ГОДИШНИК НА МИННО-ГЕОЛОЖКИЯ УНИВЕРСИТЕТ "СВ. ИВАН РИЛСКИ", Том 52, Св. I, Геология и геофизика, 2009
ANNUAL OF THE UNIVERSITY OF MINING AND GEOLOGY "ST. IVAN RILSKI", Vol. 52, Part I, Geology and Geophysics, 2009

THERMOCHEMICAL PROCESSING OF DIAMONDS

A. A. Altuhov[1], E. V. Gladchenkov[2]

[1]UralAlmazinvest inc., Ivan Franko Str. 4, 121108 Moscow, Russian Federation; uai-co@yandex.ru
[2]Moscow State Mines University, Lenin Avenue 6, Moscow 119991, Russian Federation; evgenozz@rambler.ru

ABSTRACT. Diamonds material is unique by characteristics. It has the record of high mechanical, heat physical, optical and electronic characteristics; it possesses high chemical stability. Diamond is gaining the first place among minerals according to hardness in the world. Mines get per annum hardly more than ten tons. Of that, only 25% can be used in jewelry. But the rest are used in industry due to it's extremely high hardness. Diamonds are historically used as a cutting instrument. In recent times numerous quite new diamond instruments are used to make sensors and other précised instruments. Also it traditionally is used for details on electronic chips, processors and other devices. Its unique physical parameters provide efficient and stable capacity to work in micro-mechanic and electronic devices on base of critical conditions for working processes and external influencing factor. All that requires much improvement of existing and new and developing methods for processing diamonds. Constantly it enlarges the existing area for practical application. The study reviews the thermochemical production of diamonds.

ТЕРМОХИМИЧНО ПРОИЗВОДСТВО НА ДИАМАНТИ

А. А. Алтухов[1], Е. В. Гладченков[2]
[1]Уралалмазинвест, ул. Иван Франко 4, 121108 Москва, Руска Федерация; uai-co@yandex.ru
[2]Московски държавен минен университет, пр. Ленин 6, 119991 Москва, Руска Федерация; evgenozz@rambler.ru

РЕЗЮМЕ. Диамантът е уникален по своите характеристики като материал. Той се отличава с високи механични, топлинни физични, оптични и електронни характеристики; той притежава висока химическа устойчивост. Диамънтът е на първо място в света сред другите минерали по своята твърдост. Минитего добиват едва до няколко десетки тона годишно. От тях, около 25% може да се използва ювелирни цели. Но останалите се използват за индустриални цели поради изключително високата си твърдост. Исторически, диамантитите са използвани като режещ инструмент. Напоследък много съвсем нови диамантени инструменти се използват за направа на сензори и други прецизни инструменти. Също така традиционно се използва в детайли за еликтронничшпове, процесори и други уреди. Неговите уникални физични параметри осигуряват ефикасна и стабилна работа в микро-механични и електронни уреди на основата на критичните условия на работния процес и външните влияния. Всичко това изисква доста подробрение на съществуващите и нови методи за производство на диамант. Постоянно се разширява полето на неговата практическа приложимост. Разработката изследва термохимичното производство на диаманти.

Practical application of diamonds constantly enlarges and penetrates into human life. Mostly, science and technology absorb all newly developed processing technologies. An active part of that area are technologies for microelectronics. Remarkably broad science practice shows that diamonds (and new chemical materials on base on the diamonds structures) including elements detectors for optical and radiation sensors, such as elements detectors for micro-electro-mechanical systems (MEMS), are also successful for the development in the field of semiconductor integral microcircuits (IMS) improvement research and very good for discrete elements based on diamond plates. SVCH semiconductor, for an example (as a highly precious instrument for new electronic components) meets conditions for the most part of contemporary devices and other products for microelectronics, as well. There is no doubt that these materials cause the keenest interest all over the world for developments in the field of creation of micro-size supercomputers, based on diamonds multi chip modules technology. Now, in Russia and overseas, many producers put on the sale coolers for powerful semiconductor instruments. Many types of research are released for putting on the sale precious diamond blades for microsurgery, as well as micro-instruments based on mono-crystalline diamond material.

At present, shaping high precious planar surfaces, including nano-size has many types of approach for undertaking the following technological operation: for example, lithography method, fixing hybrid and pellicle element for an integral microcircuits, etc. High quality surface layer semiconductor substrate influences upon structured perfection of the inflicted layer. Work capacity of the integral microcircuits IMS usually is of a very high importance. Dislocations and defects on a surface layer form from substrate and inherit its negative character, worsening the electro-physical features of the microcircuits. In this condition, undersurface material processing stands on the first plan and corrects inadmissibility the origin scratches, rifts, and microdefects in the main mass of the material. A removal of the surface layer material with shaping by reception nano-size is required, which makes changes to surfaces with minimum amount of defects. This method appears to be progressing.

