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(54) **METAL PATCH, METHOD FOR MANUFACTURING THE SAME AND BONDING METHOD BY USING THE SAME**

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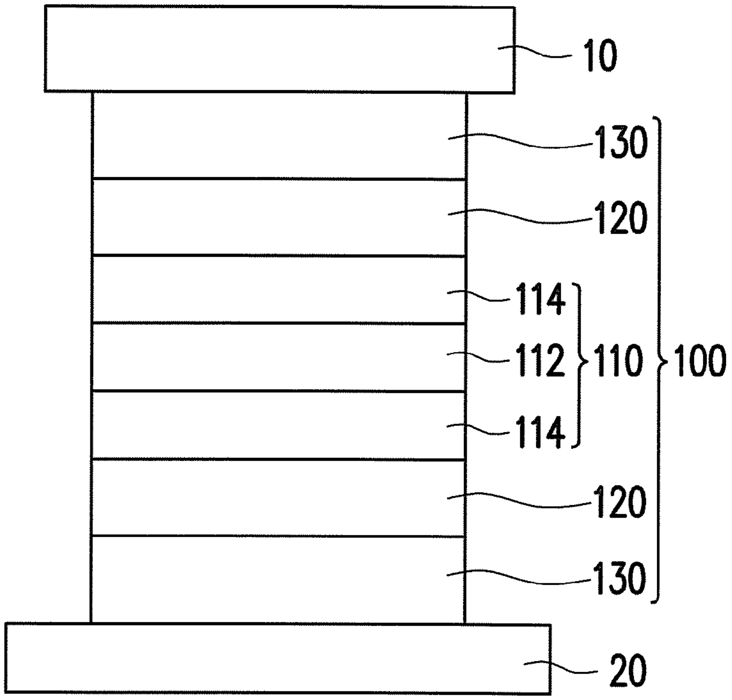
(57) **ABSTRACT**

A metal patch suitable for connecting a high-power element and a substrate is provided. The metal patch includes an intermediate metal layer, two first metal layers, and two second metal layers. The first metal layers are respectively disposed on two opposite surfaces of the intermediate metal layer. The intermediate metal layer is located between the first metal layers. The melting point of each of the first metal layers is greater than 800° C. The second metal layers are respectively disposed on the first metal layers. The intermediate metal layer and the first metal layers are located between the second metal layers. The material of each of the second metal layers includes an indium-tin alloy. Each of the first metal layers and the corresponding second metal layer can generate an intermetal via a solid-liquid diffusion reaction.



