

Experimental Production of Diamond-Like Modification of Boron Nitride in Dynamic Conditions with Early Thermal Activation

E. Sh. Chagelishvili, M. N. Gelenidze & N. M. Chikhradze

Institute of Mine, Academy of Sciences of Georgia, Tbilisi, Georgia

A. C. Dorfman

DA technologies & Development CBN. LTD, Haifa, Israel

S. A. Zelepugin

Scientific Center SD RAS, Department for Structural Mvokinetics, Tomsk, Russia

ABSTRACT: Lately the use of shock-wave technologies for metal treatment at elevated temperatures and pressure has attracted great interest. Primarily this interest is connected with the possibility to synthesize new materials and chemical compounds, whose generation by traditional methods has run into difficulties, and with the possibility to affect phase transitions. Our wide experience in the field of shock-wave action on the materials enables us to acquire results of investigations valuable for extension of traditional methods of non-organic compound synthesis. There is no substitute to the offered shock-wave technology in solving technological problems, such as hardening of metals and their products, generating of artificial diamonds and boron nitride, pressing and activation of non-organic materials. The experiments described hereinafter have for the first time proved the possibility of phase transition of a hexagonal boron nitride to a tight diamond-like lattice at low temperatures and pressure - at temperatures twice as low and pressures by two orders of magnitude lower than the normally used.

1 INTRODUCTION

Boron nitride is not found naturally. Its graphite-like modifications are synthesized by various chemical methods, whereas tight diamond-like modifications are generated in phase transitions of graphite like at high pressures.

X-ray study shows (1) that like graphite, boron nitride has a hexagonal schistose structure. Close resemblance between the crystal graphite modification and graphite-like boron nitride suggests that similarly to carbon, a more tight diamond-like structure of boron nitride might exist. Pressure and temperature needed for graphite-like boron nitride transition to diamond-like, happened to be close to diamond synthesis parameters (≈ 5 Gpa and 2000K), which result from the similarity of structures and thermodynamic properties of the respective carbon and boron nitride modifications. In both cases in order to obtain tight modifications special additives were used that activated the transition of schistose

structures at high pressures. However, in each case different chemical nature additives were used because of essential differences between the chemical properties of carbon and boron nitride.

Phase transitions in boron nitride is possible without activating additives, but at higher pressures. In 1963 American researchers Bundy and Ventorff (2) reported about direct phase transitions in boron nitride, took place at high static pressures and were accompanied by generation of a known sphalerite phase and a new tight modification of boron nitride with wurtzite structure. In 1967 Dremin A. N. (3) obtained wurtzite modification of boron nitride at high pressures shock compression (up to 50 Mpa). Further investigation showed that at shock compression only wurtzite phase of boron nitride was generated. The sphalerite phase can be generated under dynamic conditions either at repeated compression or heating at a very high temperature.

Temperature corresponding to the BN_g to BN_w transition under shock compression is 500K. As the

pressure and the original porosity of the specimen are increased, the shock compression temperature is increased (Fig.1).

The temperature dependence on pressure of BN_g powder with different initial densities under shock compression is shown in table 1.

Table 1. Temperature dependence on pressure at a shock compression of powder specimens of BN, with different initial densities

Pressure, Mpa	Temperature (K) at density	
	1.98 K/cm ³	0.8 R/cm ³
12	650	850
20	1200	1350
35	1300	1500
50	1400	1900

In order to reduce the initial temperature, cooling components with high heat conductance are added to the initial mixture (e.g. copper). The temperature of shock compression of BN_g versus pressure without additives is illustrated in Fig. 1, (4). The so-called residual temperatures (that remind after the specimen unloading) versus pressure are shown in the Figure 2.

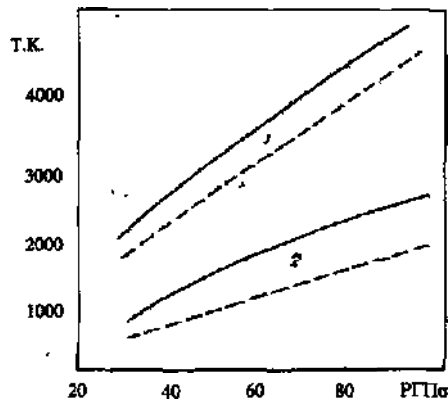


Figure 1. The temperature increase time at dynamic compression is $10^1 - 10^8$ sec, the high pressure action time is measured in microseconds.

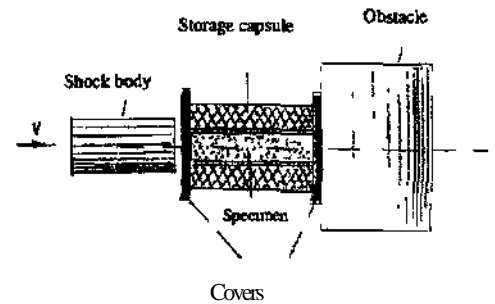


Figure 2. Schematic diagram of the experiment

The phase transition time in boron nitride determined in (5) by the electric conductance measured behind the shock wave is equal to 5×10^{-7} sec.

