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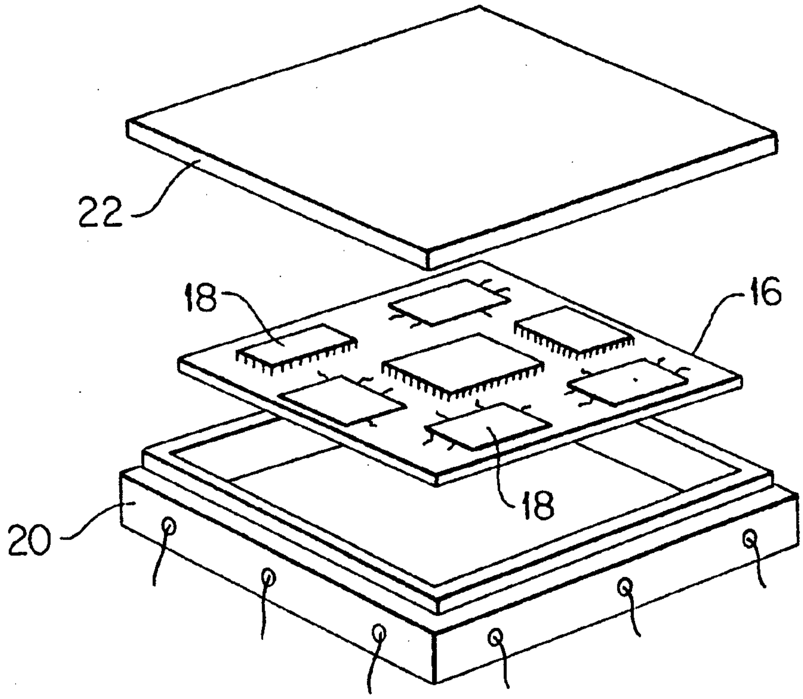
(54) Title: HIGH THERMAL CONDUCTIVITY, MATCHED CTE, LOW DENSITY COMPOSITE

(57) Abstract

The method and composite of the present invention has a significant advantage over known composites in the size of the diamond particles contained therein. Without a change in the diamond/metal ratio, the larger size diamond particles (about 110 microns and about 160 microns in size) provide a composite (20) of increased thermal conductivity without sacrificing CTE. Thus the CTE of the composite (20) may be matched with the CTE of the electrical components (18) with which it is associated and still retain the advantages of high conductivity. While exemplary embodiments of the present invention have been described, it is to be understood that the embodiments described are illustrative only and the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalence, many variations and modifications naturally occuring to those skilled in the art from a perusal hereof.



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HIGH THERMAL CONDUCTIVITY, MATCHED CTE, LOW DENSITY COMPOSITE

BACKGROUND OF THE INVENTION

This invention relates to diamond/metal composites particularly useful as electrical component mounting plates and enclosures.

Hermetically sealed enclosures for electrical components are desirable to protect the electrical components from damaging environmental conditions such as moisture and airborne dust. Electrical components and electrical circuits mounted in hermetically sealed enclosures are often used in equipment which is subjected to wide temperature and pressure variations. For instance, when electrical components are used on an aircraft which rises from ground level into the upper atmosphere the temperature can drop more than a hundred degrees fahrenheit. In addition, the electrical components often generate substantial amounts of heat which can be damaging to the components and/or their predictable operation.

Diamond/metal composites are well known as is the fact that the coefficient of thermal expansion ("CTE") of such composite is variable as a function of the diamond/metal ratio but not as to the particle size. It has been generally recognized that particles of small size are required to obtain a CTE compatible with the known uses of such composites.

By way of example, the composites disclosed in the Supan, et al. U.S. Patent No. 5,045,972 contain 5 to 80 volume percent diamond particles with a particle size from 1 to 50 microns. Similarly, the composites disclosed in the Burnham, et al. U. S. Patent No. 5,008,373 contain a diamond/metal ratio disclosed only as being compatible in its CTE with the CTE of a semiconductor material with which used with a particle size of its largest dimension no greater than 106 microns, preferably less than 38 microns and more preferably less than 3 microns.

In contrast, thermal conductivity is directly variable with particle size and applicants have discovered that, in direct contrast to the teachings of the known prior art to use diamond particles of extremely small size, diamond/metal composites may be made with large diamond particles thus enhancing the thermal conductivity of the material without affecting the CTE of the composite.

It is accordingly an object of the present invention to obviate many of the problems of the prior art and to provide a novel diamond/metal composite and method, which composite has particular utility in circuit card assembly thermal cores, multichip module substrate carriers, containers for electronic components and tamper proof electronic packaging.

