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Electrical Conduction along Dislocations in GaN Studied by Scanning Spreading Resistance Microscopy

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The electrical conduction along dislocations in semiconductors has been one of the long-standing, controversial problems in the study of dislocations. In principle, dislocations in semiconductors are expected to form one-dimensional electronic states in the bandgap and to behave like quantum wires. However, only few examples of dislocation conductions have so far been confirmed experimentally and detailed conduction mechanisms have not been clarified yet[1].

Scanning spreading resistance microscopy (SSRM) is based on atomic force microscopy (AFM) and has been developed in recent years to probe resistivity distribution in semiconductor devices. In SSRM, a conductive tip is scanned on the sample surface, giving a 2D map of local spreading resistance with a high spatial resolution. In this study, possible dislocation conduction has been investigated by SSRM in GaN, which has attracted much attention in recent years for various applications including blue light emission diodes.

n-GaN single crystals were grown according to the method reported in [2]. Rectangular specimens for compression testing, approximately $1.0 \times 1.0 \times 3.6\text{mm}^3$ in size, were cut out from a single crystal. The crystallographic orientation of the specimen is shown in Fig.1, where the slip $[1\bar{2}10]\text{-}(10\bar{1}0)$ is expected to be induced. The compression tests were conducted in an Ar atmosphere at 950℃, and the plastic strain of about 5 % was introduced. Dislocation structures on the slip plane were observed by transmission electron microscopy (TEM). The (0001) surface was mechanically polished, followed by chemical etching with HF, and SSRM experiments were conducted using a heavily-doped conductive diamond tip.

Figure 2 shows a TEM image of the slip plane, where dislocations are observed to be aligned mostly along the [0001] direction. The dislocation density was estimated to be $10^9 - 10^{10}\,\text{cm}^{-2}$. By $\mathbf{g} \cdot \mathbf{b}$ analyses, the Burgers vector of the dislocations was determined to be in the $[1\bar{2}10]$ direction. Thus, the dislocations aligned along [0001] are of the edge-type.

Figure 3 shows a SSRM image on the (0001) surface, in which many conductive spots are observed. Here, the spots are mostly aligned in a particular direction, which is approximately parallel to the slip plane. The density of the spots is roughly the same as the dislocation density evaluated by TEM. Such conductive spots were not observed in the undeformed samples. These facts indicate that the conductive spots are due to dislocation conductivity. Further experiments such as the measurements of temperature dependence of the conductivity of the spots are now in progress.

Acknowledgement
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References
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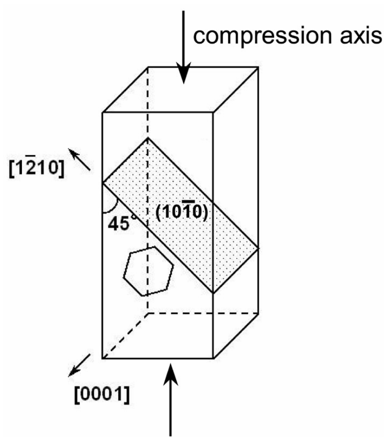

FIG. 1. Crystallographic orientation of the specimen for compression testing.

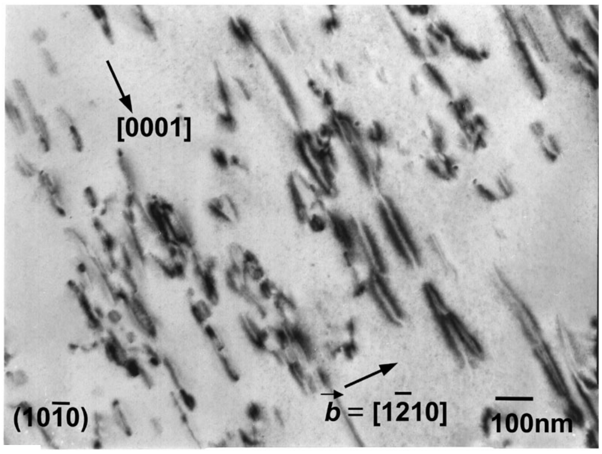

FIG. 2. A TEM image of the slip plane.

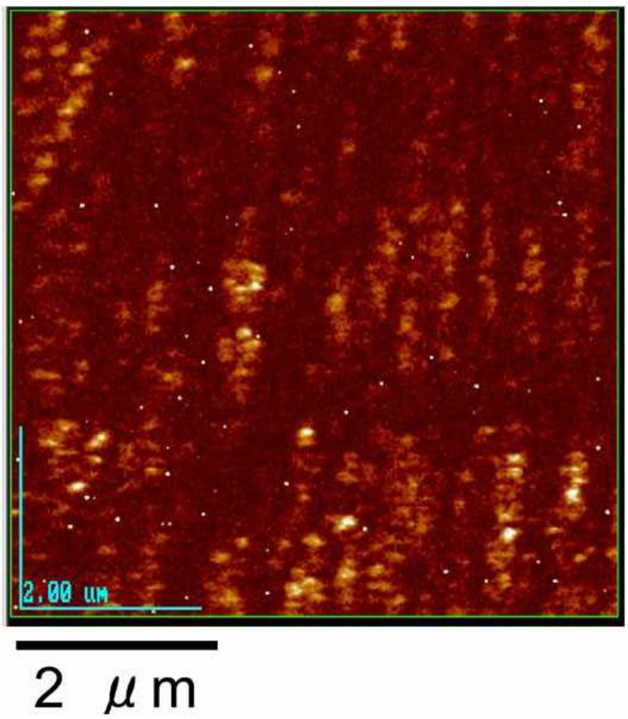

FIG. 3. A SSRM image on the (0001) surface.