METHOD AND COMPOSITIONS FOR REMOVING MICROELECTRONIC COMPONENTS FROM CIRCUIT BOARDS

This invention relates to materials and methods for removing components which have been soldered to other distinct components, or directly to a printed circuit board, using one or more connection materials, each such connection material having a particular melting temperature. For a given connection material, a removal material is comprised of at least one metallic constituent having a given melting temperature such that when contacted to the connection material, it can form an alloy having an alloy melting temperature below the particular melting temperature. This alloy melting temperature may be above or below the given melting temperature, and may be above or below room temperature. Heating above this alloy melting temperature results in at least partial melting of the connection material, allowing the removal of the soldered component at temperatures below the particular melting temperature.
METHOD AND COMPOSITIONS FOR REMOVING MICROELECTRONIC
COMPONENTS FROM CIRCUIT BOARDS

CROSS REFERENCE TO RELATED U.S APPLICATION

This patent application relates to, and claims the priority benefit from, United States Provisional Patent Application Serial No. 61/476,830 filed on April 19, 2011, entitled "METHOD FOR REMOVING ELECTRICAL COMPONENTS FROM CIRCUIT BOARDS" which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

This invention relates to materials and methods for removing one or more components from printed circuit boards (PCB), in which the components have been soldered to other distinct components, or directly to the printed circuit boards, using one or more solders.

BACKGROUND

The rework and removal of electrical components, although undesired, is common practice within the microelectronics industry. It is common to rework an existing electrical component that has ceased functioning properly (possibly due to solder joint fatigue and failure), or remove a component and replace it. To comply with the Restriction of Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) directives, the microelectronics industry transformed from using a conventional Pb-Sn eutectic solder, to any number of Pb-free solders.

The primary Pb-free solders adopted by the microelectronics industry have melting temperatures that are higher than conventional Pb-Sn eutectic solder, and as a result require higher furnace and reflow temperatures during the soldering process. As a result, the temperature for any subsequent rework has had to be increased accordingly to accommodate the increased melting temperature of the adopted Pb-free solder materials. The material used to produce the printed circuit boards (frequently FR-4 Epoxy Resin) has a glass transition temperature ($T_g$) ranging from 120°C to 180°C depending on resin
chemistry, and as a result, may be damaged after multiple heating steps to the high temperatures required for Pb-free solder processing. This high temperature cycling (as a result of soldering and rework steps) can cause the FR-4 to degrade, delaminate, and warp. This increased temperature can also have an adverse effect on the microelectronic components, and can cause chip failure.

U.S. Pat. No. 3,210,822 discloses a method for salvaging components soldered to a printed circuit board, and for the selective removal of tin-lead solder projecting in excess beyond a desired plane. The method comprises heating a fusible quaternary alloy of bismuth-lead-tin-cadmium above its melting point, dipping a printed circuit board into a molten bath of said fusible alloy for a short time thereby dissolving said tin-lead solder, removing the printed circuit board from the molten bath, and if desired pulling the components from the printed circuit board.

U.S. Pat. No. 5,326,016 discloses a method for the removal of individual surface mounted electrical components from a printed circuit board. The method includes the steps of obtaining a removal alloy composed of a plurality of constituent metals, heating the removal alloy to a temperature above its melting point so as to produce a molten state thereof, contacting the connection alloy on all of the leads with the molten removal alloy and causing thereby a reaction producing a molten state for the connection alloy; and separating the individual component from the printed circuit board.

A further understanding of the functional and advantageous aspects of the invention can be realized by reference to the following detailed description.

SUMMARY

Disclosed herein is a method and a material for removing one or more soldered components from printed circuit boards, the components having been soldered, using one or more solders, to a printed circuit board, or soldered to other components on the circuit board.

An embodiment is provided of a method of removing a soldered component, the component being soldered to a printed circuit board, or to a distinct component by a connection material. The connection material is
comprised of at least one metallic constituent, the connection material having
a particular melting temperature. The method comprises, for a given
connection material, identifying a removal material that reacts in situ with at
least one metallic constituent of the connection material to produce at least a
partially molten state in the connection material without the use of heating.
The method includes contacting the removal material to the connection
material on each of the solder connections holding said component to the
circuit board or to the distinct component thereby causing the in situ reaction
between the removal material and the connection material to produce the at
least partially molten state for the connection material. Once this occurs, the
component may be separated from the printed circuit board, or from the
distinct component.