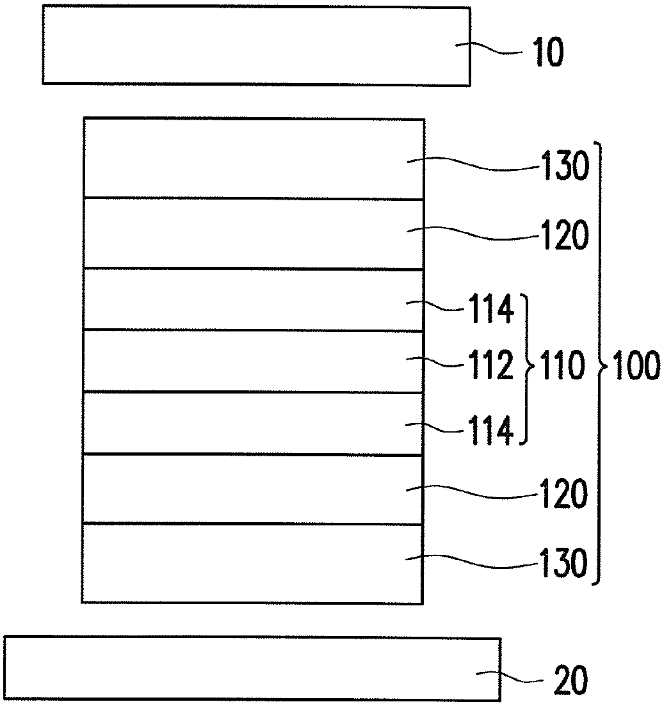

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FIG. 1A

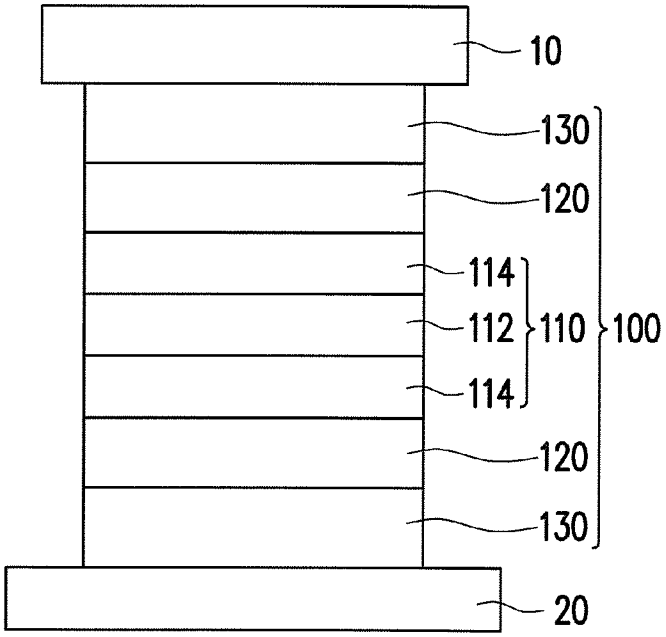
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FIG. 1B

