VARIATIONS IN DENSITY AMONG VARIETIES OF NATURAL DIAMONDS

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Fig. 1

Figure 1: Fig. 1

Abstract

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VARIATIONS IN DENSITY AMONG VARIETIES OF NATURAL DIAMONDS

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Previously, the density of diamond crystals and their polycrystalline varieties was determined by the pycnometric method, whose accuracy does not exceed 10^{-2} g/cm^3. In 1964, in paper ([1]) results were presented from studying the density of diamond crystals by the flotation method, which makes it possible to make determinations with an accuracy of up to 10^{-5} g/cm^3. The authors investigated crystals of ordinary transparent diamonds, both colorless and colored yellow and gray, which by their physical properties belong to diamonds of types I and II. From the results of this work it is evident that the densities of ordinary diamond crystals of different colors most often differ in the fourth and fifth, and rarely in the third, decimal places. These data showed the unsatisfactory nature of the old pycnometric methods for determining the densities of differently colored diamonds.

By the flotation method, the density ([1]) was determined only for colorless and colored transparent diamonds of the ordinary variety; the density of other varieties of diamond (for example, bort and diamonds with coatings—coated diamond) was not investigated.

To study density variations in different varieties of diamond crystals, we somewhat modified the apparatus described in paper ([1]). Particular attention was paid to maintaining thermostatic conditions for the flotation volume (Fig. 1). In addition, the apparatus included: a U-10 ultrathermostat, an R-306 potentiometer with an external standard resistance coil, a wall-mounted mirror ballistic galvanometer M 17/2, and a VK-6 cathetometer.

Fig. 1. System for thermostating the flotation volume.
1 —platinum resistance thermometer; 2 —metal thermostat; 3 —glass beaker for preventing possible convective currents and smoothing temperature pulsations;

Fig. 2. Dependence of the rate of displacement of a specimen in the flotation liquid on temperature.

Figure 2: Fig. 2. Dependence of the rate of displacement of a specimen in the flotation liquid on temperature.

4 —density standards (“floats”); 5 —magnet for moving the float; 6 —Pyrex flotation vessel; 7 —stirrer

The U-10 ultrathermostat maintained the temperature in the external metal thermostat with an accuracy of $\pm 0.02^{\circ}$. Since the inner part of the thermostat, as well as the glass beaker, is filled with water that smooths temperature pulsations, at the location of the flotation vessel it is possible to maintain the temperature with an accuracy of $\pm 0.001^{\circ}$. The moment at which temperature equilibrium was established was recorded with the aid of a platinum

thermometer. Before being placed in the thermostat, the flotation vessel was filled with an 87% aqueous solution of thallium malonate and thallium formate, together with the diamonds under study and the “float,” and then air was pumped out of the entire system.

To attain equilibrium more rapidly within the flotation liquid (which was rather viscous) and to bring the required specimen to a place convenient for observation, a small horseshoe-shaped magnet was used.

Fig. 2. Dependence of the rate of displacement of a specimen in the flotation liquid on temperature. 1 — “float” ; 2 —light-brown diamond (specimen No. 5); 3 —colorless (specimen No. 1); 4 —dark-brown (specimen No. 6); 5 —light-green (specimen No. 9); 6 —grayish-smoky (specimen No. 7); 7 —pinkish-lilac (specimen No. 8); 8 —dark-green (specimen No. 10)

The density values of the specimens were established by comparing the density of the diamonds and of a special density standard with the density of the flotation liquid (~3.52 g/cm^3). The density of the flotation liquid was varied by changing its temperature.

When the densities of the liquid and of the specimen under study are equal, the latter will be in a state of equilibrium, i.e., it will have zero velocity relative to the liquid. Direct observation of the moment at which equilibrium is reached requires a long time and cannot always be accurately recorded. To speed up the procedure, one can study the dependence of the rate of rising (or sinking) of the specimen on temperature. From the graph representing this dependence (Fig. 2), the equilibrium temperature corresponding to zero velocity is determined.

As the density standard, a “float” made from a quartz tube was used; its density, by combining weight and volume, was selected to be equal to 3.5 g/cm^3 and was then determined accurately by the method of hydrostatic weighing ([2]).

The density of the diamonds studied, ρ_a, at 25° is determined by the formula

$$\rho_{a(25)} = \rho_{p(25)} + \left(d\rho_\ell/dt - d\rho_p/dt\right)(t_p - 25) - (d\rho_\ell/dt - d\rho_a/dt) \times$$

$$\times (t_a - 25),$$

where $\rho_{p(25)}$ is the density of the float at 25°; $d\rho_\ell/dt$, $d\rho_p/dt$,

$d\rho_a/dt$ are the temperature coefficients of density of the flotation liquid, the "melt," and of the diamond under study, respectively; t_p and t_a are the equilibrium temperatures of the "melt"and of the diamond under study. The derivation of this formula and the substantiation of the idea of the method are set out in detail in ([1]).

From the results of the measurements performed, graphs were constructed (Fig. 2). The equilibrium temperature of the "melt" and of the diamonds was determined from the graph by their zero velocity. The experimentally found values of the quantities entering into the formula proved to be:

$$\rho_{p(25)} = 3.51568 \pm 2 \cdot 10^{-6}\ \text{g/cm}^2, \quad d\rho_p/dt = 0.00002 \pm 2 \cdot 10^{-6}/^\circ\text{C};$$

$$d\rho_{\text{liq}}/dt = 0.00138 \pm 2 \cdot 10^{-5}/\text{deg}.$$

The value $d\rho_a/dt = 0.0000145 \pm 1.26 \cdot 10^{-6}/\text{deg}$ was taken from ([1]).

