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Cu/Diamond composite heat-conducting shims

E N Galashov[1], A A Yusuf[1] and E M Mandrik[1]

[1] Department of Applied Physics, Scientific Research Department Novosibirsk State University, 2 Pirogov's Street, Novosibirsk 630090, Russia

E-mail: chessplanet86@yandex.ru

Abstract. Composite material with high thermal conductivity was obtained by the method of thermal sintering of a diamond (50 - 75 %) with a size of 20 to 250 µm in a matrix of copper.Coefficient of thermal conductivity of copper diamond composite materials was measured and is 450 – 650 $W \cdot m^{-1} \cdot K^{-1}$. The coefficient of thermal expansion CTE was measured and is 5.5 – 7.5 $\cdot 10^{-6}$/°C. The obtained copper diamond composite materials are promising objects for use in THz and microwave devices.

1. Overview

For the manufacture of heat sinks working under extreme heat loads in various areas of technology (electronics, nuclear energy, particle accelerators), materials with high thermal conductivity are required [1]. This problem can be solved through the creation of composite materials based on diamond because diamond has a thermal conductivity 1000-2600$W \cdot m^{-1} \cdot K^{-1}$ [2].The manufacturing of products entirely of diamond is technically difficult, and they have a very high cost [3]. So now diamond-containing composite materials with dispersed diamond filler, in particular metal matrix Ag, Cu, Al, are being developed actively [4].Diamond-metal composites with particles of a diamond of the 20-250 µm size with copper matrix have a high conductivity 600 – 950 $W \cdot m^{-1} \cdot K^{-1}$.

Along with the conductivity in the semiconductor device CTE is an important parameter. Semiconductor devices have a short lifespan if the heat sink substrate has a low thermal conductivity. Heat-conducting copper-diamond composites have CTE5.5 – 10 10^{-6}/°C and they have a long lifespan.

2. Fabrication

We have developed the method of obtaining diamond-copper composites with high thermal conductivity. The diamonds are covered with tungsten coating by the method of vapor deposition of tungsten carbonyl. The thickness of the coating is 0.5 – 1 µm. The coating composition may vary within W-W_2C-WC.Carbides provide adhesion of the coating to the diamond. Metallic tungsten and tungsten carbide are well moistened copper. Uncoated diamond is very poorly moistened by copper. In addition, tungsten and carbide are practically not dissolved in the melt of copper. Therefore, the tungsten coating on the diamond provides a copper-diamond composite by thermal sintering diamond in the matrix of copper.

Diamonds and copper were mixed and merged into a pill. The tablet was placed in the vacuum chamber of the furnace of the electrical resistance. The sintering temperature was 970 ˚C. The sintering time was 1 hour.

2.1. Equipment for coating of diamonds

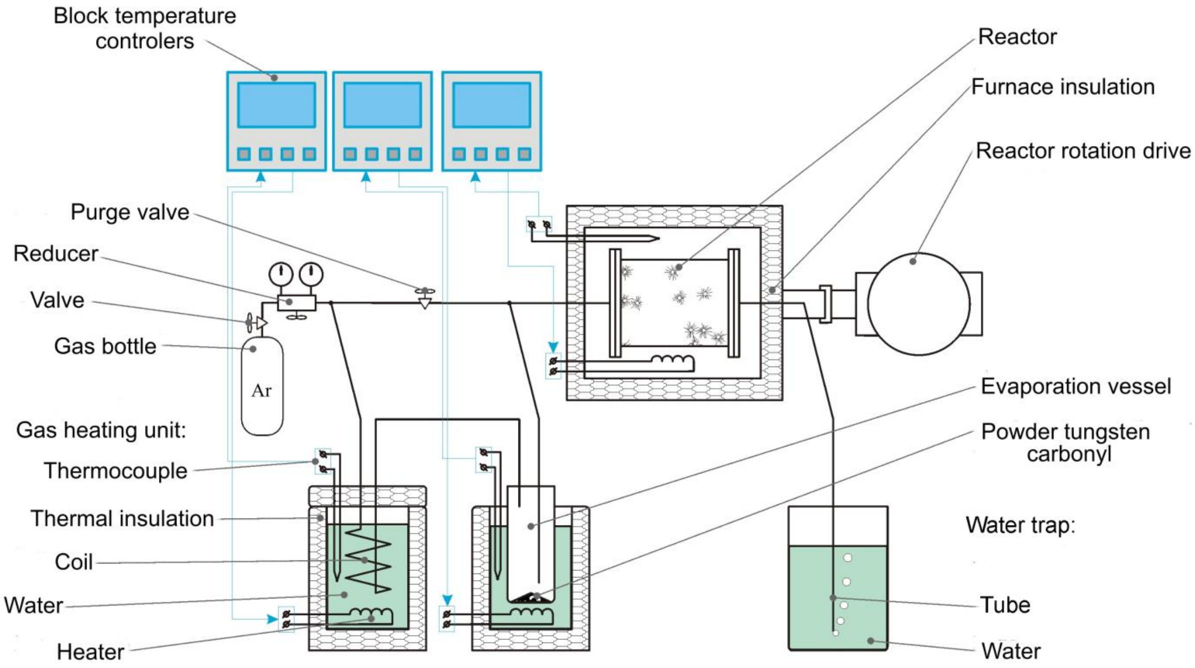

Figure 1. Diagram of the apparatus for applying coatings of tungsten.

