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The influence of tungsten carbide contamination from the milling process on PCD materials oxidation

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ABSTRACT

The most popular polycrystalline diamond (PCD) is a compact with cobalt bonding phase. The thermal resistance of this material is rather low, up to 700 °C. The best way to obtain a higher thermal resistance for diamond compacts (PCD materials) is to limit cobalt content or to sinter the diamond either without a bonding phase or with a ceramic bonding phase. The second group of commercial PCDs, used mainly in rock drilling, are materials with the Si bonding phase. Because of their residual porosity, these materials are not used for metalworking applications, where low roughness value is required. The main focus of the studies presented was the influence of methods of mixture preparation on the microstructures and selected properties of diamond compacts. The traditional method of preparing diamond powders with a bonding phase is to use WC-Co millers. This method causes tungsten carbide contamination of the material, which in these materials decreases their resistance to oxidation during machining. The second aim of these researches was lowering the level of residual porosity. The presence of nanoparticles between diamond microsize particles limits the residual porosity of diamond compacts and improves the roughness properties of cutting tools, but the addition of nanopowders requires intensive milling for good distribution of the ingredients, which increases the WC-Co contamination. In these studies, mixtures containing 90 wt.% diamond with 10 wt.% nanometric TiB_2 powders were prepared with the use of the milling method and the ultrasonic method. The resulting mixtures were formed into discs (15 mm in diameter) by pressing in a steel matrix under the pressure of 100 MPa. The samples were heated using an assembly equipped with an internal graphite heater. The compacts were sintered at the pressure of 8.0 ± 0.2 GPa and the temperature of about 2000 °C in a Bridgman-type ultra high pressure apparatus. The density of the materials was measured. Hardness measurements were carried out with a Vickers apparatus at 9.8 N load. Young's modulus was measured using the ultrasonic method. Phase composition of the diamond compacts was identified by X-ray diffraction analysis. The method of the mixtures preparation has a strong influence on the microstructure and the properties of diamond compacts. The preparation of mixtures in a PULVERISETTE 6 Planetary mill with WC grinding balls results in tungsten contamination, and thus in the presence of WC, WB and $W_2C_{0,84}$ in the compacts. The ultrasonic method of mixing allows to receive diamond materials with nanometric bonding phases without tungsten contamination.

1. Introduction

The most popular PCD sintering technology is based on the infiltration of cobalt into diamond grain surfaces with the solution of carbon in cobalt and reverse crystallization of carbon into diamond. The PCD layer is sintered at the same time with WC-Co substrate [1]. In commercial materials, the diamond layer is composed of diamond, cobalt and WC contamination of about 2 wt.%. Cobalt decreases the graphitization temperature of the diamond. One of the possibilities to increase the thermal resistance of PCD materials is to reduce the cobalt bonding phase content. Polycrystalline diamonds with the cobalt bonding phase are chemically stable up to 700 °C because of the graphitization process. During the machining processes, for this group of materials the temperature in the cutting zone may rise even higher. For WC, the thickness of the oxide layer increases significantly at 400 °C and over [2,3]. For the commercial PCD material (90 wt.% diamond, 8 wt.% Co, 2 wt.% WC), oxide phases such as: Co_3O_4, $CoWO_3$, WO_3, CoC_2O_4 appeared after heating the material up to 800 °C in air (Fig.1) [4]. These phases are forming due to the presence of WC-Co in the PCD material. In such a situation, the development of new bonding phases in diamond composites is needed. The material with higher resistance to oxidation

