

## The Role of Threading Screw Dislocations in Graphene Growth on the C- and Si-faces of SiC

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Tremendous progress has been achieved in the fabrication of high frequency epitaxial graphene (EG) RF devices. Using SiC substrates for EG growth has enabled this progress as it facilitates large areas of graphene for device processing development. However, controlling the initiation and subsequent growth of graphene on the substrate, which is crucial for improvements in device performance, remains to be addressed. Here we show that threading screw dislocations (TSDs) have a significant impact on graphene growth on C-face 6H-SiC, but a much lesser impact for growth on the Si-face.

For growth on the C-face, conditions during the Si sublimation process (temperature and Ar pressure) were chosen to produce localized graphene formation.[1] These localized graphene areas were determined to lie below the level of the surrounding substrate and are referred to as graphene covered basin (GCBs). This result is consistent with the sublimation of Si from about 3 bilayers of SiC to form a monolayer of graphene.[2] The GCBs showed a range of different morphologies based on size and are thought to represent the early stages of graphene growth. Electron channeling contrast imaging (ECCI) was used to demonstrate the presence of a TSD near the centers of each GCB. Figure 1a shows an example ECCI micrograph of a GCB; note the development of ridges and the hexagonal perimeter. An expanded view of the TSD near the center of the GCB is shown in Fig. 1b. The TSD was confirmed by the change in direction of light-to-dark contrast in the ECCI image as the deviation from the Bragg angle changes sign.[3] By removing the graphene, these dislocations were revealed to lie within the SiC substrate. Optical and Raman spectroscopy showed that island centers were generally thicker than the edges due to the removal of more substrate material. These observations imply that screw dislocations act as nucleation sites for graphene growth on C-face SiC. As a GCB expands laterally, coalescence with other GCBs occur in a stochastic manner. Using the Raman D and G band intensities, we determined the crystallite length scale increases with increasing GCB lateral dimension, from about 100 nm for small GCBs to  $> 1 \mu\text{m}$  for macroscopic areas. This implies that the crystallinity of the merged materials improves as the substrate surface is covered.

The case for EG growth on the Si-face is very different. As is well-known, 1 to 2 monolayers of EG lies over the typical terrace and step morphology of the substrate.[4] A wafer was found where ECCI showed evidence for TSDs, but the graphene is relatively unaffected by the dislocation presence. Figure 2 shows a scanning electron micrograph of graphene grown on a region of the Si-face that contains TSDs. The terrace and step morphology is straight between TSDs, but becomes curved near them, similar to the C-face case. The difference is that for the C-face, localized growth continues from the GCBs along the step edge; this is not observed for growth on the Si-face. Using Raman spectroscopy and atomic force microscopy, the thicknesses of the graphene at and near the TSDs were found to be unchanged and there were no obvious morphological changes to the graphene. The fact that there are no gross changes to the substrate in the vicinity of the TSD suggests that the dislocation is probably not a major conduit for Si sublimation during growth (that is, a source of C), in contrast to the case for C-face growth.