In another embodiment of the method, for a given connection material,
having a particular melting temperature, the method includes identifying a
removal material comprised of at least one metallic constituent having a given
melting temperature such that when contacted to the connection material, it
can form an alloy having an alloy melting temperature below both the given
melting temperature and the particular melting temperature. The removal
material is contacted to the connection material on each of the solder
connections holding the component to the circuit board or to the distinct
component. The connection material is heated, before or after it is contacted
by the removal material, to a temperature below the given melting
temperature and the particular melting temperature, but above the alloy
melting temperature thereby causing an in situ reaction between the removal
material and the connection material to produce at least a partially molten
state for at least the connection material. The component is then removed.

In another embodiment, for a given connection material, having a
particular melting temperature, the method includes identifying a removal
material comprised of a single metal only selected from the group consisting
of Bismuth, Gallium, Indium, and Tin, the removal material having a given
melting temperature. The removal material is contacted to the connection
material on each of the solder connections holding the component to the
circuit board or to the distinct component. The connection material is heated,
before or after it is contacted by the removal material, to a temperature above
the given melting temperature, but below the particular melting temperature, to produce a molten state for the removal material, thereby causing an in situ reaction between the molten removal material and the connection material to produce at least a partially molten state for the connection material. The component is then removed.

The present invention provides a removal material for reducing a melting temperature of a solder connection, wherein the removal material is a mixture of two or more constituent metals, the constituent metals being chosen such that the removal material is at least partially liquid at, around or below room temperature. The mixture of two or more constituent metals may be comprised of Gallium and at least one other constituent metal, wherein said at least one other constituent metal is present in an amount such that the melting point of the mixture does not exceed room temperature.

The present invention further provides a removal material for reducing a melting temperature of a solder connection upon heating to a temperature below the melting temperature of the material forming the solder connection, wherein the removal material is a single metal selected from the group consisting of Bismuth, Gallium, Indium, and Tin, and wherein the solder connection includes a solder selected from the group of lead containing solders and lead-free solders.

The present invention provides a removal material for reducing a melting temperature of a solder connection upon heating to a temperature below the melting temperature of the material forming the solder connection, and below the melting temperature of the removal material, wherein the removal material is a mixture of two or more constituent metals, the mixture chosen to cause a reaction when in contact with the solder connection, to reduce the material forming the solder connection to at least a partially molten state.
DETAILED DESCRIPTION

Generally speaking, the embodiments described herein are directed to methods and compositions for removing one or more components from printed circuit boards (either bonded to other components or directly to the circuit board). As required, embodiments of the present invention are disclosed herein. However, the disclosed embodiments are merely exemplary, and it should be understood that the invention may be embodied in many various and alternative forms.

For purposes of teaching and not limitation, the illustrated embodiments are directed to a method for removing components bonded to other distinct components on a circuit board, or bonded directly to a circuit board.

As used herein, the term "about" and "around", when used in conjunction with ranges of dimensions, temperatures or other physical properties or characteristics is meant to cover slight variations that may exist in the upper and lower limits of the ranges of dimensions so as to not exclude embodiments where on average most of the dimensions are satisfied but where statistically dimensions may exist outside this region. For example, in embodiments of the present invention weight percentages (w\%\) of Indium are given but it will be understood that these are not meant to be limiting. Additionally, weight percentages stated for constituents of a removal material are assumed to be stated relative to the total metals content of the material, and these percentages do not account for the weight fraction of any chemical additives that may be included with the removal material.

The traditional approach to microelectronics rework and component removal involves the application of heat sufficient to melt the connection solder material, coupled with the use of a solder vacuum nozzle or solder wick to remove the molten connection solder from the leads of the microelectronic component. The component may be removed before or after the molten connection solder has been removed.

The present disclosure provides a method for removing components from printed circuit boards, the components having been soldered to other
distinct components or directly to the circuit boards using any number of solders, with the use of a secondary material, herein referred to as removal material. The removal material is added to the surface of the solder joints, and heat may be applied to the PCB to facilitate the interaction between the removal material and the existing connection solder. The interaction between the removal material and connection solder results in the melting of at least a portion of the connection solder, allowing for the desired component to be removed from the PCB at temperatures much lower than traditional rework allows.

