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ПРОЦЕСС ПРОИЗВОДСТВА НОВОГО УСОВЕРШЕНСТВОВАННОГО КАРБИДА БОРА B_4C, ПОДОБНОГО АБРАЗИВНОМУ АЛМАЗУ, НА ОСНОВЕ НАНОМАТЕРИАЛОВ

АННОТАЦИЯ
Главный революционный результат исследовательской работы – создание нового, чистого, абсолютно прозрачного, белого продукта Карбида Бора, обладающего самыми высокими характеристиками, такими как твердость, прочность, равными алмазу. Такой материал будет иметь много практических применений в различных областях промышленности.

КЛЮЧЕВЫЕ СЛОВА: Карбид Бора, твёрдость, прочность.

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PRODUCTION PROCESS OF THE NEW ADVANCED NANO-BASED SUPER ABRASIVE DIAMOND-LIKE B_4C MATERIAL

ABSTRACT
The main revolutionary result of research work is the creation of the new advanced absolutely pure transparent white Boron Carbide product, possessing the highest possible properties such as hardness, strength, equal to those of diamond. Such material will have many practical usages in the different fields of industry.

KEYWORDS: Boron Carbide, hardness, strenght.

Introduction

The constantly accelerating development of the science and technology at the last time leads to that interest to the traditional materials diminishes because of that their properties doesn't correspond to new requirements. And their further improvement has exhausted itself, both for alloys and abrasives.

The brightest representatives of the contemporary advanced super hard materials are diamonds, both natural and synthetic ones, CBN and traditional boron carbide in bulk. However, the above mentioned materials also have some certain drawbacks. So, for example, diamonds, possessing excellent properties for industrial applications: hardness, strength, wearability and used as jewelry, are very expensive, the natural ones are limited in resources and synthetic ones require very complex technology for their production.

The synthetic diamonds, though they are cheaper than natural ones, however, are more than enough expensive for the mass usage in the abrasive industry. Besides that, their production technology is very complex and level of production is insufficient for the wider usage as abrasives in all fields of industry.

The CBN is second in hardness to diamond, but its usage is limited by very complex production technology and very specific application. It includes impurities from raw materials, which prevents its possible usage for electronics or other precision technologies.

The existing traditional boron carbide is much cheaper than above mentioned materials, possesses high strength and hardness. However, the presence of big quantity of impurities caused both by inclusions of impurities from raw materials and by not fully reacted raw materials when particles contact. We put the following task – to create a new material, which corresponds to diamond in properties of hardness, strength and wearability is relatively simple in the process of production and has very low production costs, close to traditional boron carbide production costs.

This material is a new advanced Diamond-Like Mono Crystalline Boron Carbide (DLCBC) powder according to Israeli patent № 126637. In more detail this product and technology of its production was disclosed by us in the article [1].

The task of the present article is to describe the phenomena and chemical and physical processes, taking place at the creation of this above material DLCBC.

Materials and methods

Traditional Boron Carbide

The previous technologies of traditional Boron Carbide require thorough crushing / comminution and mixing of dry powdered source raw materials for the case of two materials, marked M1 and M2, please, find Figure 1A. Nevertheless, the particle sizes of raw materials before processing may constitute from 25 to 15 μk with later compressing into tablets and sintering in the furnace, – and this presents the phenomenon of low speed solid phase hot diffusion reaction process, wherein there is the diffusion of atoms of carbon and boron from one particle to another, with according reaction between them, which is depicted by straight arrows and simple adhesion by sintering is depicted by distorted arrows.

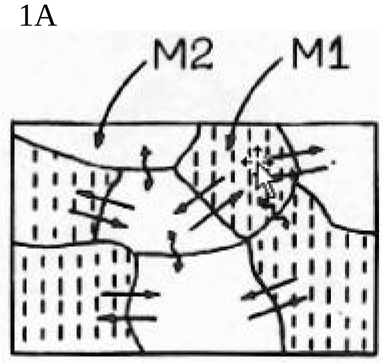
Figure 1B depicts the case for four dry powdered different raw materials, marked as M1 to M4. In the both cases Figures 1A and 1B, it is evident that diffusion process of all materials into one another is more difficult, giving insufficient quantity of atoms to secure fully reacted destination materials molecules.

Figure 2 depicts in more detail schematic formation of not fully reacted zones in the case of solid phase hot diffusion reaction process for the older powder metallurgy type boron carbide production processes. It is evident that interface between powder particles of boron or boron oxide, marked by M2, and carbon, marked M1, may easily get sufficient saturation to produce fully reacted boron carbide with formula B_4C, marked for more general case as $M1_n \cdot M2_m$ and there will remain zones with insufficient saturation, giving B_xC_y, for more general case depicted as $M2_xM1_y$ and B_yC_x, depicted for more general case as $M2_yM1_x$.