Argon passes through the tube to the coil. Coil is heat by heater and water. Heated argon enters in evaporation vessel, where gas and vapor of tungsten carbonyl are mixed. Then argon with vapor of tungsten carbonyl moves in reactor, where diamonds are sited. Surface of diamonds are cleared from dirt due to pre-heating. Reactor with diamonds is rotated by reactor rotation drive and diamonds are coated composition of W-W_2C-WC. Then unnecessary gas residues are retired in water trap.

2.2. Equipment for synthesis of Cu/Diamond composite shims

Copper and diamonds coated with tungsten are mixed and pressed in steel press mold by mechanical press.

Figure 2. Steel press mold.

Figure 3. Pressed Cu/Diamond shims.

3. Results

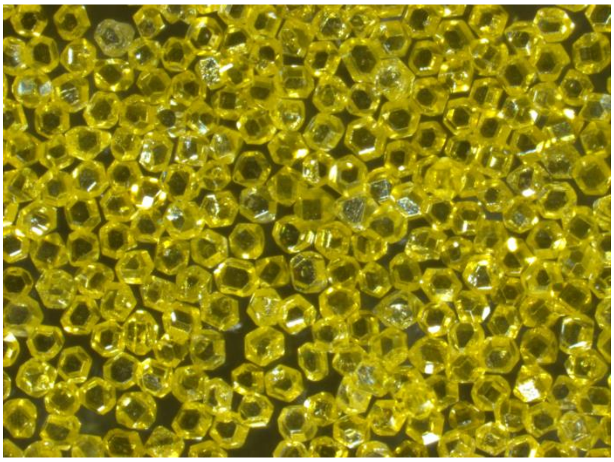

Figure 4. The original uncoated diamonds.

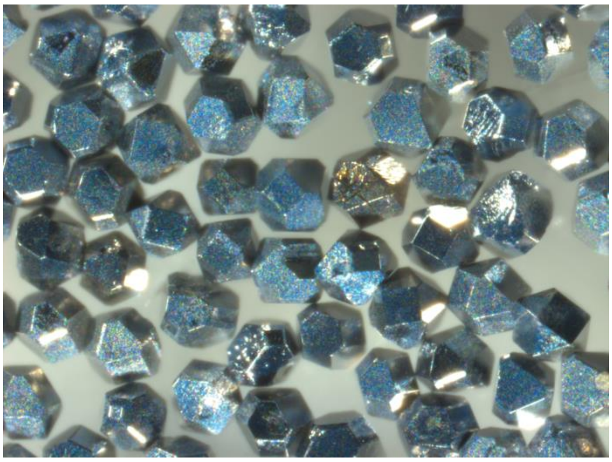

Figure 5. Covered diamonds.

By electron microscopy analysis was determined that covered diamonds have developed morphology. The coating has two types. The first is continuous. On top of a continuous coating islet coating is located.

