

Fig. 2. Comparison of synchrotron reflection, laboratory reflection, and laboratory transmission topography images of the same area. TSDs are detected identically in the synchrotron and laboratory reflection topography images. The transmission topography image includes several BPDs inside the wafer and the TSDs correspond well with the other experiments.

in this image. Large strong dots indicate threading screw dislocations (TSD), which are directed along the c -axis and are accompanied by large strain fields around the dislocation core. Its Burgers vector is $n\mathbf{c}\langle 0001 \rangle$ ($n=1, 2$). Basal plane dislocations (BPD) are extended in the (0001) plane and appear as long lines in this topography image. Weak dots and short lines are classified as threading edge dislocations (TED), which are elongated along the c -axis as were the TSDs. However, TED accompanies a smaller strain field due to its smaller Burgers vector $\mathbf{a}/3\langle 11\bar{2}0 \rangle$ compared to that of TSD, making weak dots in the topography image. We have confirmed the identification of the above described three types of dislocations by comparing the topography images with those taken at a synchrotron facility. Synchrotron topography is known as the standard method for identification of dislocations⁽²⁾. Figure 2 shows the comparison of topography images taken by synchrotron and laboratory sources, respectively. Although the dislocation image taken at the synchrotron is much clearer than that taken with the laboratory system, almost identical TSD results are obtained at the synchrotron as with laboratory Cu reflection topography. In the transmission topography image, there are a lot of BPDs and some TSDs that are unclear or missing. However, more than 80% of TSDs can be detected using transmission geometry. In addition, clearly detected BPDs are known to affect device performance; therefore, reliable quantitative detection of BPDs is a crucial function.

3. Dislocation analysis software for SiC crystals

Rigaku's new X-ray topography system enables us to acquire high-resolution digital image data, which is of sufficient quality to identify dislocation types TSD, TED, and BPD in SiC crystals. Then, automated identification software was developed. It can not only identify dislocation types, but also count the numbers of TSDs, TEDs, and BPDs. However, counting BPDs is not

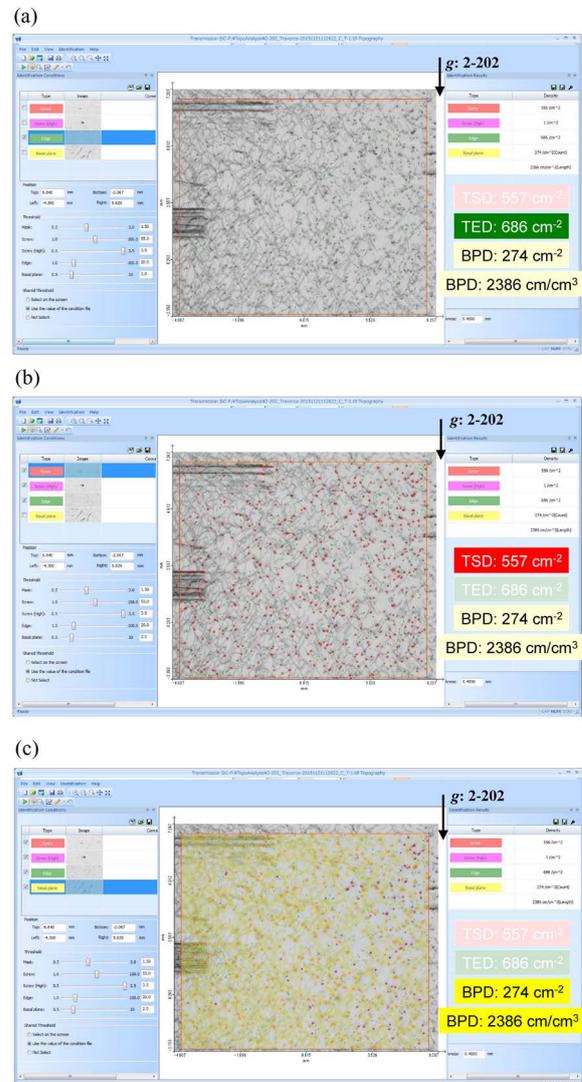


Fig. 3. Software display for the detection of dislocations for (a) TEDs, (b) TSDs, and (c) BPDs.

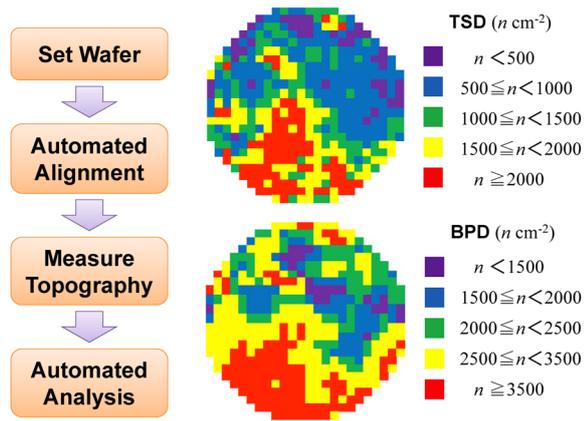


Fig. 4. Flow chart demonstrating an automated topography measurement and analysis (left) and the results of wafer mapping for TSD and BPD (right).

appropriate for transmission topography, because BPDs are connected, making networks. Therefore, a function measuring the lengths of BPDs has also been developed. How the software operates is shown in Fig. 3(a), (b), and (c), which identify TEDs, TSDs, and BPDs, respectively. The resultant dislocation density is indicated as number/area in units of cm^{-2} . The length of a BPD is converted to a dislocation density by calculating length/(area \times thickness) in units of cm/cm^3 . The software contains a field where the wafer thickness can be entered by the user. In order to avoid misdetection due to noise

in the image, the user can control the threshold of the lower detection limit for each dislocation type.

4. Whole wafer mapping of the dislocations

For quality and yields control for SiC devices, dislocation densities should be one of the key parameters. Therefore, wafer mapping of dislocation densities is strongly recommended. Combination of a topography measurement system and the dislocation analysis software can achieve automated wafer mapping of dislocations. The user can select the size of the unit area, make a whole wafer map as shown in Fig. 4 and compare device performance at each point.

X-ray topography has long been used for evaluating the crystal quality of wafers. However, very few specialists can interpret the observed topography images, so they were never used for quality and production control. Rigaku's automated topography measurement and analysis system makes it possible to utilize this analysis for the quality control of production wafers. The developed dislocation analysis software can be easily modified for other crystals, such as Si, GaN, Al_2O_3 , others. Those software enhancements will be released in the near future.

References

- (1) K. Omote: *Rigaku Journal (English version)*, **29** (2013), 1–8.
- (2) H. Tsuchida, I. Kamarta and M. Nagano: *J. Cryst. Growth*, **310** (2008), 757–765.