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HEAT SINKS AND PROCESS FOR PRODUCING THE SAME

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☒ Claim(s) : paged 7 to paged 7
☒ Abstract : paged 8 to paged 8

This invention relates to a heat sink for electronic industries, more particularly to a heat sink utilizing diamond which is suitable for semiconductor radiators and other electronic devices, and also to a process for producing the same.

As well known in the art, studies are extensively made so as to achieve extremely high densities with respect to the physical density per unit area such as microchip circuit density and substrate packaging density. The degree of heat radiation is increased as the densities are improved, so that the heat radiating capabilities of the circuits and substrates must be increased correspondingly. For such purpose, various types of heat sinks have been proposed.

As such sinks, diamond heat sinks having high thermal conductivity values can be given. This type of diamond heat sinks include a plate-like heat sink made of natural diamond as a simple substance, a heat sink having a laminar structure produced by forming an artificial diamond crystal layer on a plate-like substrate by means of vapor phase synthesis (for example, as disclosed in Japanese Unexamined Patent Publication (KOKAI) No. 2-273960) and one produced by vapor-depositing an artificial diamond crystal layer on a substrate.

Further, a heat sink made of a copper-tungsten (Cu-W) alloy is also known.

Although heat sinks produced by using natural diamond are advantageous for



obtaining high thermal conductivity, they involve problems in the aspects of processability, size and cost. It is true that the artificial diamond heat sink produced by synthesizing an artificial diamond surface layer on a substrate has better processability than in the natural diamond heat sink, but the former has a laminar structure, so that the degrees of freedom in post-processing to be applied after lamination is limited by the presence of the surface diamond layer. Further, the heat sink produced by vapor-depositing an artificial diamond on a substrate also suffers poor processability, and besides the thickness of the diamond layer to be formed by vapor deposition is limited. Anyway, the prior art heat sinks, whether they may be produced by using natural diamond or an artificial diamond by means of synthesis or vapor deposition (coating), involve too many difficulties in processing and producing final products having the desired dimensions and shapes, and they also cost very high. Accordingly, further improvements are desired.

Meanwhile, the heat sink made of a copper-tungsten alloy is superior in terms of economical aspect and workability to these diamond heat sinks described above. However, the high thermal conductivity as obtained in the diamond heat sinks cannot be expected, and if the size of the heat sink is reduced, the heat radiating performance occasionally becomes insufficient.

The present inventors noted diamond powder so as to allow it to fully exhibit the low coefficient of thermal expansion and high thermal conductivity characteristic to diamond, and they found that an economical heat sink having excellent processability can be formed without impairing the properties, i.e. low coefficient of thermal expansion and high thermal conductivity, of



diamond by using a diamond powder in combination with cemented carbide to accomplish this invention.

According to this invention, cemented carbide incorporated with a diamond powder is subjected to molding to obtain a heat sink. The proportion of the diamond powder to be admixed relative to the cemented carbide is preferably 5 to 90 %.

The thus obtained heat sink is combined with an electronic device to be in thermal contact therewith.

In the above and following descriptions, the expression "electronic device" is used to define wide meanings including microchips; IC parts such as ceramic package substrates, hybrid substrates and therdip substrate; optical parts such as stems and carriers; microwave parts such as ceramic package substrates, metal package circuit substrates and IMPATT diodes; power transistors and thyristor parts; and other parts for electronic industries.

Since cemented carbide particularly has low coefficients of thermal expansion and high thermal conductivity values among other metals, heat sink having coefficients of thermal expansion approximate to those of the designed electronic devices can be formed by combining such cemented carbide with the diamond powder without impairing the high thermal conductivity characteristic to diamond.

The heat sink formed according to this invention has excellent processability and can be wetted well by waxy materials compared with the heat sink having a



diamond layer laminated thereon and the heat sink having a diamond layer vapor-deposited (coated) on a substrate, so that it can easily be subjected to brazing and soldering, and also it is inexpensive. Further, compared with the copper-tungsten alloy heat sink, the heat sink of the invention can be reduced in the size and can be expected to exhibit heat high radiating performance.

The contents of the present invention are not limited by the above description, and the objects, advantages, features, and uses of the present invention will become apparent from the following description taken in connection with the accompanying drawing. It should be noted that any suitable changes not departing from the spirit of the invention fall within the scope of the invention.

Fig. 1 shows partly in cross section a perspective view of a heat sink according to one embodiment of this invention.

Next, this invention will be described by way of Examples. A heat sink 1 having the shape as shown in Fig. 1 was formed using cemented carbide 2 and a diamond powder 3. The following materials were used for forming the heat sink 1.

[Table 1]

Cemented carbide: composition WC-10 % Co

WC diameter ca. 1.5 μ m,

Diamond powder: RVC200/230; particle size 0.3 to 100 μ m.



manufactured by General Electric Co., Ltd.

Heat sinks having a chip size of 10 mm x 10 mm x 1 mm (thickness) were formed (Samples 1 to 4) using the above composition in which the proportion of the diamond powder relative to the cemented carbide was adjusted between 10 to 40 %, which were subjected to sintering treatment in a high pressure generator at 1300 °C under a pressure of 5 GPa. When the thermal conductivity of each heat sink thus formed was examined, the following results were obtained.

