POLYCRYSTALLINE CLUSTERS OF DIAMOND FROM THE LOMONOSOV DEPOSIT, RUSSIA

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Polycrystalline aggregates of diamond from the Arkhangelsk pipe of the Lomonosov deposit have been studied with optical and scanning electron microscope, color cathode luminescence, and infrared Fourier spectroscopy. The diamonds were divided into two morphological and structural groups referred to VIII and IX varieties by the classification of Yu.L. Orlov (1984). There are diamond crystals with high N content among them, but N-poor crystals were also found. Unzoned and zoned polycrystalline clusters related to different stages of crystallization have been established.
1 table, 4 figures, 5 references.
Keywords: diamond, polycrystalline clusters of diamond, VIII variety of diamond, IX variety of diamond, admixture defects, inclusions.

As both single crystals and polycrystalline varieties of diamond (Orlov, 1984) are widely used in various industries, the origin of diamond is one of the urgent problems of geology. Morphology and structure of diamond are the source of unique information on geological processes at the depth of 150 km. Polycrystalline clusters of diamond at present are studied poorer than single crystals (Smelova, 1991). Therefore, the examination of their outer and inner morphology ensures new evidence about the conditions of diamond formation explaining actuality of this study.

Twenty samples of polycrystalline clusters of diamond of 3–4 mm in size from the Arkhangelsk pipe were examined with optical and scanning electron microscopy, color cathode luminescence (CL), and infrared Fourier spectroscopy (FTIR).

The polycrystalline aggregates studied here are composed of octahedral, combination, and dodecahedral crystallites; these crystallites are light to dark gray, greenish gray, pink, and yellow transparent or semitransparent.

Most samples studied (12 clusters) are aggregates of numerous faced small nearly equal-sized crystals. These clusters are oval and globe-shaped. Separate individuals are combination and dodecahedral. Dark granular core is in transparent clusters. This core is aggregate of irregular-shaped diamond grains, which are dark because of inclusions of graphite. The clusters are predominantly light gray and greenish gray; pink and zoned clusters also occur (Figs. 1a–c). These clusters are referred to the VIII varieties by the mineralogical classification of Yu.L. Orlov (1984).

Eight clusters of the collection studied are irregular-shaped angular pieces. Well distinguished grains composing these clusters are predominantly octahedral. The clusters are dark gray opaque. Dark irregular-shaped inclusions, which are probably graphite typical of diamond for the Arkhangelsk diamond province, are in crystallites. Significant amount of these inclusions causes black color of the crystals (Figs. 1d–f). Green pigmentation spots resulted from natural radioactive irradiation and parallel growth striation caused by layered growth of faces (Fig. 1d) are well seen on some crystallites (octahedra). Some samples show split tips indicating change of growth conditions. Polycentric growth of faces of the samples studued testified to oversaturated medium and shifted center of growing face (Kriulina, 2012). Transformation to dodecahedroid is not observed. This type of polycrystalline clusters was referred to the IX varieties by the mineralogical classification of Orlov (1984).

All diamond crystals have traces of local dissolution. Faces of separate crystals are dull, uneven and are penetrated by etch channels (Fig. 2). Matting is resulted from effect of mobile reagent that acted with equal power through all points of surface of diamond crystal and easily penetrated all pits on the crystal. In nature, such reagent was suggested to be fluid medium (Gnevushev and Shchemanina, 1975).

The CL intensity and distribution differ in the polycrystalline clusters studied (Fig. 3).

