This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/LPT.2016.2587320, IEEE Photonics Technology Letters

Enhanced Phase Sensitivity in Plasmonic Refractive Index Sensor based on Slow Light

Rukhsar Zafar[1,2], Mohammad Salim[1]
Department of Electronics and Communication Engineering,
[1]Malviya National Institute of Technology, Jaipur, India
[2]Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur, India

Abstract- Fano spectrum exhibits an intriguing feature of narrow asymmetrical resonance profile which can be used in designing an ultra sensitive refractive index sensor. Here in this paper, an ultra compact surface plasmon sensor is investigated. The sensor is based on Metal–Dielectric–Metal (MDM) waveguide geometry and connected to a pair of stub resonators. The distance between resonators is adjusted in such a manner that their increased coupling leads to an asymmetrical profile resonance which known as Fano resonance. The Fano resonance is very sensitive to any change in refractive index of the material. To measure the sensitivity of the device, stubs are filled with liquid/ gaseous material under test. The structure is numerically simulated by the Finite difference time-domain method (FDTD) and the value of sensitivity is obtained as high as S = 510 nm/refractive index unit with a narrow line width of 19 nm and large Quality factor $Q \approx 80$. Fano resonance is generally accompanied with sharp dispersion which leads to the generation of slow light. To account an effect of slow light in the waveguide phase sensitivity is also analyzed as a function of a group delay. The large value of phase sensitivity is reported which is equal to $S_{\emptyset} = 41.9$ rad for per unit change in refractive index unit. The phase sensitivity rises linearly with the increasing value of group delay or decreasing value of group velocity. Thus, the device is well suited for designing on-chip optical sensors, optical buffers, switches, modulators, and so on.

***Key Words*— Metal-Dielectric-Metal (MDM), Fano resonance, Slow Light, group delay, phase sensitivity.**

I. INTRODUCTION

In recent years, a great interest has been attracted towards Fano resonance due to its intriguing applications in the area of Electromagnetically Induced transparency [1], generation of slow light [2], biological and chemical sensing [3],[4] etc. The Fano resonance, also referred as Fano effect, was firstly demonstrated by U Fano as quantum-mechanical phenomenon [5]. Later, this asymmetrical Fano resonance based system is also realized in the platform of photonics [6], plasmonics [7], and Meta-materials [8] using classical approach. In the last decades, the generation of Fano effect is increased in plasmonics or Surface Plasmons based systems because of its exciting feature of confining light beyond diffraction limits [9]. In a coupled system, hybridization of different plasmon modes supported by different resonating structures leads to generation of a large electromagnetic field congregation [11]. The near-field coupling between neighboring resonators significantly changes its optical behavior and result in an entirely asymmetrical shaped resonance profile known as Fano resonance [12]. When two modes have an approximately same resonant frequency, their coupling leads to so called, Electromagnetically Induced Transparency (EIT). It is characterized by a sharp transition in the transmission window which makes the system transparent to input radiation which was initially prohibited from being transmitted [13]. The Fano resonance or EIT provides sharp transition near the resonance and supports large value of quality factor. Therefore, it is intensively studied in the sensing applications [14]. Singh et. al. has achieved a high sensitivity level with Q=28 in asymmetrical spilt ring metamaterial resonator structure by exciting Fano resonance [15], but an asymmetrical profile of Fano effect is generally accompanied by sharp dispersion near the vicinity of resonance and this in turn results in large reduction in the group velocity of light [13], [16]. Wang et. al. has proposed a MDM waveguide which exhibits a significant slow-light effect based on EIT and reported the large value of group index [17]. MDM waveguide geometry is assumed to be an ideal platform for the generation of slow light.

