330 to 1.350 respectively as shown in fig. 6(a,b&c). It is found that BK7-Cu-Pt-graphene configuration, Fig. 6(a) shows the minimum reflectance (R_{min}) and sensitivity corresponding to number of graphene layer with Cu=45nm and Pt=10nm. It is noted from fig.6(a) adding single layer of graphene for above configuration increased sensitivity as 183deg/RIU and increased R_{min} as 0.061. Upon the addition of 2nd layer of graphene further increased sensitivity to 194deg/RIU and increased R_{min} as 0.167. The condition of R_{min} close to zero ensures coupling of maximum energy of incident TM polarized light with the surface plasmon and it is necessary for the design of any SPR to have improvised sensitivity and resolution[22]. It is found that maximum sensitivity with minimum reflectance (R_{min}) found for monolayer of graphene as 183.43deg/RIU and 0.062 respectively. Similar way the two configurations such as BK7-Cu-Pt-BP-sensing medium and BK7-Cu-Pt-WS_2-sensing medium were analyzed. From fig. 6(b&c) shows that the sensitivity improves with increasing number of BP layers and maximum sensitivity around 309deg/RIU is achieved for 4layer of BP with corresponding R_{min} as 0.072. It is also noted that further increasing the thickness of BP as 5 decreasing the sensitivity and largely increased the R_{min} as 0.591. Such an increase R_{min} is due to the fact that further addition of BP results in large inner damping due to large energy adsorption caused by non-vanishing imaginary function of BP layers[39]. Fig.6(c) depicts the variation of R_{min} and sensitivity corresponding to different layer of WS_2 keeping the other parameter same as before. We can found that the single layer of WS_2 the sensitivity and R_{min} values obtained are 229deg/RIU and 0.091respectively. For the bilayer of WS_2, R_{min} value obtained to 0.5819. Here R_{min} close to zero is essential parameter for SPR sensor. From fig.6 (a,b&c) It is clear that the maximum sensitivity 309deg/RIU found for 4layer of BP which is greater than bilayer of graphene and monolayer of WS_2 configuration.

Table 3. Performance parameter of proposed SPR biosensor with different 2D Materials such as graphene, BP and WS_2.

Graphene

S.No	**Layers**	**R_{min}**	**Sensitivity (deg/RIU)**	**FWHM (deg)**	**Detection Accuracy (DA) (deg^{-1})**	**Quality Factor(QF) (RIU^{-1})**
1.	1	0.061	183	2.875	1.275	63.804
2.	2	0.168	194	3.871	1.006	50.349

BP

S.No	**Layers**	**R_{min}**	**Sensitivity (deg/RIU)**	**FWHM (deg)**	**Detection Accuracy (DA) (deg^{-1})**	**Quality Factor(QF) (RIU^{-1})**
1.	1	0.00031	194	2.331	1.671	83.613
2.	2	0.0033	214	2.764	1.554	77.774
3.	3	0.0162	249	3.383	1.4735	73.71
4.	4	0.0721	309	4.461	1.387	69.391
5.	5	0.5916	309	6.15	1.0063	50.333

WS_2

S.No	**Layers**	**R_{min}**	**Sensitivity(deg/RIU)**	**FWHM (deg)**	**Detection Accuracy (DA) (deg^{-1})**	**Quality Factor(QF)(RIU^{-1})**
1.	1	0.0905	229	4.013	1.142	57.13
2.	2	0.5819	298	7.64	0.779	39.01