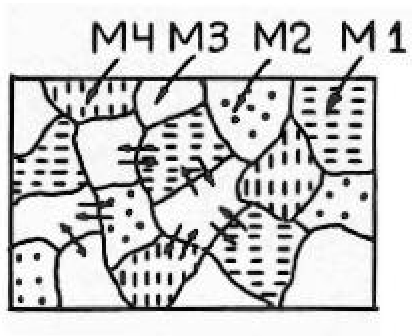
The result of the such incomplete hot diffusion reaction process is depicted in Fig. 3, wherein there are the core boron and carbon particles, marked as B and C, between which there are compounds of the types: B_yC_x and B_xC_y, and saturated zone of reaction, marked as B_4C.

The above phenomenon necessarily gives a fully reacted boron carbide surface layer B_4C on an interface of compressed macro particles within the said tablets, then partially reacted intermediate layer B_xC_y and may contain small non-reacted particle cores of Boron and Carbon, for every particle of raw materials, which are then processed into boron carbide aggregates with included impurities, originating of source materials' impurities and non-fully reacted zones. Those intermediate layers plus particle cores and impurities together weaken the resulting aggregate strength, hardness and wear resistance. *And these are the main disadvantages of the traditional technologies for production of traditional boron carbide in bulk.*

1A



1B



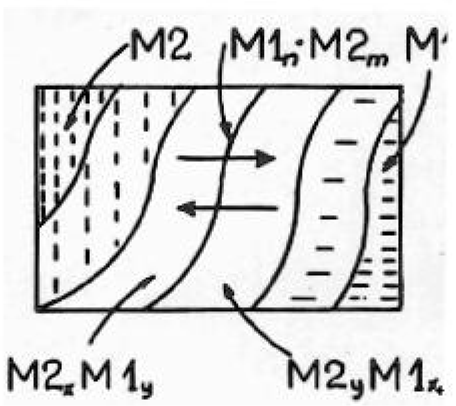


Fig. 1, 2. Thermal diffusion movement of materials M1, M2, M3 and M4 and formation of non-dtoichiometric compounds

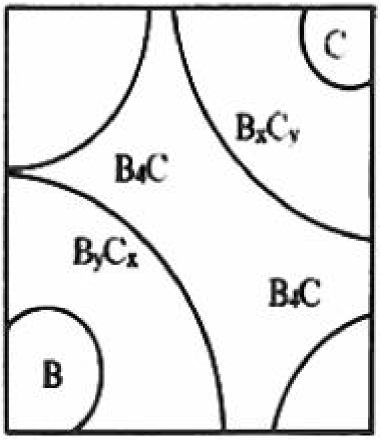


Fig. 3. Boron B and Carbon C particles interactions in the older powder metallurgy processes

The new advanced nano-based tecnological diamond-like boron carbide production process and accompanying phenomena

The offered new Nano-based solution type interdisciplinary chemical and physical Diamond-Like Boron Carbide technological production process has eliminated above disadvantages by securing an intermolecular level of mixing between soluble B-containing components and C-containing components, with the addition of activators / catalysts and synergists like organic acids in corresponding liquid medium.

New advantages and innovative features

In comparison with the old furnace – type boron carbide producing technologies, the present solution based innovative technology has immeasurable advantages: purity up to 99.9 % for boron carbide in bulk and up to 99.99 % for white high clarity mono crystalline B_4C, intended for substitution of the saw-grade and other diamond powders, intended for precision grinding, polishing powders and pastes.

The process generally comprises of three technological stages.

- ***The first*** technological stage is dissolution with mixing and filtration of the principally new soluble raw materials composition, taken from boron containing compounds like B_2O_3 or H_3BO_4, sugars and one or several organic acids. For dissolution we can use a vessel, which is preferably a heated chemical reactor, equipped with mixing, filtering and circulating devices, which operates preferably at the temperature from +25^0 Celsius up to + 100^0 Celsius and at the atmospheric pressure.

- ***The second*** stage is a special drying process of the above said true solution after which we receive a voluminous dry charge, whose components are already mixed on a intermolecular level without any insoluble impurities present. This advantage means that every molecule or atom, participating in the reaction, is placed in the closest proximity to every other participating reacting molecules, in spite of we get also condensed particles after drying.The said drying stage should preferably use an atomizing drying machine, which operates still more preferably, by way of example, at the temperature interval from +75 degrees Celsius up to +350 degrees Celsius. This advantage eliminates the low speed solid phase hot diffusion process, which was substituted with an innovative growth of mono crystals from said voluminous dry charge by means of thermal decomposition of B-containing, C-containing components and organic acids in the controlled atmosphere, that in its turn provides getting active ions and / or ionic groups, procuring multi crystals growth in the whole volume of dry voluminous charge. And this secures getting of pure crystalline boron carbide powder.