The methodologies and accompanying non-limiting examples given below are purely exemplary in nature and are not meant to limit the present invention in any way.

Not to be limited by any theory or theorem, it is believed that the mechanism by which a reaction occurs between a removal material and a connection material, is an in situ reaction driven by a diffusion mechanism between the removal material and the connection material, resulting in the formation of a new phase of matter, and a change in the melting behaviour of one or both of the removal material and the connection material.

**Removing A Component With No Heating**

An embodiment provides a method of removing a soldered component, the component soldered to a printed circuit board, or to a distinct component by a connection material comprised of at least one metallic constituent having a particular melting temperature. For a given connection material, the method involves identifying a removal material that reacts in situ with at least one metallic constituent of the connection material to produce at least a partially molten state in the connection material without the use of heating. The removal material is contacted to the connection material on each of the solder connections holding the component to the circuit board or the distinct component thereby causing the in situ reaction between the removal material and the connection material to produce at least a partially molten state for the connection material; thereby allowing removal of the component from the other component or from the circuit board.
The removal material may be a mixture of two or more constituent metals, the constituent metals being chosen such that the removal material is at least partially liquid at, around or below room temperature. As used herein, referring to "room temperature" may include temperatures several degrees above room temperature but not above 30 degrees Celsius.

In an embodiment, the mixture of two or more constituent metals is comprised of Gallium and at least one or more other constituent metals, the other constituent metal(s) are chosen, and are present in an amount, such that the melting point of the mixture does not exceed room temperature. Any other metal that satisfies this requirement may be present in the removal material.

**Example 1 - Removal Material Being A Pure Metal, No Heating**

In an exemplary embodiment, a surface mounted quad flat pack (QFP) integrated circuit (IC) is to be removed from a PCB, the leads of which have been soldered using a Tin-Silver-Copper (SAC-305) solder which has a melting point of 217°C. The removal material is chosen to be Gallium, which has a melting point of 29.8°C and is present as a solid at room temperature. The surfaces of the connecting QFP leads on the PCB are cleaned using techniques standard in the art and solid Gallium removal material in the form of flakes/pieces are placed onto these cleaned surfaces. Chemical fluxes standard in the art may be used to assist interaction between the Gallium and the SAC-305. Rubbing of the removal material along the leads of the IC may be required to promote interaction between the Gallium and the connecting SAC-305 solder, resulting in dissolution of both the Gallium flakes/pieces and SAC-305 solder joints through the formation of Gallium-Tin (-1 3.5 wt% Tin) eutectic at each SAC-305 solder bond. After a period of time, the SAC-305 joints are molten and the IC may be removed from the PCB.

If Gallium is the connecting material, then Indium or Tin may be used as the removal material. When the connecting material is Indium or Tin (or any alloy thereof) only Gallium will work as the removal material.

**Example 2 - Removal Material Being A Metal Alloy, No Heating**
In another exemplary embodiment, a through-hole mounted dual in-line package (DIP) IC is to be removed from a PCB, the leads of which have been soldered using SAC-305 solder which has a melting point of 217°C. The removal material is chosen to be a eutectic alloy of Gallium and Indium (-21 wt% Indium), which has a melting point of 15°C. This means no external heating is required to bring about a molten state for the Gallium-Indium removal material. It should be noted that any alloy of Gallium and Indium with a composition ranging from ~5 wt% to ~25 wt% Indium will be present as a liquid at room temperature. The surfaces of the connecting pin-through-hole (PTH) leads on both sides of the PCB are cleaned using techniques standard in the art and the molten Gallium-Indium removal material is dispensed onto these cleaned surfaces using a syringe. Once the leads of the IC to be removed are coated with the removal material, it is set aside to sit at room temperature for approximately 30-60 minutes. During this time, dissolution of the SAC-305 solder joints occurs through interaction with the molten Gallium-Indium removal material, after which the IC may be removed from the PCB.

Removing A Component With Heating Below \( T_m \) And \( T_{\text{Solder}} \), But Above \( T_{\text{MA}} \)

In another embodiment, there is provided a method of removing a soldered component, the component soldered to a printed circuit board, or to a distinct component by a connection material comprised of at least one metallic constituent, the connection material having a particular melting temperature.