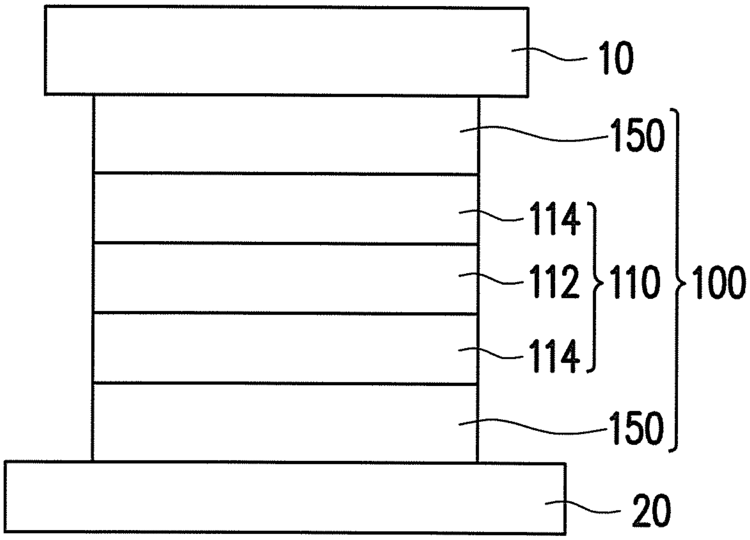

FIG. 1C

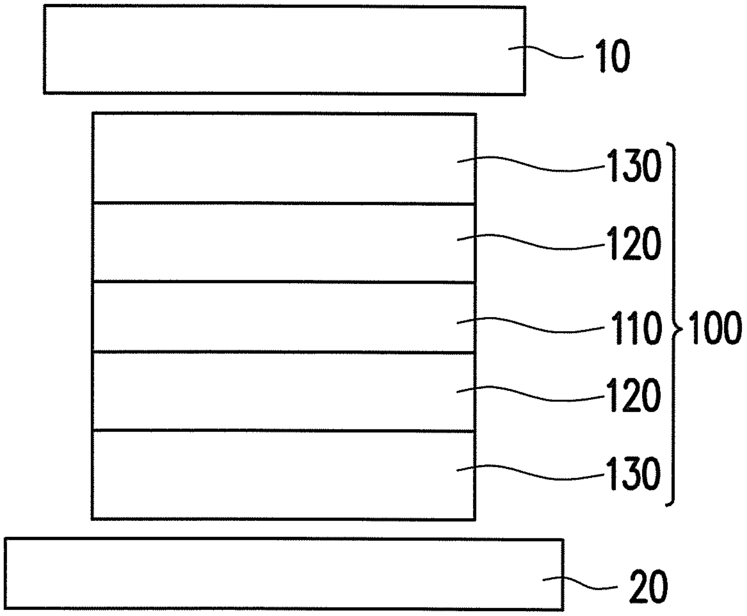

FIG. 2A

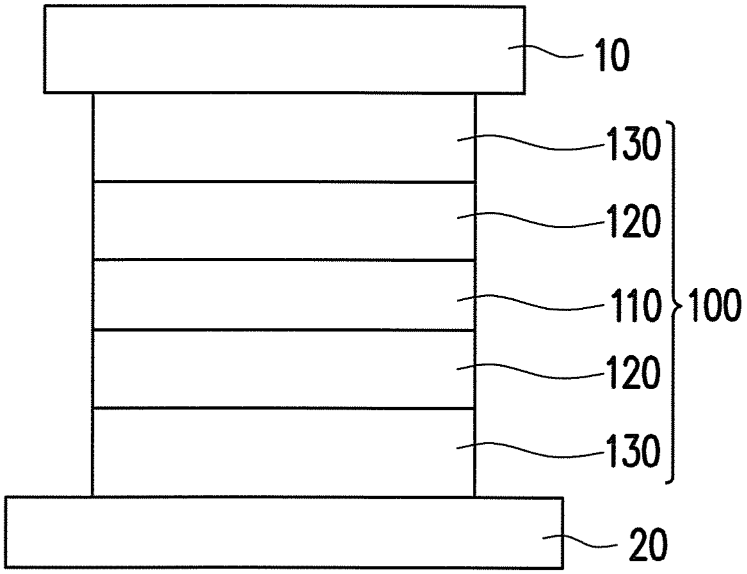

FIG. 2B

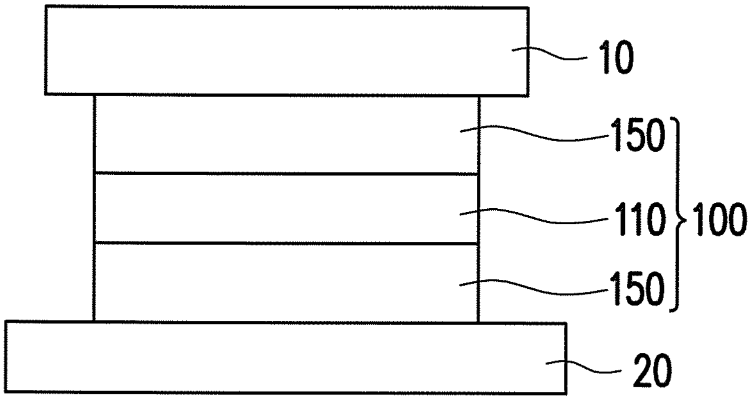

FIG. 2C

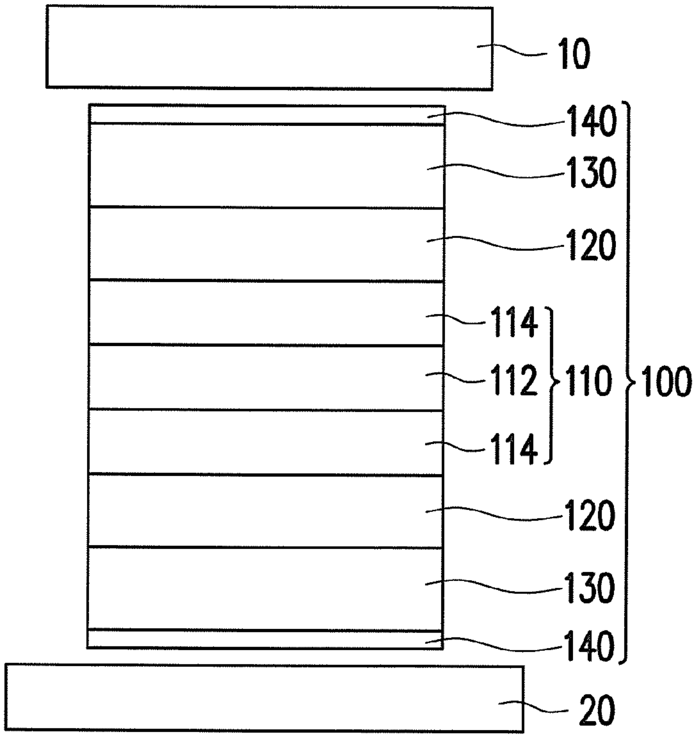
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FIG. 3A

