TEM Study of InN Films Grown with In-situ Surface Reformation by Radical Beam Irradiation

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Introduction

InN has outstanding material properties among III-nitride semiconductors, i.e. the smallest effective mass, the largest mobility, the highest peak and saturation velocities, and the smallest direct-band energy. Therefore, InN has been considered to be a very promising material for future electronic and optoelectronic devices. For a long time, however, difficulty in obtaining high quality InN due to high threading dislocation densities has hindered the realization of InN device applications. We succeeded in decreasing the threading dislocations densities in InN by growing InN films on micro-facetted InN template wet etched by KOH.[1] However, in this technique, InN template need to be taken out from MBE growth chamber for KOH wet etching and reinserted back for re-growing InN film. In this report, we propose in-situ surface reformation by radical beam irradiation (ISRRI). Threading dislocation densities in InN grown by ISRRI method and DERI method[2] are evaluated by X-ray diffraction and TEM characterization.

Experiments and Results

In this study, InN films used were grown on MOCVD-grown (0001) GaN/sapphire substrate. Prior to growth, the substrate was thermally cleaned at 750℃ for 10 min and a GaN layer was deposited for 3 min. For ISRRI method, after InN was grown at 425℃ for 1 hour, N radical-beam irradiation was performed at 330℃ with a plasma power of 200 W, and InN was then regrown for another 1 hour. As comparison, InN was grown at 425℃ for 2 hours by DERI method. TEM specimens for cross-sectional observation were prepared by focused ion beam etching and observed with a JEOL2010 electron microscope operated at 200 kV. In order to characterize the type of dislocations, cross-sectional TEM observations with a different g vector were carried out. It was found that InN grown by DERI method had a high density of edge-type and screw-type dislocations which are estimated to be more than 1×10^{10} and $\sim1\times10^{9}$ cm^{-2} respectively. This result shows that although DERI method supplies simple and reproducible growth of high-quality InN with a flat surface,[2] it shows less improvement upon threading dislocation density. In the other hand, the density of screw-type dislocation in InN grown by ISRRI method is estimated to be 1×10^{9} cm^{-2}, which propagated directly from the substrate to the top surface of InN. Fig. 1 shows a cross-sectional TEM image of InN film grown by ISRRI method with g = 1-100. A high density of dislocations with edge component is clearly observed. Furthermore, a slight of edge dislocations bending can be seen at several places along the interface between regrown region and template. However, the propagation of the edge dislocations was not completely terminated as demonstrated in InN grown on KOH wet etched InN template.[1] This can be explained by the size difference of fine asperities at the interface of regrown region and template produced by radical beam irradiation (~10 nm) compare to the large pyramids produced by KOH wet etching (~150 nm). Therefore, details studies on radical-beam irradiation conditions should be conducted in order to reduce edge dislocation density in the regrown InN.

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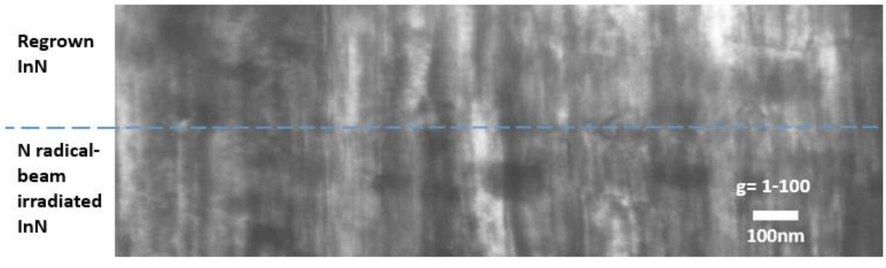

Fig. 1. Cross-sectional TEM image of the InN grown by ISRRI method with g = 1-100.