Electro-optic Polymer / Titanium Dioxide Hybrid Modulators

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1. Introduction

Inside optical transmission systems, electro-optic (EO) modulators are one of the vital building blocks. Among different types of materials used to construct modulators, EO polymer can offer intrinsic advantages such as a large EO coefficient (r_{33}), high bandwidth, low dielectric constant and loss, and excellent compatibility with other materials and substrates. Here, we present several novel designed modulators based on the EO polymer / titanium dioxide (TiO_2) hybrid structure.

2. General Instructions

The advantages of ring resonators are their compact footprint, low driving voltages, and the ability to drive them as lumped RF elements to eliminating the need for traveling-wave design. However, conventional EO polymer waveguide modulators have a bending radius of around one millimeter, thereby limiting the miniaturization of the modulators. Additionally, the typical inter-electrode distances in such waveguides are ~10 μm, but the thickness of the EO core is ~3 μm. This means that there is a large voltage in the modulator dropping across the thick cladding layers, resulting in a small resonance shift control and a high peak to peak voltage $V_{p\text{-}p}$.

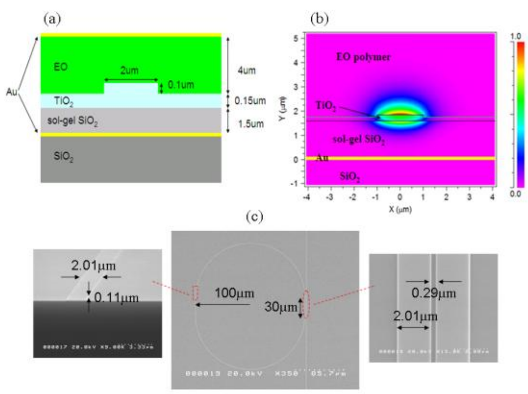

Fig. 1 *(a) Designed cross-section of the TiO_2 core / EO polymer ring resonator waveguide; (b) simulated TM_{00} mode intensity distribution; (c) top view SEM image of the TiO_2 ring structure (left: view of cross-section, right: view of bus-ring gap).*

The ring resonator modulator fabricated in this study was constructed using a thin TiO_2 ridge waveguide and EO polymer cladding layer, but without a traditional transparent cladding. The 250 nm thick TiO_2 has the benefits of a shortened electrode distance, a substantially improved poling efficiency, and a minimized ring radius in the 100 μm scale. As a result, our modulator shows the highest resonance a tunability of 0.02 nm/V and an in-device r_{33} of 105 pm/V. A modulation depth of 3dB was observed at the frequency response function at 20 kHz using a 2 $V_{p\text{-}p}$ clock signal.

In addition, an electro-optic (EO) modulator composed of an EO polymer / TiO_2 hybrid waveguide has been designed and fabricated. By using a TiO_2 strip line (0.3×0.3 μm^2 cross-section) as the core, the confinement factor in the EO polymer is optimized for the highest EO activity. The coplanar electrode spacing is examined to enable effective poling and a small propagation loss. The measured in-device EO coefficient is 100 pm/V at 1550 nm wavelength, and a Vπ is 3.2V for the 12 mm-electrode length. The results also predict a possible Vπ of ~1V in a push-pull Mach-Zehnder interferometer structure. The modulator exhibited an excellent temporal stability for the EO activity at 85 ºC for 500 hours due to the high glass transition temperature of the EO polymer and the temperature-insensitive TiO_2 strip line.

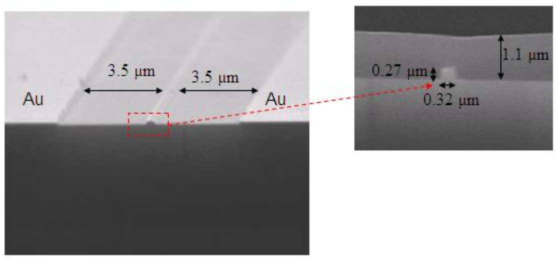

Fig. 2 *SEM images of the top-view and oomed in TiO_2 channel (after coating EO polymer) of the modulator*

References

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