Inteface reaction epitaxy of β-Si_3N_4 on Si (111) and 2H-AlN on β-Si_3N_4 for growth of 2H-AlN template using PA-MBE

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Plasma assisted molecular beam epitaxy (PA-MBE) using rf nitrogen inductively coupled plasma (ICP) cell is able to realize a growth system of group III nitride as a one process growth system from cleaning of a surface of Si substrate to fabrication of GaN related devices using a double buffer layer (DBL) of AlN/β-Si_3N_4/Si, which is prepared by interface reaction epitaxy (IRE). The IRE between N atoms and a 7x7 Si(111) clean surface forms a single crystal β-Si_3N_4 film on Si. IRE of AlN forms a single crystal AlN film on the β-Si_3N_4 by exposed Al atoms and N atoms in the β-Si_3N_4.

The cleaning of Si surface and preparation of a DBL of AlN/β-Si_3N_4/Si using by indirect exposure of nitrogen atoms were performed in a MBE growth chamber. An AlN template was grown on the DBL using activity modulation migration enhanced epitaxy (AM-MEE) with direct exposure of N atoms from a rf ICP discharge cell. The direct and indirect N fluxes were measured by an atom probe using parallel mesh plate, which was biased negatively for the self ionization of N atoms on negatively the biased electrode. The surface steps on Si(111) were controlled by the thermal decomposition of an SiO_2 layer in the MBE chamber. The surface morphology of β-Si_3N_4 was affected by the nitridation temperature and time. The interface roughness of DBL as a layer of two layers of AlN and Si, AlN/DBL/Si was characterized by grazing incidence X-ray reflectivity (GIXR) to evaluate the relationship between the interface roughness and grown AlN films. X ray reflectivity measurement and Xray diffraction studies using PANalytical MRD system were performed to characterized grown films. Atomic force microscopy measurements were performed using Seiko instrument equipment.

By increasing the thickness of the AlN template from 60 nm to 200 nm the crystalinity was improved from 53.7 arcmin, obtained by the measurement of rocking curve of ω full width at half maximum (FWHM) for AlN (0002) peak of X-ray diffraction.

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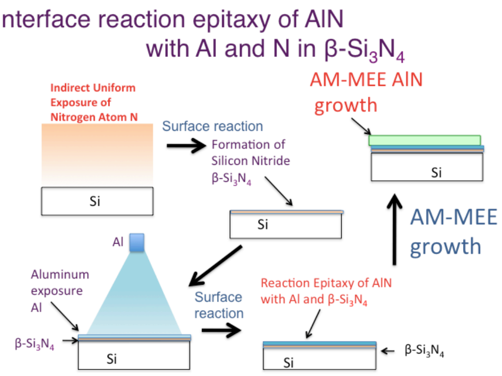
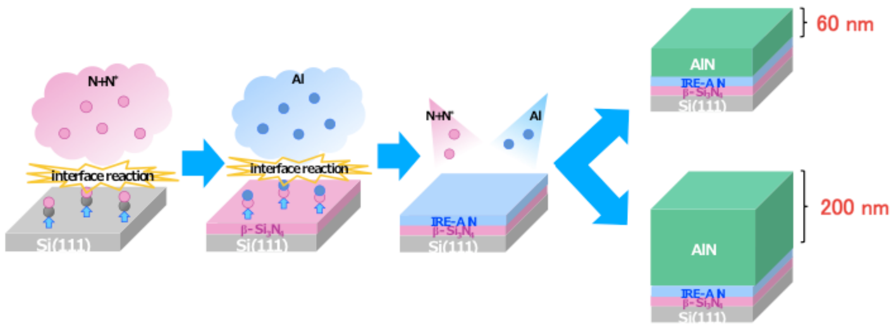


Fig.1 Processes of DBL formation in a MBE chamber with indirect exposure of (N+N*) atonms and successive exposure of Al flux.



(a) Growth of b-Si_3N_4 by IRE.

(b) Growth of IRE-ALN by IRE.

(c) Growth of different AlN templates on the DBL by AM-MEE.

Fig. 2 Preparation process of AlN templates of 30 and 200 nm thickness on Si(111) after growth of DBL, IRE-AlN/β-Si_3N_4/Si(111).

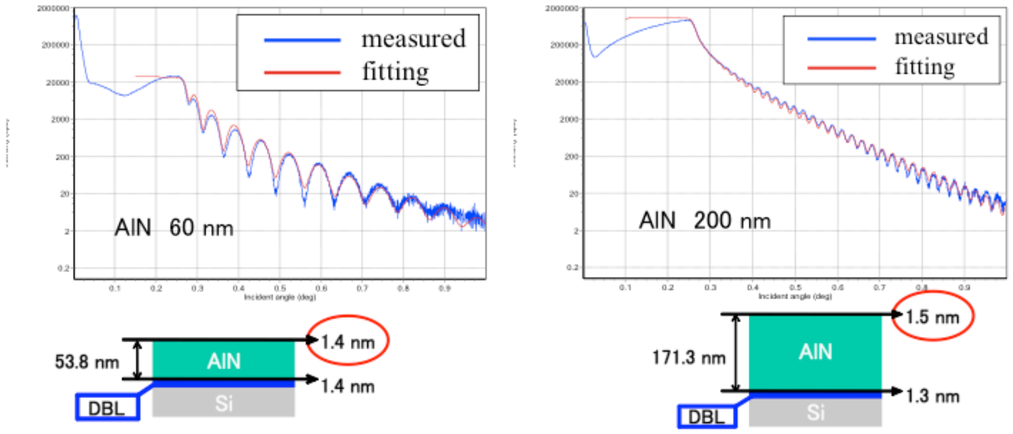


Fig. 3 GIXR patterns for 60 nm（53.8 nm by fitteing) and 200 nm (171.3 nm by fitting) AlN templates and results of simulation by a PANAlytical software of Reflectivity.