If the sensing application is explored with the slow light effect then the sensitivity of sensor is greatly enhanced due to the increased light-matter interaction [18]. Zhang et. al. has proposed an improved design of slow light based displacement sensor and demonstrated a high level sensitivity of 1.035 rad/mm [19]. The liquid refractive index sensor based on slow light is also reported recently with an ultra large sensitivity but having long active region of 1 mm [20]. Here, in this article, the sensing capability of slow light based refractive index sensor is explored with greatly reduced sensing area. The slow light effect is generated in MDM waveguide which is coupled to a pair of resonators. The large value of sensitivity $S_n = 510$ nm for per unit change in refractive index unit (RIU) is reported. The quality factor of transmission spectrum is computed equal to 80 with a narrow line-width of 19 nm. The phase sensitivity is also analytically computed and the maximum value is obtained as high as $S_{\emptyset} = 41.9\, rad\, RIU^{-1}$ or 2400.69 degree/RIU. Although a larger value of phase sensitivity is available in the previous literature for optical fibre (OF) based sensors, but comparatively larger sensing area is available for sensing in OF cable [21-22]. The proposed sensor is MDM based SP sensor, and the obtained value of phase sensitivity is very much larger than previously reported SP and LSPR (Localized Surface Plasmon Resonance) based sensors [23-24]. To account an effect of slow light, the variation of phase sensitivity is also computed against the changing group delay of the light. The obtained value of phase sensitivity can be further increased by tuning the structural parameters. Thus, by combining the merit of sub-wavelength confinement in MDM waveguide with slow light effect, the sensitivity of the device is greatly increased, and an ultra compact size of the device makes it viable for on-chip optical sensors.

Superlattices and Microstructures 92 (2016) 308–315

Contents lists available at ScienceDirect

Superlattices and Microstructures

journal homepage: www.elsevier.com/locate/superlattices

Effect of phase transformation on optical and dielectric properties of pulsed laser deposited $ZnTiO_3$ thin films

Praveen K. Jain [a, b, *], Mohammad Salim [a], Davinder Kaur [c]

[a] Department of Electronics & Communication Engineering, Malaviya National Institute of Technology, Jaipur, India
[b] Department of Electronics & Communication Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, India
[c] Department of Physics, Indian Institute of Technology Roorkee, Roorkee, India

ARTICLE INFO

Article history:
Received 29 December 2015
Received in revised form 11 February 2016
Accepted 11 February 2016
Available online 13 February 2016

Keywords:
Pulsed Laser Deposition
ZnTiO3
Dielectric Properties
Phase transformation

ABSTRACT

Zinc titanate ($ZnTiO_3$) ceramics were prepared by conventional solid state reaction method using ZnO and TiO_2 in a molar ratio of 1:1 with optimized parameters. It was found that the sample sintered at 800 °C for 12 h exhibit single hexagonal phase of $ZnTiO_3$. $ZnTiO_3$ thin film have been deposited on ITO coated glass substrate using pulsed laser deposition (PLD) technique employing a KrF laser source ($\lambda = 248$ nm). In present work, the effect of substrate temperature, which leads to transformation of hexagonal phase to cubic phase, has been studied. The XRD pattern revealed that pure hexagonal phase of $ZnTiO_3$ appear upto 400 °C and more increment in substrate temperature leads to transformation of hexagonal phase to cubic phase. We have observed the blue shift in absorption edge at lower temperature. When the substrate temperature increases from 300 to 400 °C the band gap decreases due to strong hexagonal phase, but more increment in substrate temperature increases the band gap causes by change of phase from hexagonal to cubic. The dielectric constant of $ZnTiO_3$ thin film increases as the substrate temperature increases due to the enhancement in crystallinity and improved morphology.

1. Introduction

ZnO is a wide band-gap semiconductor with outstanding optical and electrical properties [1,2] and TiO_2 is one of the most important semiconductors with high photocatalytic activity, being non-toxic, stable in aqueous solution, and relatively inexpensive [3,4]. ZnO and TiO_2 have attracted much interest on either single material [5,6] or ZnO–TiO_2 composites [7,8]. Dulin and Rase [9] reported that three compounds exist in the ZnO–TiO_2 system, including $ZnTiO_3$ (hexagonal and cubic), Zn_2TiO_4 (cubic), and $Zn_2Ti_3O_8$ (cubic). Among these compounds the stable formation of $ZnTiO_3$ phase was known to be complicated, mainly due to the decomposition of $ZnTiO_3$ into Zn_2TiO_4 and rutile TiO_2 at about 945 °C.

With the recent progress of microwave applications, including mobile telephones and satellite communication system, the development of high-quality microwave dielectrics has been intensified so that they can be used as dielectric resonators, capacitors, and filters. $ZnTiO_3$ is an attractive material for applications in microwave dielectrics [10–13]. $ZnTiO_3$ has also been regarded as a good candidate for low-temperature cofired ceramics (LTCCs) due to its relatively low sintering temperature and

* Corresponding author. Department of Electronics & Communication Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, India. Tel.:+91 141 5160400.
E-mail address: praveenjain.spsl@gmail.com (P.K. Jain).

http://dx.doi.org/10.1016/j.spmi.2016.02.018
0749-6036/