[Table 2]

Sample No.	Cemented carbide	Diamond powder	Thermal conductivity
1	60 %	40 %	1.5 cal/cm/sec/ °C
2	70 %	30 %	1.2 cal/cm/sec/ °C
3	80 %	20 %	0.8 cal/cm/sec/ °C
4	90 %	10 %	0.5 cal/cm/sec/ °C

When the heat sinks were subjected to wire cutting, they were cut with no problem under the same cutting conditions as used for cemented carbide products. When the heat sinks were further subjected to polishing using a planing machine, they were processed with no difficulty, although the grindstone wore considerably.

When each of the sample heat sinks was combined, in place of the Cu-W system heat sink, with an IC package to be in thermal contact therewith, it was confirmed that it exhibited very excellent heat radiating capability.

Further, in the cases where heat sinks were formed in the same manner as



described above, except that the proportion of the diamond powder was changed to 5 to 10 % or 40 to 90 %, the designed thermal conductivity values were obtained.

As has been described heretofore, the heat sink according to this invention is accomplished by noting the diamond powder and using it in combination with cemented carbide selected as a counterpart material thereof, in place of synthesizing or vapor-depositing (coating) a diamond layer on a substrate as has conventionally been practiced. Accordingly, the thus obtained heat sink can exhibit a coefficient of thermal expansion approximate to the designed electronic device, while the high thermal conductivity of the diamond is not impaired by the cemented carbide having particularly low coefficient of thermal expansion and high thermal conductivity among other metallic materials. The heat sink of this invention has excellent processability compared with the conventional diamond heat sinks, besides the cemented carbide can be wetted well with waxy materials, so that the heat sink can readily be subjected to blazing or soldering and also it is inexpensive. Further, compared with the copper-tungsten alloy heat sink, the heat sink of the invention enjoys a great effect that it can be reduced in the size and can exhibit high heat radiating performance.



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What is claimed is:

1. In a heat sink (1) molded employing diamond, said heat sink characterized by cemented carbide (2) and diamond powder (3) admixed thereto.
2. The heat sink according to Claim 1, characterized in that the proportion of said diamond powder admixed relative to said cemented carbide is 5 to 90 %.
3. The heat sink according to Claim 1, characterized in that said diamond powder consists of high-purity diamond particles having a particle size of 0.1 to 100 μ m, whereas said cemented carbide consists primarily of WC and, as the rest, at least one metal selected from Co, Ni and Fe and inevitable impurity.
4. An electronic device characterized in that the heat sink as set forth in any of Claims 1 to 3 which is combined in thermal contact.
5. A process for producing a heat sink characterized by a step of subjecting a particulate mixture of diamond, WC, Co, etc. to sintering at a temperature of 1200 to 1500°C under a pressure of 3 to 6 GPa.

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Abstract

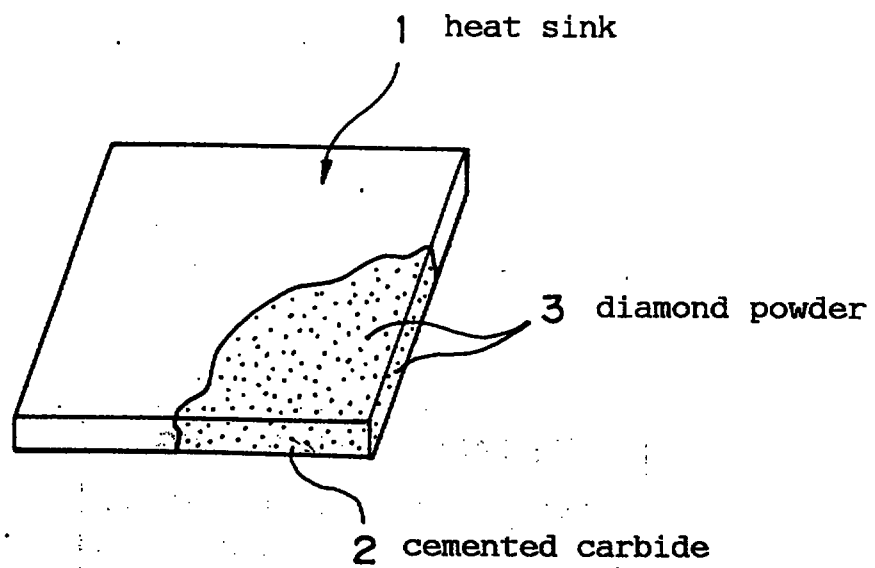
HEAT SINKS AND PROCESS FOR PRODUCING THE SAME

Provided is a heat sink which has excellent processability and is economical, even though it employs diamond, as well as, a process for producing the same. The heat sink is molded using a composition obtained by adding a diamond powder consisting of 0.1 to 100 μ m high-purity diamond particles to cemented carbide consisting primarily of WC and, as the rest, at least one metal selected from Co, Ni and Fe and inevitable impurity. The proportion of the diamond powder admixed relative to the cemented carbide is preferably 5 to 90 %, and the diamond heat sink is produced by sintering the particulate mixture of diamond, WC, Co, etc. at a temperature of 1200 to 1500 °C under a pressure of 3 to 6 GPa.