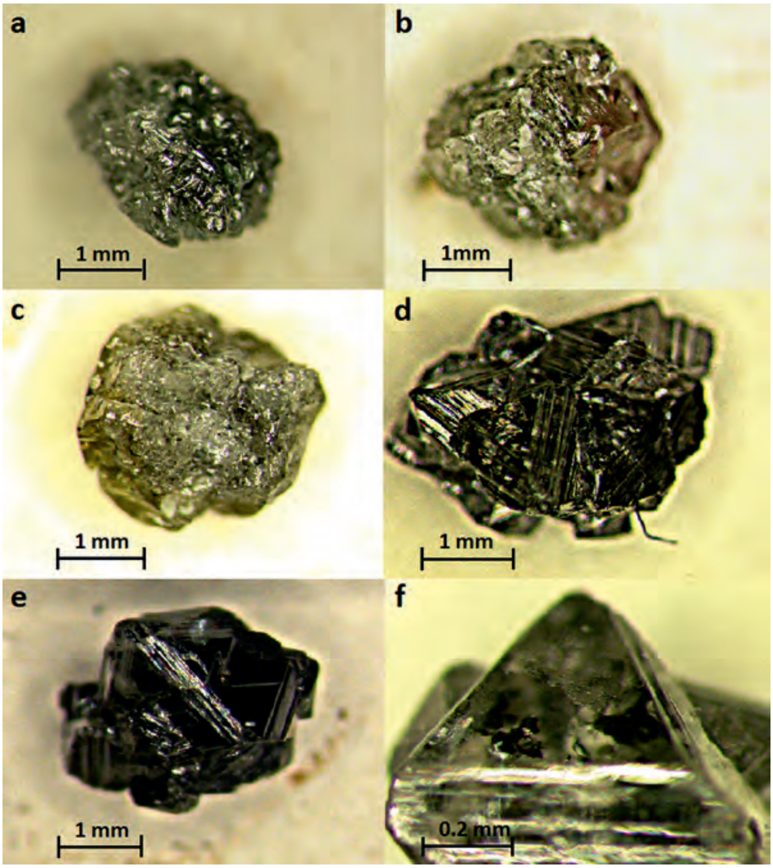

Fig. 1. Polycrystalline clusters of diamond from the Arkhangelsk pipe (transmitted light). (a) Polycrystalline clusters of the VIII variety; (b) pink crystal of diamond overgrown by small crystallites; (c) zoned polycrystalline cluster of the VIII variety; (d) cluster of octahedra with pronounced growth striation and of black color resulted from numerous inclusions, IX variety; (e) cluster with chip, IX variety; (f) irregular-shaped inclusion in crystallite of the IX-variety cluster.

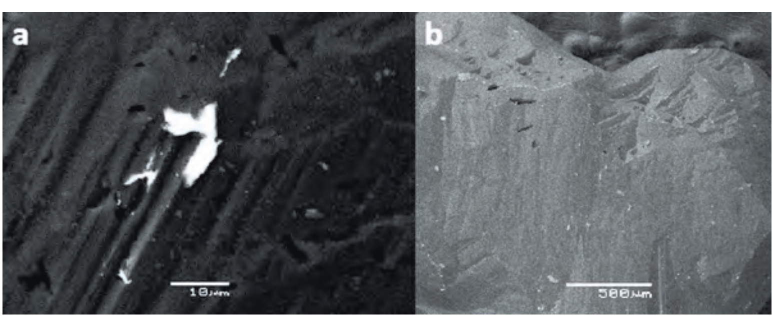

Fig. 2. Back-scattered electron image of crystallite surface. (a) Fragment of polycrystalline cluster with etch features, which are fractures, pits and rough surface; (b) fragment of polycrystalline cluster with etch caverns and negative etch pyramids.

The polycrystalline clusters studied have basically blue luminescence of varied intensity complicated with green and red lines and spots (Figs. 3a, b). The clusters, where separate crystallites with green CL are observed at the background of homogeneous blue CL (fig. 3c), were found. These crystallites are frequently complicated with blue CL spots (Fig. 3d) probably resulted from various generations and growth stages of the cluster. Zoning of crystallites is expressed as different CL of core and rims (Fig. 3b). Different CL patterns indicate testify to the different formation conditions of polycrystalline clusters.

The set of nitrogen defects in the crystal structure of diamond is extremely vast and diverse (Sobolev, 1978). According to FTIR spectroscopy, the content of nitrogen defects is higher in the studied polycrystalline clusters referred to the IX variety that that of clusters referred to the VIII variety (Fig. 4). The average content of A and B defects in the N-rich crystals is significant (1000 ppm), whereas in N-poor, that is low (260 ppm).

