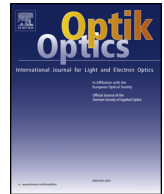




Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.com/locate/ijleo

Original research article

Effect of MoS₂ layer on the LSPR in periodic nanostructuresMohamed El Barghouti^{a,*}, Abdellatif Akjouj^b, Abdellah Mir^a^a Laboratory for the Study of Advanced Materials and Applications (LEM2A), Physics Department, Faculty of Science, Moulay Ismail University, B.P. 11201, Zitoun, Meknes, Morocco^b Institute of Electronics, Microelectronics and Nanotechnology, UMR CNRS 8520, Lille University, FST, Department of Physics, 59655 Villeneuve d'Ascq, France

ARTICLE INFO

Keywords:

Localized surface plasmon resonance
Gold nanoparticles
Layer of MoS₂
Sensitivity
Electric field

ABSTRACT

In this work, we propose a new configuration of the localized surface plasmon resonance (LSPR), based on MoS₂ hybrid structures for ultrasensitive biosensing applications. The plasmonic resonances are widely used in bimolecular detection and continue to be an active network because of the rich variety of surface configurations and measurement donations. The present work studies the interaction of gold nanoparticles with a MoS₂ film. MoS₂ is used as a thin spacer between the gold nanoparticles and the dielectric medium used for detection. MoS₂ monolayers have emerged recently as promising nanostructures for various applications in both the optics and electronics. This paper gives an overview of the optical properties of 2D nanostructures based on this new class of materials. A stronger behavior of the resonance positions in the absorption spectrum exhibits a strong coupling between the LSPR on the gold nanoparticles and the MoS₂ coating film. Numerical simulations display a significant red shift of the plasmonic resonance (λ_{max}) and the results show that using a 3.90 nm MoS₂ layer, the plasmon resonance wavelength is increased of 333.7 nm. We also study the performance of the proposed biosensors in terms of sensitivity using multilayers of MoS₂, and normal incidence to the surface of SiO_x/AuNPs/MoS₂/water and SiO_x/MoS₂/AuNPs/water. We obtain a very high sensitivity of 297.62 nm/RIU corresponding to an increase of 26% compared to the results obtained on SiO_x/AuNPs/water, with a location of the electric field on the gold nanoparticles and the covering MoS₂ layer. These characteristics should make these biosensors a preferred choice for detection applications.

1. Introduction

Plasmonic response of the metal nanoparticles is highly dependent on their size [1–3], their form [4–6] and the material constituting the chemical 2D composition [7–9]. The understanding of their properties is even more complex when they are deposited on a substrate [1,10,11] or when they interact with each other [12–14]. It appears from the theoretical and the experimental studies already completed that there are many parameters governing their behavior [15]. As part of our study, we will investigate the influence of the MoS₂ layer on the LSPR. The complex refractive index of the MoS₂ monolayer obtained from the experimental measurement data by Castellanos-Gomez et al. [16] is $n_{\text{MoS}_2} = 5.9 + 0.8i$ at 632.8 nm and the thickness of the MoS₂ layer is $d_{\text{MoS}_2} = N \times 0.65 \text{ nm}$ [17,18], where N is the number of coatings of MoS₂ [19–22], deposited on the metal nanoparticles of gold. Molybdenum disulfide (MoS₂) holds great promise for optical applications due to the variations of optical transition depending on the atomic thickness of the film [19]. A gradual red shift of the absorption bands the background absorption. Hence, Increasing MoS₂ film thickness is observed to allow tuning the absorption properties of such films. The optical processes in a low dimensional materials

* Corresponding author.

E-mail address: Mohamedaziz1989@hotmail.fr (M.E. Barghouti).

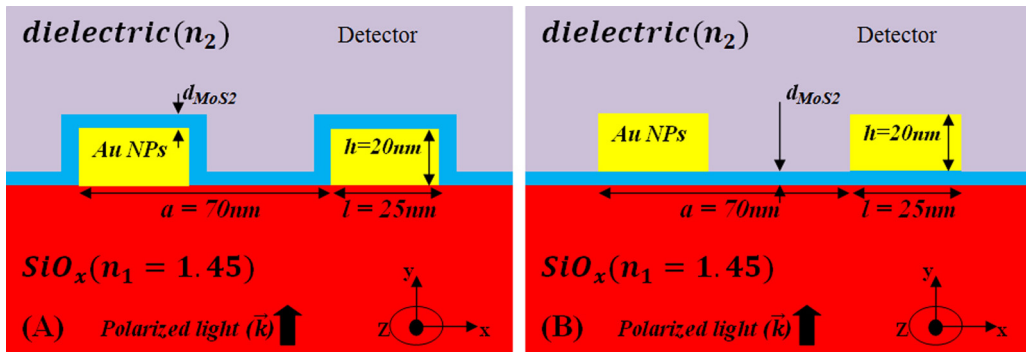


Fig. 1. Schematic representation of the plasmonic structures studied in this work. (A) Periodic gold nanoparticle (Au NPs) array on SiO_x ($n_1 = 1.45$) and coated with a layer of MoS_2 ($\text{SiO}_x/\text{AuNPs}/\text{MoS}_2$); (B) SiO_x ($n_1 = 1.45$) coated with a thin film of MoS_2 onto which a periodic gold nanoparticle (Au NPs) was deposited ($\text{SiO}_x/\text{MoS}_2/\text{Au NPs}$). The height ($h = 20 \text{ nm}$), width ($l = 25 \text{ nm}$) and lattice parameter ($a = 70 \text{ nm}$) defined as the closest distance between two adjacent AuNPs is the same in both cases. The input source is placed in the substrate (SiO_x) and the detector in the dielectric, being water ($n_2 = 1.333$).