It is another object of the present invention to provide a novel diamond/metal composite matched in CTE with the material with which used with enhanced thermal conductivity.

These and many other objects and advantages of the present invention will be readily apparent to one skilled in the art to which the invention pertains from a perusal of the claims, the appended drawings, and the following detailed description of preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a plot of CTE and thermal conductivity as a function of the diamond/metal ratio for diamond particles of different sizes.

Figure 2 is an exploded pictorial view of the composite of the present invention in an application as a high conductivity, isotropic thermal core for printed wiring boards.

Figure 3 is exploded pictorial view of the composite of the present invention in an application as a high conductivity, isotropic, tamper proof electronic package.

DESCRIPTION OF PREFERRED EMBODIMENTS

A method of producing the composite of the present invention is described in the copending Montesano U. S. application   entitled "Hermetic Packages For Single-Multiple Dies", filed currently herewith and assigned to the assignee hereof. The disclosure of said application is hereby incorporated herein by reference.

As disclosed in said copending application, an electrically insulative plate may have apertures cut therethrough in a pattern which corresponds to the leads of an electrical component or an electronic module which is to be mounted on the plate. The apertures may then be filled with diamond particles less than about 20 microns. The insulative plate with its filled apertures may then be subjected to pressure infiltration of a liquid metal, typically by placing the apertured plate inside a mold and injecting an electrically conductive liquid metal into the mold under high pressure and at a high temperature. After cooling, the plate may be removed from the mold.

The metal and the diamond particles form a monolithic composite material which is electrically conductive and is bonded to the walls of the apertures by the metal. In this way an electrically conductive path may be formed by the composite through the insulative plate of electrical package.

In the composite of the present invention, the diamond particles are between about 110 microns and about 160 microns in size, preferably between about 140 and 160 microns. The particles comprise 10% to 80% by volume, preferable 40% to 60%, and the metal may be any one or more of the group consisting of silver, copper, nickel and beryllium.

Alternatively, the composite of the present invention may be used to form the package, with the conductive paths for the electronic circuit contained therein insulated from the package in any suitable conventional way such as by glass beads or the like. Where the heat transfer characteristics of the material are desired, the composite may be used as structural members of various types.

As shown in Figure 1 where the curves at different particle size are plotted for a composite of 1100 aluminum and 2B diamonds, thermal conductivity and CTE vary inversely with respect to each other as the percentage of diamonds increases in the composite. Note that the curves for thermal conductivity vary with particle size, but that the CTE is independent of particle size. It is thus possible to take advantage of the increased thermal conductivity associated with large particles without changing the CTE of the composite.

For example, and with reference to Figure 2, the composite of the present invention may be used as a thermal core 10 for printed wiring boards ("PWBs") 12 and 14 where the core 10 provides mechanical support for the surface mounted PWBs 12 and 14 as well as a conduction path for the thermal energy to be dissipated therefrom. The CTE may be matched with the CTE of the PWBs without sacrificing the low mass, high strength-to-weight, high stiffness, isotropic characteristics of the composite core. Effective heat transfer between the core and the PWB may be insured by the use of a very thin diamond/epoxy thermally conductive adhesive.

As shown in Figure 3, the composite may also be used as a package 20 for various electronic components 18. Because accessibility to the electronics within the high strength package is restricted, such packages can be referred to as "tamper proof" packages. The components 18 may be mounted on a board 16 and the package 20 may have a concave base enclosed with a cover 22. The base may include electrically conductive paths to provide access to the components inside the package. As discussed above, the composite may form one or more of the base and cover, or may form the electrically conductive paths.

ADVANTAGES AND SCOPE OF THE INVENTION

The method and composite of the present invention has a significant advantage over known composites in the size of the diamond particles contained therein. Without a change in the diamond/metal ratio, the larger size diamond particles provide a composite of increased thermal conductivity without sacrificing CTE. Thus the CTE of the composite may be matched with the CTE of the electrical components with which associated and still retain the advantages of high conductivity.

While exemplary embodiments of the present invention have been described, it is to be understood that the embodiments described are illustrative only and the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalence, many variations and modifications naturally occurring to those skilled in the art from a perusal hereof.

What is claimed is:

1. An electronic package comprising:

an enclosure including (a) a base and (b) a cover, one of said cover and said base being generally concave and carried by the other to form an enclosure, one of said base and said cover having a plurality of spaced electrically isolated conductive paths therethrough;

at least one of said base and said cover comprising a composite of diamond particles and a metal, said particles being between about 110 microns to about 160 microns in size; and

an electronic circuit having a plurality of leads, said circuit being carried internally of said enclosure with said leads in electrical contact with said conductive paths whereby said conductive paths provide electrical access to said circuit from the exterior of said enclosure.