## References

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## Figures

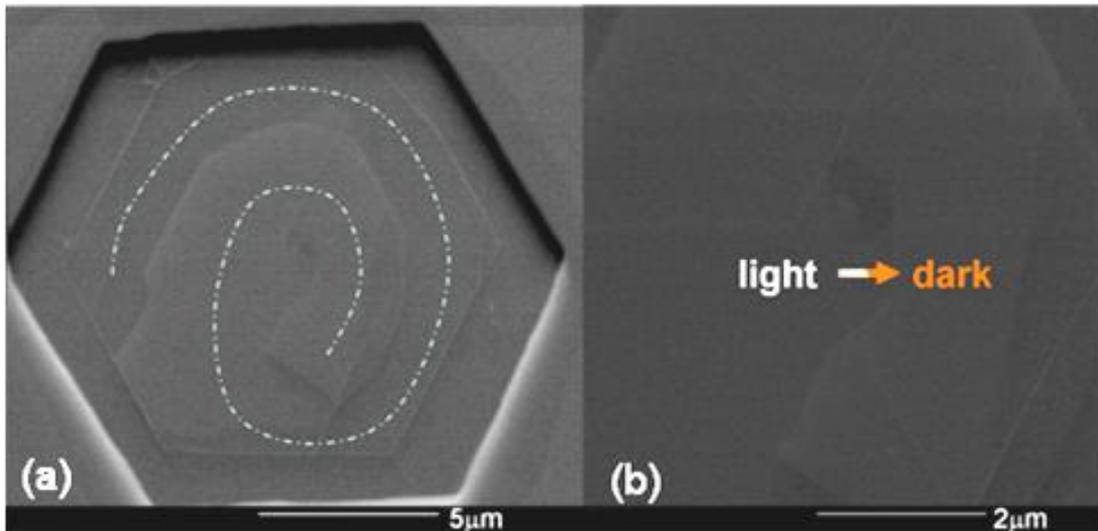


Figure 1. (a) An ECI image of a small GCB with spiraling growth highlighted by the dotted line. (b) Magnified image of the GCB center, revealing a dislocation, imaged as an area of light/dark contrast. The arrow indicates the direction of the transition of light-to-dark contrast for Bragg angle deviations, consistent with the presence of a threading screw dislocation.

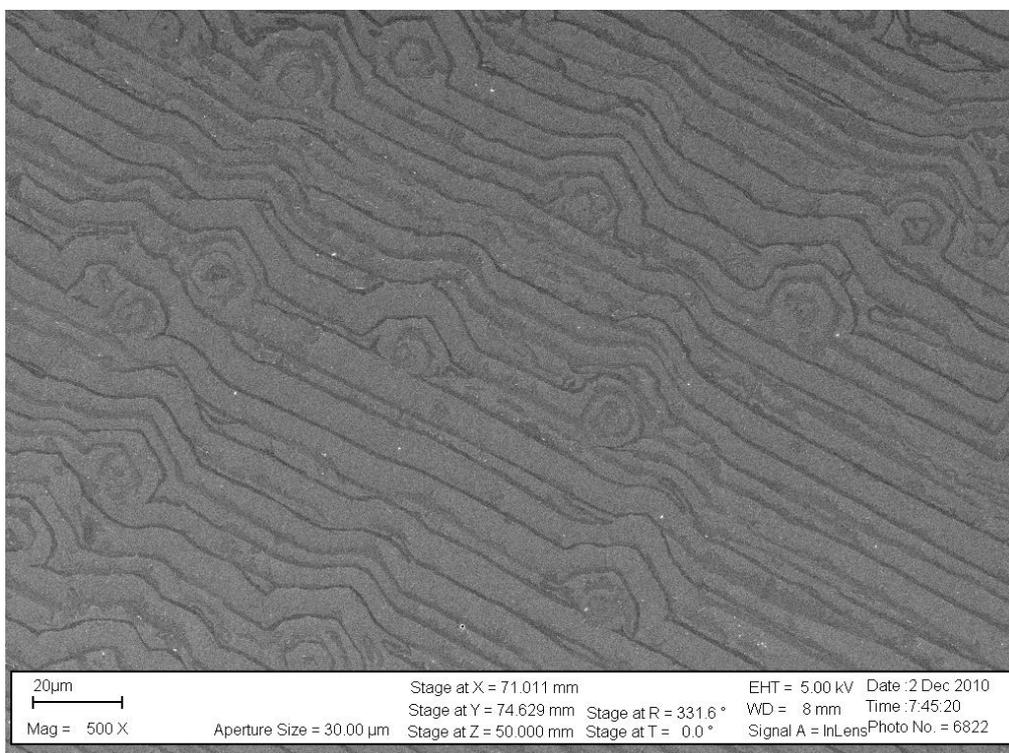


Figure 2. A scanning electron micrograph of graphene grown on the Si-face showing the typical terrace (light gray) and step bunched regions (darker gray). Note how the step bunched regions curve in some locations. ECI images of those curved regions show the presence of a threading screw dislocation near the center.