Comparison of dislocation properties in GaN epilayer grown by MOCVD with MBE

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It has been a puzzlement that GaN related devices show high luminescence efficiency in spite of its high dislocation densities in the epilayer. Though it has been suggested that the lifetime of GaN based laser diodes seems depend on the dislocation density, there have been controversial views about their optical properties; whether the dislocation is related to the nonradiative recombination centers or not. Recently, transmission electron microscopy (TEM), an atomic force microscopy (AFM) and a scanning electron microscopy (SEM) observation for etched GaN surface showed the existence of various kinds of dislocations in the GaN epilayer, that is, screw, edge and mixed dislocations.[1)] The relationship between photoluminescence (PL) intensity and etch-pit density (EPD) suggests that only screw dislocations act as the nonradiative centers.

In this study, we investigated the luminescence property of screw dislocations by comparing two GaN samples whose dislocation densities are quite different. Our results suggest that some kinds of screw dislocations do not affect the reduction of the luminescence intensity.

Two GaN samples grown on sapphire were prepared for this investigation. One was grown by metal organic chemical vapor deposition (MOCVD), and the other was by molecular beam epitaxy (MBE) using nitrogen activated by RF plasma. PL spectra of both samples show sharp band edge emission with weak deep level emission (The ratios of the band edge emission to the deep emission of the MOCVD and MBE samples are below 1/50 and 1/100, respectively). By cross sectional TEM observation with <11-20> direction, the densities of screw and mixed dislocations of MOCVD and MBE samples were estimated to be about 4×10^{-6}cm^{-2} and 10^{-9}cm^{-2}, respectively.

In order to investigate the external fluorescence quantum efficiencies, η, for each sample, we carried out photo-calorimetric spectroscopy (PCS) measurements. The details of the experimental technique of PCS have been described elsewhere.[2)] From PCS spectra, the η's derived from the band edge region were determined to be 0.18 and 0.22 for the MOCVD and MBE samples, respectively. Table I summarizes the results of the densities of the screw and mixed dislocations and the η's for both samples. It should be noted that the MBE sample shows the higher value of η in the blue light region than the MOCVD sample, in spite

of the higher density of screw and mixed dislocations. These results indicate that some screw dislocations act as nonradiative recombination centers, and the other does not.

Recent local-density functional cluster calculation showed that open-core screw dislocations have no gap state, on the other hand, the full-core ones yields deep gap states.[3] The existence of these two structures in GaN epilayer were experimentally verified by high resolution Z-contrast imaging technique.[4] Therefore, the high value of η of the MBE sample, in spite of the high density of the screw dislocations, may be caused by the domination of the open-core dislocations. The difference in the formation of the screw dislocations between MOCVD and MBE growth may affect the discrepancy of the optical and the electrical properties of the GaN epilayer between them, for example, GaN grown by the MBE generally shows the lower mobility and the larger surface roughness, compared with GaN by MOCVD, although the optical properties are comparable between them. It may be necessary to control the type of screw dislocation to improve the electrical properties of MBE grown GaN.

References

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Table I. The density of the screw and mixed dislocations (N_{dis}) and the luminescence quantum efficiency, η, for each sample.

	N_{dis} (cm^{-2})	η
MOCVD	4×10^{6}	0.18
MBE	$\sim10^{9}$	0.22