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# A novel composite diamond-containing dispersed material of natural and synthetic diamonds powders and abrasive tools made of it

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ABSTRACT

A two-stage process of producing a novel composite material based on fine-dispersed powders of natural diamonds and mesh grinding powders of synthetic diamonds. At the first stage of producing the components mixture is compacted and at the second stage it is sintered in a gas-thermal reactor of the physicochemical synthesis plant at a temperature of 1100–1200 °C and below ambient pressure in the methane atmosphere. The values of the morphometric characteristics and the uniformity of abrasive powders in these characteristics produced from the new diamond-containing material, their physico-mechanical and electrophysical properties were studied. The results of the use of these composite powders in grinding wheels for machining a hard alloy are discussed. A substitution of powders of the new composite material for synthetic diamond mesh powders in the cutting layer of a standard grinding wheel makes it possible to essentially (more than by a factor of 3) increase the wear resistance of the tool.



## 1. Introduction

The complex processing of natural diamonds involves their preliminary sorting into gem and industrial diamonds. Gem diamonds undergo a cleavage, cutting, and roughing. Industrial diamonds undergo a dispersion and classification in order to select the conditional diamond powders of various grit sizes [1]. After that there forms a residue, whose further processing is of little (mainly economical) reasons. Usually the depth of the extracting of the conditional powder is limited by fine grit sizes of micron and submicron powders, which thus pass into the waste products. However, such a status of them is to a large degree conditional. In fact these diamonds are suitable for further applications. But on the strength of the above reasons they remain unmarketable for a certain time and have a tendency to accumulate [1,2]. Taking into account the predicted increase of the gem diamond production (almost double) in 2016, the amount of unmarketable diamond will also increase [3]. According to the [1–4] papers, the amount of such diamonds is sufficient for their industrial processing and the solution of this problem will allow us to make a closed cycle of the utilization of Yakut natural diamonds, that includes mining, production of gems, industrial diamond powders, and tools of them.

An important problem of the modern material science of superhard materials (SHM) is the development of new high-tech resource-saving, highly productive technologies, which make possible the production of novel materials with specified properties that meet increasing requirements of the industry [5]. At present polycrystalline and composite diamond-containing SHM are produced both at high static pressures (5.0–12 GPa) and temperatures (1400–3000 K) [6–8], and at low pressures and temperatures with binders (metals, ceramics, glass, polymers) [9,10].

The advantage of the first methods is the production of materials with sufficiently high density (3.1–3.5 g/sm$^3$), strength, isotropy, and operational properties [6–8]. However, the disadvantages of materials produced at high $p$, $T$ parameters of synthesis is the fact that it is impossible to use they as an abrasive material and a high cost of composite SHM due to the use of the energy- and resource-demanding equipment and expensive tooling.

The advantage of the second methods is the possibility to produce composite materials at low pressures and temperatures, which allows the formation of compacts, which after crushing may be used as abrasive powders [9,10]. That's why the production of such new composite materials based on SHM, in particular, of those structured by a carbon binder is of interest.

From the theoretical point of view the use of polycrystalline and composite grains consisting of small SHM particles bound in a single strong material is justified [10], since at the surface of such a grain there are several cutting edges formed by separate small particles. During the tool operation a gradual microdestruction of the grain surface, removal of separate particles, and the initial relief of the surface

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structure take place. Besides, in producing the composites smaller grits, the demand for which is low, may be used, and the end product is composed of more valuable large grains and powders.

A new method of producing materials having properties of polycrystals and composites is the application of a structured carbon binder to produce superhard composite materials based on diamond at low pressures of carbon-containing gases. As compared with materials produced at static synthesis the materials synthesized at low *p*, *T* parameters have such a grain size that makes it possible the subsequent producing of coarse-grained powders of them with improved properties (e.g., thermostability) [10].

The authors' experience in this field gives ground to suggest a possible variant of the solution of the problem of involving unclaimed natural diamond powders (UNDP) into the sphere of the profitable practical applications. The suggested approach includes a development of superhard composite materials using synthetic grinding powders and fine-dispersed natural diamond powders at low pressures. Just in this and in producing abrasive powders from obtained composite material, in the investigation of characteristics of the produced powders, testing of experimental tools manufactured from the above powders was the aim of this paper.

## 2. Materials and methods

A technological solution of the above problem, which we propose, involves three stages. The first stage includes the compacting of UNDPs, then compacts are sintered in a gas-thermal reactor of the physicochemical synthesis plant; at the third stage from the produced composite material the mesh products of all grit sizes from 630/500 to 50/40 and −40 μm are manufactured by dispersion, classification, and sorting [10].

