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The Sensing Characteristics of Plasmonic Waveguide with Rectangular Stub and Taper

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***Abstract*—We have analyzed and simulated a two-dimensional MIM (Metal-Insulator-Metal) waveguide based sensor which consists a rectangular stub, and a taper. This device is designed and simulated numerically by Finite difference time domain (FDTD) method. The structure used to sense a refractive index of unknown material filled in taper and stub by detecting the resonance condition. The refractive index sensitivity and temperature sensitivity are analyzed for the proposed structure. The results show the linear relationship of dip position (resonant wavelength) and the refractive index of a material which is to be sensed. It also shows linear behavior with ambient temperature. In this given structure, we achieve RI sensitivity 1240 nanometer RIU^{-1} and temperature sensitivity is 0.488nanometer/°C. For 0.01 resolution of a detection device, the sensitivity resolution can reach as high as 0.80×10^{-5}.**

Keywords*— *Metal-insulator-metal waveguide, Finite difference time domain method, Refractive index sensitivity, temperature sensitivity, sensitivity resolution.

I. INTRODUCTION

Optical sensors have an interesting property of measuring the unique characteristics of the material under test when illuminated in the presence of light. The electromagnetic (EM) field launched on sensors helps to translate it into a form that is readable by an instrument. A Variety of optical sensors has been proposed previously that uses optical resonance phenomenon to detect the presence of any specific material. One method to achieve this is to use surface Plasmon Polaritons (SPPs) [1]. Surface Plasmon Polariton has ability to guide electromagnetic energy at optical frequencies at the interface of a noble metal and dielectric [2]. SPPs are EM waves that resonantly interact with free electrons on a metal surface and an interaction of free electrons present in metal and incident electromagnetic field in dielectric generates a highly localized EM field that traverses at the interface between metal and dielectric. In SPP there is exponential decay in a perpendicular direction of metal-dielectric interface[2,3].

Plasmonics is broadly categorized into propagating Surface Plasmons Polaritons (SPPs) and localized Plasmons Polaritons (LSPPs) and both of them possess an intriguing property of sensing as they are highly susceptible to any change in dielectric properties of the surrounding environment. The SPPs sensor has the ability to attain high integration because of SPPs beyond the diffraction of a limit of light, but also have high sensing sensitivity [4]. Surface plasmon polaritons have been demonstrated on various ideas over many years for sensing applications such as refractive index sensor based on metal-insulator-metal structure coupled to a nanodisk resonator resonance of nanoparticles [1].

Many noble metals have been used in SPR sensors [5]. Nowadays, popularly used surface plasmon noble metals are gold and silver [6].Many MIM waveguide structure based on SPP has been demonstrated numerically and/or experimentally, such as U-shaped waveguide[7], Mach–Zehnder interferometers [8,9], multimode interferometers [9], Y-shaped combiners [11], couplers[12,13], splitters[14]. Based on metal-insulator-metal waveguide structure different functions are performed, the splitter[14], filter [15] and the optical switch[16]. Several optical sensors structures have been demonstrated [17,1,4] tooth shaped MIM waveguide structure, Two-Dimensional plasmonic waveguide with nanodisk resonator, MIM waveguide with a defect is proposed etc.

Lots of research has been carried out previously which exhibits a large value of sensitivity. Recently Wu et. al. has proposed a single defect based RI sensor and reported an ultra high value of RI sensitivity 1736 nm/RIU with FOM=9.79 [4] RI sensor based on structure of digital versatile discs has a sensitivity of 764 nm/RIU[18], Katyal et. al proposed concentric metal–insulator–metal (MIM) structure with metal core and nanoshell separated by a thin insulated layer. It has high RI sensing factor 510 $nmRIU^{-1}$ and 470 $nmRIU^{-1}$ for Al–Air–Au and Ag-Air-Au respectively[19].

Therefore, owing to unique characteristics of MIM waveguide based SPP sensor structure is proposed in this paper and this MIM waveguide is coupled to stub resonator and taper. We have not only investigated its refractive index sensing characteristics, but also investigate its temperature sensitivity. The SPPs sensor performance is simulated numerically by the figure of Merit (FOM), a ratio of RI sensitivity to the bandwidth of resonance [20] is also calculated. This paper is arranged in the different sections. The

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