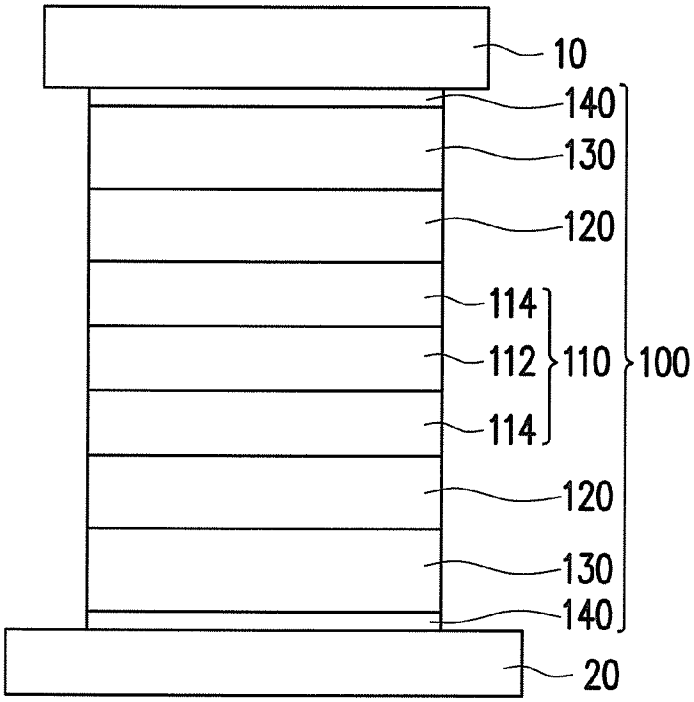
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FIG. 3B

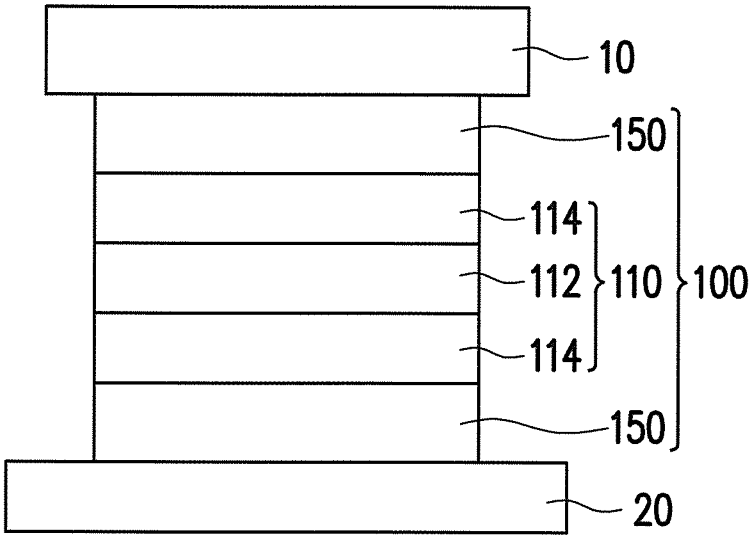

FIG. 3C

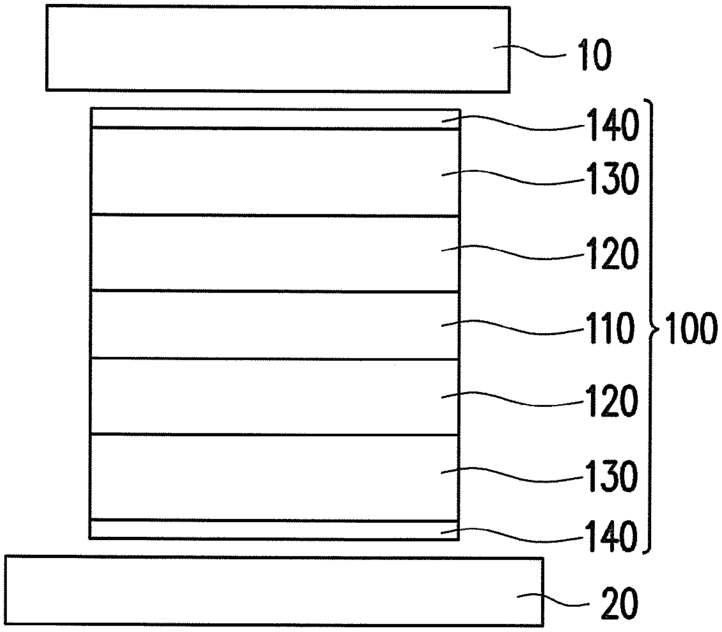
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FIG. 4A

