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Tunable graphene based plasmonic absorber with grooved metal film in near infrared region

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ABSTRACT

In this paper, we have proposed a graphene based absorber with two absorption peaks at near infrared wavelengths. The metal-graphene nanostructure is composed of a single layer of graphene on a metal film with L-shaped grooves. The results show that by utilizing only one graphene layer the absorption of the structure is increased to more than 0.9 due to the localized surface plasmon resonance (LSPR) in the grooves that amplifies the interaction of light and graphene. We have shown that the full width at half maximum (FWHM) of the absorber is enhanced by decreasing the perpendicular L-shaped grooves length. Also, the absorption spectrum of the proposed structure can be tuned by changing the geometric parameters and chemical potential of graphene.

1. Introduction

In 2004, graphene was introduced by researchers in Manchester University and after that it has been used due to its electronic and optical characteristics to obtain effective absorption in plasmonic nanostructures [1,2]. Graphene is a single atom layer which is formed in honeycomb-shaped lattice [1]. Also, graphene is considered as a two dimensional material in photonics and optoelectronics and possesses unique and remarkable properties such as optical transparency, flexibility and high electron mobility [3]. The surface conductivity is one of the important optoelectronic properties of graphene and can be controlled by chemical potential which is adjustable by external gate voltage, magnetic field and optical excitation [4–6]. Another important feature of graphene is its extraordinary band structure that is due to the negative energy of valance band and positive energy of conduction band that meet at Dirac point. Therefore, graphene can act as a zero-band gap semiconductor which is able to absorb light and produce carrier charges from terahertz (THz) to ultraviolet regions [3,7]. Considering single atom thickness of graphene, its optical absorption is high in optical frequency range [8]. Therefore, graphene can be used to improve the absorption efficiency in structures that light must be effectively trapped and absorbed such as optical cavities [9], solar cells [10], photonic crystals [11], dielectric gratings [12], and optical nanoscale antennas [13]. Also, because of the individual properties of graphene in comparison to other materials, it is utilized in applied photonic devises such as modulators [14], capacitors [15] and photodetectors [16].

So far, researchers have done many studies on plasmonic and metamaterial absorbers using graphene. A wavelength tunable absorber based on periodic cross-shaped arrays of graphene in far infrared and terahertz regions has been proposed by Ke et al. [17]. The absorption of the proposed structure is low and it is difficult to fabricate due to the cross-shaped graphene array. However, the absorber is tunable by the geometrical parameters and optical properties of graphene. Tunable and perfect absorbers based on graphene metamaterials in THz region have been studied [18,19]. The graphene absorption improvement by deep metallic grating in near infrared region has been investigated by Zhao et al. [20]. Moreover, composite graphene-plasmonic structures have been used to improve the light-matter interactions, while the fabrication of nanovoid array is not easy [21]. Utilizing graphene on metal film or ring-shaped grooves for increasing absorption at telecommunication wavelengths has been studied by Lu et al. [22]. In [22], the absorption and the FWHM are increased by four layers of graphene, which makes the structure complicated. Furthermore, we have obtained a perfect absorption in the structure which is composed of L-shaped and ring grooves [23].

In this paper, an ideal absorption and a wide FWHM have been attained simultaneously by utilizing a single layer of graphene. We have suggested a graphene based plasmonic absorber with two absorption peaks in near infrared region. In the proposed structure, graphene and metal film array with L-shaped grooves are detached by a silica layer. This structure has two absorption peaks of 0.67 and 0.88 without the graphene at 1507 nm and 1726 nm wavelengths, respectively. By using graphene, not only both absorption peaks are increased to the values of

