Study of Wet Chemical Treatments of Epitaxial GaN(0001) Surface

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Introduction> Surface cleaning of GaN is generally crucial from viewpoints of controllability and reproducibility in device fabrication processes involving device performance and it reliability [1]. However, standard cleaning method of preparing the GaN surface has not been established well. In this work, to gain a better understanding of GaN surface cleaning, we have studied morphology changes by typical wet-chemical treatments using H_2O_2 and/or NH_4OH on epitaxially-grown GaN surface.

Experimental Procedure> A ~2 μm-thick n-type GaN(0001) with an Si concentration of 5×10^{16} cm^{-3} was epitaxially grown on a free-standing GaN substrate by MOCVD. Then, the wafer dicing was performed after resist coating. For resist removal from the surface, ultrasonic cleaning of acetone and IPA solutions was carried out and followed by deionized pure-water rinse. After that, the GaN (0001) surface was immersed in any of three different chemical solutions such as NH_4OH: H_2O = 3: 7, H_2O_2: H_2O = 3: 7, and NH_4OH: H_2O_2: H_2O = 0.15: 3: 7 at 80 ºC for 10min. Subsequently, pure water rinsing for 5 min and drying by N_2 gas blow were carried out.

Results and Discussion> AFM images of the GaN (0001) surface before and after chemical treatments were taken in a tapping mode using a Si cantilever with a tip apex of ~7 nm at a scan rate of 1 Hz as shown in Fig. 1. For the initial surface before wet-chemical treatment, a clear step-terrace structure with a root mean square (RMS) roughness of ~0.1 nm was clearly observed (Fig. 1(a)). With the treatment in the NH_4OH solution, no significant change in the surface morphology was observable (Fig. 1(b)), which suggests that GaN etching in such an alkaline solution proceeds uniformly. A similar result was observed from the sample treated in a solution of NH_4OH: H_2O = 4: 6 (data not shown). In the case of H_2O_2 treatment (Fig. 1(c)), protrusions with an areal density of ~1.7×10^{10} cm^{-2} and an average height of ~1.3 nm were clearly observed, which results in an increase in the RMS value from 0.1 nm to 0.3 nm. It is well known that hydrogen peroxide acts as an oxidant, observed protrusions are likely to be Ga oxide. In fact, slight oxidation of the epitaxial GaN surface with the H_2O_2 treatment was also confirmed from the XPS analysis. In addition, very similar protrusions were also seen after a treatment in a dilute HCl solution. In the case of slight addition of NH_4OH in a solution of H_2O_2 : H_2O (Fig. 1(d)), areal density of the protrusions was markedly decreased down to ~0.5×10^{10} cm^{-2}, presumably due to the etching reaction of Ga oxide as well as GaN by NH_4OH [2]. Note that, for both cases shown in Figs. 1(c) and 1(d), protrusions were located mostly at step edges, implying that chemical reactions of H_2O_2 with GaN (0001) surface proceed from the step edges preferentially.

Conclusion> We have found that the H_2O_2 treatment of GaN(0001) induces surface protrusions involving in oxidation reaction and demonstrated that the addition of NH_4OH is quite effective to suppress such protrusions in H_2O_2 cleaning.

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Reference> [1] M. Diale et al., Appl. Surf. Sci., **246**, 279 (2005) [2] K. Prabhakaran et al., Appl. Phys. Lett., **69**, 18 (1996)

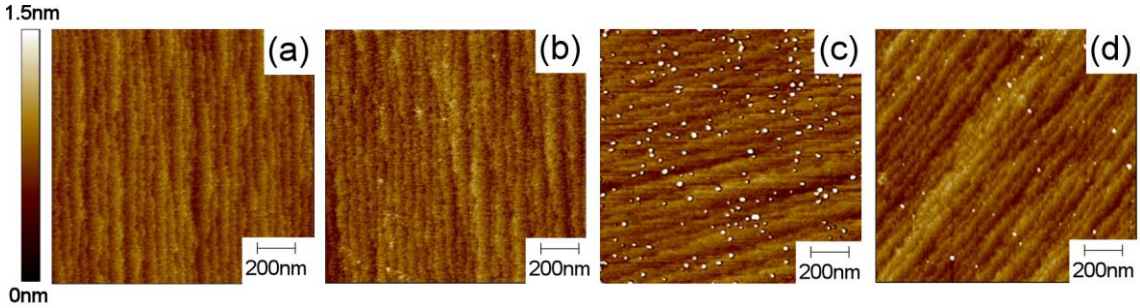

Fig. 1. AFM topographic images with the area of 1μm×1μm taken for GaN(0001) surface (a) before and after wet-chemical treatments of (b) NH_4OH, (c) H_2O_2, and (d) NH_4OH + H_2O_2 at 80ºC for 10min.