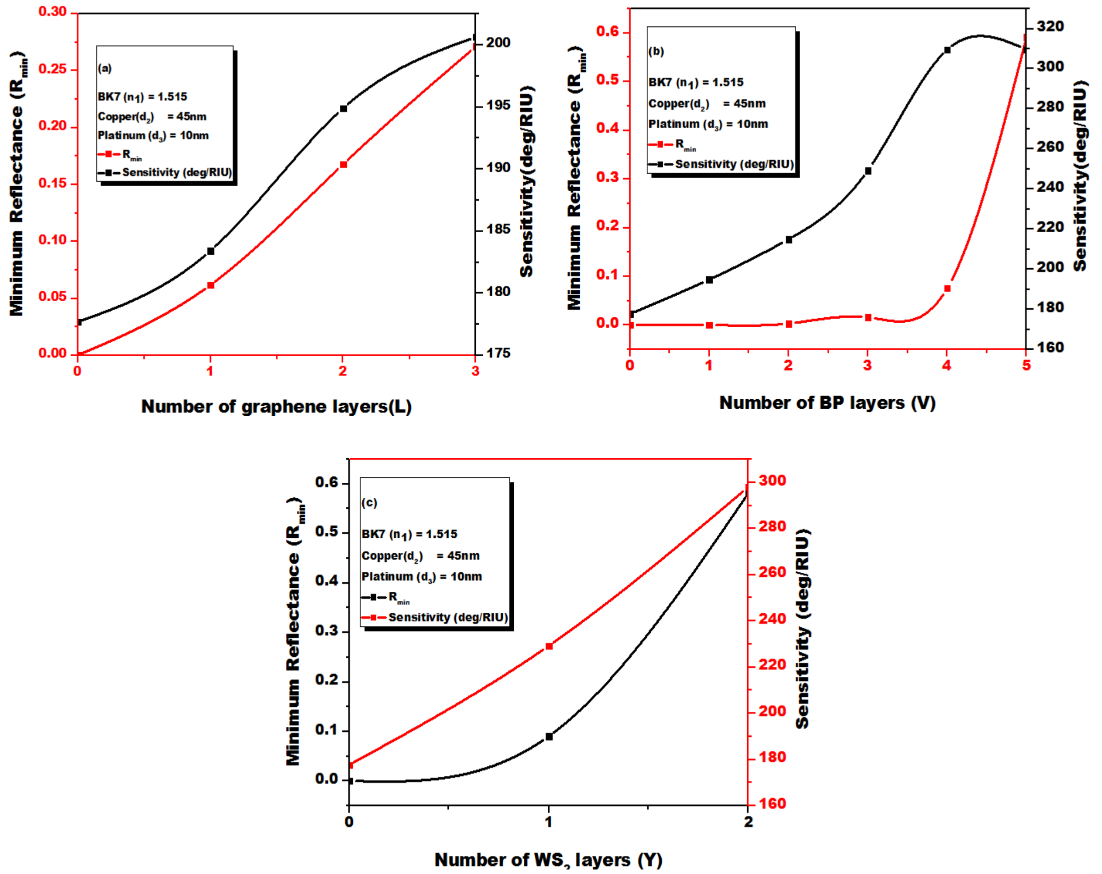

Fig. 6. (a,b&c). Minimum reflectance and Sensitivity versus number of different layers of 2D materials such as graphene, BP and WS_2 with thickness of Cu and Pt as 40nm and 10nm respectively.

Here we concluded from the above results such that few layers of graphene, BP and WS_2 would be a good choice for the efficient detection of biomolecules. From the above three configurations, BK7-Cu-Pt-BP-sensing medium found to exhibit maximum sensitivity as 309deg/RIU with FWHM 4.461deg and detection accuracy(DA) and quality factor(QF) as 1.387deg^{-1} and 69.39RIU^{-1} respectively. The FWHM obtained here is lower than Au-Ag bimetallic film based SPR sensor[40]. The proposed work has better performance compared to other reported works are tabulated in table4.

Table 4. Comparison among proposed biosensor with other existing biosensor.

Configuration	**Wavelength (nm)**	**Sensitivity (deg/RIU)**	**References**
Prism/Au/BP/WS_2	633	187	[41]
Prism/Au/Ti_3C_2Tx-WS_2/BP	633	190.22	[42]
Prism/Ag/ITO/WS_2/graphene	633	213.2	[43]
Prism/Ag/BP/Graphene	633	217	[44]
SF10/Au/Si/WS_2	633	134.6	[45]
BK7/Cu/Pt/BP	633	309	Proposed

			work

4. Conclusion

The present work proposed a novel SPR sensorstructure(BK7-Cu-Pt-Graphene/BP/WS_2) for modified Kretschmann configuration. Here, the use of BK7 prism, Cu and 2D materials such as graphene, BP and WS_2 can play a crucial role in providing superior sensing functionality. We extensively investigated and optimized each layer of the proposed biosensor to attain larger resonance angle shift, low value of FWHM and minimum reflectance. We analyzed the sensor performance with TMDCs materials, among the three 2D materials, BP has the lowest R_{min}value, the highest sensitivity and lowest FWHM, as well as high QF, which makes it the suitable cover layer in the proposed biosensors. Eventually, the proposed biosensor optimized structure comprised of BK7 prism, 45nm Cu layer, 10nm Pt and 4-layer BP achieves maximum sensitivity (309deg/RIU) with FWHM as 4.461/deg as well as high QF (69.391/RIU). The proposed SPR biosensor can show the great potential in the field of biosensing and other chemical and industrial applications.

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