Transmission-type active amplitude modulator with indium tin oxides

Yohan Lee, Sun-Je Kim, and Byoungho Lee*

Inter-University Semiconductor Research Center and School of Electrical and Computer Engineering,
Seoul National University, Gwanak-Gu, Gwanakro 1, Seoul 08826, South Korea
*E-mail: byoungho@snu.ac.kr

1. Introduction

Recent studies have focused on the demonstration of active nano-devices whose optical properties can be controlled electrically for applications. Studies using electro-optical materials, such as graphene, phase change materials, and transparent conducting oxides have been reported [1-3]. In particular, indium tin oxides (ITOs) have attracted a lot of attention owing to outstanding electro-optical characteristics, where the refractive index change reaches unity if biased in near-infrared range. However, the thickness of charge accumulation layer of which the refractive index changes is about only 1 nm when electric field is applied on ITO. In addition, owing to the structural limitation for applying the voltage, so far, only research on reflection-type with metal layers has been reported.

In this paper, we demonstrate numerically a transmission-type active amplitude modulator capable of tuning amplitude by applied fields. It is designed to induce stronger field enhancement on ITO layer. It is confirmed that proposed device acts as amplitude modulator in resonant wavelengths.

2. Design, Results, and Discussions

Proposed modulator is composed of an array of Fabry-Pérot (FP) cavities periodically arranged on a dielectric waveguide, as shown in Fig. 1. In this system, two different resonances occur, FP resonance and waveguide mode resonance, and each resonance is sensitive to the period of nanoslit (P) and the thickness of poly-Si layer (h_4). Therefore, the resonant characteristics such as amplitude and the resonant wavelength can be designed by engineering aforementioned parameters.

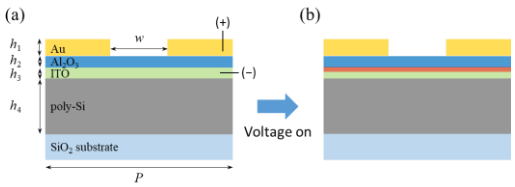

Fig. 1. (a) A schematic illustration of proposed modulator. The parameter w is slit width of gold array, and h_1, h_2, h_3, and h_4 mean the thickness of gold, aluminum oxide, ITO, and poly-Si layer, respectively. (b) Formation of accumulation layer by applied voltages (red region).

Instead of using contact metal layer, the electrodes were connected to the ITO layer directly so that the voltage could be applied as shown in Fig. 1(a). It is possible because ITO has nearly as many electrons as metals. Besides, ITO is transparent, thus suitable for use as a transmissive electrode. Poly-silicon layer on substrate supports stronger field enhancement in ITO layer due to its high refractive index. Figure 2(a) shows that z-component of electric-field is strongly enhanced between gold and poly-Si layers. We analyze transmission spectra by Fourier modal method when the applied voltage varies. It is confirmed that the intensity of transmitted wave changes from 0.3 to 0.4 in resonant wavelength of 1.8 μm when the refractive index of accumulation layer changes as shown in Fig. 2(b).

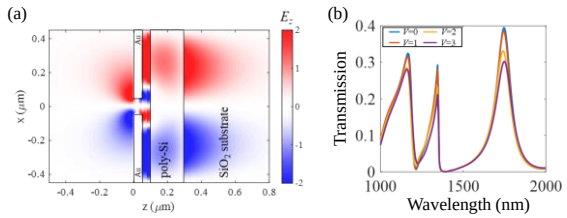

Fig. 2. (a) z-component of electric-field profile on resonant wavelength (λ_{res} = 1.8 μm). (b) Transmission spectra for various applied voltages. The permittivity of ITO is fitted by the Drude model.

3. Conclusion

We propose transmission-type absorption modulator with ITO taking advantage of the unique properties such as transparency and high electrical conductivity. To overcome the limitation of very small refractive index changing region, poly-Si is used to enhance field confinement in ITO layer. Our structure has many potential applications for flat optics elements.

Acknowledgment

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