Available online at www.sciencedirect.com
SCIENCE DIRECT®
Nuclear Instruments and Methods in Physics Research A 543 (2005) 131–133
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Registration and measurement of deformation reorientation in natural diamond lattice by the synchrotron Laue-SR method

G.M. Rylov[a,*], I.A. Sheremetyev[b], E.N. Fedorova[a], S.V. Gorfman[b], G.N. Kulipanov[c], N.V. Sobolev[a]

[a]*Institute of Mineralogy and Petrography, Novosibirsk 630090, Russian Federation*
[b]*Chelyabinsk State University, Chelyabinsk, Russian Federation*
[c]*Institute of Nuclear Physics, Novosibirsk, Russian Federation*

Available online 10 March 2005

Abstract

Under mechanical impact, several kinds of lattice defects are known to arise during plastic deformation (PD). In all crystals, the deformation processes occur such as complex sliding, mechanical kink, irregular reorientation, polygonization, and their variations. These mechanical defects can usually be successfully studied in experiments on model crystals.

However, experiments on the deformation of diamond crystal using the simulation of natural processes are hampered due to peculiar extreme properties of diamond. Here, nature itself helps us. When examining natural diamonds and their internal substructure, one can observe mechanical defects (and actually they have been revealed already) similar to those studied in other model crystals.

In this work, a directly detected defect in diamond, belonging to widely known mechanical defects of the reorientation type, is described for the first time. On the Laue-SR topograms, these defects, if in the position of reflectance, are shown by parallel strokes. One can find the orientation for a sample, when these reoriented crystal interlayers are beyond the contrast, and the main crystal, on the contrary, is in the position of reflectance. Then, the topogram looks as a black field with white empty spaces.

PACS: 61.10.Nz; 61.72.Ff

Keywords: Synchrotron radiation; Diffraction; Laue-SR method; Diamond; Lattice defect

1. Experimental

Diamond crystals are formed in the upper earth mantle at a depth of ~200 km, under colossal

*Corresponding author. Tel.: +8 3832 33 26 05; fax: +8 3832 33 27 92.
E-mail address: ryl@uiggm.nsk.ru (G.M. Rylov).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2005.01.133

pressure (P) of $\sim$150−200 kbar and temperature (T) over 1000 °C.

A large amount (more than 300) of natural imperfect crystals from different deposits all over the world were studied by the X-ray synchrotron radiation (Laue-SR method, VEPP-3, Institute of Nuclear Physics, Novosibirsk), and specific pictures of lattice distortion were found on the Laue-SR diffraction patterns [1]. Assuming that these pictures reflect certain substructural reorientations of the lattice, one can pursue distortion defects of this kind [2]. Continuous slow angular scanning of a crystal directly within the synchrotron beam, under the visual control of the whole diffraction picture, allows for selection and fixation of the necessary position for the crystal exposure.

2. Results

Laue spots, looking like a system of touch (Fig. 1a), were found when studying plastic-strained plate diamond crystals that suffered soft split natural conditions. Such a reflection was indexed on the simulated Laue diffraction pattern by means of a program [3] as $1\,\bar{1}\,3$ ($\lambda = 0.55\,\text{Å}$). Only the sections rearranged during plastic deformation were represented on the Laue diffraction patterns, as were only in the reflectance position the narrow crystal interlayers that suffered substantial off-orientation in respect to the main crystal. In this specific orientation, the main part of the crystal does not reflect X-rays, and one can see a white field with parallel black touch (Fig. 1a). To put the lattice of the main crystal part into the reflectance position, one has to turn the crystal through $\sim$2°. On the corresponding Laue diffraction pattern, the active reflection is that with $\bar{2}\,4\,\bar{2}$ indices at $\lambda = 0.38\,\text{Å}$. This Laue spot $\bar{2}\,4\,\bar{2}$ (Fig. 1b) on the Laue-SR topogram is manifested as the solid black spot with weak white open strips (they are shown by arrows), their shape and location corresponding to the black strips in Fig. 1a. White strips, in this instance, represent the extinction of contrast of interlayers, the rearranged sections of the lattice. They are most probably the deformation bands of kink type. Thin parallel lines on the crystal that were at first observed visually, represent fields of irregular, though quite definite, orientation of lattice sections formed evidently during PD under conditions of diamond crystal plasticity. Their thickness is about 20−60 μm. The tilt of 2° is not indispensable, but it can indicate deformation of kink type. The kink interlayer in a