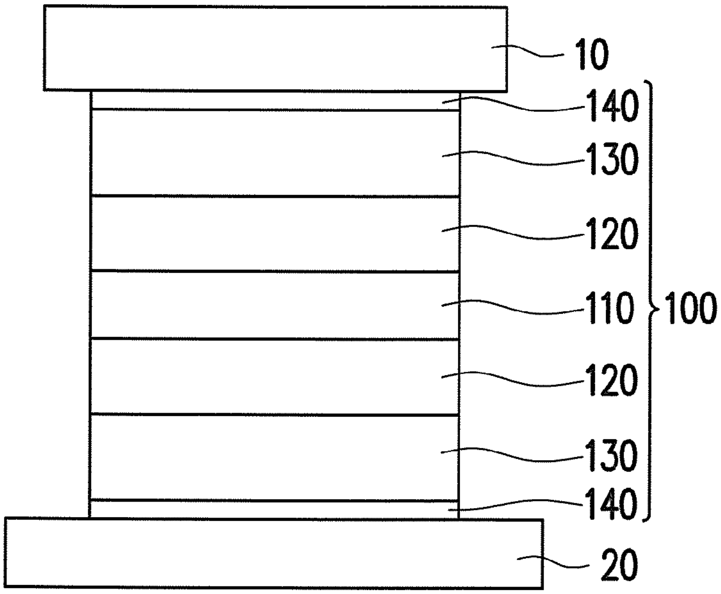
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FIG. 4B

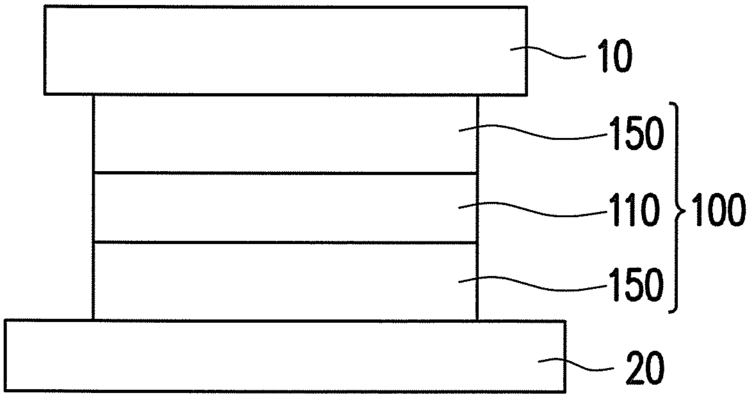

FIG. 4C

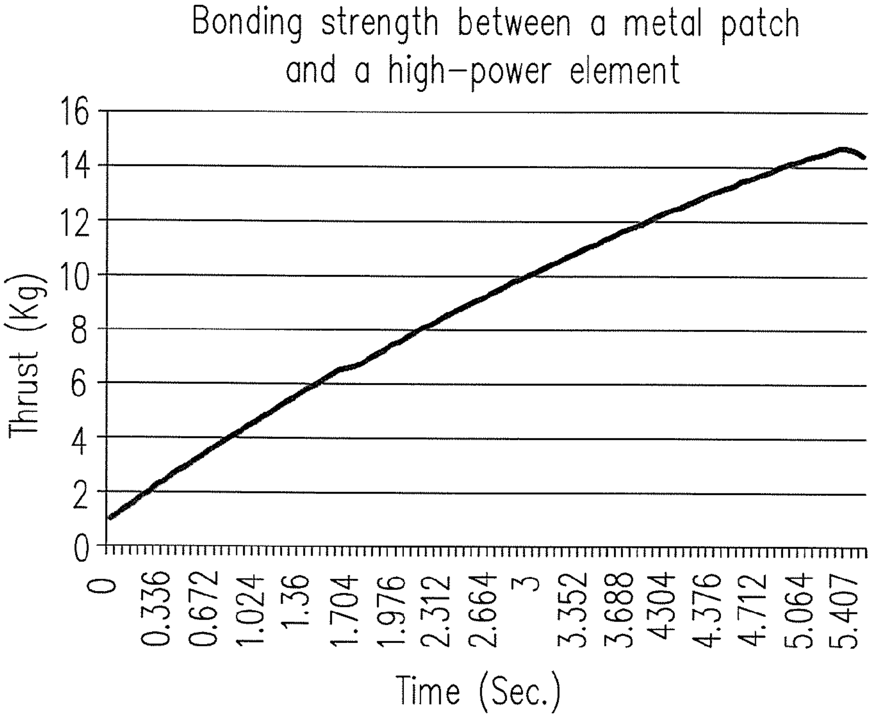
Bonding strength between a metal patch and a high-power element

