VERTICAL COUPLED METAL- INSULATOR - METAL(MIM)OPTICAL WAVEGUIDE FOR SUB WAVELENGTH LIGHT CONFINEMENT USING SURFACE PLASMON RESONANCE

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Abstract— Surface plasmon resonance (SPR) biosensor is one of the optical sensor that exploits the specific properties of electromagnetic waves. SPR biosensors have been generally utilized in the field of environmental sciences for a real-time monitoring. It is a label-free technique that is utilized to recognize biological analytes and analyze the binding interactions between a liquid sample with a biomolecular recognition element immobilized on the SPR sensor surface. We propose a vertical tiny finite thickness metal-insulator-metal(MIM) surface plasmon resonance based optical sensor that is placed on a silicon waveguide. The proposed waveguide structure act as a Fabry-perot resonator. The proposed biosensor is modeled and simulated by using RSoft CAD tool and the channel property of the device is investigated by Finite difference time domain (FDTD) solver in RSoft tool.

Key Words — finite difference time domain, RSoft CAD tool, Surface plasmons.

I. INTRODUCTION

Sensor based on surface plasmons exhibit high sensitivity which does not require the need for labelling of molecules[1]. It is highly employed in the field of science which act as powerful tool for the characterization and studying the interaction of biomolecule. Although conventional SPR sensors are simple, compact, robust and highly sensitive prism coupled the device dimensions and its optical components are too large that they are not suitable for the miniaturization and integration[2][3], thus making it out of lab on chip application. Advancement in the development of high sensitive optical fibre and waveguide based surface plasmons as resulted in the development of a sensor based on silicon which is a high refractive index material system. Also multianalyte plasmonic systems has the capability to increase the speed of operation and also capable of shrinking the device dimension for the future integration of circuits. The proposed work aims at developing a Metal-insulator-metal (MIM) plasmonic waveguide that provides a high light confinement that is suitable for the sensing application. Sensor is created and simulated using an RSoft tool which is based on finite difference time domain which is a numerical tool that provides solution to the Maxwell’s equation

II. SCOPE AND MOTIVATION

In order to study the interaction between immobilized biomolecule and an analyte by using conventional technique such as fluorescence or ELISA (enzyme linked immuno-sorben assay) requires special characteristics and labels (Radioactive or Fluorescent)[6], where as an SPR which is based on a surface sensitive technique provides the real time monitoring of binding interaction of proteins and their affinity on to the sensor surface without the need of reporter molecules. In this the measurements are based on refractive index change. Thus there is need to develop such a biosensors though the traditional prism coupled sensor developed is simple and robust in nature and provides high sensitivity it cannot be integrated. Thus developing the sensor that can be easily miniaturized and integrated is necessary and should also operate in multi-analyte mode. Thus we have created a dual channel based sensor using high refractive index material such as silicon so that the device can be miniaturized and integrated for sensing application.

III. SURFACE PLASMONS

Conductive materials consist of a large density of free electron the collective oscillation of these electrons are called as plasmons which is when confined to propagates at a metal dielectric interface they are known to be surface plasmons. These surface plasmons results in a strong electric field which is normal to the plane of interface.
reduce the wavelength of the light. Taking this design one step further, by placing a second metal layer above the dielectric layer as well as below, one can fabricate a metal-insulator-metal (MIM) waveguide. These structures allow extremely high modal confinement of light.

As it is seen from the above Fig 2. As we notice that the propagation of surface plasmons through a metal/ dielectric/metal interface is much faster when compared to the momentum of free photons which is travelling through a dielectric medium therefore we cannot excite the surface plasmon directly by shining the light onto the surface of the metal plate. By using the process of total attenuated diffraction or reflection one can increase the speed of light that can be matched to the surface plasmon. This results in the coupling between a surface plasmon and an incident light. In our design we have used waveguide as a coupling source which has the capacity to increase the wavevector of the incident light source to match that of surface plasmons. The waveguide is created using silicon which is a high refractive index material. The light propagates in the form of this guided mode is concentrated in the waveguiding layer where as portion of field propagates as an evanescent wave in the low refractive index medium surrounding the waveguiding layer. As the light from the source penetrates the region of the waveguide which contains layer of metal, results in the excitation of plasmons that generates evanescent wave at the boundary of the metal plate.

