2023 Conference on Lasers and Electro-Optics Europe & European Quantum Electronics Conference (CLEO/Europe-EQEC) | 979-8-3503-4599-5/23/$31.00 ©2023 IEEE | DOI: 10.1109/CLEO/EUROPE-EQEC57999.2023.10232699

Sputtered PZT-on-SOI Acousto-Optic Modulator Using Remote Buffer crystallisation

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On-chip Acousto-optic interaction finds applications in photonic modulators, filters, non-reciprocal light transmitters such as isolators, frequency comb generators and quantum processing of information. The acousto-optic (AO) modulation offers the highest modulation extinction than any other light modulation scheme. There have been demonstrations of such interaction on LiNbO3, GaAs, InP, and AlN [1]. However, integration of the AO modulator offers a more scalable integration opportunity than any other platform. Lead zirconate titanate (PZT) with a very strong piezoelectric coefficient (typically, d_{31} = 274 pC/N) and electro-mechanical coefficient (k^2_{31} =15%) [2], making it an efficient alternative for acousto-optic interaction. Demonstration of PZT-on-SOI [3] was done using a heterodyne set-up with a sol-gel process. The limitation of this work is the presence of a buffer layer in between PZT and waveguide leads to smaller interaction between SAW and waveguide. In this work, we use Ti/Pt as the remote buffer layer to deposit sputtered PZT, which enables us to fabricate an acousto-optic modulator on SOI. This method increases the interaction between the silicon (Si) waveguide and the SAW wave generated in the PZT layer by getting rid of the intermediate layer on top of the waveguide leading to a refractive index modulation in the Si waveguide as seen in Fig.1(a) schematic.

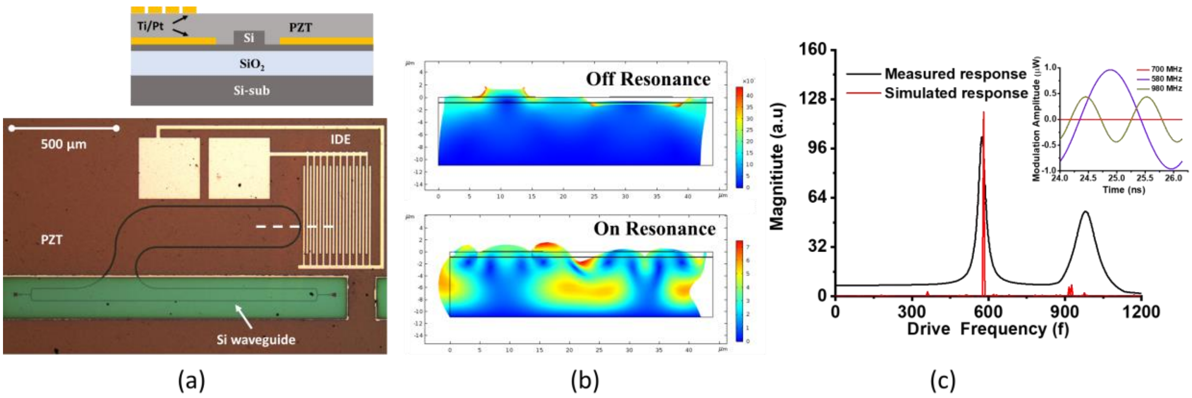

Fig. 1 (a) Microscope image of the fabricated test device and the cross-section of the stack, (b) COMSOL simulation cross-section of the acoustic modulation, and (c) Simulated and measured acousto-optic response of the fabricated device. Inset shows measured on and off-resonance time-domain signal.

Fig.1(a) shows the optical image of the fabricated device. Device fabrication starts with a 90 nm shallow etch of Si in SOI to form a Mach-Zhender interferometer (MZI). Ti/Pt layer of thickness 20/80 nm is deposited around the waveguide structure, followed by 1 µm PZT deposition. Bottom Pt serves as the seed layer to grow PZT film. PZT is removed from the unwanted sections, such as the grating coupler and is annealed at 550^{0}C. The interdigital transducer is defined with 20/80 nm of Ti/Pt layer. The number of periods is kept at 21 and an electrode width of 10 um at a distance of 4 um from the arm of MZI. As seen in Fig.1(a), the actuation of SAW waves would modulate the index of the MZI arm covered in PZT, leading to optic modulation. The displacement on resonance is four orders of magnitude that of off-resonance, as is seen in the COMSOL simulation in Fig.1(b). The resonance frequency obtained via simulation for an IDE period of 21 µm and 20 µm period is 500 MHz and 580 MHz, respectively. The surface acoustic waves are induced by applying a square wave of 2 V_{p-p}. As is seen in Fig. 1(c), the resonance for the acoustic modulation measured is at 580 MHz as the primary resonance and 1 GHz as the second harmonic, which matches with the simulated resonance behaviour for a 20 µm period IDE. The error is attributed to the period change during the process of lithography. The modulation with varying frequencies can be seen in the inset of Fig.1(c). The device can further be optimised by poling the PZT layer to increase the opto-mechanical response and, there, by increasing the depth of modulation. The bottom Pt electrode can be used to poll the whole arm of MZI compared to poling with a coplanar electrode which would require a higher electric field.

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