Physics

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1968

SovietRxiv

Abstract

Full Text

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Comparative Study of Natural and Synthesized Ballases

Among natural diamonds, varieties are distinguished that differ from one another in their properties, external form, and the character of their internal structure. One such specific variety of diamond is ballas—spherulites of spherical form, with a radial-fibrous internal structure.

Differences in the external appearance of natural ballases are associated with the character of their internal structure. Among ballases there occur specimens that are perfectly regular spheres, as well as rounded and droplet-shaped formations close to spheres, with a smooth or sculptured uneven surface (Fig. 1a).

On fracture surfaces of ballas one can see their radial-fibrous structure: fine-rayed, needle-like, or with coarser rays clearly distinguishable with the naked eye. In studying the morphological features of ballases in specimens that have no fractures, it is impossible to establish their internal radial-fibrous structure. In this connection, some investigators ([1], [2]) assumed that ballases have a monocrystalline core overgrown by a polycrystalline granular shell. However, among diamonds in the department of the Ministry of Finance of the USSR, Yu. L. Orlov studied ballases of ideal spherical form that had been split in half. On the fracture surfaces of these specimens it was clearly visible that they are typical spherulites, and that the rays diverge radially from a center in which no monocrystalline core is observed (Fig. 2a).

Sometimes individual ray-like individuals within a single specimen have unequal dimensions, which indicates their nonuniform growth during formation of the spherulite (ballas).

The character of the internal structure of ballas is well revealed when radiographs are taken. In ballases composed of very thin individuals of identical size, the radiograph shows no individualized spots; only rings corresponding to the principal lines of diamond are observed. In appearance, these radiographs correspond to radiographs obtained from carbonado—a cryptocrystalline, submicrogranular variety of diamond.

In ballases composed of coarser ray-like individuals, more or less identical in size and clearly distinguishable by eye, the radiographs show separate elongated spots, commensurate with the size of the individuals, arranged radially from the center, as if imitating the radial-fibrous structure of the ballases themselves (Fig. 3a). In addition to the radial-fibrous pattern, the elongated spots on the radiographs usually form discontinuous, quite clearly noticeable rings, corresponding in their position to the principal interplanar spacings of diamond. If a ballas contains relatively large sectors formed during nonuniform growth of the ray-like individuals, then, together with the radially arranged elongated spots, there appear individual larger spots, well noticeable against the general background, from this part of the spherulite, as from a single crystal.

When ballases having an even, smooth surface are photographed, the resulting X-ray diffraction patterns have rings without distinguishable spots, or with very small spots, which indicates the fine-rayed structure of such spherulites.

In ballases composed of comparatively large individuals, sculpture and irregularities are visible on the rounded surface. The characteristic appearance of the sculptured surface of ballases makes it easy to distinguish them from diamond single crystals. The latter sometimes have a shape very close to that of a sphere, but on their surface one can see sculptural elements usual for single crystals (triangular blocks, geometrically regular etch figures, etc.). On the surface of ballas, hatching is visible in the form of closed contours, which as a whole form a very complex pattern. The angles within the closed contours of the hatching indicate that the individual rays composing the ballas are often in twin intergrowth and form cyclic polysynthetic twins, which is also confirmed by the character of the X-ray diffraction patterns.

As a result of experimental work on synthesizing varieties of diamond at the Department of Physics and Chemistry of High Pressures of Moscow University, together with the Institute of High-Pressure Physics of the Academy of Sciences of the USSR, spherical diamond formations ([3]) were obtained, having a radial-rayed structure, which in their external appearance and internal structure correspond to natural ballases (Fig. 1b). Depending on the synthesis conditions, it is possible to obtain fine-rayed ballases with a completely smooth surface, as well as specimens on whose surface crystallites are clearly visible, as if crowning comparatively large rays composing the ballas.

The crystallites on the surface of the spherulite have the form of octahedra strongly flattened along L_3, forming spinel twins of hexagonal shape in plan view. The most strongly developed faces $(\bar{1}11)$ of the twinned individuals are sometimes arranged perpendicular to the rays of the spherulite, forming, as it were, tangent planes to the round surface of the ballas, but more often the twin plane coincides with the direction of the rays of the spherulite.

When synthesized ballases are split along a fracture, their radial-rayed structure is well revealed. In the photograph of the fracture surface of one of the ballases shown in Fig. 2b, the character of the internal structure of a fine-rayed spherulite is clearly visible. In order to study the character of the internal structure of ballases formed by larger rays, some of them were polished in various sections,

Fig. 1. Ballas: a —natural, b —synthetic

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Fig. 2. Cleavages from ballas samples. Designations are the same

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and the surfaces of the cut planes were studied under a microscope. On a polished surface passing through the middle of the ballas, it is clearly seen that the individual rays have the character of fir-tree-like dendrites growing radially from the center of the ballas (spherulite), increasing segment-like toward its surface.

The X-ray diffraction patterns obtained when synthesized ballases are photographed are identical to the X-ray diffraction patterns of natural ballases. From their appearance one can easily judge the internal structure of the spherulite, i.e., the size of the rays composing it. Submicroscopic fine-rayed ballases with a completely smooth enamel-like surface were synthesized, whose X-ray diffraction patterns corresponded to carbonado, as well as specimens with a larger ray size, on whose X-ray diffraction patterns spots of different sizes, commensurate with the rays of the spherulite (ballas), were visible.

Study and comparison of the X-ray diffraction patterns and the character of the structure of natural and synthesized ballases showed their identity and made it possible to establish that ballases are radial-rayed spherulites of diamond, formed under specific growth conditions. As is known from works on diamond synthesis ([4]), the absence of cubic faces and

Fig. 1. Ballas: *a* —natural, *b* —synthetic

Fig. 2. Cleavages from ballas samples. The designations are the same

Fig. 3. X-ray diffraction patterns of ballas. The designations are the same

The polycentric character of the development of the $(\bar{1}\bar{1}\bar{1})$ faces on crystals observed on the surface of synthesized ballas diamonds indicates that they form under conditions of rapid growth, with the growth direction of the rays being the $L3$ axis, and the growing surface the (111) plane. It should be noted that the rounded surface of natural ballas diamonds quite often bears traces of partial dissolution, as a result of which sculptures are formed on it that are not observed on synthesized ballas diamonds. In all other respects they are identical to synthesized ballas diamonds, which makes it possible to conclude that natural ballas diamonds form under conditions of rapid crystallization.

Fig. 3. X-ray diffraction patterns of ballas. Designations are the same

Figure 3: Fig. 3. X-ray diffraction patterns of ballas. Designations are the same

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Received
29 V 1968

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Note: Figure translations are in progress. See original paper for figures.