As can be seen from the data of Table 1, the densities of ordinary, variously colored transparent diamond crystals (specimens Nos. 1-15), irrespective of their color, differ only in the third and fourth decimal places.

It has been established that smoky, brown, and pinkish-violet coloration is epigenetic ([3,4]) and is associated with defects on glide planes. For this type of crystal one might have expected a lowered density. As can be seen from Table 1, the density of a diamond colored light brown (specimen No. 5) corresponds to the density of colorless diamonds, whereas the density of the dark-brown one (specimen No. 6) is noticeably reduced. Still lower was the density of the smoky diamond (specimen No. 7) from the "Mir" pipe and of the pinkish-violet crystal from South Africa (specimen No. 8), on the surface of which glide lines are clearly manifested. For the four crystals investigated, the mean density of this type of diamond is 3.51523 g/cm^3.

The density of a diamond pigmented with green spots (specimen No. 9) is somewhat lower than the density of colorless diamonds. For comparison, the density was measured of green diamonds colored by irradiation (Nos. 10, 11).

In terms of the mean density value (3.51516 g/cm^3), yellow diamonds proved to be lighter than colorless and smoky-brown diamonds. The lowest density among the yellow crystals was possessed by the most intensely colored ones (specimens Nos. 14 and 15). It was previously assumed ([4,5]) that the yellow coloration of

diamonds is due to an impurity of Fe, Cr, or Ti. Recent data indicate that this coloration is caused by an impurity of nitrogen replacing carbon atoms, which leads to an increase in the lattice constant and a decrease in density. This is confirmed by the results of precision density determinations, which refute the earlier conclusion that yellow diamonds have a density higher than that of colorless diamonds.

Semitransparent and opaque diamonds with coats (coated diamond) ([6]), colored yellowish-green, gray-green, and dark green, have a lowered density in comparison with variously colored ordinary transparent crystals. The coat itself has the minimum density (3.50869 g/cm^3). Hence it may be assumed that the thicker the coat on the crystal, the lower its density should be. It is known that in crystals of this variety that have a cubic form, the coat has the greatest volume and, consequently, in octahedral crystals with a very thin coat the density should be higher than in cubic ones. However, the results obtained do not confirm this. The large fluctuations in density values for this variety of diamond are evidently due to different amounts of inclusions, which, as a rule, are present in the external fibrous-sheaflike coat.

Of the other varieties of diamond, we investigated ballas and carbonado. Ballas (spherical spherulites) were selected by color: from colorless to completely black. Their coloration depends on the amount of dark graphite inclusions. The density of ballas varies regularly as a function of the intensity of coloration, i.e., the amount of inclusions.

Table 1

No.	Characteristics of diamonds	Deposit	Sample weight, mg	Density, g/cm^3 ± 0.0003
	Ordinary transparent crystals			
1	Colorless octahedron, isometric	“Mir” pipe	64.7	3.51543
2	Colorless, twin of octahedra, flattened	“Mir” pipe	92.7	3.51544
3	Colorless octahedron, flattened	“Mir” pipe	96.0	3.51541

No.	Characteristics of diamonds	Deposit	Sample weight, mg	Density, g/cm^3 ± 0.0003
4	Colorless octahedron	“Mir” pipe	102.5	3.51541
5	Light-brown, dodecahedroid	Urals	130.0	3.51546
6	Dark-brown, octahedroid	Brazil	208.8	3.51538
7	Grayish-smoky, octahedron	“Mir” pipe	157.3	3.51510
8	Pinkish-lilac, combination form	South Africa	63.6	3.51500
9	Green, spotted-colored octahedroid (natural pigmentation)	Brazil	174.6	3.51517
10	Dark-green, twin of octahedra (artificial coloration caused by irradiation)	Brazil	101.2	3.51288
11	Dark-green (brownish after annealing), artificially colored by irradiation	“Mir” pipe	62.5	3.51170

No.	Characteristics of diamonds	Deposit	Sample weight, mg	Density, g/cm^3 ± 0.0003
12	Bright yellow, dodecahedroid	Urals	42.1	3.51521
13	Bright yellow, octahedroid	South Africa	79.2	3.51527
14	Amber-yellow, isometric cube	South Africa	352.3	3.51509
15	Amber-yellow, isometric cube	South Africa	32.7	3.51500
	Crystals with opaque coatings (coated diamonds)			
16	Gray-green octahedron with small faces of cube and rhombododecahedron	Africa	52.1	3.51095
17	Grayish-green, isometric cube	Africa	51.9	3.51067
18	Light yellowish-green, cube	Africa	48.6	3.51434
19	Yellowish-greenish	Africa	55.1	3.51455
20	Dark-green, piece of coating	Africa	10.5	3.50869

No.	Characteristics of diamonds	Deposit	Sample weight, mg	Density, g/cm^3 ± 0.0003
21	Light-gray, isometric cube	"Aikhol" pipe	81.0	3.51330
	Balases (spherolites)			
22	Colorless, transparent	Urals	224.0	3.51511
23	Light-gray, transparent	Urals	323.9	3.51462
24	Gray, translucent	Urals	139.4	3.51417
25	Dark-gray, opaque	Urals	372.3	3.50985
26	Black, opaque	Urals	360.6	3.50884
	Carbonado			
27	Dark greenish-gray, weakly porous	Brazil	127.4	3.4340

Carbonado consists of granular formations of diamond and is usually porous. The weakly porous specimen investigated by us had a density of 3.434 g/cm^3. In view of the varying porosity of carbonado, high-precision determinations of their density are of no interest.

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