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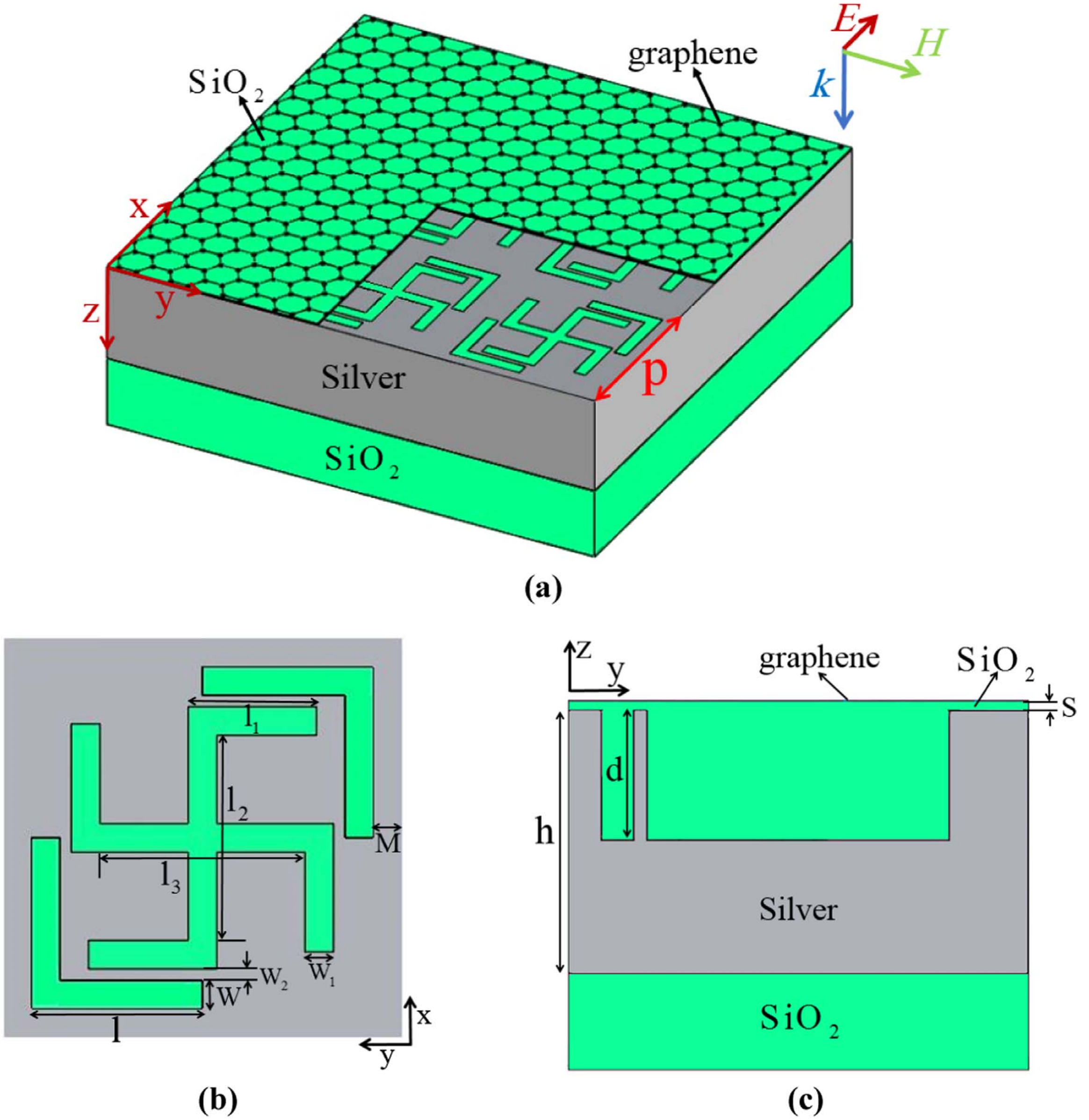

Fig. 1. a) The geometry of the proposed absorber that consists of a metal film array with L-shaped grooves and a single layer of graphene that are detached by a silica layer. b) Top and c) cross section views of a unit cell of the structure. In the top view, the graphene and silica layers are removed for more clarity.

Table 1
Geometric parameters of the proposed absorber.

Parameter	Value (nm)	Parameter	Value (nm)
l	300	W_2	20
l_1	225	M	50
l_2	360	P	700
l_3	360	s	5
W	50	d	200
W_1	50	h	400

0.98 and 0.91, respectively, but also the FWHM of each absorption peaks is increased. In this proposed absorber, the greater value of absorption is due to the localized surface plasmon resonances (LSPRs) in metal L-shaped grooves. Also, in order to increase the FWHM of the structure, the length of L-shaped grooves that are located in the center of the structure is decreased. Moreover, the effects of chemical potential of graphene and the grooves depth and width on the absorption spectrum and FWHM have been studied. The proposed absorber has potential to be utilized in plasmonic sensors, modulators

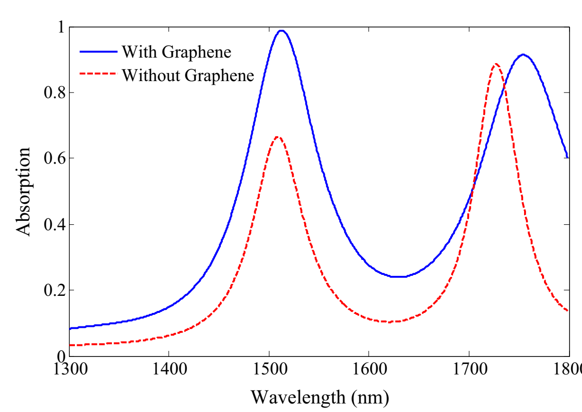

Fig. 2. Absorption spectrum of the structure of Fig. 1 with and without the graphene layer.