The solution of this complex problem included the determination of the physical properties, elemental composition of impurities, and technological properties of the UNDPs themselves as an abrasive material. Studied were also their geometrical characteristics, forms of the grain projections (i.e., morphometric characteristics). The procedures of experimental studies of the initial UNDPs and results obtained are in detail described elsewhere [10]. Fig. 1 shows a SEM photo of the UNDP sample taken from paper [10]. It is distinctly seen in the photo both grains to 2–3 μm of size and finer grains (0.1 μm and below); in the percentage the smaller grains prevail. Based on these investigations, the authors state that the submicron UNDPs under study are suitable for manufacturing compacts and subsequent physicochemical synthesis of them at the below ambient pressure.

### 2.1. Preparation of samples of UNDPs composite materials

The composite material based on UNDP was prepared by compaction with a subsequent sintering in a gas-thermal reactor of the plant for physicochemical synthesis at a temperature of 1100–1200 °C and pressure below ambient in the atmosphere of a methane. The procedures of the preparation of powder compositions for compacting and physicochemical synthesis are described in detail in [10]. On the strength of the experimental data we established the optimal technological conditions of the UNDP compaction by pressing. Studied were several surface-active substances, optimal of which turned out to be the solution of a BF adhesive in the ethyl alcohol and a solution of the gelatin in distilled water.

We obtained compacts as cylinders 12–15 mm in diameter and 15 mm in height (see Fig. 2).

### 2.2. Preparation of powders from composite compacts

Powders from the composite material based on UNDP and the AC6 160/125 according to [11] standard grinding powder (reference designation is КЯ 160/125) were prepared using the corresponding crushing and classification equipments and vibrators operating at optimal modes. Morphometrical characteristics of the powder made from such a composite material structured by nanocarbon (Fig. 3), were diagnosed on a DiaInspect OSM device [12]. In the present study we defined: the grain projection area ($A_t$, μm$^2$), maximum ($F_{max}$, μm) and minimum ($F_{min}$, μm), Feret diameters, equivalent grain diameter ($d_e$, μm), shape factor of an actual image of the grain projection ($f_r$), ellipticity ($El$), Feret elongation ($F_e$), roughness ($Rg$) of the grain projections. In addition we defined such characteristics as specific perimeter of the projection ($P_{sp}$) and coefficient of flattening ($f_{fl}$). The interpretation of the geometric essence of the above morphometric characteristics and their more detail description are given in [13,14]. The uniformity in morphometric characteristics, which is important quantity sign of the powder quality was defined by the system-criterial method [15]. The analyses of the shape of grain projection were made using the indentation method described in [16]. This characteristic as well as the other characteristics of the powder grains (the surface development, specific perimeter, outer specific surface, symmetry of shapes, projection roughness) belongs to the complex of factors that exert an essential effect on the strength of grains retention in a bond of the tool cutting layer and, hence, on the tool life.

The technological properties like the outer specific surface ($F_{sp}$), number of grains in one carat of the powder ($N$), number (n) and average value of cutting edge angles (φ) were defined from the data of the DiaInspect device using the original computer-analytical procedures

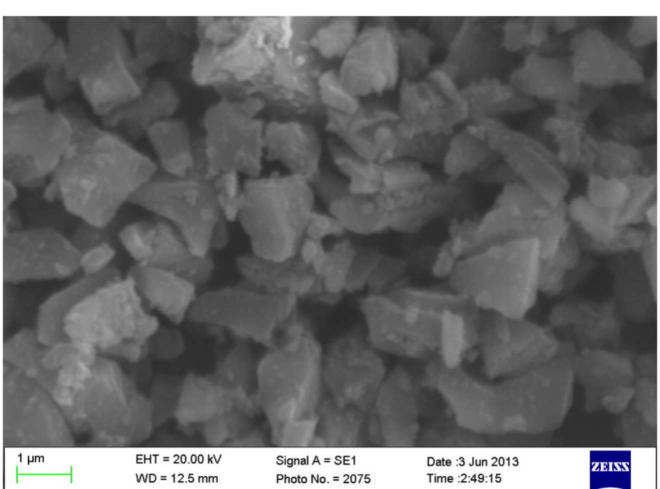


**Fig. 1.** SEM photo of UNDP at a magnification of 25,000 [2].

**Fig. 2.** Appearance of UNDP compacts.