Nonuniform Contact Potential Profile of AlGaN/GaN on SiC Measured by Kelvin Probe Force Microscopy

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GaN-based devices have attracted much attention because of their potential for blue light-emitting devices and high-power electron devices. Uniformity of the epitaxial layer is very important in order to develop their full potential. However, there are few reports which studies the uniformity of the epitaxial wafers microscopically with nondestructive manner. We have recently demonstrated that Kelvin probe force microscopy (KFM) is a powerful technique to measure the two-dimensional potential profile of the GaAs HEMTs and InAlAs/InGaAs heterostructure in a nondestructive manner with high spatial resolution [1],[2]. We have applied this technique to the measurement of contact potential of AlGaN/GaN on SiC substrate and obtained nonuniform potential profile suggesting the existence of the effects of dislocations.

Figure 1 shows a schematic diagram of the KFM system [1]. KFM is similar to noncontact-mode atomic force microscopy (AFM). The system is equipped with two feedback loops to measure atomic force (z feedback) and the electrostatic force (V feedback: contact potential measurement). The epitaxial layer structure on SiC substrate is shown in Fig. 2. The density of the surface defects with diameter of 20-40 nm measured by AFM was 10^7-10^9 cm^{-2}.

Figure 3 shows the measured topographic image (a) and the corresponding contact potential image (b) of the wafer surface. Concentric contact potential image with 1-2 μm diameter was obtained at the area where the surface defect was observed as shown in the figure. Figure 4 shows topographic and potential profiles along the AA' and BB' lines in Fig. 3(a) and (b). The potential around the surface defect is lower than other area except the center of the surface defect where potential peak is observed. These results suggest that the electronic properties of the area surrounding the surface defect are different from those of other area because the contact potential obtained by KFM reflects the work function of the material.

In order to study the origin of the measured potential profile, the contact potential of the cleaved surface was measured. Figure 5 shows the measured contact potential image of the cleaved surface. Even though the topographic image of the cleaved surface was sufficiently flat, inhomogeneous contact potential image which extended to the substrate was obtained as shown in the figure. This suggests that the concentric potential image of the wafer surface originates from the substrate, presumably being caused by the threading dislocations. Strain and/or stoichiometry change around the dislocation might be responsible for this inhomogeneous contact potential profile.

In the case of AlGaAs/GaAs on GaAs and InAlAs/InGaAs on InP, the uniform contact potential image was obtained. This suggests that the crystal quality of the present AlGaN/GaN on SiC requires further improvement in the uniformity because the nonuniformity will affect the device performance such as the threshold voltage and the breakdown voltage of the AlGaN/GaN HEMTs.

Kelvin probe force microscopy was successfully applied to evaluate the microscopic contact potential profile of AlGaN/GaN on SiC with nondestructive manner. Nonuniform potential profile suggesting the existence of the effects of dislocations was obtained.

[1] T. Mizutani et al., IEEE Electron Device Letter, **18**, pp. 423-425, 1997.
[2] T. Usunami et al., Jpn J. Appl. Phys., **37**, pp. 1522-1526, 1998.