When the two waves that is plasmon wave and the incident light wave which is given by the equation below are equal then coupling takes place between the guided mode and plasmon mode.

\[ \beta_{\text{Mode}} = \Re{\beta} \]

When the guided mode from source penetrates inside the layer of waveguide structure that is created, resonance matching condition occurs when the wave vector of both the wave that is incident light wave inside the waveguide structure and that of surface plasmon wave are matched with each other were the above equation is satisfied. This results in the excitation of electrons in the metal plate as a result there is a decline in the intensity of the transmitted spectrum at a specific wavelength known as a resonant wavelength.

IV. IMPLEMENTATION

The design of vertical coupled metal-insulator-metal (MIM) surface plasmon sensor is shown in the Fig 3. The device composes of two metal plates separated by a dielectric medium, this vertically integrated on a high refractive index medium like silicon membrane above which a layer of silica is used as supporting layer. When the gold layer is illuminated by a TM or P-polarized mode from the light source is guided along the slab waveguide made up of silicon results in the creation of evanescent field of the si waveguide will be coupled into a f-MIM plasmonic waveguide structure acting as a Fabry-perot resonator. The sensor that we modeled is divided into three sections Input section, Waveguide section, and Output section. The light is made to pass through the input section which is further guided on the silicon membrane as it propagates through the length of the section it excites the gold plate in the waveguide section where the sensor surface is sensitive to the refractive index change due to the change the surrounding environment[8] such a change can be measured as a shift in the wavelength across the output section of the guiding device.

The sensor which is shown in the figure is constructed using the silica with refractive index of 3.45 and sio2 with RI of 1.44 with their thickness of 1µm and 2µm. The refractive index of the test region is 1.33 and the length of the sensor is 8.14µm.

The optical setup for the excitation and interrogation of SPs requires a broadband P-polarized optical signal with the range of about 550nm-850nm which is applied at the input section of the sensor. Fig.4 shows the flow of the project.

Vertical Coupled Metal-Insulator-Metal(MIM)/Optical Waveguide For Sub Wavelength Light Confinement Using Surface Plasmon Resonance
In order to monitor the binding interaction that exists between a biological molecules a thin film of bio-recognition element will be placed on the surface of the gold plate then the layer will be probed by the evanescent wave which is generated by the excitation of surface plasmons on the metal plate. The wave that is generated will be in contact with the dielectric medium where the analyte molecule tend to bind to the recognition element placed on the sensor surface which results in the change in the refractive index $\delta n$ of the surrounding metal surface this results in change in the propagation constant $\delta \beta$ and consequently changes the coupling condition of the surface plasmons. Therefore, the molecular binding events can be detected by measuring variations of the characteristics of the light wave coupled to the SP. we are the measuring such a change in the propagation constant in terms of shift in the wavelength. This determines the changes in the quantity of bound analyte and subsequently the amount of the analyte present in a sample medium.

V. RESULTS AND ANALYSIS

RSOFT CAD tool is a photonic component design suite that allow the user to design and simulate the photonic devices that can be used for the optical communication. The RSOFT tool contains FULLWAVE as one of the simulation engine which is based on FDTD method .For the structure designed it computes the electromagnetic field distribution with respect to time and space to a given excitation.

**CONCLUSION**

In this paper a waveguide based surface plasmon resonance biosensor is designed and simulated using a FDTD solver in RSOFT. The structure involves multianalyte configuration which is suitable for the application where the simultaneous detection of analyte is required, with the proper selection of structural parameters the designed sensor can achieve a sensitivity of 400nm/RIU.[7]

**FUTURE SCOPE**

The analysis above is carried out by varying refractive index which is resulted in the proper functioning of the device by producing the shift in the wavelength thus making the proposed design compact and relatively easy to fabricate using optical
Vertical Coupled Metal-Insulator-Metal(Mim) Optical Waveguide For Sub Wavelength Light Confinement Using Surface Plasmon Resonance

REFERENCES