such as MoS_2 can furthermore be changed by the presence of resonance cavities and plasmonic nanostructures [16]. In biosensing applications, the gold is not well adapted because of its poor absorption of biomolecules, causing limitations on the sensitivity of the biosensor [23]. As a solution to this limitations, the gold layer is substituted for the gold nanoparticles (AuNPs). Gold nanoparticles have a unique property called localized surface plasmon (LSPR). The AuNPs-based LSPR is widely used for the detection [24]. In addition, the dielectric environment of the Localized surface plasmons resonance (LSPR) has been extensively studied in recent years [25,26] 2D networks nanoparticles of gold (AuNPs). In this work, we theoretically study the impact of the MoS_2 substrate thickness on the plasmonic signal of gold nanoparticle (AuNPs) arrays (Fig. 1B). Throughout this paper, the geometrical parameters of the AuNPs is fixed with l is the particles length, a is the lattice parameter (along x-axis), and h is the particles height. It is well established that AuNPs strongly absorb within narrow frequency bands in the visible range as their localized surface plasmon resonances get excited. Besides, the effect of the dielectric environment surrounding the AuNPs has been widely studied [27,28]. A part of this work consists of investigating numerically the influence of MoS_2 coatings (0–7.15 nm) on the localized surface plasmon resonance signal of AuNPs arrays (Fig. 1A). In the first part, the idea is to highlight the role of a few layers of MoS_2 as one of the finest collection thickness of layers deposited on MoS_2 nanostructures. The considered ranging is from 0 nm to 3.90 nm (strong red shift of the resonance). The layers of the dielectric have been deposited on a substrate of SiO_x ($n_1 = 1.45$) over which two types of nanostructures have been investigated. In the second part, numerical simulations of structures $\text{SiO}_x/\text{AuNPs}/\text{MoS}_2/\text{water}$ and $\text{SiO}_x/\text{MoS}_2/\text{AuNPs}/\text{water}$ with a normal bias following the z-axis, show significant sensitivity $\sim 300 \text{ (nm RIU}^{-1})$ Fig. 1(A) and $\sim 171 \text{ (nm RIU}^{-1})$ Fig. 1(B) for the eight layers MoS_2 5.20 nm [29–34]. In addition, the plasmonic response of metal nanoparticles with various geometrical parameters gold nanoparticles $l = 125 \text{ nm}$, $a = 300 \text{ nm}$, and $h = 15 \text{ nm}$. These results are consistent with other reports in the literature showing long row detecting refractive index on plasmonic nanostructures [15,20,22]. The distributions of the electric field structures excited to resonance at normal incidence and represented by the maps of the 2D and 3D electrical fields which indicate that this mode is a localized surface plasmon dipole whose hot spots (areas of high intensities field) are pushed to the top and bottom corners of AuNPs for the structure $\text{SiO}_x/\text{AuNPs}/\text{MoS}_2/\text{water}$, and top corners of AuNPs to layer MoS_2 under the nanoparticles to the structure $\text{SiO}_x/\text{MoS}_2/\text{AuNPs}/\text{water}$ to the lengths wave resonances (λ_{max}).

One observes a significant enhancement of the sensitivity of localized surface plasmon resonances of coated AuNPs with layers of MoS_2 to the surrounding environment as compared to bare nanoparticles. Hence, the design of Au nanoparticles/ MoS_2 based-plasmonic bio-sensors with more sensitive could be reached. Indeed, we show that AuNPs coating with few layers of MoS_2 leads to approximately a 26% higher sensitivity. The optimal thickness of MoS_2 layers is numerically investigated to achieve a high LSPR sensitive system.

2. Theoretical methods

The optical properties of gold nanoparticles are solved numerically, in the frequency domain, using the scattered field formulation. Field analysis was performed using a commercially available Finite Elements Method (FEM) method package (COMSOL Multiphysics 4.4) [35,36]. The simulation method has been well documented [37–39]. A layer of gold nanoparticles of diameter (l), height (h) and interparticle distance (a), is coated with a MoS_2 thin-layer and immersed in a homogeneous matrix. A transparent glass of SiO_x (refractive index $n_1 = 1.45$) is used as a substrate. The frequency-dependent complex permittivity of metal (gold) is described by the Lorentz–Drude model (Eq. (1)) [40,41].

$$\varepsilon(\omega) = \varepsilon_{r,\infty} + \sum_{m=0}^M \frac{f_m \omega_p^2}{\omega_m^2 - \omega^2 + j\omega\Gamma_m} \quad (1)$$

where $\varepsilon_{r,\infty}$ is the relative permittivity at infinite frequency, ω_p the plasma frequency, and ω_m , f_m and Γ_m the resonance frequency,

Download English Version:

<https://daneshyari.com/en/article/7223078>

Download Persian Version:

<https://daneshyari.com/article/7223078>

[Daneshyari.com](https://daneshyari.com)