2. The package of Claim 1 wherein the size of said particles is greater than about 140 microns.

3. The package of Claim 1 wherein said particles are between about 140 and about 160 microns; and

wherein said metal is aluminum.

4. The package of Claim 1 wherein said metal is one or more of the group consisting of silver, copper, nickel and beryllium.

5. The package of Claim 1 wherein the CTE of said composite is independent of particle size.

6. The package of Claim 1 wherein the ratio of diamond to metal in said composite is between about 10% and about 80%.

7. The package of Claim 1 wherein the ratio of diamond to metal in said composite is between about 40% and about 60%.

8. A mounting plate for a semiconductor circuit comprising a composite of a metal having a plurality of diamond particles interspersed therein,

said particles being between about 110 microns to about 160 microns in size, and

said composite having a CTE which approximates the CTE of said semiconductor circuit.

9. The mounting plate of Claim 8 wherein the size of said particles is greater than about 140 microns and wherein the CTE of said composite is independent of particle size.

10. The mounting plate of Claim 8 wherein said metal is one or more of the group consisting of silver, copper, nickel and beryllium; and

wherein the ratio of diamond to metal in said composite is between about 10% and about 80%.

11. The mounting plate of Claim 8 wherein said particles are between about 140 and about 160 microns; and

wherein the ratio of diamond to metal in said composite is between about 40% and about 60%.

12. The mounting plate of Claim 8 wherein the CTE of said composite is independent of particle size and independent of thermal conductivity.

13. A method of making an thermally conductive, isotropic composite having a thermal conductivity dependant on

the size of particles within a conductive matrix comprising the steps of:

a. filling a mold for the item with diamond particles greater than about 110 microns; and

b. infiltrating the particulate with a molten metal to (i) mechanically bond the particles while (ii) providing a plurality of thermally conductive paths therethrough;

c. solidifying the metal to form the composite; and

d. separating the item from the mold.

14. The method of Claim 13 wherein the particles are infiltrated by the metal under a pressure of about 2,000 to about 12,000 pounds per square inch.

15. The method of Claim 13 wherein the size of said particles is between about 110 and 160 microns; and

wherein said metal is one or more of the group consisting of aluminum, silver, copper, nickel and beryllium.

16. The method of Claim 13 wherein the CTE of said composite is independent of particle size.

17. The method of Claim 13 wherein the ratio of diamond to metal in said composite is between about 10% and about 80%.

18. The method of Claim 13 wherein the ratio of diamond to metal in said composite is between about 40% and about 60%.

19. The method of Claim 13 wherein the particles are coated prior to the infiltration with a thin layer of a metal from the group consisting of copper, nickel, aluminum, silver and gold.

20. The method of Claim 13 wherein the particles are substantially coated with a metal prior to infiltration to

enhance the thermal conductivity through the matrix metal/diamond interface and to reduce chemical reactions between the particles and the matrix metal.

21. A structural material for an electronic package comprising a composite of a metal and diamond particles, said diamond particles being between about 110 microns and 160 microns in size and being between about 10% and 80% of the volume of said composite.

22. The material of Claim 21 wherein said metal comprises one or more of the group of electrically conductive metals consisting of aluminum, silver, copper, nickel, gold, and beryllium.

23. The material of Claim 21 wherein said particles are between 140 and 160 microns in size and wherein said particles comprise 40% to 60% of the volume of said composite.

