SELECTION OF MINERAL-BASED MATERIALS

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Abstract. Natural non-metallic materials of inorganic nature were the first materials used by humans for making implements and it was actually the first stone axe that opened the technology era hundreds thousands years ago. The properties of mineral-based non-metallic materials are various. They include the hardest materials applied for metal processing by cutting (diamond, corundum, boron nitride, etc.) and relatively soft solid lubricating substances (graphite, molykote).

Keywords: Boron carbide; silicon carbide; ceramics-metals; synthetic electrocorundums; glass-fibre materials; synthetic diamonds; composition materials.

Machine building widely applies natural minerals (asbestos, graphite, mica, etc.), products of their processing (ceramics, glass, stone casting, abrasive products, etc.) and synthetic minerals created in the image of natural (diamonds, sapphires, rubies, mica, etc.).

Regulation of phase and structural composition of glass, glass-ceramic substances (pyroceramics) and different types of ceramics is used to attain a necessary level of service properties of a great number of materials applied in different areas of technology. Inorganic non-metallic materials are the most important components of composition materials that strengthen them, make them heat resistant and give them other properties required in atomic power engineering, aviation and astronautics.

Diamond is a crystalline modification of carbon with a face-centered cubic lattice in which each carbon atom is bound by strong covalent bonds to the three neighbours located in the vertex of a tetrahedron (dashed lines in Figure 1).

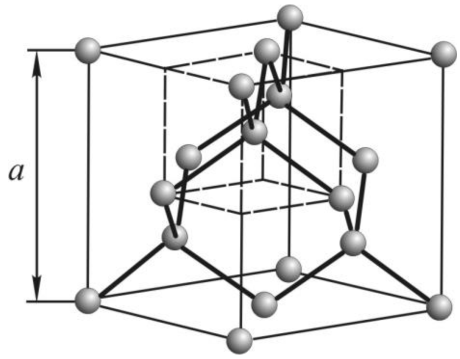

Figure 1. Schematic representation of diamond crystalline lattice: *a* is the parameter of lattice

The strong bonds and small distances between the atoms (0.154 nm) stipulate hardness of diamond maximum for minerals (10 units on the Mohs scale) and its high chemical stability. On heating up to 1800ºC in the absence of oxygen diamond is converted into graphite, and in the presence of oxygen diamond burns at 870ºC. Diamond has very high heat conductivity (5 times as high as copper heat conductivity), but it is a dielectric. In nature, diamonds occur as individual monocrystals whose size is measured in carats (one carat is equal to 200 mg) and artificial (synthetic) diamonds are mainly produced from graphite at temperatures of 1300-1600ºC and pressure of 4.5-8.0 HPa.

Synthetic diamonds as dense polycrystalline formations (similar to the types of diamond called ballas and carbonado) are used in manufacture of portages, cutting tools and smoothers while synthetic diamonds as powders are applied for production of abrasive tools and abrasive pastes.

Baking of mixtures of synthetic and natural diamond micropowders serves for production of dense polycrystalline materials with a fine-grain structure, SV and sintered diamond powder. Their strength in uniaxial contraction reaches 5000 MPa. Diamond materials of SB type are designated for crown bits and drilling instruments as well as saws used in cutting of hard non-metallic materials. Sintered diamond powder is used in manufacturing of chisels as well as cutting instruments (chisels, drilling tools, etc.) used in processing of nonferrous metals and alloys and plastics, including glass-fibre materials.

Boron nitride (BN) of crystalline cubic modification is produced only by synthesis from ordinary graphite-like BN. It is inferior to diamond in hardness but significantly surpasses it in heat stability. Moreover, boron nitride is chemically less active in respect to iron-and cobalt-based materials. In the United States, cubic boron nitride is produced under the name of borazon, and in the CIS countries it bears the names of el'bor and kubonit borazon materials. They are used for metal-cutting instrument used for processing of chilled steels, iron and alloys with the hardness CHR > 40. The stability of such an instrument is 10- to 20-fold higher than the stability of a hardmetal one. This property contributes to 2- to 4-fold increases in productivity of processing.

The covalent carbides, boron and silicon carbides belong to very hard and chemical-resistant materials.

Boron carbide is a chemical compound of boron with carbon (B_4C), a dense substance with conchoidal fracture of a greyish-black color. It is only inferior to diamond and cubic boron nitride in hardness and abrasive effect (Table 1).

Silicon carbide or carborundum is a compound of silicon with carbon (SiC). It has two crystalline modifications – with a hexagonal lattice (α-SiC) and a cubic structure of a diamond type (β-SiC). Silicon carbide is distinguished by high hardness, heat conductivity, refractoriness, it is stable in various chemical media and also at high temperatures. It is used as abrasive (in grinding) for cutting of hard metals, for production of high temperature heaters, durable face seals as well as parts subjected to intensive corrosion and abrasive effects.

