Burgers Vector Determination of Dislocation in 4H-SiC by LACBED

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TEM is a method for characterizing the dislocation structures. However, conventional weak-beam dark-field (WBDF) method is insufficient for determining Burgers vector ***b*** for anisotropic crystals such as SiC. This is because the large anisotropic strain around dislocations in hexagonal SiC degrades the validity of the ***g·b*** criteria between reciprocal lattice vector ***g*** and ***b***. It is thus hard to unambiguously determine the ***b*** of dislocations in such a crystal. In this study, we demonstrate that the large-angle convergent-beam electron diffraction (LACBED) [1, 2], which can determine the sign and absolute value of the Burgers vector, is useful for the dislocation analysis in hexagonal SiC.

An n-type 4H-SiC wafer (Cree Inc., Durham, NC) with an off-axis angle of 8^{o} toward $[11\bar{2}0]$ direction was used to characterize a basal plane dislocation (BPD). As the dislocation densities in the SiC are too low to observe in TEM images, we combined etch pit method and focused ion beam microsampling technique [3, 4] for TEM specimen preparation. In order to define the BPD position, wafer was etched in molten $KOH+Na_2O_2$ (KN) at 510 ^{o}C [5], and then observing area was selected around a seashell pit as shown in Fig. 1.

Figure 2 shows the BPD image under the seashell pit taken by a ***g***/3***g*** WBDF using the $\bar{1}2\bar{1}0$ reflection of the 4H-SiC. It is found that the BPD is dissociated into two partials and a stacking fault is formed between the partials. The BPD line is tilted by an angle about 25^{o} with respect to the $[\bar{1}2\bar{1}0]$ direction.

The bright-field LACBED patterns obtained from an area containing the BPD are shown in Figs. 3(a)-(c). The area size was large enough to analyze resultant vector of partials in BPD. White dotted lines show the position of the BPD. Black lines extending from top left to bottom right and intersecting with this BPD are reflection lines. The reflection lines within the high dislocation strain field generate the nodes. The LACBED patterns in Figs. 3(a)-(c) were taken using $\bar{2}20\bar{2}$, $\bar{3}300$ and $\bar{3}030$ reflections, respectively. In the intersecting region in Fig. 3(a)-(c), 2, 3 and 0 nodes are observed, respectively (A bright line between neighbouring dark fringes is counted as one node). From the nodes of the reflection line, ***n*** can be determined as follows: the absolute value of ***n*** indicates the number of nodes and the sign of ***n*** show the deviation from the reflection line. In Fig. 3(a) and (b), the deviations from the reflection lines are same and positive [2]. Equation $\boldsymbol{g}_{hkil}\cdot\boldsymbol{b}_{uvtw}=\boldsymbol{n}$ indicates the relationship between vector of nodes ***n*** and reciprocal lattice vector of the reflection $\boldsymbol{g}_{hkil}$. According to this equation, the sign and the absolute value of Burgers vector can be determined. Substituting the ***g*** value in the equation, the Burgers vector ($\boldsymbol{b}_{uvtw}=(\boldsymbol{b}_u, \boldsymbol{b}_v, \boldsymbol{b}_t, \boldsymbol{b}_w)$, $\boldsymbol{b}_t=-(\boldsymbol{b}_u+\boldsymbol{b}_v)$) of the BPD satisfies the following equations.

$$-2\boldsymbol{b}_u+2\boldsymbol{b}_v-2\boldsymbol{b}_w=2 \quad (1)$$
$$-3\boldsymbol{b}_u+3\boldsymbol{b}_v=3 \quad (2)$$
$$-3\boldsymbol{b}_u+3\boldsymbol{b}_t=0 \quad (3)$$

Solution of these equations gives the Burgers vector of the BPD $\boldsymbol{b}_{uvtw}=(1/3)[\bar{1}2\bar{1}0]$. Therefore, the observed BPD is determined to be a mixed dislocation so as that an angle between the estimated Burgers vector and the measured dislocation line is about 25^{o}. Another advantage of dislocation analysis by TEM is to obtain the microstructural information because this type of mixed dislocation dissociation has been hardly observed by the techniques such as electron beam induced current method and X-ray topography.

References

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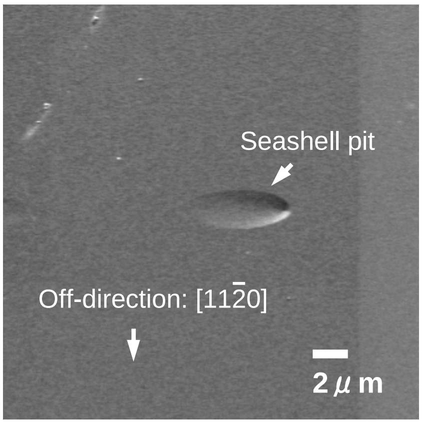

Fig. 1 Seashell pit image on a (0001) 4H-SiC substrate after KN etching. The seashell pit is perpendicular to the $[11\bar{2}0]$ (off-) direction.

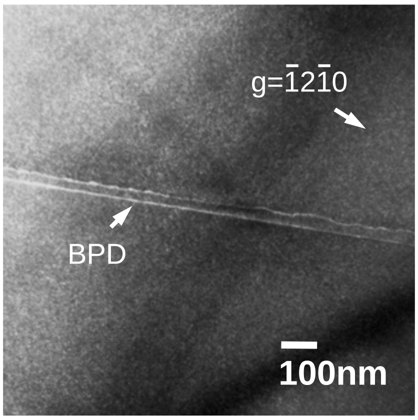

Fig. 2 A $\boldsymbol{g}$-3$\boldsymbol{g}$ WBDF image using $\bar{1}2\bar{1}0$ reflection of the 4H-SiC containing the BPD. The BPD is dissociated into partial dislocation pairs.

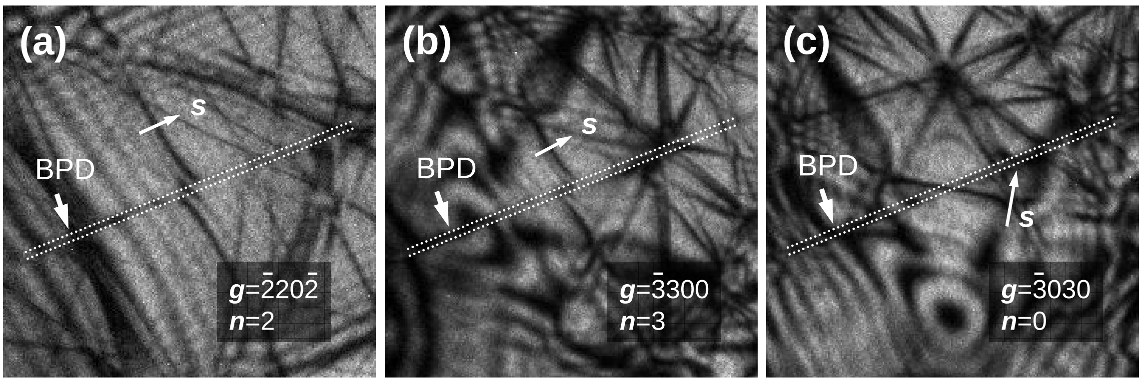

Fig. 3 Bright-field LACBED patterns obtained around the BPD containing a perfect area. $\boldsymbol{s}$, $\boldsymbol{g}$ and n denote the direction of excitation error, the reciprocal lattice vector of the reflection and the number of nodes, respectively.