FIG. 5

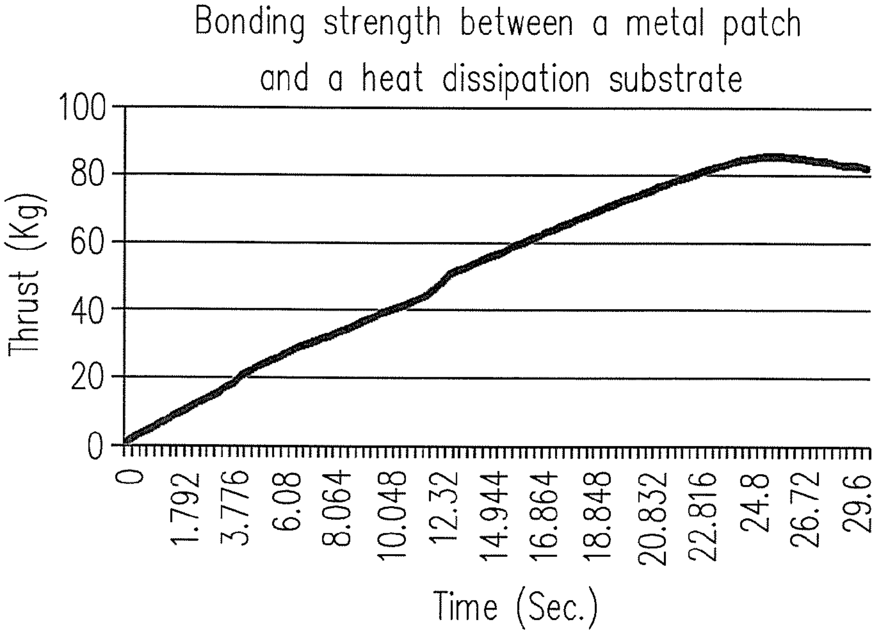
Bonding strength between a metal patch and a heat dissipation substrate

FIG. 6

METAL PATCH, METHOD FOR MANUFACTURING THE SAME AND BONDING METHOD BY USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority benefit of Taiwan application serial no. 104142373, filed on Dec. 16, 2015. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

TECHNICAL FIELD

[0002] The invention relates to a connecting element for packaging, and more particularly, to a metal patch for connecting a high-power element and a substrate and a manufacturing method thereof, and a bonding method for connecting the high-power element and the substrate using the metal patch.

BACKGROUND

[0003] A high-power element (an element such as MOSFET, IGBT, and LED) has the characteristics of large area and high heat flux density. Therefore, the high-power element is generally disposed on a heat dissipation substrate to reduce the temperature of the high-power element, so as to ensure the high-power element can operate normally. Common materials currently used to bond the high-power element to the substrate include silver paste and lead-free solder. The silver paste is formed by mixing silver metal particles and a polymer material. However, the polymer material is readily degraded due to temperature change in the external environment, and therefore the reliability of the silver paste is reduced. Moreover, the lead-free solder can tolerate temperatures of about 150° C. or less, and therefore when the temperature of the high-power element is higher than 175, a severe creep effect occurs to the lead-free solder, such that the reliability of the lead-free solder is reduced.

SUMMARY

[0004] The invention provides a metal patch suitable for connecting a high-power element and a substrate.

[0005] A metal patch of the invention includes an intermediate metal layer, two first metal layers, and two second metal layers. The first metal layers are respectively disposed on two opposite surfaces of the intermediate metal layer. The intermediate metal layer is located between the first metal layers. The melting point of each of the first metal layers is greater than 800° C. The second metal layers are respectively disposed on the first metal layers. The intermediate metal layer and the first metal layers are located between the second metal layers. The material of each of the second metal layers includes an indium-tin alloy. Each of the first metal layers and the corresponding second metal layer can generate an intermetal via a solid-liquid diffusion reaction.

[0006] Based on the above, in the invention, the metal patch can be made beforehand and then connected to the high-power element and the substrate, and therefore a bonding layer (such as a solder layer or a metal layer) does not need to be formed on the high-power element and the substrate beforehand. Moreover, the material of the second metal layers of the metal patch adopts an indium-tin alloy, and therefore the metal patch can be bonded at a lower temperature. After the bonding is complete, the bonding interface (i.e., intermetal layer) between the metal patch and the high-power element has higher temperature tolerance, and the bonding interface (i.e., intermetal layer) between the metal patch and the substrate also has higher temperature tolerance. Therefore, for the bonding of the high-power element and the substrate, the metal patch has the characteristics of "low-temperature bonding" and "high-temperature usage".

[0007] Several exemplary embodiments accompanied with figures are described in detail below to further describe the invention in details.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1**A to FIG. **1**C are respectively cross-sectional schematics of a metal patch connecting a high-power element and a substrate before, during, and after bonding according to an embodiment of the invention.

[0009] FIG. **2**A to FIG. **2**C are respectively cross-sectional schematics of a metal patch connecting a high-power element and a substrate before, during, and after bonding according to another embodiment of the invention.