Properties and areas of application of metal carbides are exceptionally various. They are most high-melting of all the known substances, hard, durable and heat resistant. For example, the melting point of niobium carbide is equal to 3983ºC and the microhardness is 25000 MPa. The unique properties of these carbides are due to them representing interstitial phases when carbon atoms occupy cavities of densely packed metallic sublattices. Carbides are widely used as the main component of hard alloys, surfacing materials, coatings and as a strengthening phase of alloy steel.

Ceramics-metals (kermets) containing tungsten, titanium, tantalum, niobium carbides are the best instrumental materials for cutting metals and boring of rocks. Kermets are used to manufacture vanes for gas turbines and parts of jet engines.

Borides and nitrides of a wide range of metals are widely used in engineering, for example, molybdenum and tungsten borides are components of hard alloys; chrome and zirconium borides are heat resistant materials; titanium, chrome and tungsten borides are components of durable coating materials. Corrosion-proof and wear-resistant coatings are applied on goods made of creep-resisting steel.

Mineral silicate-based materials. Silicate materials of the natural origin are mainly used as components of building materials, ceramics and glass. Some of them find application in various products of machine engineering.

This material has a complex of unique natural properties (high mechanical strength, thermal stability, low heat and electric conductivities, high friction coefficient, elasticity, resistance to alkali, good adhesion to synthetic polymers, etc.).

The most important industrial type of asbestos is *chrysotile* (the chemical formula is $3MgO \cdot 2\ SiO_2 \cdot 2H_2O$, the main properties are listed in Table 1) which serves for manufacture of asbestos cement, asbestos concrete, asbestos bitumen and textile goods as well as for production of asbestos cardboard, paper, felt, filters, heat insulating materials, brake bands, heat-resistant fillings and gaskets. etc.

Table 1. Main properties of chrysotile asbestos

Parameters	Values
Density, 10^3 kg/m^3	2,4-2,6
Hardness on the Mohs scale	2-3
Bursting stress in stretching along fibres, HPa	2,4-3,17
Elasticity modulus at a 0.01- mm^2 fibre cross-sectional area, HPa	175-210
Friction coefficient (according to steel without lubrication)	0,8
Relative elongation, %	1-2
Melting point, ^{0}C	1550
Heat resistance, ^{0}C - on long-term heating - on short-term heating	 500 700
Heat conductivity, Wt/ (m·K)	0,147-0,151
Electric insulativity, Om·m	10^6-10^{10}

Over the last 80-90 years asbestos has been widely used as the main filling of friction materials for brake mechanisms. However, as early as the late 1970s industrially developed countries started antiasbestos campaigns. It was found that fibrous asbestos microparticles released into the environment on abrasion of the material are biologically active substances with a pronounced carcinogenic effect.

Nevertheless the necessity of development of asbestos-free friction materials created a problem in export of domestic automobiles and tractors. Research carried out in different countries (including Belarus) showed prospects in substitution of asbestos in manufacturing friction materials by such fibres as basalt, aramid fibre, carbon and glass fibres.

Quartz is the crystalline form of silicon dioxide , one of the most distributed (up to 12% of the Earth crust) wear resistant and stable materials. Its compression strength reaches 2000 MPa and its tensile strength -100 MPa, the melting point is

1470ºC , the density – 2650 kg/m^3, the hardness on the Mohs scale – 7 units. Quartz is chemically stable, optically anisotropic and possesses piezoelectrical properties. It occurs in nature mainly in a colorless state as well as in the form of colored crystals.

The varieties of quartz are amethyst, smoky quartz / topaz, mountain crystal etc. Single crystals of quartz are used in electrical engineering and radio engineering as piezoelectric transducers, filters, generators, whereas quartz powders are applied as components of abrasive materials and composites. Quartz sands and pure, the so-called veined quartz, are widely used in production of glass (including thermostable one, with special properties), porcelain and silicate bricks.

Mica is of crucial importance of all natural mineral electric insulating materials. Owing to high electrical strength, thermal stability and moisture-resistance, mechanical strength and flexibility mica is applied as insulation in condensers and electric machines operating at high voltages. Mica occurs in nature as crystals which represent aluminium silicates and are capable of splitting into thin, flexible and strong plates.

We should also note one more wonderful material, corundum, natural anhydrous alumina Al_2O_3. Pure aluminium oxide is crystallized in a hexagonal lattice, and it is inferior only to diamond (9 units on the Mohs scale) in hardness and has a melting point of 2050ºC and the Young modulus of the order of 350 HPa. The most clear transparent corundums are precious stones, such as red ruby and blue sapphire. The main raw materials for production of pure aluminium oxide are bauxites containing from 50 to 100 % Al_2O_3.

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The geological material used for production of technical goods includes basalt, gabbro and diabase. Their density is 2900...3300 kg/m^3, the ultimate compressive strength is up to 500 MPa. They are used to manufacture measuring plates, sliding bearings, and components of some frictionless bearings. A promising and developing direction in application of these materials is manufacture of cast products (stone casting) and fibres.

The latter are successfully applied as strengthening wear-resistant components of composition materials. Presently stone casting is also used for processing of slags of metallurgic industry.

Stone casted products have ultimate compressive strength of 240 MPa, their ultimate tensile strength is 30 MPa and they also possess high wear-resistance.

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