EPITAXIALLY-GROWN GALLIUM NITRIDE ON GALLIUM OXIDE SUBSTRATE FOR PHOTON PAIR GENERATION IN VISIBLE AND TELECOMM WAVELENGTHS

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Gallium Nitride (GaN), along with other III-Nitrides, is attractive for optoelectronic and electronic applications due to its wide direct energy bandgap, as well as high thermal stability. GaN is transparent over a wide wavelength range from infra-red to the visible band, which makes it suitable for lasers and LEDs. It is also expected to be a suitable candidate for integrated nonlinear photonic circuits for a wide range of applications from all-optical signal processing to quantum computing and on-chip wavelength conversion. Despite its abundant use in commercial devices, there is still need for suitable substrate materials to reduce high densities of threading dislocations (TDs) and other structural defects like stacking faults, and grain boundaries. All these defects degrade the optical quality of the epi-grown GaN layer as they act as non-radiative recombination centers.

GaN is commonly grown on transparent Sapphire (Al_2O_3) as well as conductive Silicon Carbide (SiC) substrates. The former, however, suffers from lattice mismatch of 14%, leading to higher density of TDs [1] and, while the latter is expensive but lacks transparency in the visible range due to doping [2]. Studies have shown that GaN grown on (-201) β-Gallium Oxide (Ga_2O_3) has superior optical quality due to a better lattice matching. In addition, it is also a conductive, thermally stable and transparent substrate [3, 4]. In this work, we propose GaN epitaxially grown on (-201) β-Ga_2O_3 as a suitable candidate for correlated photon pair generation, leading to on-chip quantum sources for both telecomm and visible spectrum. We also present designs for GaN waveguides to achieve efficient four-wave mixing (FWM) based on the experimental absorption and dispersion data of epitaxially grown GaN on Ga_2O_3.

We also present a detailed modal and dispersion analysis of GaN waveguide designs for enhanced optical nonlinear interactions, resulting in efficient FWM. These waveguides can later be used as on-chip sources for correlated photon pair generation using spontaneous FWM. Such sources could be realized in both simple straight waveguides and microring resonators [5, 6]. We present two separate waveguide designs: one for the visible spectrum, and another one for the telecom C-band. Both designs are optimized for the modal confinement, as well as dispersion and losses induced due to fabrication tolerances [7]. With the improvement in the optical quality, offered by the growth on the lattice-matched Ga_2O_3 substrate, and the optimization of the waveguide geometry to enhance FWM efficiency, we believe that this study can be a stepping stone toward realizing the first on-chip source of correlated photon pairs in the visible spectral range.

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