Fig 1



FIG.1



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☒ Drawing(s) : paged 11. to paged
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DATE OF RECEIPT 10/10/96

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HEAT SINKS AND PROCESS FOR PRODUCING THE SAME

This invention relates to a heat sink for electronic industries, more particularly to a heat sink utilizing diamond which is suitable for semiconductor radiators and other electronic devices, and also to a process for producing the same.

As well known in the art, studies are extensively made so as to achieve extremely high densities with respect to the physical density per unit area such as microchip circuit density and substrate packaging density. The degree of heat radiation is increased as the densities are improved, so that the heat radiating capabilities of the circuits and substrates must be increased correspondingly. For such purpose, various types of heat sinks have been proposed.

As such sinks, diamond heat sinks having high thermal conductivity values can be given. This type of diamond heat sinks include a plate-like heat sink made of natural diamond as a simple substance, a heat sink having a laminar structure produced by forming an artificial diamond crystal layer on a plate-like substrate by means of vapor phase synthesis (for example, as disclosed in Japanese Unexamined Patent Publication (KOKAI) No. 2-273960) and one produced by vapor-depositing an artificial diamond crystal layer on a substrate.

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The thus obtained heat sink is combined with an electronic device to be in thermal contact therewith.

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2. The heat sink according to Claim 1, characterized in that the proportion of said diamond powder admixed relative to said cemented carbide is 5 to 90 %.
3. The heat sink according to Claim 1, characterized in that said diamond powder consists of high-purity diamond particles having a particle size of 0.1 to 100 μ m, whereas said cemented carbide consists primarily of WC and, as the rest, at least one metal selected from Co, Ni and Fe and inevitable impurity.
4. An electronic device characterized in that the heat sink as set forth in any of Claims 1 to 3 which is combined in thermal contact.
5. A process for producing a heat sink characterized by a step of subjecting a particulate mixture of diamond, WC, Co, etc. to sintering at a temperature of 1200 to 1500°C under a pressure of 3 to 6 GPa.

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Abstract**HEAT SINKS AND PROCESS FOR PRODUCING THE SAME**

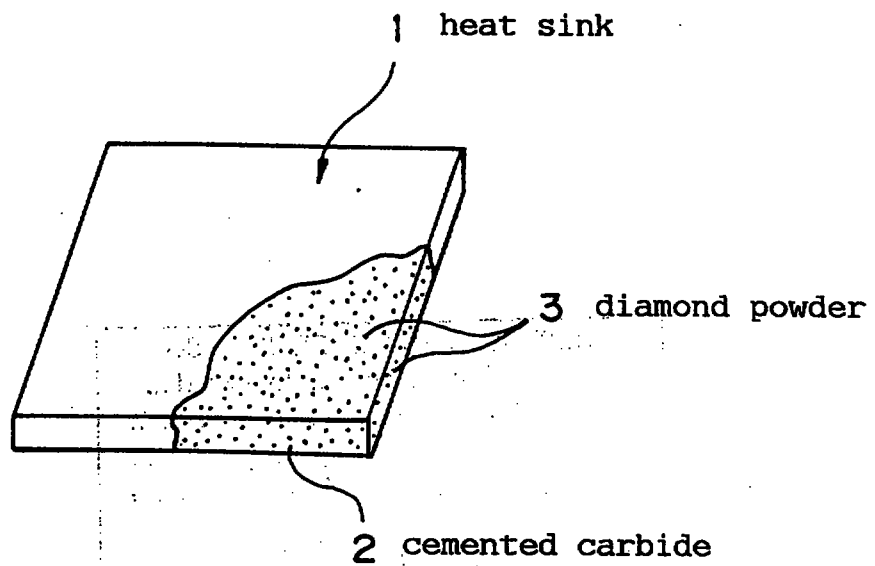
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Fig 1

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FIG.1



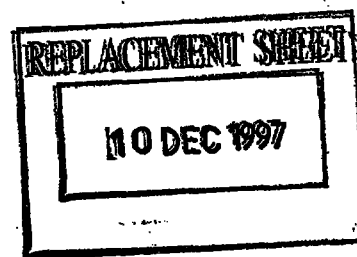
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What is claimed is :

1. In a heat sink (1) molded employing diamond, said heat sink characterized by cemented carbide (2) and diamond powder (3) admixed thereto;

wherein the said diamond powder consists of high-purity diamond particles having a particle size of 0.1 to 100 μm , whereas said cemented carbide consists primarily of WC and, as the rest, at least one metal selected from Co, Ni and Fe and inevitable impurity.

2. The heat sink according to Claim 1, characterized in that the proportion of said diamond powder admixed relative to said cemented carbide is 5 to 90%.

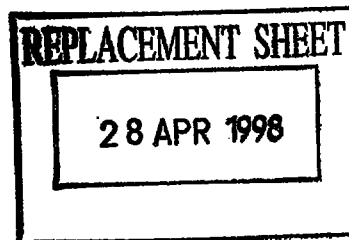
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