Evaluation of dislocation densities in n-GaN films by photoassisted anodic etching

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Epitaxial GaN films grown on sapphire (0001) substrates have very high dislocation densities, typically 10^8 ～ 10^{11} cm^{-2}. It is widely recognized that high density of dislocations influence the device characteristics. Therefore, it is important to investigate to evaluate dislocation densities in GaN films. To date, the characterization of dislocation densities in GaN films is carried out through transmission electron microscopy (TEM).[1,2] However, evaluation of dislocation densities by TEM requires extensive and skillful sample preparation. Wet etching of semiconductor have proven useful for revealing defect densities, and this process is carried out with a relatively simple apparatus. Presently, it is well known that chemical etching process by molten KOH can be used for revealing etch pits at emergent dislocation sites in GaN films. Recently, Youtsey et al. [3,4] described a photoelectrochemical etching process that reveals the dislocation of GaN films by selectively removing material between dislocations. They evaluated the dislocation densities in n-GaN films using etched GaN "whiskers" for the first time. In this study, a technique has been developed for revealing dislocations densities in n-GaN films using etch pits on the etched surface through photoassisted anodic etching.

Unintentionally doped n-GaN were grown on (0001) sapphire substrates at 1000 ℃ with a buffer layer using metal organic chemical vapor deposition (MOCVD). No pit or hillock were observed on as-grown surface of the GaN films. The carrier concentration of GaN films is 2 x 10^{18} cm^{-3} with an electron mobility of 170 cm^2/Vs. A GaN electrode was used as an anode and a Pt electrode was used as a cathode. The ultraviolet (UV) source was a 500W super high pressure mercury UV lamp.

The pH dependence of the etch rate of GaN films by photoassisted anodic etching is shown in Fig. 1. The photoassisted anodic etching of n-GaN films in NaOH electrolyte are characterized by two main features : at pH＞11 the etch rate increases significantly ; at pH＜11 effective etching is prevented by the formation of an oxide film on the GaN surface. For NaOH electrolyte at pH 10.4, the anodic current is drastically decreased as shown in Fig.2. It seems that this decrease of the anodic current is caused by the formation of the oxide film on the GaN surface as shown in Fig. 3. This oxide film was dissolved by NaOH electrolyte at pH 14 for 6 h in the dark. Furthermore, it was found that etch pits were observed on the etched surface as shown in Fig. 4. It seems that these etch pits on the GaN films are associated with dislocations. The SEM image indicates the etch pits density of approximately 10^7 ～10^8 cm^{-2}. This is the same order as the etch pit density revealed by molten KOH at 360 ℃ in the same GaN films. It is necessary to study further in details in order to know the correlation between the dislocations and the appearance of the etch pits produced by photoassisted anodic etching.

In conclusion, a technique has been developed for revealing dislocations densities in n-GaN films using etch pits on the etched surface.

References

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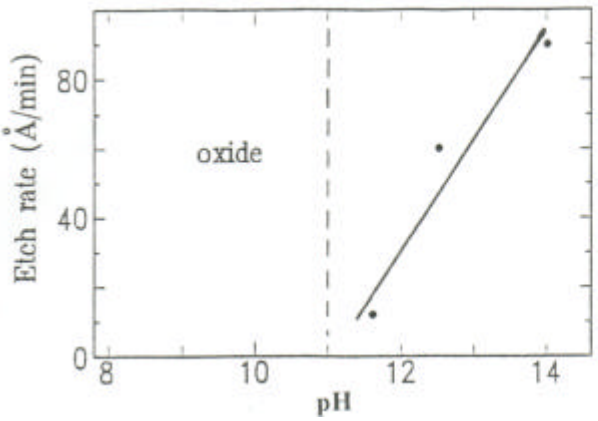

Fig. 1. Etch rate of n-GaN films as a function of pH in NaOH electrolyte.

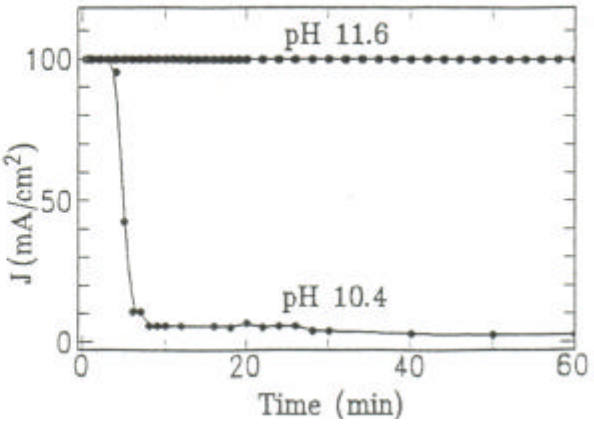

Fig. 2. The time dependence of anodic current density in NaOH electrolyte at pH 10.4 and 11.6, respectively.

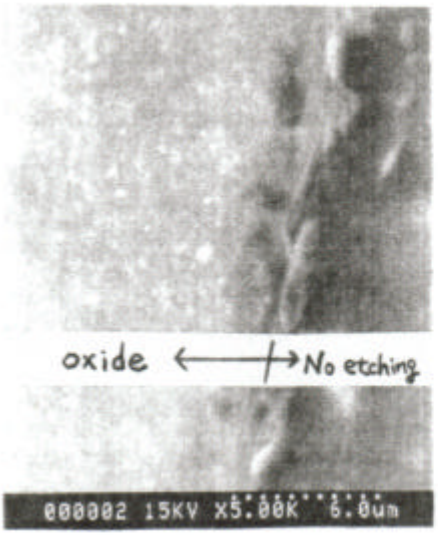

Fig. 3. SEM image of oxide film formed on the GaN surface in NaOH electrolyte at pH 10.4.

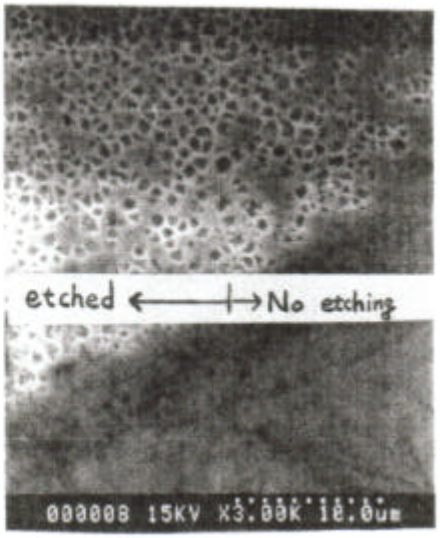

Fig. 4. SEM image of surface morphology of GaN films after oxide film was dissolved by NaOH electrolyte at pH 14.