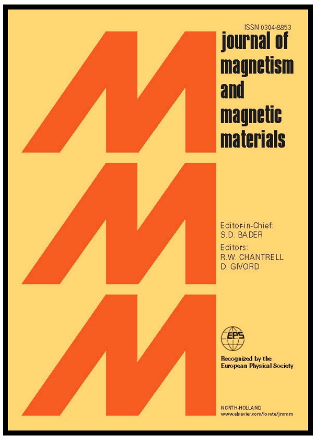

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A Reconfigurable Subwavelength Plasmonic Fano Nano-antenna Based on Split Ring Resonator

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Abstract

In this article, a reconfigurable subwavelength plasmonic nano-antenna with Fano resonance effect is presented based on the dual ring structure. In order to achieve reconfigurable characteristics, the interaction of gold with graphene is studied. SiN substrate with refractive index of 1.98 and gold with Palik optical characteristic modified for metal layer are utilized in the design of the proposed nano-antenna. Simulations are performed by using CST Microwave Studio. The biasing effect on extinction cross section is studied for 0 to 0.8 *eV*. It is shown that the gap method is useful for exciting the Fano resonance in the dual ring nano-antenna and there is only a plasmonic resonance in the simple dual ring antenna. The proposed nano-antenna is useful for THz medical spectroscopy due to its simple design and the ability to control the second resonance frequency by changing the bias of the graphene.

Keywords

Fano resonance, Subwavelength, Controllable field enhancement, Split Ring Resoantor , Plasmonic

I. INTRODUCTION

Nano-antennas are attractive for the strong enhancement of energy due to the interaction of light and metal at visible or infrared regime. This characteristic has made nano-antenna suitable for experimental applications such as Raman spectroscopy or surface enhanced Raman spectroscopy, bio sensing and enhancement of the fluorescence of molecules based on gold nano-particles plasmonic properties (localized surface plasmon resonances) and Mie theory [1]. A plasmonic structure can be achieved by mounting a silver or gold layer on a dielectric substrate. In order to model the dielectric characteristics, the Drude model has been suggested [2] to calculate real and imaginary parts of the dielectric permittivity.

Subwavelength components and structures have been designed based on metamaterial (MM) particles in a wide range of applications such as ultrasensitive bio-chemical sensors, light emitters and nano-antenna with Fano characteristics [1-3].

The Fano resonance is one of the most interesting phenomena in quantum interference, which originated from the quantum-mechanical interference between a discrete excited state of an atom and a continuum sharing the same energy level [4]. Over the last few years, plasmonic nano-systems have been investigated in order to excite Fano resonances with sharp dispersion [5].

On the other hand, the novel properties of nano-carbon have allowed designing graphene with special properties in the infrared and optical domains [6]. Graphene is a monolayer of hexagonally arranged carbon atoms which can be used as tunable plasmonic material by changing its excitation voltage [7]. However, graphene is significantly less lossy than traditional plasmonic materials and its plasmon can exhibit large Q-factors resulting in narrow absorption profiles [8]. In the last decade, various devices have been modeled with graphene for IR and optical applications such as absorber [9], antenna [10] and filter [11]. It has been shown that the working frequency in all of these structures has been altered by biasing the graphene.

The Kubo formula performances are implemented for graphene in this study where graphene conductivity has two various terms of the σ_{inter} and σ_{intra}; therefore, $\sigma_G(\omega) = \sigma_{\text{inter}}(\omega) + \sigma_{\text{intra}}(\omega)$, where [12-13]:

$$\sigma_{\text{intra}}(\omega) = \frac{-2e^2 jk_B \mathrm{T}}{\pi\hbar^2\omega}\ln[2\cosh(\frac{\mu_c}{2k_B\mathrm{T}})]$$

$$\sigma_{\text{inter}}(\omega) = \frac{e^2}{4\hbar}[\frac{1}{2}+\frac{1}{\pi}\tan^{-1}\left(\frac{\hbar\omega-2\mu_c}{2k_BT}\right)$$

$$-\frac{i}{2\pi}\ln\left(\frac{(\hbar\omega+2\mu_c)^2}{(\hbar\omega-2\mu_c)^2+(2k_BT)^2}\right)$$

Surface conductivity of graphene depends on the radian frequency ω, temperature T, and chemical potential (or Fermi Energy Level) μ_c where e is the charge of an electron, k_B is Boltzmann's constant, and $\hbar = h/2\pi$ is the reduced Planck's constant. Chemical potential μ_c is currently attainable involving charge-carrier densities $n = \mu_c\big/\left(\pi\hbar^2 v_F{}^2\right)$, where v_F is the Fermi velocity [12-13].

split ring Resonator (SRR) is one of the well-known models of metamaterial that is implemented in microwave and optical devices or absorbers to improve the bandwidth and the gain of the antenna or multi resonance absorber. It is used for making negative permeability and permittivity around the structure resonance frequency. The main benefit of SRR is the quasi-static resonance at a larger wavelength in spite of its size. This leads to the use of SRR in designing small devices [14-15].

Combinations of SRRs are studied for nano applications as a plasmonic planer split ring trimer [16] and single and dual band THz absorbers [17]. In addition, the gap in metamaterial, SRR and nano-antenna is known as the best parameter to control the resonance frequency and polarization of the structure [18-20].