Intersectoral boron-impurity-related fluctuations of local electrical properties in semiconductor HPHT diamond plates of different orientations

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Introduction

Diamond due to its unique physical properties - a record-high thermal conductivity value (22 Wt/(cm·K) at T = 300K), breakdown voltage (10 MV/cm), holes and electrons mobility (1800 and 2200 $cm^2 \cdot V^{-1} \cdot c^{-1}$), bandgap (~5.5 eV) - is a promising semiconductor material for high-power, high-frequency and high-temperature electronics [1,2]. There are two main methods of diamond growth - crystallization from carbon solutions in molten metals at high pressure and high temperature (HPHT) and chemical vapor deposition (CVD). Both methods allow obtaining samples of high structural perfection and purity, almost identical in the cost of production of sizes up to 5-10 mm.

Methods

HPHT diamonds usually reveal inhomogeneous zonal-sectoral distribution of impurities, which is due to the selective absorption of impurities by the crystal faces during the growth. As a result, octahedral {111} sectors usually have the maximum content of nitrogen and boron impurities. In order to control spatial distribution of defect-impurity state of diamond crystals, development of local characterization techniques is needed. Mapping the local surface potential by Kelvin force probe microscopy (KPFM) is a fast and informative way of such nanoscale characterization. In this work, KPFM method is used to quantitatively characterize the variation of surface potential in boron doped HPHT diamond plates cut parallel (fig.1) and perpendicular (fig.2) to the growth axis.

Results

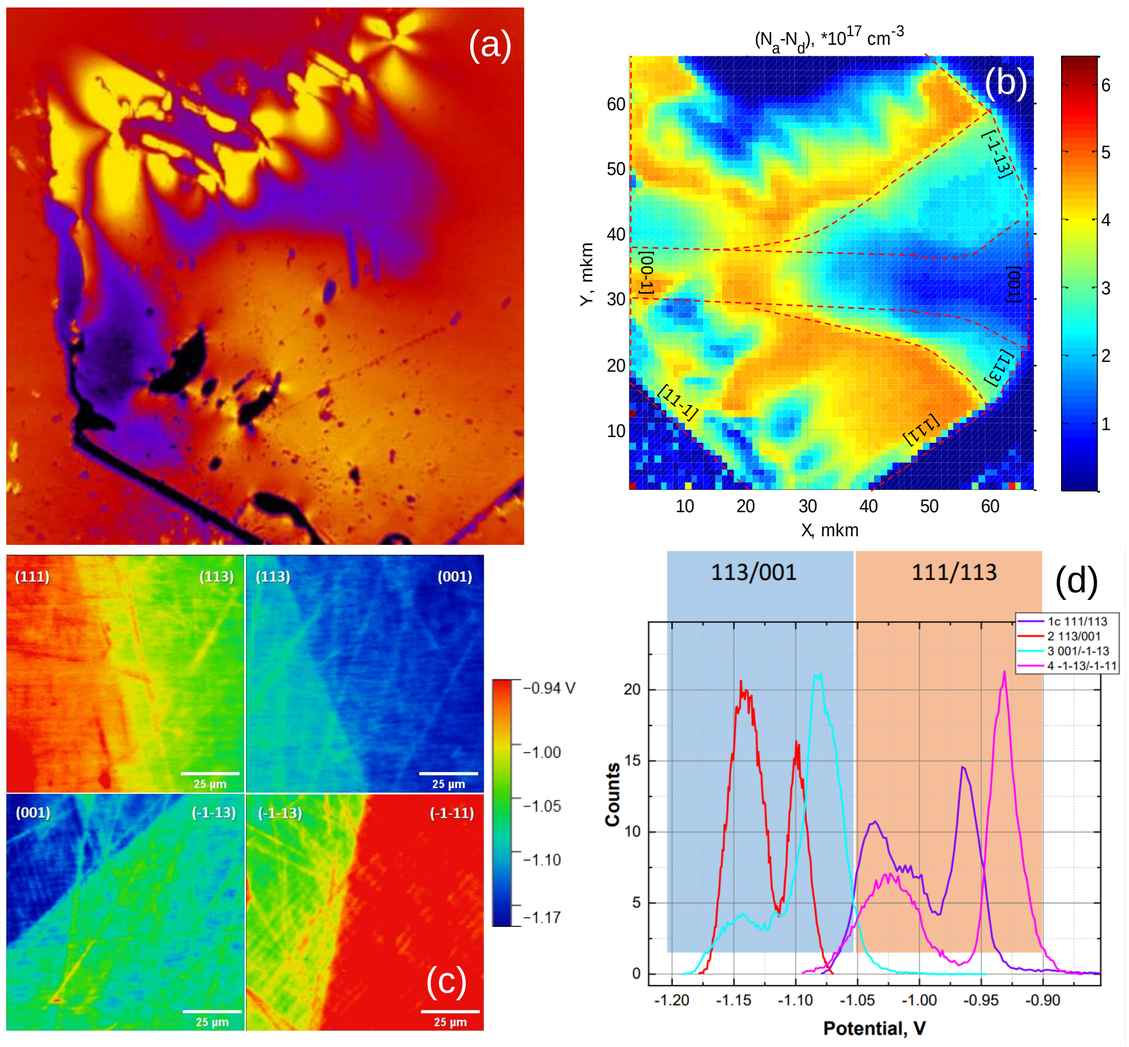

Fig.1. HPHT diamond plate grown in the Ni-Mn-C system with the addition boron and cut parallel to the growth axis. Image of deformation fields (birefringence effect) (a), spatial distribution of uncompensated boron impurity obtained by IR mapping (b), KPFM images of the distribution (c) and histograms (d) of the contact potential difference at the boundaries of the growth sectors [111], [113], [001], [-1-13], [-1-11].

