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A method to determine the Burgers vector value of superscrew dislocations in SiC at the wafer level

This application note introduces a fundamental defect study method which can be used for determining the magnitude and sign of Burgers vector of each screw dislocation in a SiC single crystal. This atomic-level investigation can be performed systematically over an entire wafer, providing a variety of detailed fundamental parameters, including their spatial distribution. Since it is nearly nondestructive and correspondingly the investigated sample can be used for further use, this method provides an opportunity for various fine and sophisticated investigation in material science. Though the discussion in this note is mainly related to silicon carbide (SiC), a similar approach can be developed for other materials.

Micropipes in SiC were successfully predicted by Frank's model over fifty years ago. Currently, superscrew dislocations in SiC can be easily delineated by synchrotron white beam X-ray topography (SWBXT) and a newly developed polarized light microscopy (PLM) system. However, a direct structural demonstration that leads to clear understanding of their precise nature is still needed. It is rather difficult for modern instruments, such as the high-resolution transmission electron microscopy (HRTEM) and atomic force microscope (AFM), to capture the individual dislocation structure due to the relatively low density of closed-core screw dislocations (10^3~10^4/cm^{-2}), and to image a whole micropipe at atomic level due to the large dimension of micropipes (with diameters of submicron or microns). Up to now, quantitative studies were mainly limited to the experiments performed on as-grown SiC surfaces. The footprints of growth spirals associated with micropipes on as-grown surface could be greatly influenced by step flow direction, specific growth technique and growth history of each boule, reducing accuracy of the measured data. The magnitude of Burgers vector of superscrew dislocations could also be determined by non-destructive back-reflection SWBXT, which, however, has less capability to determine the sign of Burgers vector of elementary screw dislocation. Other image mode such as back-reflection section topography or synchrotron x-ray reticulography has to be used for the sign measurement.

In this note, in order to quantitatively determine the magnitude and the sign of the Burger vectors, three steps have to be performed: (a) highlight the fine structure of defects through a proper surface treatment, (b) locate the position of screw dislocations or micropipes using a PLM system, and (c) detect the detailed structure of each defect using atomic force microscopy (AFM). The PLM technique was recently developed by our group which could nondestructively map micropipes, screw dislocations, grain boundaries and stressed zones on a wafer-scale. Under PLM system, the micropipe is usually highlighted as a butterfly shape, with a size bigger than the wave-shaped pattern associated with an elementary screw dislocation. Chemical-mechanical polishing (CMP) or high temperature gas etching can be performed on SiC sample to highlight the atomic-level structures of defects. Figure 1 shows a typical AFM image of the etched surface.

Figure 1a has two screw dislocations in the center close to each other. The step height between the terraces was about 1.5 nm, corresponding to the height of 6H SiC unit cell along c direction (6 bilayers). From these images, the sign and the magnitude of Burgers vector of each screw dislocation can be determined through the evaluation of the surface height around the dislocation, as illustrated in Figs. 1(b).

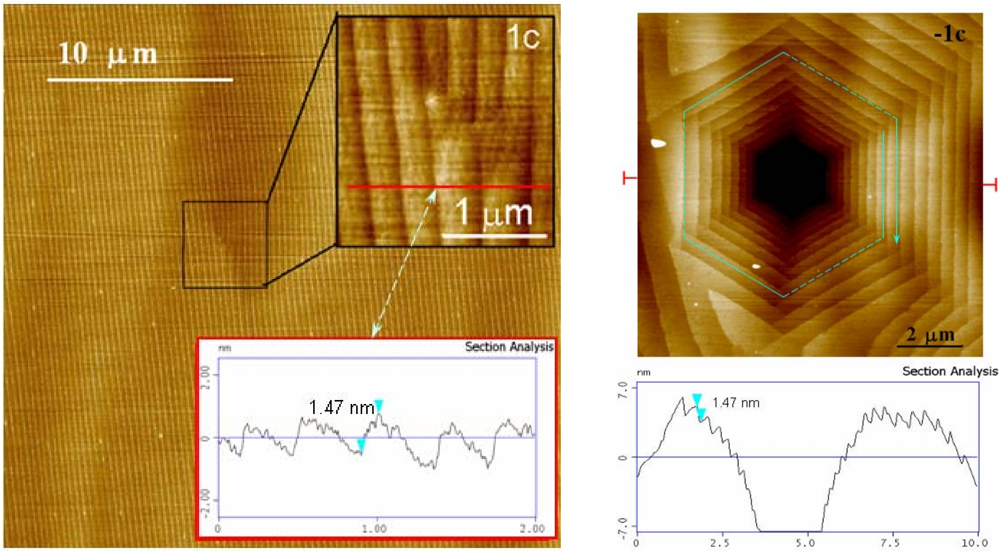

Figure 1, typical terrace structure on the surface of 6H SiC after high temperature hydrogen etching (a) with two close 1c screw dislocations in the center. (b) -1c screw dislocation with a hexagonal hydrogen-etching pit.

Using the above combined PLM/AFM method, we investigated hundreds of micropipes and screw dislocations on various samples. A thorough investigation on several relatively large areas (up to several square millimeters for each) was also performed. From these investigations, various quantitative information and several unique behaviors of superscrew dislocations in SiC single crystal have been revealed. For more detailed information, please check reference 1 & 2.

This fundamental defect study method can be used for:

- defect formation theory testification
- micropipe elimination
- seed material quality evaluation
- fundamental defect study
- quantitative investigation on Frank's equation
- micropipe-free SiC development

Reference:

[1] ““Superscrew Dislocation in Silicon Carbide: Dissociation, Aggregation and Formation”, to be published.
[2] “A Method to Determine Superscrew Dislocation Structure in Silicon Carbide,” to be published.