GALLIUM NITRIDE ON GALLIUM OXIDE SUBSTRATE FOR INTEGRATED NONLINEAR OPTICS

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Gallium Nitride (GaN), being a direct bandgap semiconductor with a wide bandgap and high thermal stability, is attractive for optoelectronic and electronic applications. Furthermore, due to its high optical nonlinearity—the characteristic of all III-V semiconductors— GaN is also expected to be a suitable candidate for integrated nonlinear photonic circuits for a plethora of applications, ranging from on-chip wavelength conversion to quantum computing. Although GaN devices are in commercial production, it still suffers from lack of a suitable substrate material to reduce structural defects like high densities of threading dislocations (TDs), stacking faults, and grain boundaries. These defects significantly deteriorate the optical quality of the epi-grown GaN layer, since they act as non-radiative recombination centers. Recent studies have shown that GaN grown on (-201) β-Gallium Oxide (Ga_2O_3) has superior optical quality due to a better lattice matching as compared to GaN grown on Sapphire (Al_2O_3) [1-3]. In this work, we report on the fabrication of GaN waveguides on Ga_2O_3 substrate and their optical characterization to assess their feasibility for efficient four-wave mixing (FWM).

GaN waveguides on Gallium Oxide were designed using *Lumerical Mode Solutions*' eigensolver. The design was optimized for a better mode confinement that would allow for enhanced nonlinear optical interactions [4]. GaN was epitaxially grown on (-201) β-Ga_2O_3, and commercially available high quality GaN on Al_2O_3 was purchased for comparative studies. Initial material characterization showed a much lower lattice mismatch of ~4.7% between (-201) β-Ga_2O_3 and the GaN film, compared to ~14% between Al_2O_3 and GaN [1, 5]. Room temperature photoluminescence study further showed that Gallium Oxide substrate has better optical quality than Sapphire, as shown in Fig.1 (a).

GaN on (-201) β-Ga_2O_3 wafer was first patterned with the designed waveguides using hard mask and subsequently dry-etched using ICP-RIE system. Both patterning and etching parameters were optimized to reduce roughness on the etched surface with the potential of reducing the propagation losses due to scattering. Furthermore, the sidewall roughness was reduced by employing a post-processing wet etching technique. Scanning Electron Microscopy (SEM) images of as-etched and post-processed GaN waveguides are shown in Fig.1 (b).

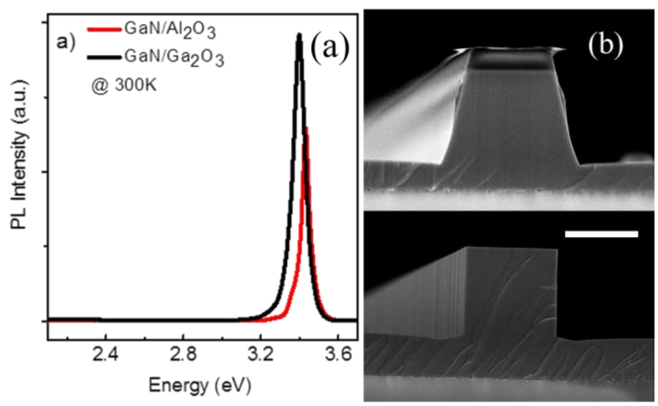

Fig. 1: (a) Room temperature photoluminescence data for GaN grown on Sapphire and Gallium Oxide. (b) SEM images of cross-section of as-etched (top) and post-processed (bottom) GaN waveguides, scale bar represents 1μm.

The optical characterizations of the fabricated waveguides are currently in progress. The aim is to experimentally demonstrate that the improvement in the optical quality, offered by the growth of the lattice-matched β-Ga_2O_3 substrate, the optimization of the waveguide geometry and fabrication process can enhance FWM efficiency. This study can be a stepping stone toward realizing first on-chip source of correlated photon pairs in the visible spectral range.

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