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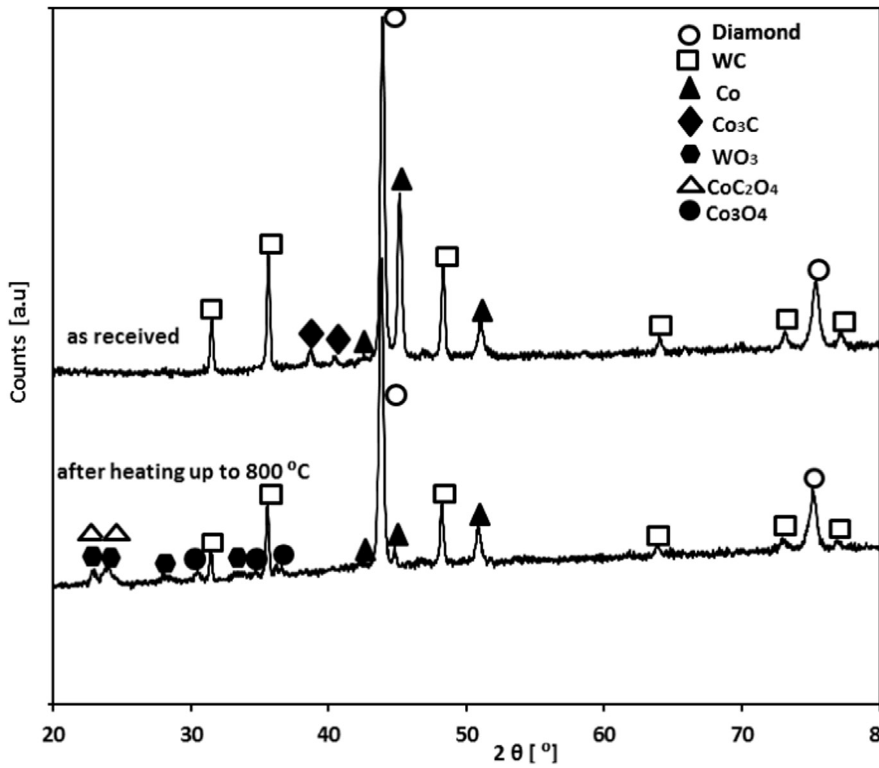

Fig. 1. Diffraction pattern of commercial PCD with Co bonding phase, as received and after heating up to 800 °C.

would be the most beneficial for the diamond composite. It was proven that diamond compacts with TiB_2 participation have a higher thermal resistance than diamond with Co and WC participation [5].

The thermal resistance of diamond composite depends on the oxidation process more than on the graphitization process [6,7]. In earlier research [4,5], a new type of composites consisting of micron-size diamonds with titanium borides was investigated. Titanium diboride proves to be an attractive candidate for a diamond bonding material due to their desirable mechanical, thermal and electrical properties combined with a high level of flexural strength and fracture toughness [8,9]. During the production of PCD materials by infiltration with Co or Si (to form a ceramic SiC matrix [10]), there are no problems associated with mixing/milling processes, but when a hard ceramic phase is directly sintered with diamond, an extensive homogenization process is required [11,12]. This mixing/milling process is mostly carried out with the use of tungsten carbide millers which, as described above, contaminate the prepared mixture with the material that the millers and the vessel are made out of. It is known that ultrasonication can be used to successfully disperse nanopowder agglomerates to help obtain well homogenized powder mixtures [13,14]. This method can also be applied to obtain mixtures of ceramic powders with hard-to-mix carbon nanotubes [15]. This paper presents the results of using ultrasonic method

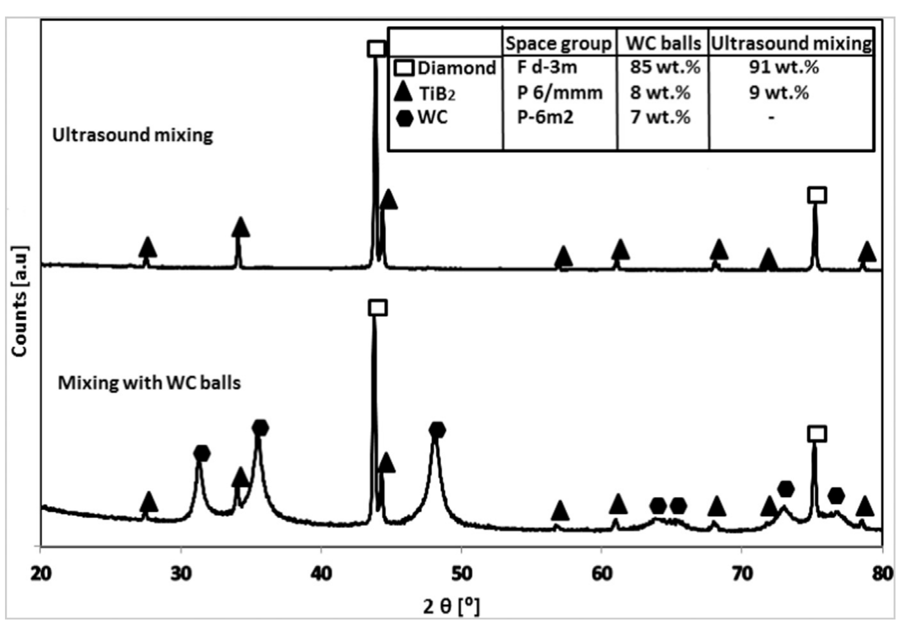

Fig. 2. Diffraction pattern of mixtures with 10 wt.% TiB_2 prepared by milling and by ultrasonic mixing.