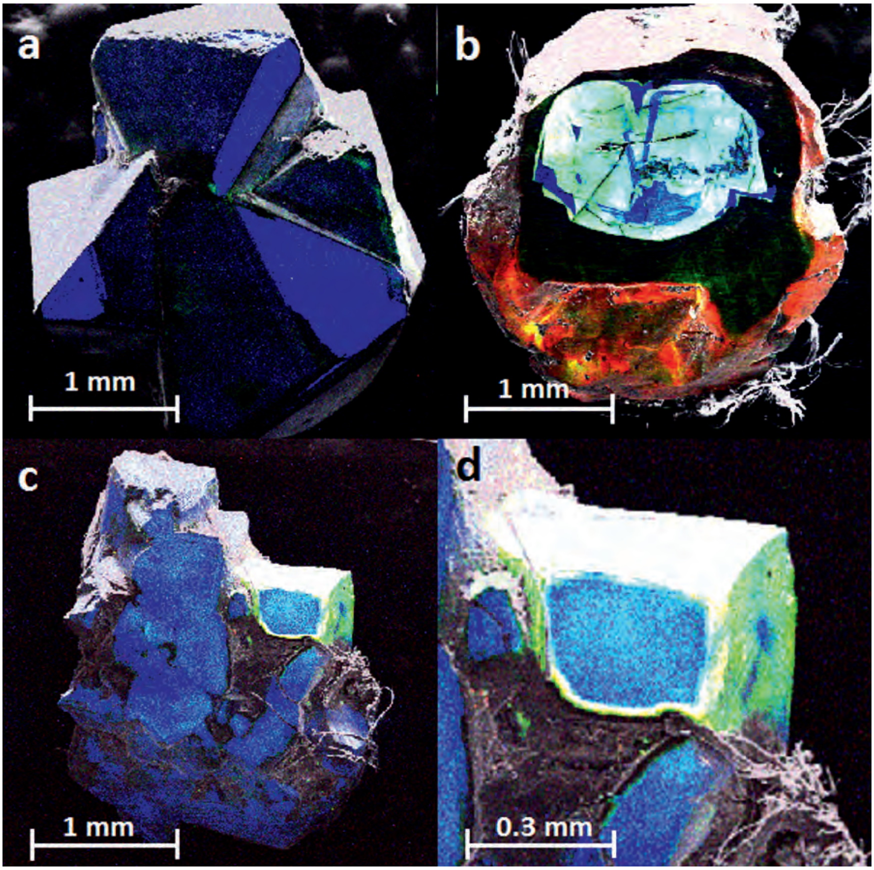

Fig. 3. Cathode luminescence pattern of diamond.
(a) monotonous blue luminescence

(b) blue luminescence complicated with lines of green luminescence;

(c) monotonous blue luminescence with green luminescence of one crystal;

(d) green luminescence of separate crystallite complicated with blue luminescence.

Table 1. **Concentration of structural defects in polycrystalline clusters of diamond from the Arkhangelsk pipe estimated from IR-Fourier spectroscopy**

Number of sample	N_{tot}, at.ppm	A, at.ppm	B1, at.ppm	B1, %	B2, cm^{-1}
1787-3-2	1002	948	54	5.39	10.36
1787-3-17	267	208	59	22.09	2.18

Notes. N_{tot} means total concentration of nitrogen in crystal; A (at. ppm) and B1 (at.ppm) are nitrogen defect A and B1 and their content; B1 (%) is content of defect B1 expressed as percent of total concentration A + B1 (aggregation of nitrogen); B2 (cm^{-1}) is concentration of defect B2 (planar defect). IR spectra were measured at National Mineral Resources University (University of Mines), St. Petersburg, Russia (V.A. Vasil'ev analyst).

C defects were not found. The aggregation of nitrogen is all polycrystalline clusters ranges from 5 to 25% with the average value 15%. The content of B2 defects ranges from 2.18 to 10.36 cm^{-1}. Average content of B2 defects in crystals with high content of nitrogen defects is 10 cm^{-1}, whereas that in the crystals with low content of nitrogen is 2.3 cm^{-1}. Both N-rich and N-poor diamond contains hydrogen.

