Fabrication of 2D GaN photonic crystals

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Photonic crystals (PCs) are increasingly drawing attention since the pioneering work of Yablonovitch. GaN PCs are especially interesting because of prospective improvement of the internal quantum efficiency, light extract efficiency and the directionality of GaN based LEDs, and novel PC lasers.

However, the difficulty of GaN nanostructure fabrication [1] is well known because of its inert material property. Profile verticality, depth and azimuthal anisotropy are the generally recognized problems for GaN PCs fabrication. Shakya et al suggested that further enhancement of light extract efficiency can be achieved by improving the GaN PCs hole anisotropy [2]. Wierer et al reported that their PCs were 75º tilted and suggested etching deep PCs to extract the first pass of light [3]. David et al suggested azimuthal anisotropic PCs for ultra efficient PC LEDs [4].

We have developed a reliable fabrication process for high quality GaN PCs in STS-ICP Cl plasma. Fig. 1 shows SEM images of hole and pillar type GaN PCs. Obviously the PCs have vertical profile. They are sufficient deep (about 1μm) for LED application and azimuthal anisotropy. The bottom of hole is flat and smooth. The sidewalls of PCs are smooth.

To verify the quality of GaN PCs, we have fabricated and characterized GaN PC waveguides. In order to confine light into a single mode in the vertical direction for 1.55μm wavelength light source, the material with 650nm GaN epitaxial layer on sapphire has been employed for device fabrication. Fig. 2a and 2b are the cross section and the top view of the device, respectively. It can be seen that PC holes are etched through the GaN layer. The dark layer in between GaN and sapphire is the AlN buffer layer. Fig. 3a shows waveguide facet for light to couple in. The ΓM dielectric band and air band in hole type photonic crystal have been obtained as shown in fig. 3b. This result highlights the excellent quality of the fabrication achieved and launches the field of photonic bandgap engineering in gallium nitride and its related semiconductors.

The detailed process development and optical result discussion will be presented.

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2)J. Shakya, K. H. Kim, J. Y. Lin and H. X. Jiang, Apl. Phys. Lett. 85(1), 142, 2004
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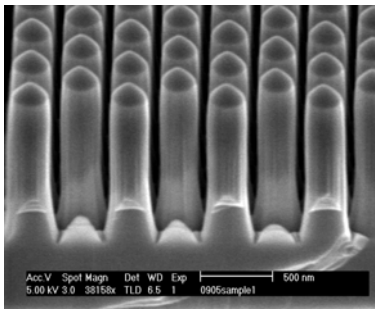
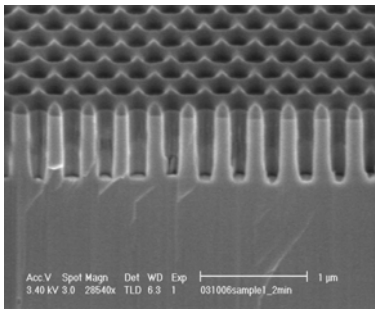
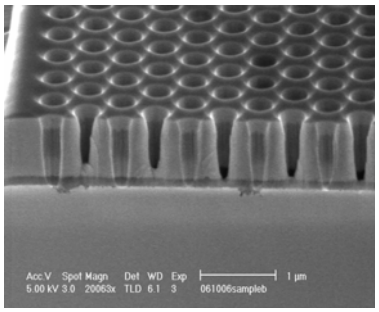


1a

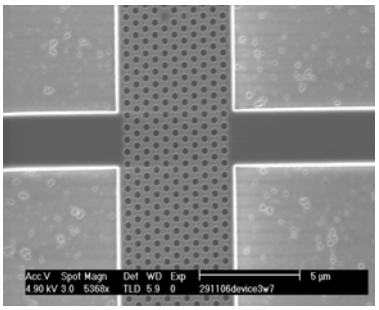


1b

Fig. 1a) and 1b) are SEM images of pillar and hole type GaN PCs, respectively. The depth of PCs is about 1 μm. The GaN PCs are azimuthal anisotropic. The bottom of hole is flat and smooth. The sidewalls are smooth.

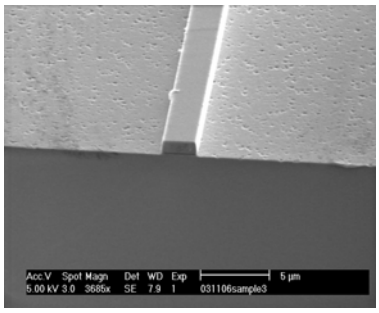


2a

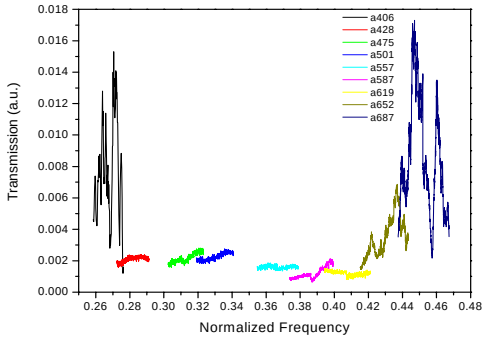


2b

Fig. 2a) shows cross section, and 2b) shows the top view of GaN photonic device designed. The photonic crystals are etched through GaN layer. The dark layer in between GaN and sapphire is AlN buffer layer.



3a



3b

Fig. 3a) is SEM image of the facet of GaN waveguide for light to couple in, 3b) is the preliminary result of the first GaN photonic crystal device, the dielectric band and air band are obtained.