Description

Technical Field

This invention concerns with heat-sinks for removal of variable amounts of heat from elements of the electronic circuits, such as Hybrid Integrated Circuits (HICs).

Background of the Invention

Hybrid Integrated Circuits (HIC) often include active chips, such as Integrated Circuit (IC) chips, or some other elements or devices which during operation either generate heat or are subjected to heat generated by other elements of the HIC. Some of the devices may be susceptible to heat-induced changes in operating characteristics or other heat-induced damage, such as warping, separation, wire breakage, fracture, etc. These adverse effects may become more pronounced in circuits, in which the elements are densely clustered. Thus, it is desirable to remove excess heat from at least some of the individual elements of the HICs by providing them with "heat-sinks" of a high heat-conductivity metal to pick-up and transfer the heat away from these elements. In some instances, it may be desirable to remove a variable amount of heat. For example, when an element or a device is programmed to operate at a certain temperature or when the circuitry is in a cold environment, removal of an excess amount of heat could adversely affect the operational characteristics of the element or device. Therefore, it may be desirable to remove heat only when a certain temperature level is reached which is in excess of the normal operating temperature of the element or device.

U.S. Patent 4,408,220 issued to A.D. Calabro on October 4, 1983 discloses a heat-dissipator (a heat sink) structure including top and bottom metal plates interconnected by an intermediate metal section. This structure is formed so as to be slidably mounted on an IC package which is mounted on a support base, such as a printed circuit board. The top plate of the heat-sink is resiliently connected to the intermediate section and when in position contacts a heat spreader plate common to a number of such heat-sinks. However, with further miniaturization and automation of manufacture and assembly, such a mechanically secured heat-sink may prove difficult to use. Furthermore, that heat sink is not programmed for variable heat transfer from the IC to the heat spreader.

It is, thus, desirable to provide HICs with a heat-sink attached to an element such as a chip or some other device and capable of transferring varied amounts of heat energy to a heat spreader or dissipator in response to a correspondingly varied temperature of the element or device or environment so as to stabilize the operating temperature of the HIC.

IBM Technical Disclosure Bulletin 20 No. 5., October 1977, N.Y., U.S. page 1768; EE Zirnis: "Semiconductor Module With Improved Air Cooling", discloses a fixed position heat sink having a bottom portion, and a thermal bridge attached to the bottom portion. The bridge includes a slanted portion and a bent portion which contacts the heat spreader.

IBM Technical Disclosure Bulletin 21, No. 3, August 1978 N.Y., U.S., pages 1141-1142; H.H. Goodman: "Intramodular Thermal Shunt" shows a bottom segment in contact with the circuit module, and wings in fixed contact with the heat spreader. The thermal shunt module may be bimetallic so that the shunt will exert a force on the circuit module which is in proportion to the amount of heat generated.

DE-A-3 144 759 describes a thermal matching element exhibiting high thermal and electrical conductivity, which is used to join a heat generating semiconductor device with a heat transmissive electrical conductor.

According to the present invention there is provided an article as defined in claim 1.

The present invention is an electronic circuit, such as a Hybrid Integrated Circuit (HIC), having an element mounted on a suitable support base, and a heat sink mounted on the element. A heat spreader is located in spaced relationship with the support base. The heat sink has a bottom portion and at least one flange for conducting heat energy to the heat spreader. The bottom portion is secured to the element. Each flange includes an upright segment projecting from the bottom portion of the heat sink toward the heat spreader, a free end segment bent away from the heat spreader and a knee-bend segment intermediate the upright segment and the free-end segment and adjacent to the heat spreader. Each flange is also provided with a thermally responsive section, hereinafter referred to as "thermostat", which forms a part of the upright segment and in response to the presence or absence of a certain amount of heat energy causes movement of the free end segment of the heat sink, respectively, toward or away from the heat spreader so as to establish a greater or lesser area of contact with the heat spreader. This thermostat is formable in several ways including inlaying into an upright segment of the flange a metal with a coefficient of thermal expansion different from that of the flange or by attaching such a metal to the upright segment.

Brief Description of the Drawing

FIG. 1 is a cross-sectional view of one variant of an exemplary device constructed in accordance with the present invention.

FIG. 2 is a cross-sectional view of another variant of the exemplary device constructed in accordance with the present invention.

FIG. 3 is a cross-sectional view of said one variant of the exemplary device provided with a thermally balancing insert.

FIG. 4 is a cross-sectional view of said another variant of the exemplary device provided with a thermally balancing insert.

