Plasmonic refractive index sensor based on metal insulator metal waveguide

Publisher: IEEE

Shikha Gaur ; Rukhsar Zafar ; Devendra Somwanshi **All Authors**

Abstract:
We proposed and analyze numerically an ultra high figure of merit based refractive index sensor in Plasmonic Bragg grating. Structure is simulated by FDTD (Finite difference time domain) method under a PML (perfectly matched layer) absorbing boundary condition. Silver metal is used as metallic part in MIM (Metal insulator metal) waveguide geometry and insulating layer is taken as air. Permittivity of metal is frequency dependent and is characterized by Drude model. The Bragg grating is analyzed as a sensor by changing the parameters of defect area. Various Structures are analyzed by tailoring the block length of the defect waveguide from 0.3 μm to 0.5 μm and keeping block width constant (0.2 μm). Sensitivity is computed by detecting change in resonant wavelength for per unit change in RIU (Refractive Index Unit). Large value of sensitivity obtained is 1535 nm/ RIU. Also high value of quality factor (Q=242) and Figure of Merit (FOM=152) is reported with the optimized structural parameter. The proposed design can be a suitable choice for refractive index sensor. Thus, this device is suited to design optical sensor circuits.

Published in: 2016 International Conference on Recent Advances and Innovations in Engineering (ICRAIE)

Plasmonic Refractive Index Sensor Based on Metal Insulator Metal Waveguide

Shikha Gaur[1]
Swami Keshvanand Institute of Technology Management and Gramothan, Jaipur, 302017
shikha.gaur5@gmail.com

Rukhsar Zafar[2]
Swami Keshvanand Institute of Technology Management and Gramothan, Jaipur, 302017
rukhsar.zafar@gmail.com

Devendra Somwanshi[3]
Poornima University
Imdev.som@gmail.com

Abstract- **We proposed and analyze numerically an ultra high figure of merit based refractive index sensor in Plasmonic Bragg grating. Structure is simulated by FDTD (Finite difference time domain) method under a PML (perfectly matched layer) absorbing boundary condition. Silver metal is used as metallic part in MIM (Metal insulator metal) waveguide geometry and insulating layer is taken as air. Permittivity of metal is frequency dependent and is characterized by Drude model. The Bragg grating is analyzed as a sensor by changing the parameters of defect area. Various Structures are analyzed by tailoring the block length of the defect waveguide from 0.3 μm to 0.5 μm and keeping block width constant (0.2 μm). Sensitivity is computed by detecting change in resonant wavelength for per unit change in RIU (Refractive Index Unit). Large value of sensitivity obtained is 1535 nm/ RIU. Also high value of quality factor (Q=242) and Figure of Merit (FOM=152) is reported with the optimized structural parameter. The proposed design can be a suitable choice for refractive index sensor. Thus, this device is suited to design optical sensor circuits.**

Keywords: **MIM waveguide, Drude model, Plasmonic, Refractive Index sensor, Quality factor, Figure of merit.**

I. INTRODUCTION

At the interface of two materials (specifically metal and dielectric) charge density oscillations known as Surface Plasmons exists, which have dielectric constant having opposite signs [1]. When maximum excitation of surface plasmon is detected it is called surface Plasmon resonance (SPR). We have seen from past few years that surface Plasmon resonance (SPR) based sensors, biosensing sensors and refractive index based sensors are vastly studied and many researches has been done on them [2-4]. On surface of metal insulator in waveguide travels some light particles called Surface plasmon polaritons (SPPs) which are coupled to oscillations of free electrons. Transfer of information in nanostructures done through surface plasmons known as plasmonics. Near-field coupling between closely spaced metal nanoparticles allows information propagation and manipulation below the diffraction limit.

Metal insulator metal waveguide (MIM) consist of dielectric core between two claddings in which cladding is metal and core is dielectric. Considering so far among all the nanostructures, the main reason due to which many researchers have shown interest in MIM waveguide based structures is that they have deep-sub-wavelength confinement of light. These waveguide posses other applications that are acceptable propagation length, relative ease fabrication, and low bend loss, suitable for the optical circuit chip design, optical sensors [5], filters [6], demultiplexers [7].

Among all highly integrated optical networks, plasmonic sensors are the key component which led to the establishment of a number of industrial companies. Mainly two types of sensing are done by plasmonic sensors they are surface-enhanced spectroscopic sensors such as surface-enhanced Raman scattering (SERS) [8–10], surface-enhanced fluorescence [11, 12] and surface-enhanced infrared absorption [13]. SPR sensors are based on the resonant peak shift of SPs due to the change of the refractive index of the surrounding environment. Compared to other sensors, plasmonic sensors with MIM structures have an inherent advantage to achieve high integration. To analyze sensor performance sensitivity is an important parameter which is used to detect the change in intensity or phase with respect to refractive index per unit. According to many researchers there is another reliable parameter called FOM (Figure of merit) to measure the performance of the sensor [14]. FOM is a relevant option to measure peak width of the sensing performance of the device. Large value of FOM has obtained by studying numerous nanostructures and sensing techniques [15].As a refractive-index sensor, its sensitivity can reach as high as 1150 nm per refractive index unit near the resonance wavelength of 1550 nm, and its sensing resolution can reach 10^{-6} for a wavelength resolution of 0.01 nm [16-20]

By employing the MIM waveguide structure, we proposed a plasmonic refractive index sensor having ultra high figure of merit and improved sensitivity and quality factor. Based on plasmonic Bragg grating, MIM waveguide is designed by using Optiwave software. Simulations were done in 2D configuration by FDTD method under a PML absorbing boundary condition. An improved design of Plasmonic Bragg Grating waveguide structure is simulated with silver as metal and dielectric air. Permittivity of Silver shows frequency dependent behaviour and is characterized by Drude model.

Sensitivity and Quality factor are calculated for a small change of 0.1 unit in refractive index of defective length of (1μm) created in insulator part of waveguide. Total three waveguides taken by varying block length while keeping block width constant. At input light wavelength of 1550nm, transmittance curve is obtained in which through resonant peak sensitivity and Quality factor is calculated. From same curve full width half maximum (FWHM) is obtained to measure figure of merit (FOM).

[978-1-5090-2807-8/16/$31.00 ©2016 IEEE]