Realization of that scientific idea in concrete types of instruments is mainly defined on the technological possibilities. Thus, development of the technological problem is a priority problem to science and technology in the constructing instruments spheres. General technological solution for receiving new types of product from preprocessing as the described new type of material demands exact and specific technological approaches to such new material (Grigoriev et al., 1981; 1983; *Natural Diamonds…,* 1997; Pleskov, 2003; Mityagin et al.).

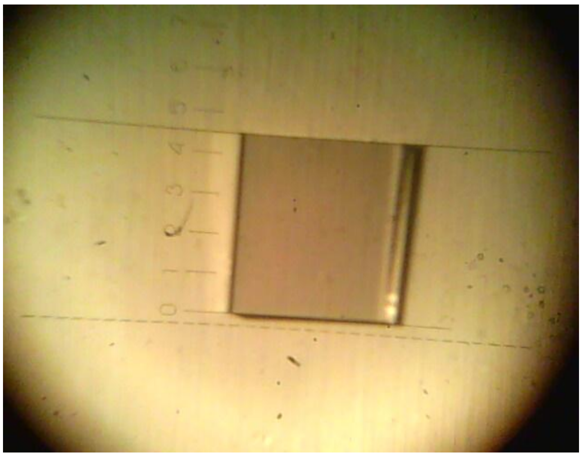

Fig. 1. Diamond substrate

Hardness of the surface is an important factor in technical approach as a feature of the product. It influences upon all processing characteristics, including machine's parameters: so as details, elements and nodes-wear capabilities for surfaces treatment and, also, toughness, stability etc.

Shaping surfaces of nano-size dimensions meets demands and raises interest for new methods in microelectronics. In most cases, it provides minimum importance of surfaces hardness (Ra) at a rate of not more than 10 nm, on all the 14 classes, based with lehght 0.08 mm (*GOST*; Russian Standards Register Number GOST2.309-73 – indications to hardness surfaces). To undertake the following, we need to optimize the technological operations (fixing element hybrid and nano-film surface integral microcircuits, etc.) and numerate its importance for operations. The quality of a surface layer substrate strongly influences upon its future capacity for work in an integral microcircuit.

The traditional way of processing hard frail mineral (including crystal) is by precise mechanical polishing abrasive, free and compounded with combined abrasive. Abrasive processing is a roughly mechanical way for polishing to remove the extra mass of diamonds. It usually occurs to be too rough for mechanical sharpness, especially with blowing particle of non-sized abrasive under quick rotation of the diamond disk on tool. As a result, the springy voltage problem arising occurs, scratching the processed material.

Usually it would wear quickly, because of the damaged in hardness space. In addition, diamonds have different properties in various crystallographic directions. The hardness of the different planes of a diamond differ. And within each plane its importance very much depends on directions. In connection with the anisotropy of hardness and toughness of a diamond being under processing by abrasive mechanical way it is necessary to orientate the crystals so, that processing was produced toward the least hardness. But wear-out of the diamond instrument depends on thir application to the most hard planes. Mechanical processing of diamonds surfaces no more satisfies the demands for necessity and importance in the microelectronics sphere. The mechanical method of processing only allows reaching on a maximum hardness 12-13 classes, that forms 100-50 nm.

Using such a diamond in electronics is an insufficiently structured perfection of the material. Big partition of the marriage diamonds are IMS processed diamonds, polished with processing the surfaces substrate. A more perspective way for mechanical processing of hard minerals and crystals is polishing in a mode of quasiplastic. Theoretical and experimental studies attested that in determined condition under mechanical influence frail hard material display plastic characteristic.

Mode of quasiplastic surface processing of frail minerals and materials makes it possible to provide such a parameter within special selection. The pressure and velocities of the moving instrument on the parallel surface must vary. The latter is subjected to mechanical influence. The first drawback of this way is because of the difficulty of the method's realization. The second is the comparatively high costal for the equipment (the machine module with CHPU), greater expenses and much processing time.

A quite new perspective method for processing diamonds is the thermochemical method. The essence of it is that at the temperature above 600^{o}C in an atmosphere of hydrogen the carbon atoms begin to open in heated metal and then interact with hydrogen, forming gas methane, which abandons the total zone to the reactor. Metal in it plays the role of the catalyst. By this thermochemical method it is possible also to polish diamonds very precisely without an error. The processing abrasive, as thin power, acting on crystal, makes defects on it under the instrument. But the chemical nature of the processing method does not cause the material. The mechanical processing is effectively possible only on "soft" crystal directions of the diamond. This new method does not require a precise orientation of the crystal, nor of the polishing powder (Shamaev et al., 2002).