For a given connection material, the method includes identifying a removal material comprised of at least one metallic constituent having a given melting temperature such that when contacted to the connection material, it can form an alloy having an alloy melting temperature below both the given melting temperature and the particular melting temperature. The removal material is contacted to the connection material on each of the solder connections holding the component to the circuit board or to the distinct component. The connection material is heated, before or after it is contacted by the removal material, to a temperature below the given melting temperature and the particular melting temperature, but above the alloy...
melting temperature thereby causing an in situ reaction between the removal material and the connection material to produce at least a partially molten state for at least the connection material. The component is then removed.

Example 3 - Removal Material Being A Pure Metal, Heated \( T_{ma} < T_{heat} < T_m \)

In another exemplary embodiment of the present invention, it is desired to remove a small outline integrated circuit (SOIC) that has been surface mounted to a PCB using SAC-305 solder which has a melting point of 217°C.

The removal material is chosen to be Indium which has a melting point \( T_m \) of 156°C, and is in wire form. The surface of the connecting leads and solder are cleaned using techniques standard in the art, and fluxed Indium wire pieces are placed along the leads of the SOIC. Using a temperature controlled heating stage the area of the PCB containing the SOIC to be removed is heated to a peak temperature, \( T_{heat} \), of 130°C, which is above the melting point, \( T_{ma} \), of an alloy that forms between the connecting solder and the removal material, but below the melting point, \( T_m \), of the removal material.

Upon heating to peak temperature, the Indium wire begins to interact with the existing SAC-305 solder joint, promoting dissolution of said solder joint through the formation of a Tin-Indium eutectic alloy, which has a \( T_{ma} \) of 118°C. After several minutes the desired SOIC may be removed from the surface of the PCB.

Example 4 - Removal Material Being A Pure Metal, Heated \( T_{ma} < T_{heat} < T_m \) Applied To A Lead-Containing Connection Alloy

In yet another exemplary embodiment, it is desired to remove a ceramic leaded chip carrier (CLCC) with gullwing leads that has been surface mounted to a circuit board using a Lead-Tin eutectic connection alloy with a melting point of 183°C. The removal material is chosen to be Bismuth which has a melting point \( T_m \) of 271 °C, and is in foil form. The surface of the connecting leads and solder are cleaned using techniques standard in the art, and fluxed Bismuth foil pieces are placed along the gullwing leads of the CLCC. Using a temperature controlled heating stage the area of the PCB containing the CLCC to be removed is heated to a peak temperature, \( T_{heat} \), of
115°C, which is above the melting point, $T_{ma}$, of an alloy that forms between
the connecting solder and the removal material, but below the melting point of
both the removal material, $T_m$, and the connection solder, $T_{solder}$. Upon
heating to peak temperature, the Bismuth begins to interact with the existing
Lead-Tin solder joint, promoting dissolution of said solder joint through the
formation of a Bismuth-Lead-Tin alloy, which has a $T_{ma}$ of 105°C. After
several minutes the desired CLCC may be removed from the surface of the
PCB.

Removing A Component With Heating Above $T_m$, But Below $T_{solder}$

In another embodiment provides a method of removing a soldered
component, the component soldered to a printed circuit board, or to a distinct
component by a connection material comprised of at least one metallic
constituent, the connection material having a particular melting temperature.

For a given connection material, the method includes identifying a
removal material comprised of a single metal only selected from the group
consisting of Bismuth, Gallium, Indium, and Tin, the removal material having a
given melting temperature. The removal material is contacted to the
connection material on each of the solder connections holding the component
to the circuit board or to the distinct component. The connection material is
heated, before or after it is contacted by the removal material, to a
temperature above the given melting temperature, but below the particular
melting temperature, to produce a molten state for the removal material,
thereby causing an in situ reaction between the molten removal material and
the connection material to produce at least a partially molten state for the
connection material. The component is then removed.

Example 5 - Removal Material Being A Pure Metal Heated Above $T_m$ For
A Lead-Free Connection Alloy

In another exemplary embodiment of the present invention, it is desired
to remove a SOIC that has been surface mounted to a PCB using SAC-305
solder which has a melting point of 217°C. The removal material is chosen to
be Indium which has a melting point $T_m$ of 156°C, and may be in wire form.
The surface of the connecting leads and solder are cleaned using techniques
standard in the art, and fluxed Indium wire pieces are placed along the leads of the SOIC. Using a temperature controlled heating stage the area of the PCB containing the SOIC to be removed is heated to a peak temperature of 165°C. Upon heating to peak temperature, the Indium wire melts and begins to interact with the existing SAC-305 solder joint, promoting the dissolution of said solder joint. The Indium wire and SAC-305 solder joint may be molten in as little as one minute, after which the desired SOIC may be removed from the surface of the PCB.