2 RESULTS OF EXPERIMENTALLY GENERATED DIAMOND-LIKE MODIFICATION OF BN

Reactive mixture was prepared from 125μ, size graphite-like BN powder and 50n size copper powder used as a catalyst in the following ratios:

1. 8%BN and 92%Cu; 2. 20%BN and 80%Cu. A steel container formed as a metal pipe with external diameter 26.9 mm and internal diameter 22 mm was filled with a thoroughly mixed mixture. Two containers that contained 8% of BN and 20% of BN were subjected to early explosive compression in accordance with the diagram shown in Fig.2. Containers pressed by the explosive load were cut to 40 mm and 60 mm long specimens. The specimens were inserted to metal capsules diameter 40 mm for storage. The specimens density was 6.7 g/cm^3 . The parameters of Shock worker and specimen used in the experiment are listed in Table 2.

Results for option 7c-A1 shock body, rigid wall at the specimen rear, thick steel wall surrounding the specimen are given such that shock body - diameter 30 mm, height 60mm, initial temperature 600K, mix density 7.22, porosity 6% (real density with taking into account the porosity 6/8), mix diameter 18 mm, thickness of the steel walls 11 mm (11 mm from the both specimen flanges in die illustrated section).

Table 2 The parameters of shock worker and specimen

#	Shock worker			Specimen			
	Material	length	weight	Mix	Diameter, mm	Length, mm	Speed M/sec
1B	Al	128	230	BN8%	22	40	650
2B	Al	128	230	BN20%	22	60	650
3B	Al	53	95	BN8%	22	40	800
4B	Al	53	95	BN20%	22	60	800
5B	Fe	46	230	BN8%	22	40	650
6B	Fe	46	230	BN20%	22	60	650
7B	Fe	30	150	BN8%	22	40	730
8B	Fe	30	150	BN20%	22	60	730

The mix and steel wall interface can be tracked by the lower ruler (9 and 11 mm)

Experiments 1B- specimen with a preservation cassette after collision is illustrated in fig 3 From the examination it appears that the hit rather than being central is offset by 10 mm from the center. The reason is the specimen deviation from the previous experiments to the target. The reactive mix compression depth is about 22 mm.

For quantitative evaluation of boron nitride crystals distributions in the specimen polished slices were investigated under the microscope. In Fig 4 the investigated reactive mix specimen is illustrated. One section was made at a distance of 2 mm from the rear specimen flange perpendicular to its axis. The other section was made at a distance of 11 mm from the specimen rear surface.

The reactive mix was cut along the symmetry axis. A 9 mm long polished specimen section from the rear surface was examined.

Fig 5 illustrates distribution of the diamond-like BN crystals along the specimen axis line. As seen from this picture the distribution density is increased close to the rear surface. These stems from the presence of unload waves close to the rear surface at the plastic wave reflection from the free specimen surface.

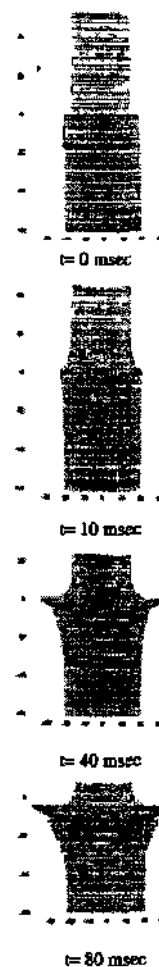


Figure 3 Specimen after collision



a



b

Figure 4 Crystals distribution in the second specimen part along the symmetry axis; a-in the slice area, b-at a distance of 3 mm from the slice, c-at a distance of 6 mm from the slice, d-at a distance of 8 mm from the slice (close to the rear surface). Sample 4B, Magnification X100.



Figure 5. BN crystals distribution across the radial section of the specimen at a distance of 9 mm from the face surface along the X, Y, axes at a distance of 5 mm from the center x 50 A-along the X axis, b-along the Y axis

From visual scanning of the entire slice area along the vertical and horizontal axes with the scanning pace of 2 mm it appeared that in quantitative sense the crystals distribution density across the entire surface is almost alike. The density distribution is increased towards the external specimen borders. Visual scanning enabled to make up a quantitative pattern of the distribution of crystals across the entire section area, which is illustrated in Fig. 6



Figure 6 Distribution of crystals across the entire section area

CONCLUSIONS

1. The conducted experimental generation of diamond-like modification of boron nitride with early thermal activation evidences the possibility to obtain boron nitride under low pressures and temperatures, contrary to the commonly accepted
2. In phase transition of boron nitride the compression and die unloading waves have the same importance.
3. From the investigation of specimen polished sections under microscope it follows that the distribuion of boron nitride crystals along the enure specimen length is homogenous. Moreover, the typical size of crystals; measured on the polished slice is in the range 100 to 300*μ*m.

4. A 20% of boron nitride nrix is specified by higher crystal density distribution in the specimen section than the 8% mix, which is due to give us a higher yeld of the final product.

REFERENCES

- Bundy F.P., Wentorf R.H., Jr. direct transformation of hexagonal boron nitride to denser forms, J. Chem. Phys. m. 1963,38 #5
- Corrigan F.R. Bundy F.P. Direct transitions among the allotropic forms of boron nitride at high pressures and temperatures. J. Chem. Phys., 1975,63, #9
- Dremin A.N., Alicv Z.G. et all, Generation of wurtzite-like modification of boron nitride in shock compression, DAN SSSR, 1967, 172,5
- Goldshmidt V.M. Darstellung und Eingenscbafien dès kristallisierten Bornitrides, norkgeol. Tidsskr., 1926,9, #3/4
- Soma T., Sawaoka A., Saito-Sh. Synthesis of dense form boron nitride and diamond by shock compression, In:proc 4* Int Conf., High pressures, Kyoto:Pftys, Chem.Soc. Jap-, 1975