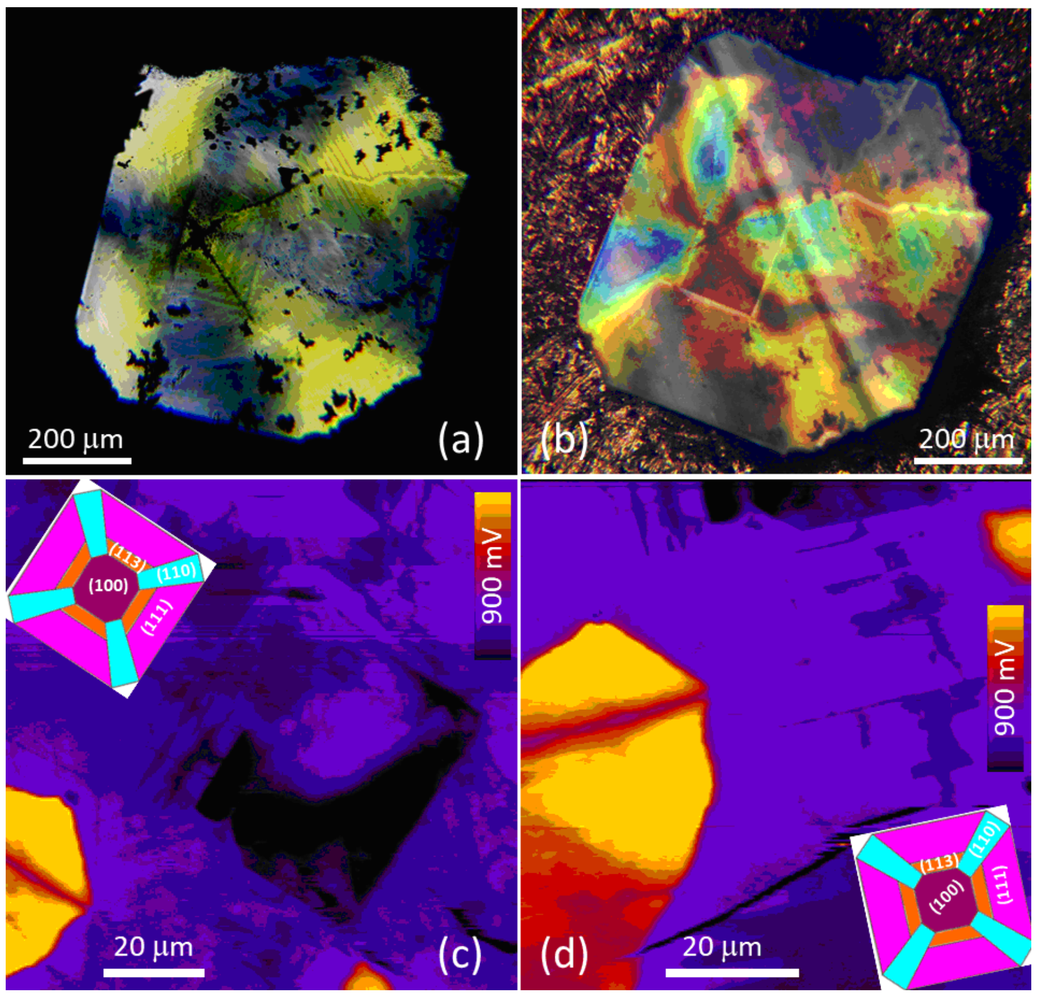

Fig.2. HPHT diamond plate grown in the Ni-Mn-C system with the addition boron and cut perpendicular to the growth axis. Visualization of impurity distribution (a) and deformation fields (b) by transmission and polarization optical microscopy. Surface potential maps at intersectoral boundaries (c, d). The insets show the diagram of the growth sectors in correspondence with the potential maps.

The intersectoral jumps of the surface potential and the distribution of surface potential in the axial and radial directions of the growth sectors are studied, and the influence of the built-in strain fields on the intrasectoral distribution of impurities is revealed. The obtained results are complete with the μ-Raman and μ-FTIR mapping data concerning the distribution of structural quality, strains and boron content through the interfaces of different growth sectors.

Conclusion

A high level of structural perfection of intersectoral boundaries is demonstrated (absence of twins, massive dislocation walls, impurity gettering) and, accordingly, the absence of electrically active defects in these boundaries. The features of the band structure of local sections of multisector diamond plates are estimated.

Thus, the proposed comprehensive approach allows for reliable estimation of local structural and electro-physical parameters of HPHT diamond plates, which is useful for solving actual problems of novel diamond electronics.

References

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