[0010] FIG. **3**A to FIG. **3**C are respectively cross-sectional schematics of a metal patch connecting a high-power element and a substrate before, during, and after bonding according to an embodiment of the invention.

[0011] FIG. **4**A to FIG. **4**C are respectively cross-sectional schematics of a metal patch connecting a high-power element and a substrate before, during, and after bonding according to another embodiment of the invention.

[0012] FIG. **5** shows the relationship of the bond strength between a metal patch and a high-power element against time and thrust.

[0013] FIG. **6** shows the relationship of the bond strength between a metal patch and a substrate against time and thrust.

DETAILED DESCRIPTION OF DISCLOSED EMBODIMENTS

[0014] Referring to FIG. **1**A, in the present embodiment, a metal patch **100** is suitable for connecting a high-power element **10** and a substrate **20**. The high-power element **10** is, for instance, an element such as a metal-oxide-semiconductor field-effect transistor (MOSFET), an insulated gate bipolar transistor (IGBT), and a light-emitting diode (LED), but the invention is not limited thereto. The substrate **20** can have a cooling function, such as a copper substrate, but the invention is not limited thereto. The metal patch **100** includes an intermediate metal layer **110**. The intermediate metal layer **110** is a multilayered structure. The intermediate metal layer **110** includes a base layer **112** and two barrier layers **114**. The barrier layers **114** are respectively disposed on two opposite surfaces of the base layer **112**, such that the base layer **112** is located between the barrier layers **114**. In the present embodiment, the material of the base layer **112** includes copper, and the thickness can be 10 micrometers to 50 micrometers, but are not limited thereto. The material of each of the barrier layers **114** includes nickel, a nickel-phosphorus alloy, titanium, or chromium. The barrier layers **114** are used as a shield in the solid-liquid diffusion reaction in the manufacture, and can also be used as adhesive layers, as described in detail later.

[0015] The metal patch **100** further includes two first metal layers **120**. The first metal layers **120** are respectively disposed on two opposite surfaces of the intermediate metal layer **110**, such that the intermediate metal layer **110** is located between the first metal layers **120**. Specifically, the first metal layers **120** are respectively disposed on the corresponding barrier layer **114**, and are respectively connected to the surface of the barrier layers **114** opposite to the base layer **112**. In particular, the barrier layers **114** can be used as adhesive layers at the same time, and bonding between the base layer **112** and the first metal layers **130** can be improved via the barrier layers **114**. The melting point of each of the first metal layers **120** is greater than 800° C. In the present embodiment, the material of each of the first metal layers **120** includes silver or gold. Moreover, a metal of the same material can be selected for the two first metal layers **120** and be disposed on two opposite surfaces of the intermediate metal layer **110**. In another embodiment, the two first metal layers **120** can also adopt metals of different materials.

[0016] The metal patch **100** further includes two second metal layers **130**. The second metal layers **130** are respectively disposed on the first metal layers **120**, such that the intermediate metal layer **110** and the first metal layers **120** are located between the second metal layers **130**. Specifically, the metal patch **100** is a sandwich structure including, in the order of outside to inside, the second metal layers **130**, the first metal layers **120**, and the intermediate metal layer **110**. The material of each of the second metal layers **130** includes an indium-tin alloy. Each of the first metal layers **120** and the corresponding second metal layer **130** generate an intermetal via solid-liquid diffusion. In the present embodiment, each of the second metal layers **130** contains 5% to 55% of tin, such that the range of melting point of each of the second metal layers **130** is 118° C. to 150° C. In an embodiment, the indium-tin percentage of each of the second metal layers **130** is 52:48, and the melting point thereof can be substantially about 125° C. Since the second metal layers **130** have a lower melting point, during the bonding procedure, a lower bonding temperature can be used, such as lower than 200° C.