The studied polycrystalline clusters were compared with those from the Udachanaya pipe in the Yakutia diamond province. The latter are predominantly bort (IX variety). Ellipsoidal and nearly rounded clusters, in which faced tips of diamond individuals are observed over the entire surface, indicate the growth in the medium contributing uniform influx of feed substance that is possible only in mobile medium. According to Smelova (1991), the chemical composition of cogenetic solid inclusions (olivine, richterite, magnesite, and phlogopite) and their assemblages in polycrystalline clusters attribute the latter to the ultramafic medium.

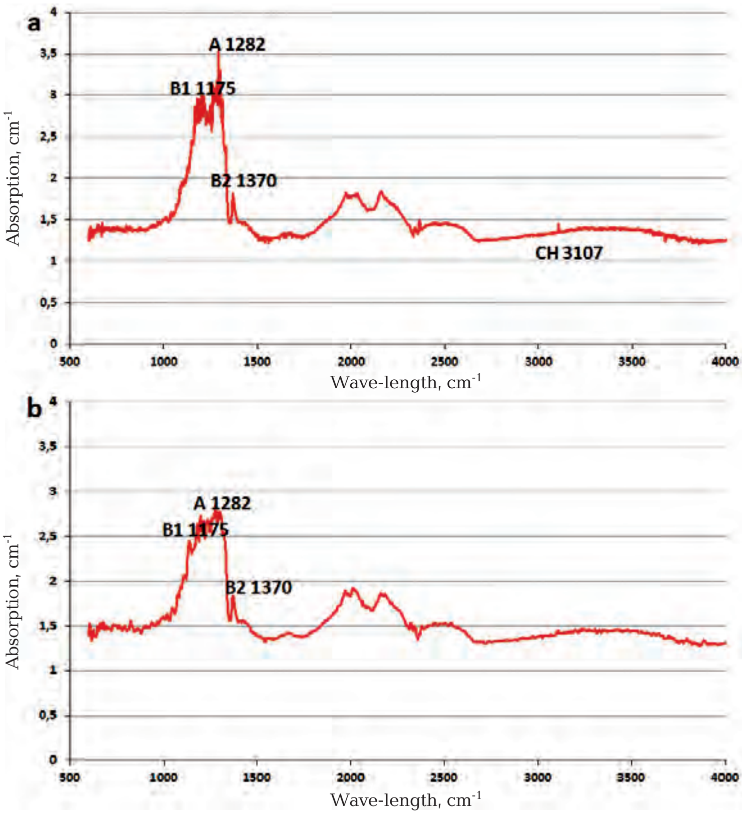

Fig. 4. IR spectra of polycrystalline varieties of diamond. (a) IR spectrum of polycrystalline cluster of the IX variety (sample no. 1787-3-2) with high content of nitrogen defects A, B, and B2 and hydrogen defect CH; (b) IR spectra of the VIII-variety cluster (sample no 1787-3-17) with low content of nitrogen defects.

Conclusions

The polycrystalline clusters studied are divided into two groups. The first group is clusters with dark gray to nearly black well-faced octahedral crystallites. Evenly distributed inclusions are typical for these clusters. These clusters belong to the IX variety by the classification of Orlov (1984). Uniform CL indicating one-stage growth of the clusters is typical of these clusters. The high content of nitrogen and low aggregation testify short post-crystallization annealing.

The second group is clusters with small nearly equal-sized predominantly octahedral and dodecahedroidal crystallites. These clusters are light gray. These samples are referred to the VIII variety by the mineralogical classification of Orlov (1984). They are characterized by heterogeneous CL, low content of nitrogen, and higher aggregation testifying to longer annealing of the clusters.

The clusters referred to the VIII variety is suggested to crystallize earlier at higher temperature than those of the IX variety. Similar morphology of polycrystalline clusters of diamond from the Arkhangelsk pipe and those from the Udachnaya pipe indicates similar conditions of formation in ultramafic medium.

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