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Material characterisation of LPCVD SiN and understanding loss behavior

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SiN photonic integrated circuit (PIC) technology has emerged as an attractive platform for a variety of sensing, LIDAR, and communication uses.[1] In comparison to Si and InP photonics, SiN offers a wide transparency window, negligible nonlinear losses (*i.e.* two photon absorption), and possesses a low refractive index and a low thermal coefficient. Thus, ultralow loss SiN waveguides have been achieved which are less susceptible to thermal fluctuations.[2] Driving out hydrogen content in SiN via high temperature anneal is critical during processing to minimize optical losses in the C-band (1550nm) wavelength.[3] Here, we discuss possible reasons for increased losses observed in our devices including; 1) cladding oxide, 2) SiN impurities and 3) proximity of a-Si, see process in Fig. 1(a). Note the stack indicated in the scheme illustrates the cross-section at spiral test structure sites only (Fig.1b). An a-Si intermediate layer is also introduced to mitigate the large index difference between SiN and III-V materials for light amplification or detection purposes. Pan *et al*. used the same stack to demonstrate a narrow-linewidth laser post III-V gain medium micro transfer printing.[4] Exemplar SEM images are shown in Fig.1(b) of a SiN waveguide with 1 um oxide top cladding (left image) and an a-Si waveguide layer close to the SiN waveguide (right image). The distance between the a-Si waveguide layer and SiN is 100 nm (nominal, see blue arrows in Fig.1(b). We will outline the SiN waveguides losses as were measured using the cut-back method of varying spiral lengths at process steps 1, 3 and 4.

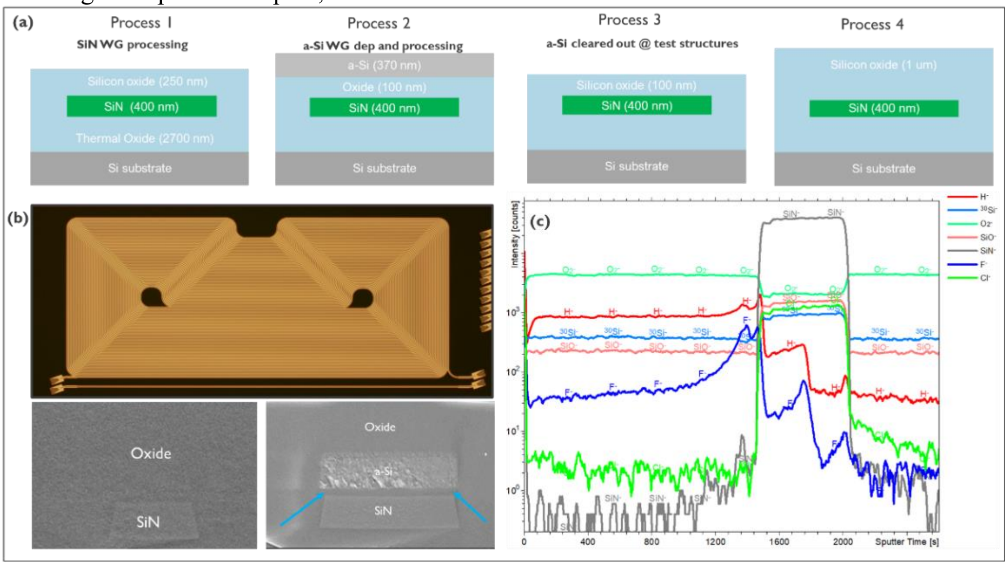

Fig. 1 (a) Overview of scheme for processsing a-Si WGs on LPCVD SiN WGs. (b) Optical image of spiral structures at test sites. (c) X-SEM images of SiN (400 nm) and a-Si (370 nm) stack. (d) TOF-SIMS data displaying H and Cl content in the current stack.

For example, an optical loss decrease is exhibited progressing from process 1 to process 4 at 1550nm for 2.5 um wide SiN waveguides. While overall optical losses decrease, larger spiral structures show an increase in losses post a-Si processing (process 3). We note that the H and Cl content, see TOF-SIMS in Fig 1. (c), potentially impacts the overall losses determined. The optical loss is reversed following top cladding oxide deposition at 400˚C, inferring the process sensitivity to temperature. Therefore, we hypothesize that the final oxide deposition temperature contributes to the lowering of the optical losses. We will outline the critical process parameters, *viz.* the oxide distance and oxide quality between the SiN waveguide and the a-Si intermediate layer, a-Si precursors, and oxide deposition temperature. Moreover, future work will entail further chemical analysis to fully comprehend the interface properties at the SiN waveguides due to close presence of the a-Si layer to improve overall SiN PIC performance.

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