Example 6 - Removal Material Being A Pure Metal Heated Above $T_m$ For Variable Melting Point (VMP) Connection Alloy

In another exemplary embodiment of the present invention, it is desired to remove a quad flat pack (QFP) with gullwing leads that has been surface mounted to a PCB using a variable melting point (VMP) connection solder as described in US. Patent Publication No. 2012/0055586. After initial processing, the VMP connection solder has a melting temperature of ~260°C, and consists of Nickel-Tin intermetallic phase mixed throughout a substantially pure Bismuth matrix. The removal material is chosen to be Indium which has a melting point $T_m$ of 156°C, and is in paste form. The surface of the connecting leads and solder are cleaned using techniques standard in the art and Indium paste is placed along the connecting solder on the leads of the QFP. Using a temperature controlled heat gun the area of the PCB containing the QFP to be removed is heated to a peak temperature of 165°C. Upon heating to peak temperature, the Indium powder in the paste melts and begins to interact with the existing VMP solder joint, promoting the dissolution of said solder joint through the dissolution of the Bismuth matrix. It is not necessary to completely melt the connection solder joint, provided enough of the connection solder is dissolved by the interaction with the removal material to allow for removal of the QFP. The Indium paste and at least a portion of the VMP solder joint may be molten in as little as one minute, after which the desired QFP may be removed from the surface of the PCB.
Example 7 - Removal Material Being A Pure Metal Heated Above $T_m$ Before Applying To Lead-Containing Connection Alloy

In another exemplary embodiment of the present invention, it is desired to remove a ball grid array (BGA) which has been soldered using a connection alloy containing high Lead content, for example, 95 wt% Lead with 5 wt% Tin, which has a melting point, $T_{solder}$, of ~31°C. The removal material is chosen to be Bismuth which has a melting point $T_m$ of 271°C, and is heated prior to application on the high-Lead solder bumps to a temperature, $T_{heat}$, above $T_m$, but below the melting temperature of the high-Lead solder bumps, $T_{solder}$, such that $T_m < T_{heat} < T_{solder}$. Using a hot air nozzle the portion of the circuit board containing the BGA is heated to a temperature of ~140°C, which is above the temperature of an alloy that forms between the Bismuth removal material and the high-Lead containing BGA bumps. The molten Bismuth is dispensed using a heated nozzle via a heat gun to the underside of the BGA chip, whereupon the molten Bismuth reacts with the high-Lead containing BGA bumps, and in as little as 1-2 minutes, the BGA bumps have been dissolved.

Example 8 - Removal Material Being A Pure Metal Heated Above $T_m$ After Applying To Lead-Containing Connection Alloy

In yet another exemplary embodiment of the present invention, it is desired to remove a ball grid array (BGA) which has been soldered using a connection alloy containing high Lead content, for example, 95 wt% Lead with 5 wt% Tin, which has a melting point, $T_{solder}$, of ~31°C. The removal material is chosen to be Bismuth which has a melting point $T_m$ of 271°C. The Bismuth is dispensed to the underside of the BGA in the form of a solder paste, after which a temperature controlled heating stage is used to heat the portion of the circuit board containing the BGA to a temperature, $T_{heat}$, above $T_m$, but below the melting temperature of the high-Lead solder bumps, $T_{solder}$, such that $T_m < T_{heat} < T_{solder}$, whereupon the Bismuth powder present in the paste melts and reacts with the high-Lead containing BGA bumps, and in as little as 1-2 minutes, the BGA bumps have been dissolved.

The foregoing description of the preferred embodiments of the invention has been presented to illustrate the principles of the invention and
not to limit the invention to the particular embodiments illustrated. It is intended that the scope of the invention be defined by all of the embodiments encompassed within the following claims and their equivalents.
THEREFORE, WHAT IS CLAIMED IS:

1. A method of removing a soldered component, said component soldered to a printed circuit board, or to a distinct component by a connection material comprised of at least one metallic constituent, said connection material having a particular melting temperature, the method comprising:
   - for a given connection material, identifying a removal material that reacts in situ with at least one metallic constituent of said connection material to produce at least a partially molten state in said connection material without the use of heating, contacting said removal material to said connection material on each of the solder connections holding said component to said circuit board or to said distinct component thereby causing the in situ reaction between said removal material and said connection material to produce the at least partially molten state for said connection material; and
   - separating said component from said printed circuit board, or from said distinct component.

