C-band linear propagation characteristics for a 300 nm film height Silicon Nitride photonics platform

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Silicon Nitride (Si_3N_4) material is widely used in the fabrication of microelectronic circuits, as a basic material for developing the electronic devices mainly due to its electronic, structural and chemical properties [1]. For photonics, the first fabrication of Si_3N_4 films on a SiO_2 buffer on Silicon wafers, for propagation of red visible light was reported early in 1977 [2]. After similar works during the 1980s, a fully integrated Mach-Zehnder Interferometer (MZI) sensor was reported a few years latter [3]. Renewed interests on this material platform started again back in 2005 [4,5] with developed processes and applications in the NIR. They were followed developments of SiONx waveguides [6], whereas [7-9] developed Si_3N_4 waveguides (2008-2011). Up to 2011 the demonstrations by telecom related groups were for NIR C-Band at 1550 nm, with waveguide cross-sections for moderate confinement (film heights h>100nm), despite other researchers [8] reported by 2011 low confinement waveguides (film h<100 nm). In 2013 some groups [10,11] set new paths of Si_3N_4 technology for visible light applications. In parallel since 2011, there is a growing interest on high confinement (h>400 nm) waveguides for NIR+ (λ>2000nm), [12-15], whereas very recently new moderate confinement platforms appear [16-18]. In general, medium film height, 100-400nm, provides moderate propagation loss, confinement and non-linear effects with comparatively simpler fabrication processes. For the NIR, moderate confinement waveguides (h=150-400nm) have been demonstrated by several groups [4,17]. LPCVD Si_3N_4 guiding film heights of 150-200nm, with waveguide widths 0.8-2.0µm resulted into propagation losses of 0.11-1.45 dB/cm at 1550 nm, for BOX heights up to 5.0µm. Other groups as [19] have reported 3D integration on top of SOI, employing LPCVD Si_3N_4 guiding film heights 300-400nm, with waveguide widths 0.8-1.0µm, resulting into propagation loss of 1.30-2.10 dB/cm at 1550 nm for BOX heights in between 2.0-5.0µm.

In this paper we present the characterization of the linear propagation properties (loss, group index, dispersion, birefringence, thermo-optic phase shift) for Si_3N_4 strip waveguides with guiding film height of 300nm. The devices were fabricated on a 100mm Si wafer, composed of a SiO_2 buffer (2.5µm thick, n=1.464) grown by thermal oxidation of the silicon substrate, following a LPCVD Si_3N_4 layer with thickness 300nm (n= 2.01) and a 2.0µm thick SiO_2 (n=1.45) deposited by PECVD. The metal layer stack is 30nm Cr and 100nm Au. In some wafers of the batch, additional process steps were deployed to improve the optical quality of the structures (cf. [4]). A set of test structures, MZIs, spiral waveguides and ring resonators (RRs), Fig. 1, was deployed for strip waveguides of width 1.0µm. The MZI layout was devised so as to have the length difference only in straight sections of the width of interest, with a bend radius of 50µm to reduce the footprint. The RRs and spiral waveguides (radius 150μm for negligible bend loss) were deployed to perform full-field time resolved measurements using optical frequency domain reflectometry (OFDR) [20], in transmission and reflection mode respectively.

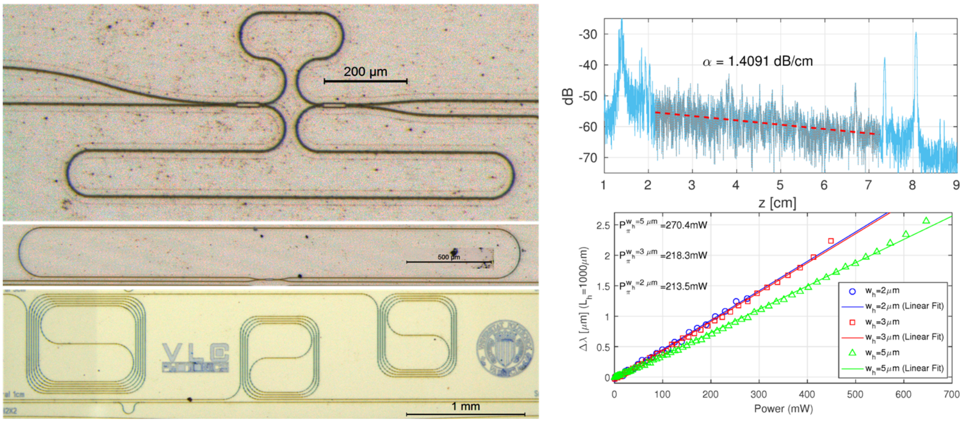

Fig. 1. Test structures (left), MZI, RR and spirals, and measurements (right), OFDR backscattering and thermo-optic tuners switching power Δλ=1 nm corresponds to P_π).

The propagation loss was derived both from the transmission spectrum of MZIs [21] and the backscattering of spiral waveguides, Fig. 1. Values in the range of 1.2-1.6 dB/cm were obtained for devices in the wafers without oxidation and annealing, so further loss reduction can be expected [4]. From the relative positions of the nulls in the transmission spectra of MZIs, n_g=1.90-1.92 was inferred. The dispersion was derived from transmission OFDR measurements of RRs, yielding [-0.7,-1.0] ps/nm·m, that match those from the second derivative of the simulated effective index (-0.75 ps/nm·m). Time resolved OFDR measurements provided the TE and TM propagation delay difference leading to birefringence of 0.168. Finally, thermal tuners of different lengths and widths were characterized, with P_π in [213,270] mW as shown in Fig. 1.

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