Distributed Bragg reflectors (DBRs) composed of an AlN/GaN superlattice were demonstrated for the first time on Si(100) substrates. Single-crystal wurtzite superlattice structures were achieved on this cubic substrate by employing offcut Si(100) wafers with the surface normal pointing 4\degree towards the [110] direction. This misorientation introduced an additional epitaxial constraint that prevented the growth of a two-domain GaN surface as well as cubic GaN inclusions. A crack-free 600 nm GaN cap/5 × AlN/GaN DBR structure on Si(100) was demonstrated. This accomplishment of a wurtzite III–nitride DBRs on Si(100) opens the possibility to integrate novel optical and optoelectronic devices with established Si microelectronics technology.

KEYWORDS: distributed Bragg reflectors, gallium nitride, silicon, superlattice
250 Torr directly on the SL. The higher deposition pressure resulted in GaN layers with larger grains and lower defect densities. Details of this procedure and apparatus have been reported elsewhere.\textsuperscript{14)}

Structural characterization was performed with a Hitachi H-9000 top-entry transmission electron microscope operated at 300 kV and a Panalytical X’pert x-ray diffraction (XRD) system. The \textit{ex situ} reflectance was measured at normal incidence using a halogen lamp as a source and reflected beam was dispersed through an Ocean Optics S2000 spectrometer with a 50 μm slit.

In this work, sharp interfaces were found in the SL, as displayed in Fig. 1, which is an electron micrograph of a 600 nm GaN cap/5 × AlN/GaN DBR on Si(100) structure. Additionally, the alternating sequence of AlN and GaN in a SL acts to filter dislocations originating from the interface. Transmission electron microscopy (not shown) found an extremely high level of threading dislocations at the Si/AlN interface ($>10^{13}$ dislocations/cm$^2$). The dislocation level was observed to drop by more than two orders of magnitude through the SL. A similar dislocation annihilation mechanism was reported by the authors for DBR structures grown on Si(111).\textsuperscript{11)} Still, the dislocation density in the GaN cap layer on Si(100) is approximately an order of magnitude higher than that reported for a GaN cap layer on Si(111).\textsuperscript{12)} A more detailed comparison is in progress and will be reported elsewhere.

The theoretical and experimental reflectance of a 600 nm GaN cap/5 × DBR on Si(100) is displayed in Fig. 2. The theoretical reflectance was calculated via the standard transfer matrix method\textsuperscript{15)} for a stop band centered in the blue-green portion of the visible spectrum at 495 nm. The wavelength (or energy) dependent refractive indices were reported in Mastro \textit{et al.}\textsuperscript{11)} To estimate the reflectance, the calculation assumed an ideal SL for the particular stop band. An experimental primary reflectance of 69.8% at 495 nm is compared against a theoretical primary reflectance of 75.1% in Fig. 2. For the DBR on Si(100), the relatively lower reflectance of the experimental reflectance compared to the theoretical reflectance is attributed to scattering due to roughness at the surface and absorption due to defects in the material as well as alloy mixing within the DBR layers.

Strong wurtzite GaN(0002) and (0004) peaks in the XRD scan are observable in Fig. 3(a). The diffraction intensity from the GaN cap layer is much larger than the diffraction intensity from GaN layers in the 5 × DBR. Thus, the intensity of GaN cap diffraction obscures the diffraction signal of the GaN layers in the DBR. An expansion along $\omega$ revealed a full width at half maximum (FWHM) of 0.92° for the GaN(0004) peak. The wide FWHM of the GaN(0004) $\omega$ rocking curve is attributed to the high level of lattice distortion and dislocations in the GaN cap layer. A broadening of the $\omega$ (0004) rocking curve, as was seen in this film, is typically attributed to slight distortions (tilt) between grains in the film.\textsuperscript{6)} Additionally, the AlN(0004) diffraction peak is observable but is not clearly defined. The weakness of the AlN(0004) diffraction is attributed to poor material quality while the broadening of the reflection is attributed to alloy mixing that occurred during AlN and GaN layer growth in the DBR.

In summary, a novel MOCVD grown III–nitride DBR structure on Si(100) was demonstrated. The reflectance of the III–nitride DBR was enhanced by growing the superlattice directly on a Si substrate to augment the overall reflectance due to the high index of refraction contrast at the Si/AlN interface. The DBR structure consisted of alternating layers of AlN and GaN that introduced a compressive stress to balance the large tensile stress generated during cool down from growth temperature. This report demonstrates that III–nitride DBR structures can be fabricated on Si(100) substrates and conceivably within Si integrated circuits.
Research at the Naval Research Laboratory is supported by Office of Naval Research; support for two of the authors (M.A.M. and N.D.B.) was partially provided by the American Society for Engineering Education. The authors thank Mohammad Fatemi for technical discussions.

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