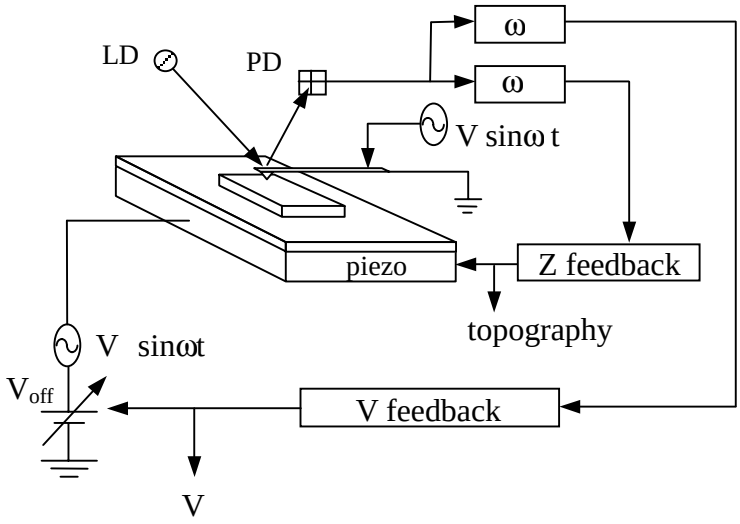
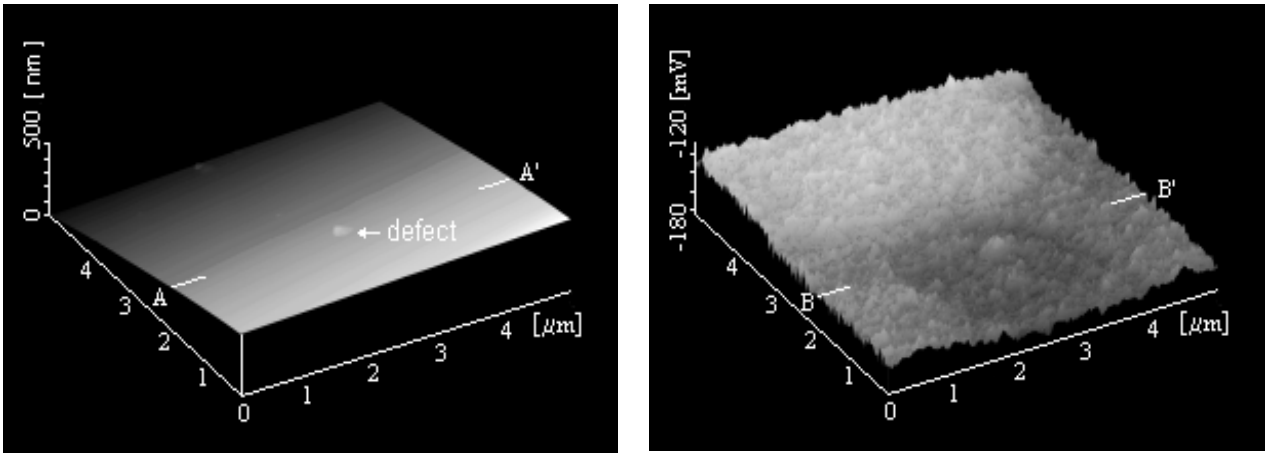


Fig. 1 Schematic diagram of the KFM measurement system.

i-GaN		50nm
n-$Al_{0.25}Ga_{0.75}N$	$2\times10^{18}(cm^{-3})$	20nm
i-$Al_{0.25}Ga_{0.75}N$		2nm
i-GaN		3μm
i-AlN		100nm
4H-SiC Substrate		

Fig. 2 AlGaN/GaN epitaxial layer structure.



(a) (b)

Fig. 3 Measured topographic image (a) and the corresponding contact potential image (b).

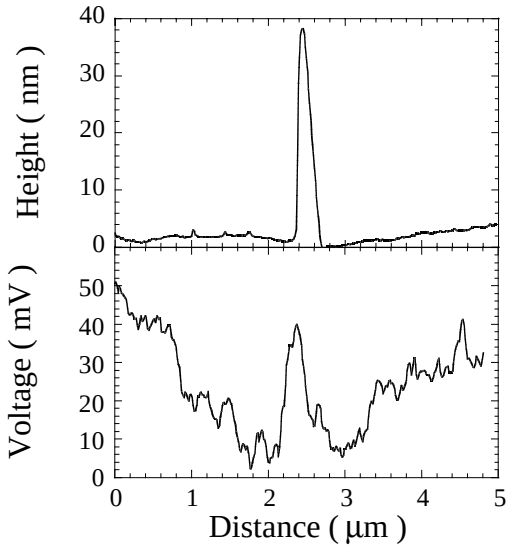


Fig. 4 Topographic and potential profiles.

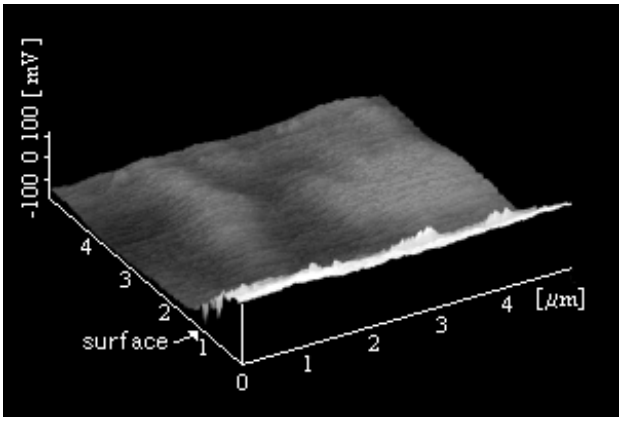


Fig. 5 Contact potential image of the cleaved surface.