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Fig. 1

Figure 1: Fig. 1

Abstract**Full Text**

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PHYSICS

Academician L. F. Vereshchagin, E. V. Zubova, L. N. Burenkova,
N. I. Revin

OBTAINING DENSE MODIFICATIONS OF BORON NITRIDE AT HIGH PRESSURES AND SHEAR STRESSES

It is known that at high pressures and high temperatures it is possible to obtain new dense modifications of a number of substances. The synthesis of artificial diamonds, borazon, and a new dense modification of silica is apparently only the beginning of investigations at high pressures aimed at obtaining substances with new physicochemical properties. When the pressure is raised above the point of transformation of a substance into a new phase of higher density, the difference in the thermodynamic potentials of the initial and the new modifications increases; at the same time, internal friction increases, which reduces the rate of transformation of one phase into another. When the temperature is raised, the rate of transformation increases, and in this case the equilibrium transition can be more readily attained.

However, as studies of recent years have shown, shear stresses created in a specimen in one way or another also substantially change the kinetics of the transition. It was shown by one of us and V. V. Evdokimova (¹) that the polymorphic transformation occurring in sodium chloride under pressure is promoted to a considerable extent by shear stresses arising in the specimen. An analogous example is the obtaining of new dense modifications of germanium and silicon (²⁻⁴) under conditions of the simultaneous action of high pressure and shear stresses.

Fig. 1

The authors of the present work attempted to carry out the transformation of hexagonal boron nitride into cubic boron nitride at high pressures and shear stresses.

The investigations were carried out on an apparatus (⁵) developed by the Institute of High Pressure Physics of the Academy of Sciences of the USSR jointly

with the Department of High-Pressure Physics and Chemistry of Moscow State University. The apparatus was calibrated for pressure by polymorphic transitions in bismuth, thallium, and barium, and at the same time the pressure was determined by a piston manometer (⁶). The starting material was hexagonal boron nitride with lattice parameters $a = 2.504 \text{ \AA}$ and $c = 6.661 \text{ \AA}$. Antimony was used as the catalyst. Hexagonal boron nitride, preliminarily thoroughly mixed with antimony, was compressed to pressures of 110 kbar at a shear stress of $19,000 \text{ kg/cm}^2$. On the curve of the dependence of shear force on pressure (see Fig. 1), a break is clearly visible, indicating a change that occurred in the substance. After the experiment the substance was a semitransparent plate with black inclusions. Dents were found on the mirror surfaces of the punches, indicating the high hardness of the product formed. From the antimony

the specimen was washed in concentrated nitric acid. After release of the pressure, X-ray structural analysis was carried out. The X-ray patterns were taken in copper radiation with a nickel filter. Along with the lines of the initial phase, lines of an unknown modification were found. The X-ray patterns were indexed analytically and graphically. The interplanar spacings of the new modifications are given in Table 1.

As a result of analysis of the X-ray patterns it was established that two dense modifications of boron nitride had been obtained. One of these modifications was identified as a hexagonal dense wurtzite-type modification with parameters $a = 2.54 \text{ \AA}$ and $c = 4.18 \text{ \AA}$ and theoretical density $\rho = 3.52 \text{ g/cm}^3$. The parameters we obtained for the wurtzite form of boron nitride agree well with the data of works (8, 9), in which the wurtzite form of boron nitride was obtained at high pressures and high temperatures by the method of shock compression.

Table 1

Borazon, line no.	Borazon, d	Borazon, inten- sity	Borazon, hkl	Wurtzite, line no.	Wurtzite, d	Wurtzite, inten- sity	Wurtzite, hkl
1	2.108	v. av.	111	1	2.196	weak	100
2	1.797	v. weak	200	2	2.108	v. av.	002
3	1.29	weak	220	3	1.899	v. av.	101
4	1.093	v. weak	311	4	1.516	weak	102
5	1.045	v. weak	222	5	1.267	weak	110
6	0.902	v. weak	400	6	1.176	weak	103
7	0.8317	v. weak	331	7	1.106	v. weak	200

Borazon	Wurtzite
$a = 3.615 \text{ \AA} \pm 0.01;$ $\rho = 3.50 \text{ g/cm}^3$	$a = 2.54 \text{ \AA}, c = 4.18 \text{ \AA},$ $\rho = 3.52 \text{ g/cm}^3$

The second unknown modification was identified as a cubic diamond-like modification of boron nitride—borazon—with lattice parameter $a = 3.61 \text{ \AA}$ and theoretical density $\rho = 3.50 \text{ g/cm}^3$. The cubic boron nitride previously obtained at high pressures and high temperatures had parameters $a = 3.62 \text{ \AA}$ and density $\rho = 3.68 \text{ g/cm}^3$ (7).

The presence of one break on the curve of shear stress versus pressure can apparently be explained by the almost simultaneous transformation of hexagonal boron nitride into wurtzite and diamond-like boron nitride, since their densities are very close. The results obtained allow the authors to conclude that, at high pressures and shear stresses, dense modifications of boron nitride of the wurtzite type and cubic diamond-like boron nitride—borazon—were obtained for the first time.

Moscow State University
named after M. V. Lomonosov

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