2. The method according to claim 1 wherein said removal material is a mixture of two or more constituent metals, the constituent metals being chosen such that said removal material is at least partially liquid at, around or below room temperature.

3. The method according to claim 2 wherein said mixture of two or more constituent metals is comprised of Gallium and at least one other constituent metal.

4. The method according to claim 3 wherein said mixture of two or more constituent metals is comprised of Gallium and at least one other constituent metal selected from the group consisting of Cadmium, Indium, Tin and any combination thereof.
5. The method according to claim 4 wherein said mixture of two or more constituent metals is a eutectic alloy.

6. The method according to claim 5 wherein said eutectic alloy is a eutectic alloy of Gallium and Indium.

7. The method according to claim 5 wherein said eutectic alloy is a eutectic alloy of Gallium and Tin (about ~13.5 wt% Tin).

8. The method according to claim 5 wherein said eutectic alloy is a eutectic alloy of Gallium, Indium, and Tin (~22 wt% Indium, ~16 wt% Tin).

9. The method according to claim 1 wherein said removal material is comprised of a single metallic constituent.

10. The method according to claim 9 wherein said single metallic constituent is selected from the group consisting of Gallium, Indium, Tin.

11. A method of removing a soldered component, said component soldered to a printed circuit board, or to a distinct component by a connection material comprised of at least one metallic constituent, said connection material having a particular melting temperature, the method comprising:

   for a given connection material, identifying a removal material comprised of at least one metallic constituent having a given melting temperature such that when contacted to said connection material, it can form an alloy having an alloy melting temperature below both said given melting temperature and said particular melting temperature;

   contacting said removal material to said connection material on each of the solder connections holding said component to said circuit board or to said distinct component;

   heating said connection material, before or after contacting said removal material to said connection material, to a temperature below said given melting
temperature and said particular melting temperature, but above said alloy melting
temperature thereby causing an \textit{in situ} reaction between said removal material
and said connection material to produce at least a partially molten state for at
least said connection material, and
separating said component from said printed circuit board, or separating
said component from said distinct component.

12. The method according to claim 11 wherein said removal material is a
single metal selected from the group consisting of Bismuth, Gallium, Indium, and
Tin.

13. The method according to claim 11 wherein said removal material is a
mixture of at least two metals selected from the group consisting of Bismuth,
Gallium, Indium, Tin.

14. The method according to claim 11 wherein said removal material is an
alloy of at least two constituent metals selected from the group consisting of
Bismuth, Gallium, Indium, Tin.

15. A method of removing a soldered component, said component soldered to
a printed circuit board, or to a distinct component by a connection material
comprised of at least one metallic constituent, said connection material having a
particular melting temperature, the method comprising:

for a given connection material, identifying a removal material comprised
of a single metal only selected from the group consisting of Bismuth, Gallium,
Indium, and Tin, said removal material having a given melting temperature;

contacting said removal material to said connection material on each of
the solder connections holding said component to said circuit board or to said
distinct component;

heating said connection material, before or after contacting said removal
material to said connection material, to a temperature above said given melting
temperature, but below said particular melting temperature, to produce a molten
state for said removal material, thereby causing an _in situ_ reaction between said molten removal material and said connection material to produce at least a partially molten state for said connection material, and separating said component from said printed circuit board, or separating said component from said distinct component.

16. The method according to claim 15 including heating of the removal material prior to contacting said removal material to said connection material.

17. A removal material for reducing a melting temperature of a solder connection, wherein said removal material is a mixture of two or more constituent metals, the constituent metals being chosen such that said removal material is at least partially liquid at, around or below room temperature.

18. The removal material according to claim 17 wherein said mixture of two or more constituent metals is comprised of Gallium and at least one other constituent metal, and wherein said at least one other constituent metal is present in an amount, such that the melting point of the mixture does not exceed room temperature.