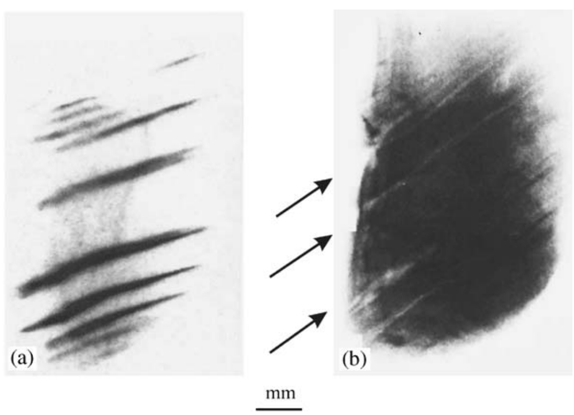

Fig. 1. Laue-SR topograms of reoriented fields in natural diamond crystal: (a) only the reoriented fields in the form of interlayers diffract (light background), operating reflection $1\,\bar{1}\,3$; (b) the main crystal diffracts (dark background), arrows show the open space caused by the interlayers, operating reflection $\bar{2}\,4\,\bar{2}$.

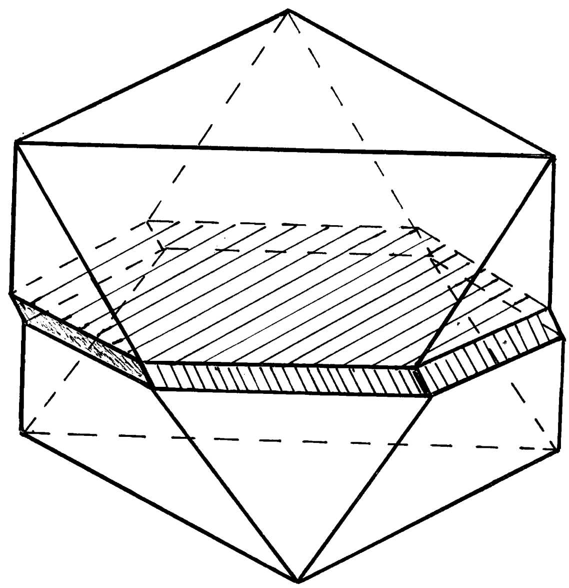

Fig. 2. Sketch of kink interlayer in a diamond octahedron.

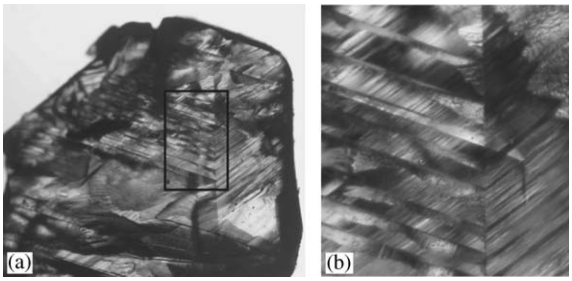

Fig. 3. Surface of natural tilt in a diamond that had suffered strong plastic deformation (a), a magnified picture of the surface fragment (b).

diamond crystal can be sketched as a dashed field in a diamond octahedron (Fig. 2). However, actually the substructure of strongly distorted diamond is much more complicated, as is seen on the photograph of the natural split (Fig. 3). In other crystals and under different conditions, the tilt and width of sections can be different. The split surfaces often have a zigzag relief (Fig. 3a), as strongly distorted crystals contain many split fields and blocks. Split surfaces often do not coincide with cleavage faces {1 1 1}, the deviation reaching several degrees. The photograph of such a surface demonstrates lines of substructures of different orders, both continuous, that are referred to different slip systems, and short ones, that are referred to strain interlayers with micro-structural fragments (Fig. 3b).

Thus, the examination of a large quantity of natural diamond crystals that had suffered PD provided the possibility to find in the lattice reoriented fields of kink type, similar to the deformation defects in plastic crystals. Apparently, PD in diamond proceeds under high temperatures that render them plastic.

Acknowledgements

This work was supported by RFBR, Grant 04-05-64948.

References

[1] G.M. Rylov, E.S. Efimova, N.V. Sobolev, G.N. Kulipanov, et al., Nucl. Instr. and Meth. A (2001) 182.
[2] G.M. Rylov, N.P. Pokhilenko, G.N. Kulipanov, et al., Surface (2003) 74 (in Russian).
[3] I.A. Sheremetyev, S.V. Gofman, Nucl. Instr. and Meth. (2001) 223.