Unusual boron distribution in as-grown boron-doped diamond

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The experimental discovery of superconductivity in boron-doped diamond has attracted considerable attention [1,2]. However, until present time, there is no evident explanation of how boron atoms are incorporated into the diamond crystal lattice and what the structure of the doped crystal is. In the present study, basing on our experimental data, we propose a way boron incorporates into the diamond crystal lattice.

TEM studies of the boron doped diamond (BDD) were performed using a JEM-2010 high resolution electron microscope with a GIF Quantum attachment for EELS. The diamond surface was studied by JEM-7600F and by the fluorescence.

Fig. 1 shows a (111) facet of BDD with a small boron concentration. The surface represents triangles. This contrast disappears after the polishing. It was found that the thickness of the layer, which is responsible for the contrast, is not more than 1 micron. The majority of the research works on BDD performed their experiments on the polycrystalline diamond. This can be one of the reasons why such contrast on the diamond (111) surface was not reported earlier.

Boron distribution in the diamond was realized in two ways. Fig. 2 shows a high resolution image of a diamond crystal lattice with zone axis [110]. The irregularity of the crystal lattice and a noticeable change in contrast are seen in the horizontal band in the middle of the image (this band consist of several {111}-layers). The EEL spectrum obtained from this area has shown that the boron atomic content was approximately 2.5 atomic %. Apparently, boron forms point defects, which accumulate and form such seams as in Fig. 2, parallel to one of {111} planes. Planes $(11\bar{1})$, $(1\bar{1}1)$ and $(\bar{1}11)$ compose 70.52° with the upper facet (111). These three planes intersect with (111) at <110> directions, which compose a 60°-angles. Since boron atoms spread in the diamond along {111} planes, the areas where boron atoms are present will be bordered by intersections of different {111} planes. All these boundaries compose 60°-angles and are seen as equilateral triangles. Fast Fourier transform from 2 is shown in the inset. Besides the main diamond reflections, the given diffraction pattern includes some additional spots indicating a narrow boron-doped diamond layers.

The second option of boron presence in the sample is the boron carbide formation. We have created a stereographic projection of two phases matching: diamond and B_4C based on the analysis of all the diffraction patterns. Orientation relationship between the diamond and boron carbide lattices looks as the following:

$(1\text{-}10)_{diam} \parallel (01\text{-}10)_{B4C}$ и $[001]_{diam} \parallel [0001]_{B4C}$.

References

[1] Ekimov E.A. et. al., Nature, 428, 2004, 542-545
[2] Ohta Y., New diamond and frontier carbon technology, 17, 2007, 33-44

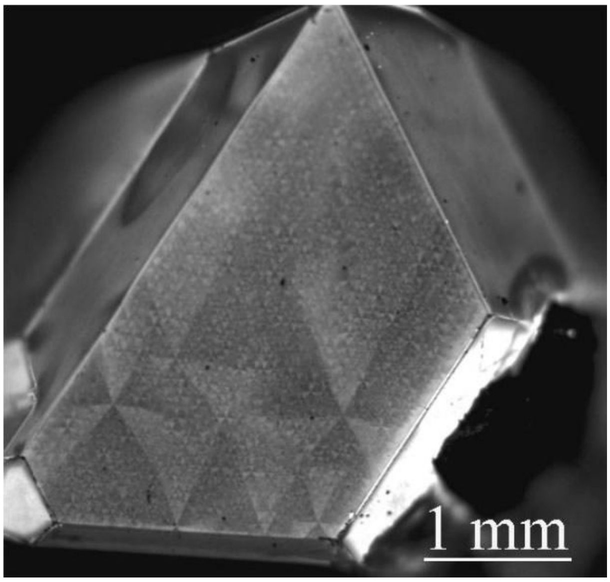

Figure 1. Fluorescence of the boron-doped diamond surface (111) in ultraviolet (wavelength 225 nm). There can be seen numerous triangles in this image, which sides are parallel to the intersections of {111} planes.

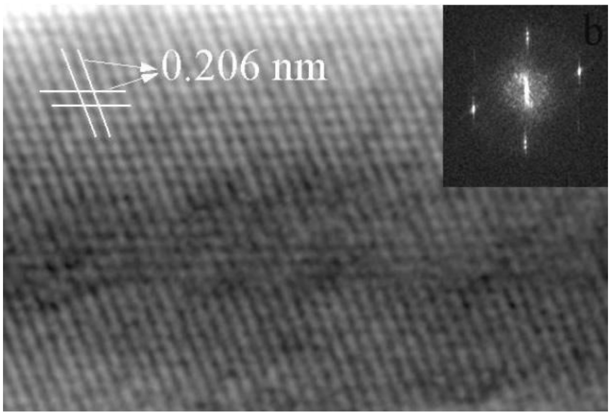

Figure 2. High resolution transmission electron microscopy image of the diamond lattice, zone axis [110]. There are some irregularity of the lattice ({111} planes) and change in contrast in the horizontal band in the middle of the image; FFT from a) is shown in the inset.