Detailed Description

Reference numeral 1 designates an exemplary electronic circuit, such as a Hybrid Integrated Circuit, only a portion of which is shown. Reference numeral 2 designates a support base made of a suitable material such as ceramic, semiconductor (e.g. silicon), glass, plastic (e.g. epoxy), glass fiber-reinforced epoxy, resin coated metal (e.g. epoxy coated aluminum), molded circuit board and other suitable conventionally used materials. Reference numeral 3 designates an element or device mounted on the support base. In an exemplary embodiment, element 3 is an active semiconductor chip, such as an Integrated Circuit (IC) chip. The chip is mounted on the support base in a so-called "flip-chip" manner in conductive contact between any circuitry (not shown) on the chip and conductive leads and pads (not shown) on the support base. The chip is secured to the support base in a conventional manner such as by solder, alloying, gold eutectic bonding, conductive adhesive and the like.

A heat-sink, identified generally by numeral 4, is attached to an upper or non-active surface of the chip, that is to that surface of the chip which is opposite the surface facing the support base. Alternatively, the support base may, in fact, be a base of the thermostat, and the now free active surface of the IC chip can be wire bonded to a lead frame. The heat-sink is of a suitable metal or alloy having high heat conductivity, such as aluminum, copper, nickel, their alloys, brass, bronze, stainless steel. Noble metals or their alloys, such as gold, palladium, platinum, or silver, can be used. The metal should not lead to contamination of the element.

The heat sink is provided with a bottom portion, 6, attached to the chip, and at least one flange, 8, for conducting heat to a heat spreader, 7, which is positioned a spaced distance from support base 2. In the exemplary embodiment, the heat sink has a U-shaped configuration and has at least two flanges 8. Each flange includes an upright segment, 9, projecting from bottom portion 6, a free end segment, 10, and a knee-bend segment, 11. Bottom portion 6 of the heat-sink is secured to the upper or non-active surface of chip 3 by suitable means such as an adhesive, 12, having suitable temperature and processing characteristics. Free end segment 10 of each flange 8 is at an acute angle to the respective upright segment 9, so that each free end, 13, points normally toward support base 2. The knee-bend segment 11 of each flange is placed near or in contact with heat spreader 7. Heat spreader 7 is also of a high heat conductivity metal, such as aluminum, copper, nickel, their alloys, brass, bronze, stainless steel, provided to pick-up heat from the heat sink(s) and to conduct away or dissipate the heat to the environment. The heat spreader may be a plate provided especially for this purpose or it may form a part of a housing enclosing the HIC.

Each flange 8 is provided with a thermostat which automatically controls an area of contact between free end segment 10 and heat spreader 7. The thermostat is, preferably, located between bottom portion 6 and knee-bend segment 11; however, some other positioning of thermostat on the heat-sink, such as on each respective free-end segment 10 is possible. The thermostat is programmed to cause movement of free end segment 10 toward heat spreader 7 from its normal position at an acute angle of less than 45° to the heat spreader. Depending on operating conditions and, thus, the termperature of the environment, the free end segment will move toward contacting position with heat spreader or shall move away from the heat spreader toward its normal position.

The thermostat is composed of two metals and/or alloys having different thermal coefficients of expansion (TCE) forming a bimetallic element. Materials of this construction are obtainable commercially, and would undergo predictable bending as a function of temperature, physical design, and materials. Some of suitable materials and their respective coefficients of thermal expansion (α) for a temperature range of from 0 to 100°C (32 to 212°F) are given in TABLE I below:

TABLE I

Metal	α(ppm/°C) [α(ppm/°F)]		Metal	α(ppm/°C) [α(ppm/°F)]	
Al	20.7-24.7	(11.5-13.7)	"Kovar" (RTM)	5.9	[3.3]
Cu	16.7	[9.3]	"Monel" (RTM)	~ 27	[~15]
Ag	18.9-19	[10.5-10.6]	Stainless steel 416	17.8	[9.9]
Au	14.2	[7.9]	Stainless steel 303	31.3	[17.4]
Pt	9	[5.0]	Al alloy	~ 41.4	[~23]
Pd	11.7	[6.5]	Phosporbronze	17.8	[9.9]
Ni	12.8	[7.1]	"Invar" (RTM)	1.4-1.6	[0.8-0.9]
Brass	17.6-19.8	[9.8-11]			

The thermostat may be formed in a number of variants. For example, in one variant, shown in FIG. 1, an inlay, 16, of a metal having one value of TCE, α_1, is embedded into upright segment 9 of a metal having another TCE value, α_2; in another variant, shown in FIG. 2, a thin platelet, 17, of a metal having said one TCE value, α_1, is attached to upright segment 9 constructed of a metal having said another TCE value, α_2, in a conventional manner such as by soldering, alloying or adhesively, e.g., by means of an epoxy composition. One example of a pair of metals forming the thermostat could be aluminum for the heat sink and "Invar" for the inlay. Other variants may include a bimetallic composite which may be inlayed into or attached to upright segment 9.

