Peculiarities of nanoscale structural defects in multisectoral HPHT-diamond plates reviled by selective etching

Lytvyn P.M.[1], Strelchuk V.V.[1], Nikolenko A.S.[1], Malyuta S.V.[1], Danylenko I.M.[1], Gontar O.G.[2], Kovalenko T.V.[2], Suprun O.M.[2], Ivakhnenko S.O.[2]

1 V.E. Lashkaryov Institute of Semiconductor Physics NASU, pr. Nauky 41, 03028 Kyiv, Ukraine
E-mail: igor.tesV@gmail.com
2 V. Bakul Institute for Superhard Materials NASU, Avtozavodska str. 2, 04074 Kyiv, Ukraine

Introduction

Boron doped diamond (BDD) due to its unique physical properties is promising material for high-power and high-frequency electronics. However, the performance of diamond-based devices could be significantly affected by defects having non-uniform distribution within the BDD crystal.

Methods

In this study, BDD crystals were obtained by temperature gradient method at high pressure and high temperature (HPHT) conditions in Fe-Al-B-C system. Multisectoral BDD plates oriented along the growth axis were produced by laser cutting and mechanical polishing. The growth faces of BDD crystals and multi-sector plates were studied at different stages of selective etching by Atomic-Force Microscopy (AFM), Kelvin-Probe Force Microscopy (KPFM) and Spreading Resistance Microscopy (SRM). Selective etching was carried out in a melt of KOH and KNO_3 at a temperature of 550°C, that allowed to investigate the defects in the early nanoscale (~1-2 nm in relief) stages of their appearance way before they can be detected by optical microscopy.

Results

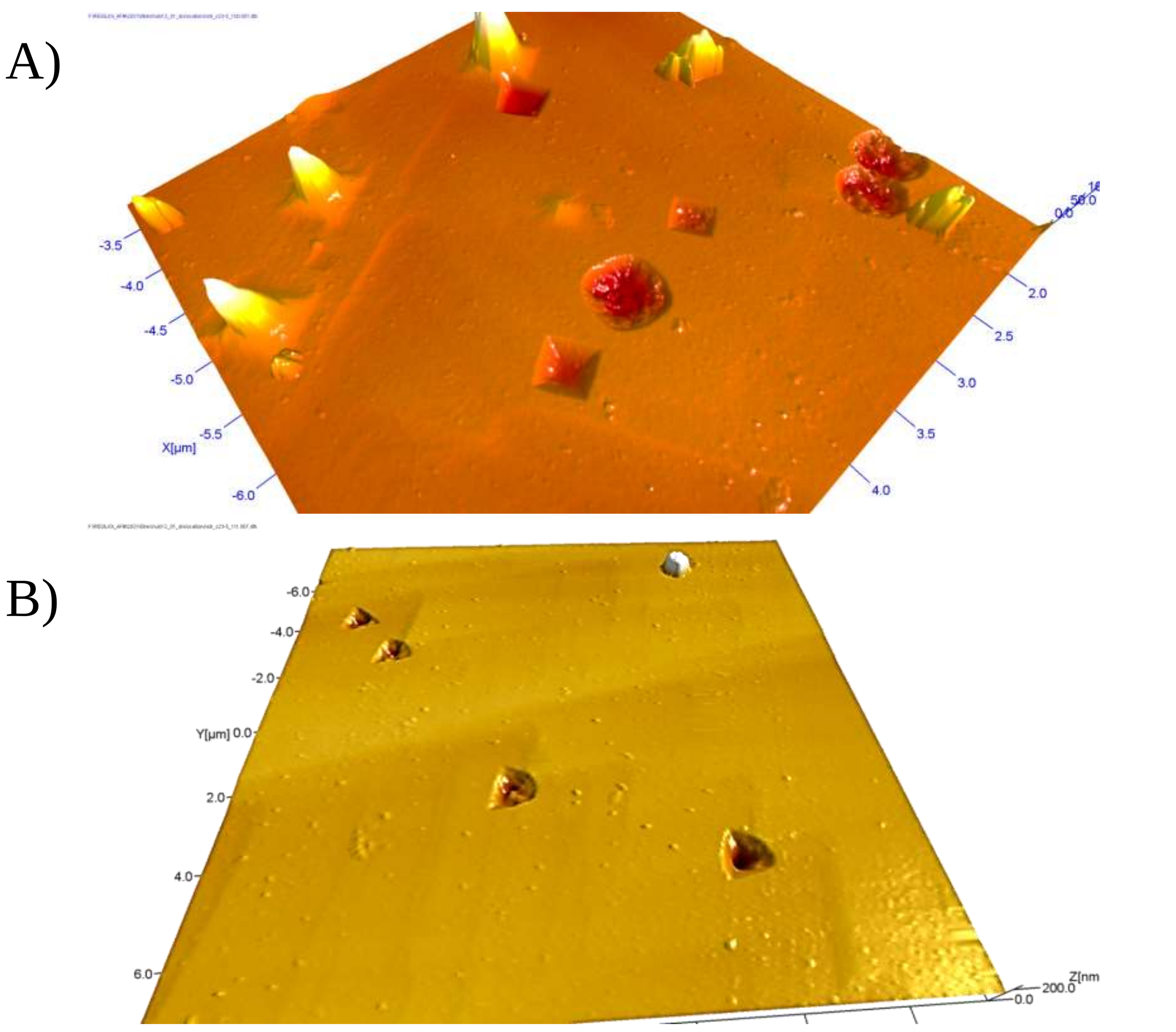

Fig.1. 3D images of fragments of the surfaces of the crystal faces (001) (A) and (111) (B).