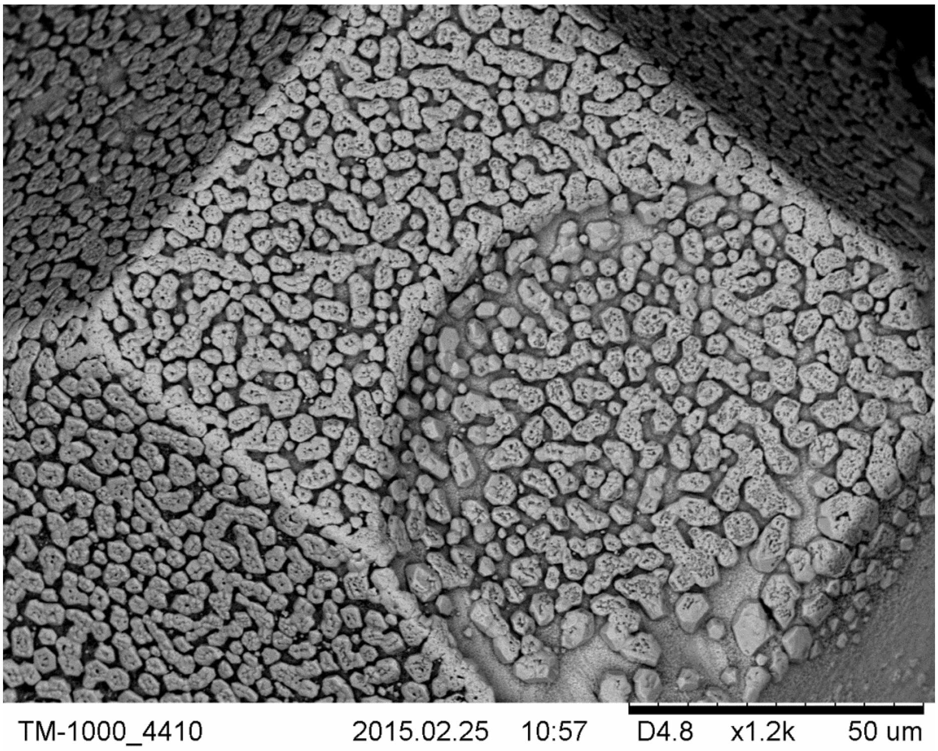

Figure 6. Electron microscopy of coated diamond with size 230 µm.

By X-ray analysis was determined that covered diamonds have diamond phase, tungsten carbide phase and tungsten phase. According to electron microscopy (Fig. 6) and X-ray diffraction (Fig. 7) is suggested that continuous coating has tungsten carbide phase and islet coating has tungsten carbide phase.

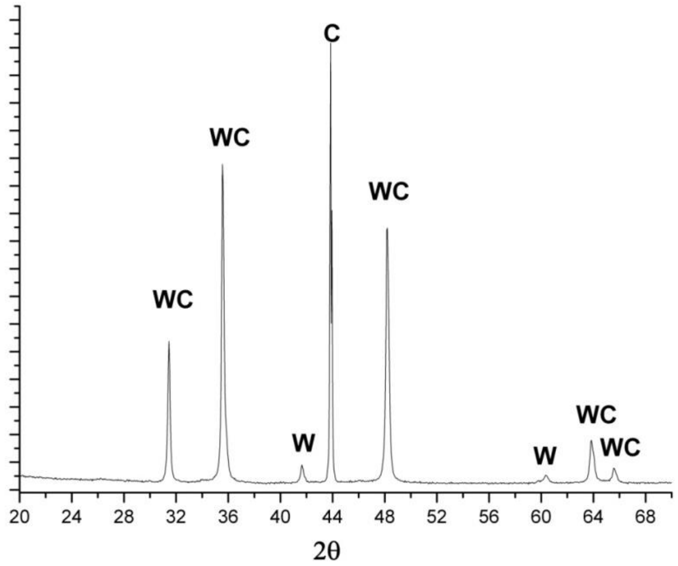

Figure 7. Diffraction pattern of coated diamond with size 230 μm.

Copper diamond tablet was obtained. Pores are practically absent, the surface is smooth. The thickness of the tablets is 1 mm. Coefficient of thermal conductivity of copper diamond composite materials was measured and is 450 – 650 $W \cdot m^{-1} \cdot K^{-1}$.The coefficient of thermal expansion CTE was measured and is 5.5 – 7.5 10^{-6}/°C.

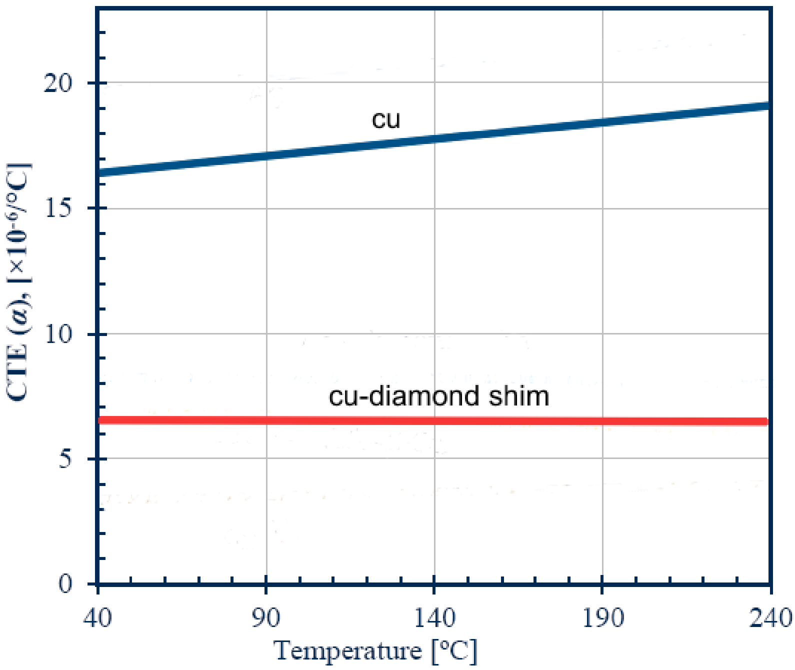

Figure 8. CTE of Cu and Cu-Diamond shim with diamond size 230 μm

References

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