The thermochemical method for natural diamonds processing and for polycrystalline diamonds is the same. It becomes possible to process diamonds in combination with other methods since there are new technologies without "fall out" crystals. Turning diamond to cutting instrument on its "hard" direction brings two different crystals like twins. It makes possible to germinate diamonds to the varieties of "boart". This method also makes possible the manufacture of flat diamonds and twin crystals as "macles" (the crystals of the diamond correspond to the variety III on the genetic classification of diamond by Yu. L. Orlov, 1974).

The essence of the thermochemical method

At the temperature of the processing from 600 to 1300°C, diamonds do not react with hydrogen directly. But hydrogen reacts with the dissolved metal carbon rendering from a diamond, forming methane gas. Thereby, safety of the crystal can be reached by not being subjected to a hard processing area, but to a small laboratory with chemical requirements and unceasing regeneration diamond processing metal equipment. All that means that the method is close to a catalytic hydrolysis of carbon reaction on the diamond (Fig. 2).

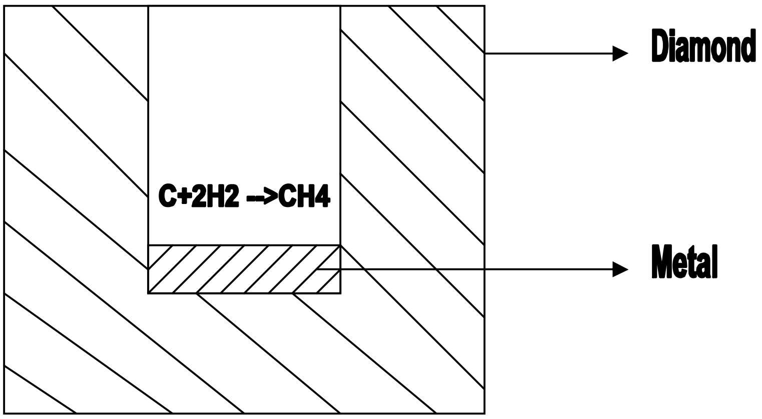

Fig. 2. Diamond-solution from carbon in metal and gas (CH_4)

Catalytic hydrolysis is hydrogen or organic gas joining the reaction. Realization of that means the reaction takes place on molecular hydrogen catalyst or donor to hydrogen (in our case, as catalyst emerges the metal from a group or alloy of metals as iron, nickel and cobalt). During processing diamonds are still under an instrument process the crystal surface takes its shape proceeding on the metal's surface. Diamond contacts are under minimum load with slowly revolving warmed instrumental disk. As it can be seen on Figure 3, the thermochemical installation is (in a simplified variant) not a very complicated equipment by design. The method can be recommended and adapted by others as a main method for contemporary diamond's processing.

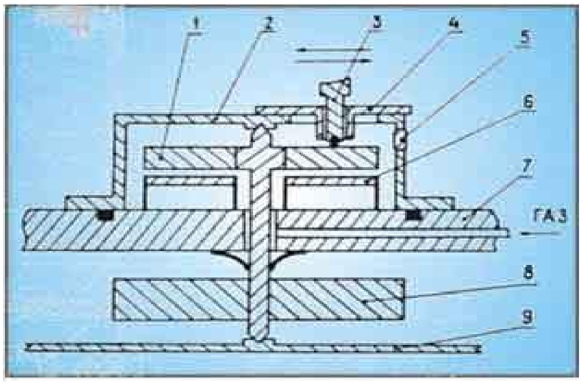

Fig. 3. A scheme for the thermochemical installation (http://st-yak.narod.ru/index2-4-1.html): 1 – diamond processing disk; 2 – cover; 3 – the holder with diamond; 4 – lid; 5 – observation window; 6 – heater; 7 – base; 8 – pulley; 9 – spring stress

An experimental equipment of the thermochemical method, composed by the only installation is shown on Figure 4. It is possible to slice diamonds (and other similar materials), as well as to perform holes of the complex stenciled forms in the material. It can be possible emboss the diamond, inflict on crystal signs, or drawings on its surface.

The technology was designed on the base of research of thermochemical polished diamond and of sharpening blade mono-crystal diamond instrument for eye microsurgery. Removing the waste mass of a diamond needs to take into account the dissolution of carbon diamond by simple metallic disk. All this allows using the thermochemical polishing method to bring precious high processed diamonds and rigid hard instruments.

Fig. 4. An experimental sample for the thermochemical method installation: processing diamond (modification PTC "URALALMAZINVEST")

The thermochemical way of processing makes real effects to the after processed diamonds hardness factors. The factor of removing wasted mass from the material is limited by the velocity by extraction of carbon from metal, which leads the processing. The velocity of processing forms before 0.3 mm per hour. Hardness in thermochemical polishing reaches Rz=6 nm for a monocrystal of a natural diamond. These factors suit the diamond for its application as a new, perspective material namely in the sphere of microelectronics.

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