Migration enhanced MBE growth of GaN, AlN and AlGaN using RF discharge mode change

T. Ohachi, H. Shimomura, N. Yamabe,
Department of Electrical Engineering, Doshisha University

Osamu Ariyada
Arios Inc. 3-2-20 Musashino Akishima, Tokyo 196-0021, Japan

Aiming at energy saving a radio frequency molecular beam epitaxial (RF-MBE) growth of group III nitride semiconductors and their alloys on Si substrates was investigated. Improvement of nitrogen source, suitable template preparation for cubic and hexagonal phases, the precise control of Ga and exited nitrogen atom flux densities (i.e., J_{Ga} and J_{N}) are our target to investigate. In order to grow high quality layers on a Si substrate a mode-change migration enhanced epitaxial (MC-MEE) growth method was developed.

Inductively coupled RF discharge has two discharge modes, E and H modes for low bright (LB) and high brightens (HB) discharges, respectively. Excited atomic nitrogen species creates only the HB mode. The mode of discharge was controlled depending on pressure by the input RF power for both modes. The MC-MEE uses the discharge mode change between LB mode (E mode) and HB one (H mode). The time sequence of the opening of the shatter of a Ga effusion cell was used for the trigger signal to operate the mode change operation of nitrogen RF discharge. The sequence of the LB and HB nitrogen flux irradiation plays an important role to control the amount of excited molecules, which do not react with Ga, and the amount of N atoms, which are active nitrogen species.

As a template for hetero epitaxial growth of group III nitride semiconductors and their alloys on Si substrates AlN was used because of maintaining clean environment in a growth chamber. Epi-ready (001) or (111) 2 or 3 inch Si wafers were used without any prior chemical treatment. Prior to the growth of AlN by the MC-MEE for hexagonal phase, 7x7 surface reconstruction of Si (111) surface was exposed for 3 sec for about 1 mono layer Al deposit at about 800 ^{0}C to form γ-Al/Si. Growth of 2H-GaN on Si(111) was confirmed *in situ* using reflection high energy electron diffraction. For cubic phase Si(001) substrates were used. During the growth stoichiometric adjustment of Ga (or Al) and N fluxes was carefully monitored through RHEED pattern. Combinatorial methodology, which realizes various III/V flux ratio without substrate rotation due to non-uniform flux, showed that cubic-GaN(001) was obtained under slightly larger than unity of the flux ratio (i.e., $J_{\mathrm{Ga}} / J_{\mathrm{N}} = 1.1$). Flux ratio of J_{Ga} and J_{N} was sensitive in suppressing the formation of Ga droplets.

The crystalline structural purity of cubic-GaN (001) was calculated from the ratio of the integrated intensities between cubic (002) peak and total intensity including hexagonal peak and X-ray diffraction pole figure. The crystal structure of the epilayer was characterized by XRD (PANalytical, X'pert MRD system) , FE-SEM and HRTEM.

Brief review of RF-MBE and optical properties of grown films will be presented.