Functional oxide for linear and nonlinear optics

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ABSTRACT

Intensive researches are currently conducted on the miniaturization of photonic devices and on the combination of photonics and electronics to decrease the power consumption and to create novel functionalities for a myriad of applications including datacom, telecom, sensing and quantum optics, to name few. In this context, functional oxides have emerged as a promising material family to expand the functionalities of current photonic circuit thanks to their wide range of properties such as multiferroicity, piezoelectricity and optical nonlinearities. Among these materials, Yttria-Stabilized Zirconia (YSZ) is well known as a buffer layer for oxide-based thin films heterostructures, extensively used for $LiNbO_3$, $PbTiO_3$, $Pb(Zr,Ti)O_3$ and $YBa_2Cu_3O_7$ integration on silicon, but has not yet been studied for integrated optics. YSZ is also well known for its extraordinary thermal and chemical stability, as well as its hardness and mechanical durability. An increasing quantity of applications uses this material for the combination of its excellent mechanical and optical properties, such as its high refractive index, large optical band gap and transparency from the ultraviolet (UV) to the mid-infrared (mIR).

The work has been mainly focus on the integration of YSZ functional oxide on sapphire substrates. Due to the refractive index contrast between sapphire (1.75) and YSZ (2.12) at a wavelength of 1300 nm, optical YSZ waveguides can be designed with good mode confinement. The study and optimization of growth parameters using Pulsed-Laser Deposition (PLD) technique allowed achieving high quality YSZ on sapphire (0001) with remarkably sharp X-Ray diffraction rocking curve peaks in 10^{-3} degrees range for two different out-of-plane orientations. We have demonstrated that a thermal annealing of sapphire substrate before the growth, played an important role in thin film orientation. Passive photonic structures such as grating couplers, single-mode waveguides and resonators have been then designed and fabricated thanks to electronic lithography and Ion-Beam Etching (IBE) techniques. Preliminary optical characterization results of integrated structures will be presented, for instance propagation losses in YSZ waveguides as low as 2 dB/cm, ring and disk resonators with Q factors up to 12000, sub-wavelength Bragg filters with 16.2dB extinction ratio for 1.5 nm bandwidth. Finally, large third-order nonlinear susceptibilities has been estimated three times larger than in silicon with the absence of two photon absorption at telecom wavelengths. Our results demonstrate the fabrication of passive devices and basic building blocks, which combined with the outstanding nonlinear properties, provide a promising robust platform for functional oxides-based nonlinear on-chip applications. Furthermore, the first integration of YSZ on silicon photonics platform will also be reported.

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