In the two embodiments shown in FIGS. 1 and 2, the TCE, α_1, of inlay 16 or platelet 17 is smaller than the TCE, α_2, of the material of upright segment 9 ($\alpha_1 < \alpha_2$). This disparity in TCEs will result, upon being subjected to a certain increase of temperature, in greater expansion of the metal of upright segment 9 than of inlay 16 (or platelet 17), causing movement of free end 13 toward heat spreader 7. By properly selecting the respective TCEs of the two metals as well as the respective physical dimensions of the metal with smaller TCE value, it is possible to preselect the sensitivity of the heat sink to a certain value of temperature.

The thermostats may be arranged on the heat sink in a suitable preselected arrangement. For example, they may be both positioned on the outside of each respective upright segments 9, as shown in FIG. 2, both on the inside (not shown) of the upright segments or may be positioned on the same side of each upright segment, such as on the right-hand side as shown in FIG. 1 or on the left-hand side (not shown) with free end of one flange pointing in a direction opposite to the free end of the other flange.

Positioning of inlays 16 or platelets 17 relative to the heat sink, determines the direction in which the respective free ends 13 will be facing and/or the response to increased heat flow. For TCEs with $\alpha_1 < \alpha_2$, positioning of the platelets 17 on the outside of the heat sink, as is shown in FIG. 2, requires free ends 13 to be on the inside of the heat sink. A similar situation would arise if both inlays 16 were on the outside of the heat sink. Positioning of both inlays 16 or platelets 17 on the inside of the heat sink and $\alpha_1 < \alpha_2$ would require free ends 13 to face outwardly of the heat sink. Other arrangement would result either in configuration shown in FIG. 1, or with opposite positioning of inlays 16 or platelets 17 in a configuration (not shown) opposite to that of FIG. 1. Similarly, a different relation in respective TCEs (e.g. $\alpha_1 > \alpha_2$) could lead to other predictable arrangements. These variations in configurations could be useful in designing an architecture of a circuit including devices with such heat sinks.

The structure may additionally be stabilized against possible warpage and/or delamination damage due to the disparity between the TCE of heat sink 6 and TCE of element 3. One efficient manner for achieving the stabilization is disclosed in the application U.S. Serial No.07/599947 on October 19, 1990 (Dahringer, D. W. Case 5). Use of that invention is shown in FIGs. 3 and 4 wherein similar numbers identify similar parts already disclosed in connection with FIGs. 1 and 2. The stabilization is achieved by placing onto the bottom portion 6 and within heat sink 4 a stress-balancing insert, 18, having a TCE different from the TCE of the material of the heat sink and, preferably, equal to the TCE of the material of element 3. The stress-balancing insert may be of the same material as element 3, e.g. it may be a semiconductor chip, such as a "dummy" chip or may be

of another suitable material with a TCE different from or equal to the TCE of element 3. The insert may be secured to bottom portion 6 of the heat sink in any conventional fashion, such as by means of an adhesive which is preferably similar to adhesive 12.

Claims

1. An article comprising
   an element (3) mounted on a surface of a support base (2),
   a heat spreader (7) arranged at a spaced distance from the element for dissipating heat energy,
   a metal heat sink (4) arranged between the element and the heat spreader for conducting the said heat energy from the element to the heat spreader, the heat sink being of a high heat-conductivity material, the heat sink having a bottom portion attached to the element and at least one heat-conducting flange (8) for conducting the heat energy to the heat spreader,
   each heat-conducting flange (8) including
   a) a first segment (9) projecting from the bottom portion of the heat sink,
   b) a free-end segment (10) arranged at an acute angle to the first segment (9) and normally pointing away from the heat spreader, and
   c) a knee-bend segment (11) interconnecting the first segment and the free-end segment, characterised in that said first segment is an upright segment, and
   a thermostat formed by a metal of the flange having a preselected coefficient of thermal expansion, α_2, and another metal having a different preselected coefficient of thermal expansion α_1, said other metal being an inlay (16) in the flange or a platelet (17) attached to the flange wherein α_1 and α_2 are preselected to cause movement of the free end segment toward or away from the heat spreader in response to an increase or decrease respectively in an operating temperature of the element.

2. The article of claim 1, in which said inlay is in said upright segment.

3. The article of claim 1, in which said platelet is attached to said upright segment.

4. The article of claim 3, in which $\alpha_1<\alpha_2$, and said other metal with α_1 is on the side of the upright segment opposite the free-end segment or $\alpha_1<\alpha_2$, and said other metal with α_1 is on the same side of the upright segment as the free-end segment.

