Name of the scientific solution / development/ methodology, tool, prototype

Intensive electro sintering (IES) of diamond-containing composite materials (DCM) and tools

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Problem Description

Production of the tool-oriented DCMs is conventionally based of the methods of powder metallurgy. The study of materials obtained this way indicates that the traditional technologies of pressureless sintering or hot pressing assuming long exposure time at high temperature inevitably cause significant damage (graphitization, cracking, etc.) to the diamond grains. First, this leads to the strength reduction and fracture of diamond grains. Second, the surface graphitization of diamond prevents strong mechanical bond with the matrix material. In turn, the lack of reliable adhesive bonding results in premature loss of diamond grains and thus reduces the performance of the DCM-based tools.

The way of the problem solving

Intensive electro sintering (IES) that belongs to a new generation of so-called FAST-technologies appears a promising alternative manufacturing technology of DCM. Institute of Superhard Materials of NAS of Ukraine conducts research on developing the method of intensive electro sintering at high pressure. IES offers an opportunity of obtaining the high quality DCM with metal binder because its *pT*-parameters shifted toward higher pressures and lower temperatures, which significantly reduces the time and energy of sintering. In doing so, a number of factors contribute to preserving integrity of diamonds. Specifically, no graphitization and degradation of mechanical properties of diamond happens during IES, and the presence of significant pressure prevents cracking due to internal defects of diamond grains on the heating stage. However, the only possible way to ensure quality of DCM consists in using the evidence-based selection of IES parameters that provide the optimal structure formation.

The idea is to develop a *single* technological cycle of manufacturing the DCM-based tools without applying (at any step!) the thermobaric parameters that could affect quality of diamonds in the DCM. The uncontested basic technology of this cycle is intensive electro sintering whose parameters (temperature of 800-850 ^{o} C, pressure of 100-300 MPa, time 10-40 seconds) is the most favorable in terms of maintaining the integrity of diamonds.

Basic publications:

1. *Maystrenko A.L., Ivanov S.A., Pereyaslov V.P., Voloshin M.N. Intensive electro sintering of diamond composites // Journal of Superhard Materials. -2000. - № 5. - S. 39-45*

2. *Kushch V.I., Ivanov S.A., Maystrenko A.L., Pereyaslov V.P. Investigation of the mechanism and kinetics of densification of the porous solid due to intensive electro sintering. Part 1. Laboratory studies // Journal of Superhard Materials. - 2007 - № 2. - P. 18-25.*

3. *Kushch V.I., Ivanov S.A., Maystrenko A.L., Pereyaslov V.P. Investigation of the mechanism and kinetics of densification of the porous solid due to intensive electro sintering. Part 2. The theoretical model and its validation // Journal of Superhard Materials. - 2007 - № 4. - P. 21-29*

4. *Kushch V.I., Ivanov S.A., Maystrenko A.L., Pereyaslov V.P. Investigation of the mechanism and kinetics of densification of the porous solid due to intensive electro sintering. Part 3. Prediction of shrinkage kinetics and comparison with experiment // Journal of Superhard Materials. - 2007 - № 5. - S. 49-56.*

5. *Novikov N.V., Maystrenko A.L., Kushch V.I., Ivanov S.A. Non-destructive technique of the metal matrix-diamond composite quality monitoring // Proceedings of 2-nd International Industrial Diamond Conference Rome, Italy, 2007.*

6. *Kushch V.I. Yield limit of particulate reinforced composite with porous matrix // Scripta Materialia.- 2007.- 57.- 723–726.*

7. *Kushch V.I., Podoba Ya.O., Shtern M.B. Effect of micro-structure on yield strength of porous solid: A comparative study of two simple cell models // Computational Materials Science 2008. -v.42.- P.113–121.*

Innovative Aspects of the solution / development/ methodology, tool, prototype

A comprehensive approach will be used to improving the quality of all DCM components, namely, diamonds, bonding matrix and interfaces. In particular,

1) The multi-component system with the addition of alloying elements will be used as the bonding matrix. The additives produce a certain portion of liquid phase (that is fundamentally new in practice of IES) and thus a significant intensification of the consolidation process. It allows to get practically dense (poreless) materials with high tensile strength and fracture toughness. Also, the presence of several components allows to vary widely the physical and mechanical properties and wear resistance of the matrix material and thus produce the tool optimized for a certain specific application.

2) The appropriate values of IES parameters will be chosen to ensure integrity of the diamond grains. Improving the retention of diamond grains in matrix and their working conditions is achieved by a hard graded layer formation around them.

3) Ensuring reliable diamond-matrix bonding is essential both in terms of mechanical retention and thermal regime of the diamond grain, since the presence of thermal barrier at the diamond-matrix interface significantly increases the temperature of the working area and hence wear intensity of the DCM-based tools. To form adhesive interface bonding, the layered granulation of diamond with activating components will be used. The optimum sintering parameters will be selected ensuring wetting of diamond, dissolution of surface defects, formation of a thin carbide layer and lack of free graphite.

Main advantages of the solution / development/ methodology, tool, prototype

Implementation of the above steps is expected to significantly improve DCM quality and performance and thus provide a first step in developing a new generation of diamond tools. Other advantages of the proposed technology involve (a) short (tens of seconds instead of hours) process time, (b) low energy consumption and (c) low environmental contamination, which allows us to position IES as a modern *green* technology.

Financial and Economic Parameters

Investment Offer *(is not obligatory)*

Current stage of development of the offered solution / development/ methodology, tool, prototype *(please, select)*

The methodology has been developed and the prototype of setup for electro sintering of the drilling crowns is available.

Intellectual Property Rights *(please, select)*

1. Patent 20674 A Ukraine, MPK B22F 3/14. Technological hub for electro sintering of diamond-containing products / V.P.Pereyaslov, A.L.Maystrenko, S.A.Ivanov. - Appl. 14.03.97, Publ. 15.10.01. Bull. № 9.

2. Patent 57471 A Ukraine, MPK B22F 3/14, V01J3/06. Technological hub for electro sintering / V.P.Pereyaslov, S.A.Ivanov, A.L.Maystrenko, R.I.Sorobey. - Appl 10/24/02, Publ. 16.06.03. Bull. № 6.

Collaboration Details

1. Technical co-operation. Type of collaboration sought; *more than one option can be selected)*

Technology Key Words

Intensive electrosintering, diamond-containing composite material (DCM), DCM-based tool