- ***The third*** stage is the synthesis stage, wherein during processing time period of 1 hour we can produce mono crystalline almost 99.99 % pure boron carbide of the uniform size and form, in the form of fully transparent white pyramidal crystals with fraction sizes about 5 to 15 µk, and during processing time up to 4 hours we can produce mono crystals up to 50-75 µk in one technological operation, without need to comminute and sieve them once more, please, find Figure 4.

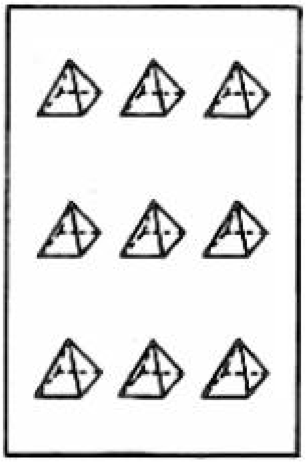


Fig. 4. The Produced Diamond-Like Boron Carbide Mono Crystals

The synthesis stage phenomena is thermal decomposition of the dry voluminous charge particles, formation of the activated / excited plasma-like ion cloud, formation of boron carbide molecules by attraction according to their level of affinity and another attraction type, securing formation of boron carbide molecules clusters and then growth of boron carbide molecules clusters into mono crystals with Natural lattice.

The said synthesis operation begins with thermal decomposition of source chemicals charge at 300 ^{0}C to 350 ^{0}C and is substantially performed within temperature

Table

Calculation of the possible reaction of raw materials components

Formula of compound	Carbon (12) content	Boron (10.82) content	Hydrogen (1) content	Oxygen (16) content	Weight of 1 g*mol, gram
1*$C_6H_{14}O_7$	6	–	14	7	1*198.00 = 198.00
12*H_3BO_3	–	12	36	36	12*61.82 = 741.84
2*($C_2H_4O_2$)	4	–	8	4	2*60.00 = 120.00
Total left	10	12	58	47	1,059.84
Formation					
- 3*B_4C	- 3	- 12			- 3*55.28 = -165.84
- 29*H_2O			- 58	- 29	- 29*18 = - 522.00
Subtotal 1 right	7	0	0	18	
- 7*CO_2	- 7			- 14	- 7*44 = - 308
Subtotal 2 right	0	0	0	4	
- 2*O_2				4	- 4*16 = - 64
Total right					- 1,059.84

range from about 1,200 ^{0}C and higher and still more preferably within temperature interval from 1,750 ^{0}C to 2,450 ^{0}C. The phenomenon of synthesis can be called a plasma-like activated / excited ion cloud crystalline boron carbide growth process.

Soluble impurities are removed during synthesis stage by sublimation, as affinity of activated boron atoms to activated carbon atoms and then of boron carbide molecules to one another is immeasurably higher than ability of soluble impurities, suspended in the overheated gas phase of CO_2 and H_2O, to be deposited on crystal growth surfaces.

In the Table 1 we show a preferable approach to calculation of the possible reaction balance according to gram mole concentrations of raw materials components, which helps to envision the preferable formation of new molecules according to their affinity and also exhaust gas composition

Conclusion

1. Product. The main revolutionary result is the creation of the new advanced absolutely pure transparent white pyramidal Diamond-Like Mono Crystalline Boron Carbide product, possessing the highest possible properties such as hardness, strength, wearability, equal to those of diamond. And such material will have many practical usages in the different fields of industry. For example, cutting formed tools, saws and disks, precision grinding, polishing powders and pastes, heat protective coatings, substrates for high T ^{0}C high power microchips in electronics, magnetron sputtering targets, jewelry, and other conventional applications

2. Process. There was developed a Nano-based solution-type interdisciplinary (chemical and physical) process for the production of the above new Diamond-Like Boron Carbide product. The process uses an innovative soluble raw materials composition, chosen of very cheap industrial quality materials. This technology is very simple and uses standard industrial equipment for this process.

3. Phenomena of the DLCBC product processing.

- ***The first phenomenon*** is dissolution with mixing and filtering out of insoluble impurities of the principally new soluble raw materials composition, taken from boron containing compounds like B_2O_3 or H_3BO_4, sugars and one or several organic acids, at temperatures preferably 25 ^{0}C to 100 ^{0}C, if medium is water or water plus alcohol.

- ***The second phenomenon*** is a special atomizing drying process of the above said true solution after which we receive a voluminous dry charge, whose components are already mixed on an intermolecular level without any insoluble impurities present. The preferable temperature interval is from +75 ^{0}C up to +350 ^{0}C.

- ***The third phenomena*** is the integrated thermal decomposition of dry source chemicals charge at 300 ^{0}C to 350 ^{0}C, and synthesis which goes through 1,200 ^{0}C up to 1,750 ^{0}C to 2,450 ^{0}C. This phenomenon can be called a plasma-like activated / excited ion cloud crystalline boron carbide growth process.

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