5. The article of claim 1 in which said thermostat causes the free-end segment to be in maximum contact with the heat spreader in response to a preselected value of temperature.

6. The article of claim 1 in which the knee bend segment is in contact with the heat spreader.

7. The article of claim 1 in which the heat-sink has a U-shaped cross section.

8. The article of claim 1 in which the heat-sink has a plurality of flanges 8.

9. The article of claim 1 in which the metal of the heat sink is selected from the group of metals consisting of aluminum, copper, nickel, their alloys, bronze, brass, stainless steel.

10. The article of claim 1 in which said other metal is selected from the group of metals consisting of Kovar (RTM), Invar (RTM), Monel (RTM), and nickel.

11. The article of claim 2 in which the material of the heat sink comprises aluminum and the material of the other metal forming the thermostat is Invar (RTM).

Patentansprüche

1. Gegenstand mit folgenden Merkmalen:
   ein Element (3) , das auf der Oberfläche einer Trägerplatte (2) befestigt ist,
   ein Wärmeverteiler (7), der in einem bestimmten Abstand von dem Element angeordnet ist, um die

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of another suitable material with a TCE different from or equal to the TCE of element 3. The insert may be secured to bottom portion 6 of the heat sink in any conventional fashion, such as by means of an adhesive which is preferably similar to adhesive 12.

Claims

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   a thermostat formed by a metal of the flange having a preselected coefficient of thermal expansion, α_2, and another metal having a different preselected coefficient of thermal expansion α_1, said other metal being an inlay (16) in the flange or a platelet (17) attached to the flange wherein α_1 and α_2 are preselected to cause movement of the free end segment toward or away from the heat spreader in response to an increase or decrease respectively in an operating temperature of the element.

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   ein Wärmeverteiler (7), der in einem bestimmten Abstand von dem Element angeordnet ist, um die

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Wärmeenergie abzuleiten,

eine metallische Wärmesenke (4), die zwischen dem Element und dem Wärmeverteiler angeordnet ist, um die Wärmeenergie von dem Element zu dem Wärmeverteiler zu leiten und aus einem hochwärmeleitfähigen Material besteht,

ein an dem Element befestigtes Bodenteil und mindestens ein wärmeleitendes Seitenteil (8) besitzt, das die Wärmeenergie zu dem Wärmeverteiler weiterleitet;

jedes wärmeleitende Seitenteil (8) enthält

a) ein erstes Segment (9), das von dem Bodenteil der Wärmesenke absteht,

b) ein Segment mit freiem Ende (10), das in spitzem Winkel zu dem ersten Segment (9) angeordnet ist und normalerweise von dem Wärmeverteiler wegzeigt, und

c) ein knieartig gebogenes Segment (11), das das erste Segment und das Segment mit freiem Ende verbindet;

dadurch gekennzeichnet, daß

das erste Segment vertikal ausgerichtet ist und daß ein Thermostat vorgesehen ist, der aus dem Metall des Seitenteils mit einem vorgewählten Wärmeausdehnungskoeffizienten α_2 und einem anderen Metall mit einem anderen vorgewählten Wärmeausdehnungskoeffizienten α_1 besteht; dabei kann das andere Metall ein Einsatz (16) in dem Seitenteil oder ein Plättchen (17) sein, das an dem Seitenteil angebracht wird, wobei α_1 und α_2 so vorgewählt sind, daß in Abhängigkeit einer steigenden bzw. fallenden Temperatur des Elementes eine Bewegung des Segmentes mit dem freien Ende, entweder in Richtung des Kühlverteilers oder von dem Kühlverteiler weg, bewirkt wird.

2. Gegenstand nach Anspruch 1, bei dem der Einsatz in dem vertikalen Segment sitz.

3. Gegenstand nach Anspruch 1, bei dem das Plättchen an dem vertikalen Segment befestigt ist.

4. Gegenstand nach Anspruch 3, bei dem $\alpha_1 < \alpha_2$ ist und das andere Metall mit α_1 an der Seite des vertikalen Segmentes gegenüber dem Segment mit freiem Ende angeordnet ist, oder $\alpha_1 < \alpha_2$ ist und das andere Metall mit $\alpha 1$ an der gleichen Seite des vertikalen Segmentes wie das Segment mit freiem Ende befestigt ist.

5. Gegenstand nach Anspruch 1, bei dem der Thermostat bei einer bestimmten, vorgewählten Temperatur den maximalen Kontakt zwischen dem Segment mit dem freien Ende und dem Wärmeverteiler herstellt.

