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Bloch Surface Waves Based Platform for Integrated Optics

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Abstract— **A dielectric multilayer platform sustaining Bloch surface waves is investigated for planar integrated optics. We study the optical properties of high refractive index material (TiO_2) and obtain propagation lengths in the range of millimeters.**

Keywords— Bloch surface waves (BSW), Multilayer platform, Scanning near-field optical microscopy (SNOM), Two-dimensional optics, Photonics, Optics, Light and matter interaction, Micro and nanostructures.

I. INTRODUCTION

Optical surface electromagnetic modes, highly confined to the interface, which can be excited in the photonic band gap of truncated dielectric periodic multilayers are called Bloch surface waves (BSW). Dielectric materials possess low loss characteristics which results in high propagation length and large resonance strength. These features are highly desirable for two dimensional (2D) optics and hence make BSW as a best candidate for integrated optics domain [1]. Another advantage is, a strong field intensity, increased by several orders of magnitudes, can be achieved by tuning the maximum intensity associated with the BSW on the surface. Thereby enhance the light-matter interaction close to the surface. Furthermore, platform provides the possibility to work with both polarizations and with any wavelength by properly choosing the refractive index and thickness of the layers constituting the multilayer. Taking the advantage of field confinement, the platform has also an application in the sensing domain [2].

II. PLATFORM CONCEPT AND METHODS

The design of the multilayer platform is based on one dimensional photonics crystal which consists of six periodic stacks of alternative silicon dioxide (SiO_2) and silicon nitride (Si_3N_4) layers. The multilayer platform is fabricated using plasma-enhanced chemical vapor deposition (PECVD) and designed to work around the telecommunication wavelengths, 1.5 µm. The thicknesses of SiO_2 and Si_3N_4 layers are 472 nm and 283 nm, and refractive indexes are 1.45 and 1.79 at λ = 1500 nm, respectively. Total thickness of the multilayer platform is around 4.5 µm. The whole pattern is deposited on a glass wafer just as a Bragg mirror shown in Fig.1. To terminate the periodicity of multilayers, a 50 nm thick layer of Si_3N_4, called top layer, is deposited on the top of the platform. The high index material, Titanium dioxide (TiO_2, n=2.23), layer is deposited on the top of the platform (Bragg mirror + top layer) and will be used to shape the photonic devices on the top.

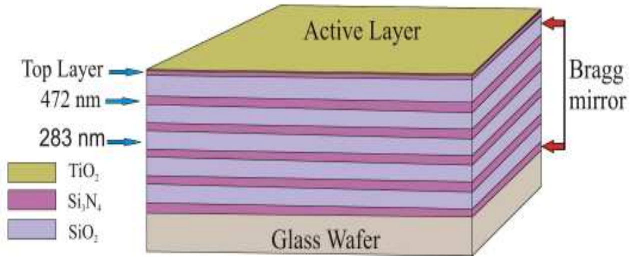

Fig.1 Schematic of BSW Multilayer platform (BSW-ML) deposited on the glass wafer.

To excite BSW, the propagation constant of the incoming beam should match with the propagation constant of BSW. Therefore, we use total internal reflection configuration for this purpose by using a BK7-glass prism. The schematic of the excitation configuration is shown in Fig. 2.

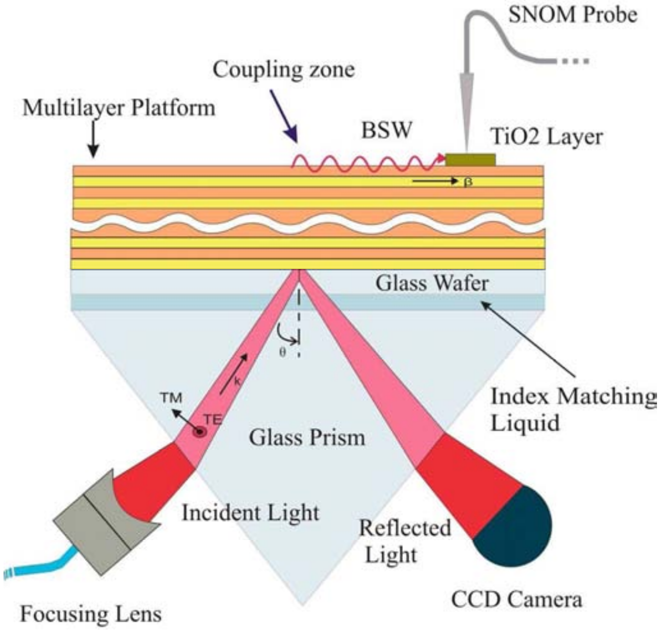

Fig.2. Total internal reflection configuration using BK7-glass prism to excite BSW.

Because of the surface behavior of BSW, near field optical microscopy is the best tool for optical characterization. The evanescent surface waves is collected with a subwavelength aperture probe of multi-heterodyne scanning near-field optical microscope (MH-SNOM) which allows a simultaneous measurement of the amplitude and the phase is used for the optical.