24. The package of Claim 1 wherein said conductive paths comprise said composite.

25. The package of Claim 1 wherein said base comprises said composite.

26. The package of Claim 1 wherein said cover comprises said composite.

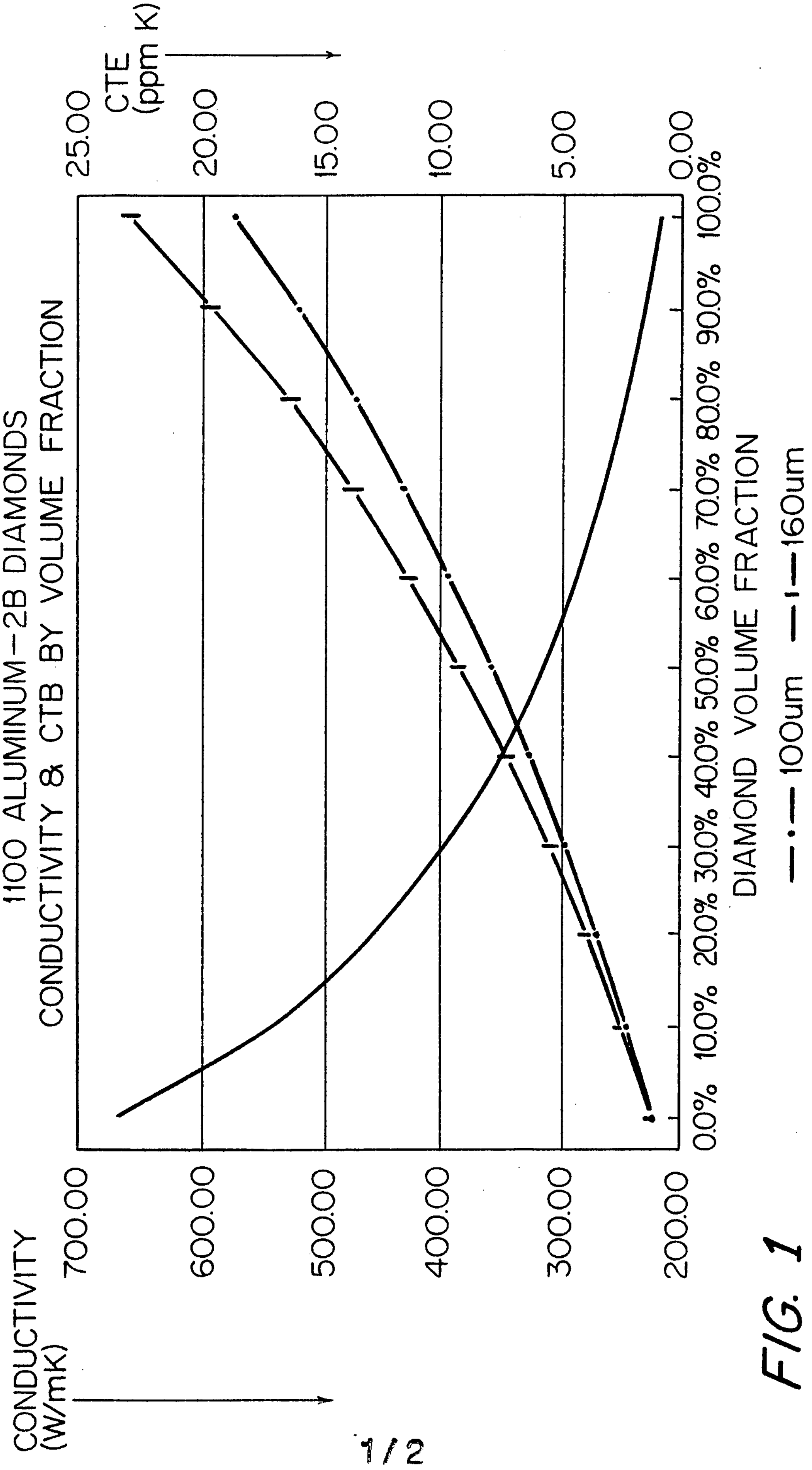
1100 ALUMINUM–2B DIAMONDS
CONDUCTIVITY & CTB BY VOLUME FRACTION
CONDUCTIVITY (W/mK)
700.00
600.00
500.00
400.00
300.00
200.00
CTE (ppm K)
25.00
20.00
15.00
10.00
5.00
0.00
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%
DIAMOND VOLUME FRACTION
—•— 100um
—ı— 160um