19. A removal material for reducing a melting temperature of a solder connection upon heating to a temperature below the melting temperature of the material forming said solder connection, wherein said removal material is a single metal selected from the group consisting of Bismuth, Gallium, Indium, and Tin, and wherein said solder connection includes a solder selected from the group of lead containing solders and lead-free solders.

20. A removal material for reducing a melting temperature of a solder connection upon heating to a temperature below the melting temperature of the material forming said solder connection, and said removal material, wherein said removal material is a mixture of two or more constituent metals, said mixture
chosen to cause a reaction when in contact with said solder connection, to reduce the material forming said solder connection to at least a partially molten state.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC: B23K 1/018 (2006.01) , C23F 8/04 (2006.01)

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)
IPC (2006.01): B23K, C23F, H01L, H05K

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

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

EPOQIJE, TotalPatent, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US201 1240716A1 (ZTNN et al.) 06 October 2011 (06-10-2011) &quot;full document*&quot;</td>
<td>1-3, 9-17, 19, 20</td>
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<td>A</td>
<td>US4398975A (OHSAWA et al.) 16 August 1983 (16-08-1983) &quot;full document*&quot;</td>
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[X] Further documents are listed in the continuation of Box C.  [X] See patent family annex.

Date of the actual completion of the international search 24 June 2012 (24-06-2012)

Date of mailing of the international search report 04 September 2012 (04-09-2012)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 001-819-953-2476

Authorized officer
Zoran Novakovic (819) 956-0843
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<td>US5871139A (MOYER) 16 February 1999 (16-02-1999) <em>full document</em></td>
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**INTERNATIONAL SEARCH REPORT**

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of the first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claim Nos. :
   because they relate to subject matter not required to be searched by this Authority, namely:

2. [ ] Claim Nos. :
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claim Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see Supplemental Box

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [X] As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claim Nos. :

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim Nos. :

**Remark on Protest**

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.
The claims are directed to a plurality of inventive concepts as follows:

Group A - Claims 1-10 are directed to a method of removing a soldered component, said component soldered to a printed circuit board by a connection material comprised of at least one metallic constituent, said connection material having a particular melting temperature, the method comprising: for a given connection material, identifying a removal material that reacts in situ with at least one metallic constituent of said connection material to produce at least a partially molten state in said connection material without the use of heating, contacting said removal material to said connection material on each of the solder connections holding said component to said circuit board or to said distinct component thereby causing the in situ reaction between said removal material and said connection material to produce the at least partially molten state for said connection material: and separating said component from said printed circuit board.

Group B - Claims 11-14, 20 are directed to a removal material and a method of removing a soldered component, said component soldered to a printed circuit board by a connection material comprised of at least one metallic constituent, said connection material having a particular melting temperature, the method comprising: for a given connection material, identifying said removal material comprised of at least one metallic constituent having a given melting temperature such that when contacted to said connection material, it can form an alloy having an alloy melting temperature below both said given melting temperature and said particular melting temperature: contacting said removal material to said connection material on each of the solder connections holding said component to said circuit board or to said distinct component: heating said connection material, before or after contacting said removal material to said connection material, to a temperature below said given melting temperature and said particular melting temperature, but above said alloy melting temperature thereby causing an in situ reaction between said removal material and said connection material to produce at least a partially molten state for at least said connection material, and separating said component from said printed circuit board.

Group C - Claims 15, 16, 19 are directed to a removal material and a method of removing a soldered component, said component soldered to a printed circuit board by a connection material comprised of at least one metallic constituent, said connection material having a particular melting temperature, the method comprising: for a given connection material, identifying said removal material comprised of a single metal only selected from the group consisting of Bismuth, Gallium, Indium, and Tin. said removal material having a given melting temperature: contacting said removal material to said connection material on each of the solder connections holding said component to said circuit board or to said distinct component: heating said connection material, before or after contacting said removal material to said connection material, to a temperature above said given melting temperature, but below said particular melting temperature, to produce a molten state for said removal material, thereby causing an in situ reaction between said molten material and said connection material to produce at least a partially molten state for said connection material, and separating said component from said printed circuit board.

Group D - Claim 17 is directed to a removal material for reducing a melting temperature of a solder connection, wherein said removal material is a mixture of two or more constituent metals, the constituent metals being chosen such that said removal material is at least partially liquid at, around or below room temperature.

Claims of groups A and D are vaguely sharing the same inventive feature.

The claims must be limited to one inventive concept as set out in Rule 13 of the PCT.
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