III. Result and Discussion - Propagation length and Effective refractive index analysis

In this paper, we study two of the key parameters of BSW, such as, propagation length (L_{BSW}) and the effective refractive index (n_{eff}). These parameters play an important role in characterizing the losses associated with the multilayer platform and determining the optical properties of 2D components.

The propagation length for bare multilayer and different thicknesses of TiO_2 has been measured experimentally. The Near field image of BSW propagation has been shown in Fig.3.(a). L_{BSW} is obtained by exponentially fitting the decrease of the field amplitude of the surface wave along the propagation direction, as demonstrated in Fig.3.(b) . For 15 nm thickness of TiO_2, we achieved a propagation length of around 2.5 millimeters in near field, which is ~ 30 times longer than the recently obtained "Long-Range SPPs" studied by Lin et al [3] and ~ 4 times longer than the one studied by L. Yu [4].

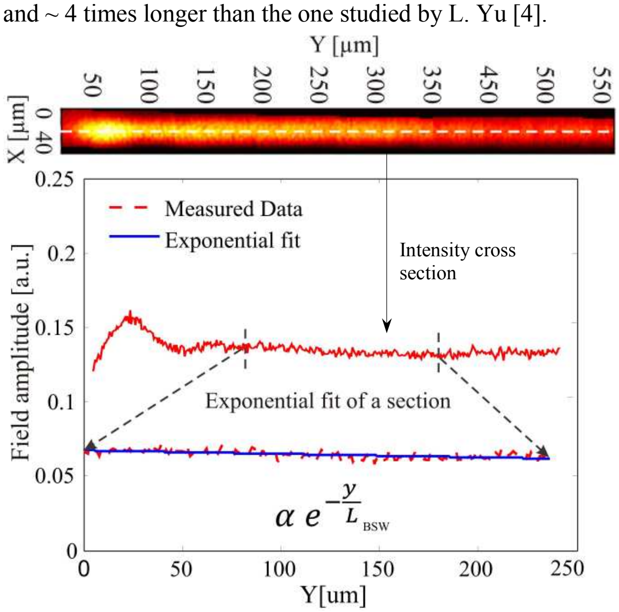

Fig.3.(a). Intensity distribution of 15 nm thick TiO_2 layer, measured in near field, demonstrating BSW propagation. (b). Exponential fit of the field amplitude along the direction of propagation to measure propagation length.

Effective refractive index (n_{eff}) is introduced by propagation constant of surface waves. The presence of the additional layer modifies the local n_{eff} which creates a contrast between bare multilayer and coated multilayer. The refractive index contrast (Δn) between the platform and polymer layer affects the capability to manipulate BSW most effectively. We measured the refractive index contrast for different thicknesses of TiO_2 such as 15nm, 30 nm and 60 nm. As the thickness of TiO_2 increases, Δn shifts towards higher values. In near field, Δn of 0.15 has been obtained for 60 nm thickness of TiO_2. From the theory (matrix transfer method), it has been proven that Δn of ~ 0.2 can be achieved with 100 nm thickness of TiO_2, which is good for low loss and compact photonic devices. In figure 4, we plotted the theoretical and the measured results of Δn as a function of the TiO_2 thicknesses. It can be seen that both results are close to each other. The effective index contrast has been confirmed in the near field and far field as well.

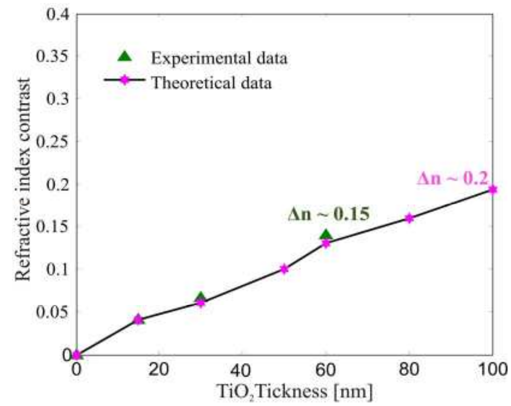

Fig.4. Plot of simulated and measured values of Δn for different thicknesses of TiO_2.

IV. Conclusion

To conclude, dielectric multilayers are considered as a platform for a planner manipulation of the Bloch surface waves. We obtained a propagation length of ~ 2.5 millimeters for 15 nm thickness of TiO_2 layer and a Δn of ~ 0.15 for 60 nm of TiO_2. Experimental results show good agreement with simulation results.

Graphene layer and Silicon, as a high index material, are under near field investigation. In near future, we aim to characterize different optical components on the top of platform with the aid of multi-heterodyne scanning near-field optical microscopy in near field in near-infrared. These components include 2D Ring resonators and 2D Interferometers.

Acknowledgment

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References

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