FIG. 1

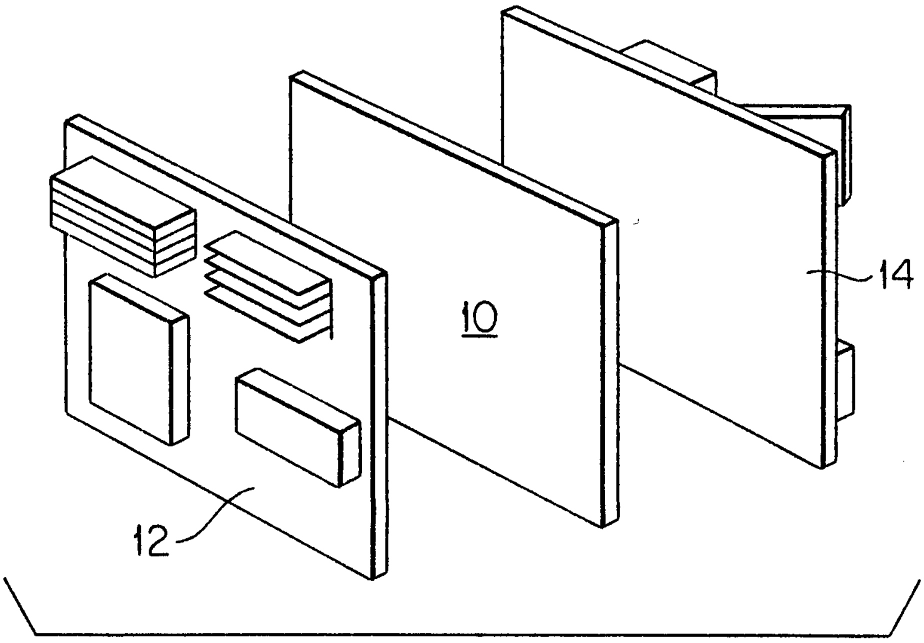

FIG. 2

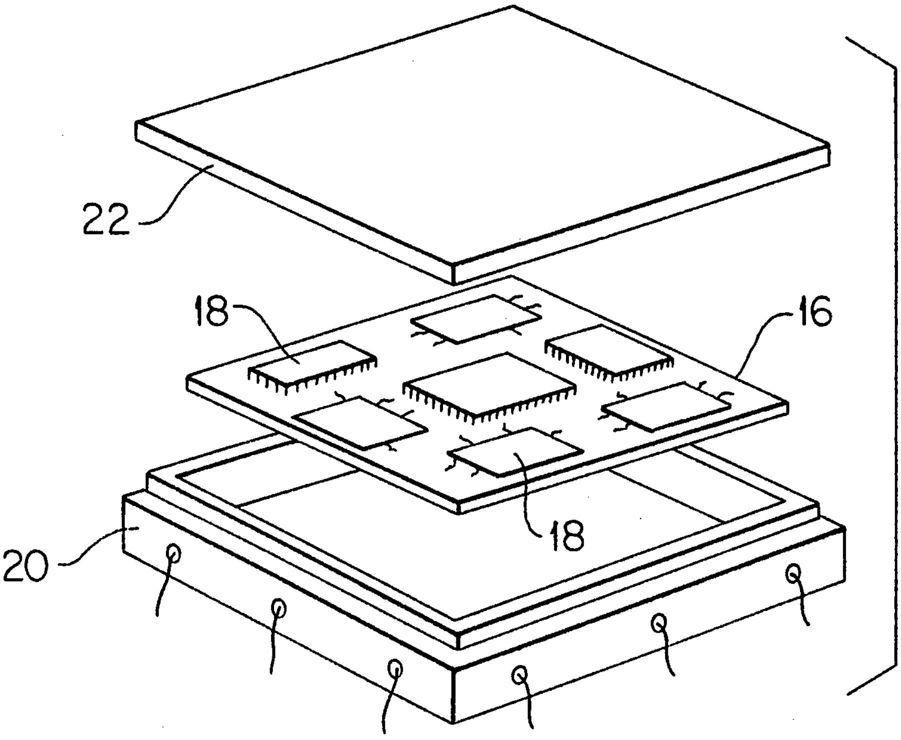

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/08151

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :Please See Extra Sheet.
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,146,314 (PANKOVE) 08 September 1992, see entire doucment.	1-7, 13-26
Y	US, A, 5,130,771 (BURNHAM ET AL) 14 July 1992, see entire document.	1-7, 13-26
Y	US, A, 5,008,737 (BURNHAM ET AL) 16 April 1991, see entire document.	1-7, 13-26

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier document published on or after the international filing date
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A. CLASSIFICATION OF SUBJECT MATTER:
IPC (5):

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A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

75/243, 247, 249, 174/52.4; 361/714, 715; 419/23; 428/539.5, 561, 565

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

75/200, 243, 247, 249; 174/52.4; 361/704, 705, 708, 712, 714, 715, 720; 419/11, 23, 448; 423/466; 428/539.5, 402, 446, 551-554, 558-559, 561-565

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

Group I = claims 1-7, 24-26
Group II = claims 8-12
Group III = claims 13-20
Group IV = claims 21-23

Claims 1-7, 24-26 recite an electronic package of a base and cover. Claims 8-12 recite a mounting plate. Claims 13-20 recite method of making using a mold, mechanically bonding, solidifying and separating. Claims 21-23 recite a composite structural material only. Unity of invention is lacking because special technical features (such as "conductive paths" and "circuit" with "leads....conductive paths") of the invention of claim 1 of Group I are not included in the inventions of claims 8,13 and 21 of the inventions of the other Groups II, III and IV.