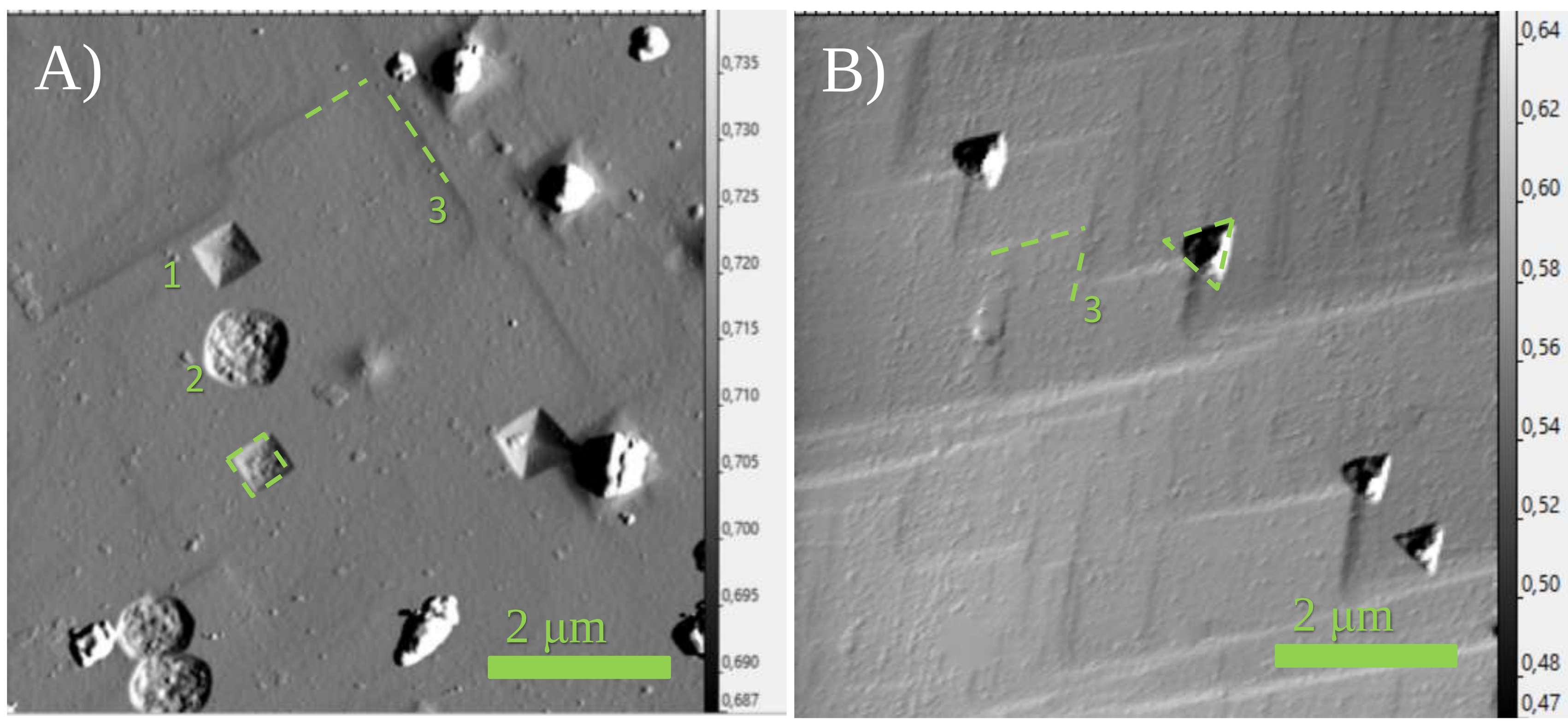

Fig.2. Contrasted SPM images of etching pits on (001) (A), (111) (B) faces. Square and hexagonal etching pits are marked with the numbers 1 and 2, the edges of the growth terraces are marked with the number 3.

Dependence of etching rate on boron concentration allowed for visualizing the intersectoral boundaries. Both dislocations etch pits in the form of hexagons and protrusions in the form of triangles associated with agglomerates of impurity defects were revealed. No variation in size, orientation, and density of defects was revealed at the intersectoral boundaries. The concentration of agglomerates remains constant, while the density of growth dislocations increases from seed to surface. The dislocation density near the surface was estimated at 10^5 - 10^6 cm^{-2}.

Conclusion

Dislocation pits are often decorated with clusters of impurity defects. The defects are electrically neutral and are activated when bias potential is applied. Both pits and impurity agglomerates demonstrate lower SR in the probe-surface contact relative to the overall level of sector resistance. These changes in SR are less than 20 % of the difference in SR at intersectoral boundaries. A comparison is made of the defects on the growth faces of BDD crystals and corresponding plates.

Acknowledgements

The authors are grateful to the National Research Foundation of Ukraine for financial support in the framework of the project № 2020.02/0160 “Development of new carbon solvents compositions for diamond single crystals growth in the thermodynamic stability area with a controlled content of nitrogen and boron impurities in order to create conceptual electronic devices construction”.