6. Artikel nach Anspruch 1, bei dem das gebogene Segment den Wärmeverteiler berührt.

7. Gegenstand nach Anspruch 1, bei dem die Wärmesenke einen U-förmigen Querschnitt aufweist.

8. Gegenstand nach Anspruch 1, bei dem die Wärmesenke mehrere Seitenteile aufweist.

9. Gegenstand nach Anspruch 1, bei dem das Metall des Kühlkörpers aus der Gruppe von Metallen gewählt wird, die aus Aluminium, Kupfer, Nickel, deren Legierungen, Bronze, Messing und Edelstahl bestehen.

10. Gegenstand nach Anspruch 1, bei dem das andere Metall aus der Gruppe von Metallen ausgewählt wird, die aus Kovar (Wz), Invar (Wz), Monel (Wz) und Nickel bestehen.

11. Gegenstand nach Anspruch 2, bei dem das Material der Wärmesenke Aluminium enthält und das Material des anderen Metalls, das den Thermostat bildet, aus Invar (Wz) besteht.

Revendications

1. Un article comprenant

un élément (3) monté sur une surface d'une base de support (2),

un dispositif de dispersion de chaleur (7) disposé à distance de l'élément, pour dissiper de l'énergie thermique,

un dissipateur de chaleur (4) en métal, disposé entre l'élément et le dispositif de dispersion de chaleur, pour conduire l'énergie thermique de l'élément vers le dispositif de dispersion de chaleur, le dissipateur de chaleur consistant en un matériau à conductivité thermique élevée, le dissipateur de chaleur

ayant une partie inférieure fixée à l'élément et au moins une aile conductrice de la chaleur (8) pour conduire l'énergie thermique vers le dispositif de dispersion de chaleur,

chaque aile conductrice de la chaleur (8) comprenant

a) un premier segment (9) qui s'étend à partir de la partie inférieure du dissipateur de chaleur,

b) un segment d'extrémité libre (10) disposé sous un angle aigu par rapport au premier segment (9) et pointant normalement dans un sens qui s'éloigne du dispositif de dispersion de chaleur, et

c) un segment de coude (11) reliant le premier segment et le segment d'extrémité libre, caractérisé en ce que le premier segment est un segment vertical, et

il existe un thermostat formé par un métal de l'aile ayant un coefficient de dilatation thermique présélectionné, α_2, et par un autre métal ayant un coefficient de dilatation thermique présélectionné différent, α_1, cet autre métal consistant en une incrustation (16) dans l'aile ou en une plaquette (17) fixée sur l'aile, α_1 et α_2 étant présélectionnés pour produire un mouvement du segment d'extrémité libre vers le dispositif de dispersion de chaleur ou dans la direction opposée, sous l'effet respectivement d'une augmentation ou d'une diminution d'une température de fonctionnement de l'élément.

2. L'article de la revendication 1, dans lequel l'incrustation se trouve dans le segment vertical.

3. L'article de la revendication 1, dans lequel la plaquette est fixée sur le segment vertical.

4. L'article de la revendication 3, dans lequel $\alpha_1<\alpha_2$, et l'autre métal avec α_1 se trouve du côté du segment vertical qui est opposé au segment d'extrémité libre, ou bien $\alpha_1 > \alpha_2$ et l'autre métal avec α_1 se trouve du même côté du segment vertical que le segment d'extrémité libre.

5. L'article de la revendication 1, dans lequel le thermostat fait en sorte que le segment d'extrémité libre soit en contact maximal avec le dispositif de dispersion de chaleur sous l'effet d'une valeur de température présélectionnée.

6. L'article de la revendication 1, dans lequel le segment de coude est en contact avec le dispositif de dispersion de chaleur.

7. L'article de la revendication 1, dans lequel le dissipateur de chaleur a une section transversale en forme de U.

8. L'article de la revendication 1, dans lequel le dissipateur de chaleur comporte un ensemble d'ailes (8).

9. L'article de la revendication 1, dans lequel le métal du dissipateur de chaleur est sélectionné dans le groupe de métaux comprenant l'aluminium, le cuivre, le nickel, leurs alliages, le bronze, le laiton et l'acier inoxydable.

10. L'article de la revendication 1, dans lequel l'autre métal est sélectionné dans le groupe de métaux comprenant le Kovar (marque déposée), l'Invar (marque déposée), le Monel (marque déposée) et le nickel.

11. L'article de la revendication 2, dans lequel le matériau du dissipateur de chaleur consiste en aluminium et le matériau de l'autre métal formant le thermostat consiste en Invar (marque déposée).