[0017] Referring to FIG. **1**A and FIG. **1**B, the metal patch **100** is positioned between the high-power element **10** and the substrate **20**, such that the metal patch **100** connects the high-power element **10** and the substrate **20**. Then, referring to FIG. **1**B and FIG. **1**C, each of the first metal layers **120** and the corresponding second metal layer **130** in contact therewith are reacted in solid-liquid diffusion at a lower bonding temperature such as 150° C. or 180° C. and an intermetal having a high melting point is generated. The high melting point here is, for instance, 400° C. or more. Specifically, the metal patch **100** is first preliminarily bonded respectively at the contact surface with the high-power element **10** and the substrate **20**, mainly to preliminarily fix the positions of the metal patch **100**, the high-power element **10**, and the substrate **20**. The preliminary bonding temperature only needs to be greater than the melting point of each of the second metal layers **130**, such as 150° C. or 180° C., the reaction time of the preliminary bonding is less than 10 seconds, and an intermetal thin film is respectively generated at the contact surface of the metal patch **100** with the high-power element **10** and the substrate **20** at this point, such that the high-power element **10** and the substrate **20** are preliminarily bonded and fixed via the metal patch **100**. Then, the preliminarily bonded metal patch **100**, high-power element **10**, and substrate **20** are placed in an oven to perform a solid-liquid diffusion reaction. The bonding temperature at this point is also greater than the melting point of each of the second metal layers **130**, such as 150° C. or 180° C., and the reaction time of the solid-liquid diffusion is greater than or equal to 0.5 hours, but are not limited thereto. Mainly, the material of each of the first metal layers **120** and the corresponding second metal layer **130** in contact therewith are to be reacted in the solid-liquid diffusion into a high-melting point intermetal until each of the second metal layers **130** is completely consumed.

[0018] More specifically, since the bonding process adopts a low bonding temperature, only the second metal layers **130** generate a melting reaction, and the first metal layers **120** in contact with the second metal layers **130** generate a solid-liquid diffusion reaction with the second metal layers **130** in molten state, so as to generate an intermetal having a high melting point at the contact surfaces of the metal patch **100** with the high-power element **10** and the substrate **20**, such as an alloy rich in silver-indium, silver-tin, gold-indium, or gold-tin. It should be mentioned that, the composition of the intermetal is mainly decided according to the material selected for the first metal layers **120** and the second metal layers **130**. Moreover, the reaction time of the bonding process and the thickness of the first metal layers **120** and the second metal layers **130** also affect the composition of the intermetal. Referring to FIG. **1**C, each of the first metal layers **120** and the corresponding second metal layer **130** are completely consumed in the solid-liquid diffusion reaction of the first metal layers **120** and the second metal layers **130** after bonding. Therefore, after the bonding is complete, an intermetal layer **150** is formed between the intermediate metal layer **110** and the high-power element **10**, and another intermetal layer **150** is also formed between the intermediate metal layer **110** and the substrate **20**. The intermetal layer **150** has a higher melting point in comparison to the first metal layers **120** and the second metal layers **130**, and has good mechanical properties. Moreover, since the intermediate metal layer **110** has the barrier layers **114**, the solid-liquid diffusion reaction stops after completely consuming the first metal layers **130**, and the barrier layers **114** and the base layer **112** of the metal patch **100** do not further participate in the solid-liquid diffusion reaction. The composition of the intermetal layer **150** at this point is an alloy formed by the material selected for the first metal layers **120** and the second metal layers **130**. However, in another embodiment, after the bonding is complete, the first metal layers **120** are not completely consumed in the solid-liquid diffusion reaction, and at this point, residual first metal layer **120** exists in the bonded metal patch **100**. Specifically, the first metal layer **120** exists between the intermetal layer **150** and the intermediate metal layer **110**.

[0019] Since the material of the second metal layers **130** adopts an indium-tin alloy, the second metal layers **130** have the characteristic of lower melting point at a specific ratio, and therefore the metal patch **100** can be bonded at a lower temperature. As a result, damage to the high-power element **10** from the bonding temperature can be reduced. Moreover, after bonding of the metal patch **100** with the high-power element **10** and the substrate **20** is complete, the bonding interface (i.e., the intermetal layer **150**) between the metal patch **100** and the high-power element **10** has higher temperature tolerance and good mechanical strength, and the bonding interface (i.e., the intermetal layer **150**) between the metal patch **100** and the substrate **20** also has higher temperature tolerance and good mechanical strength, such that the bonded high-power element **10** and substrate **20** can tolerate high operation temperature. Therefore, for the bonding of the high-power element **10** and the substrate **20**, the metal patch **100** has the characteristics of "low-temperature bonding" and "high-temperature usage".

[0020] Referring to FIG. **2**A, in comparison to the metal patch **100** of the embodiment of FIG. **1**A, the intermediate metal layer **110** of the metal patch **100** shown in FIG. **2**A is a single-layer structure. In the present embodiment, the intermediate metal layer **110** can be used for blocking and adhering at the same time, and therefore the material selected for the intermediate metal layer **110** needs to have a shielding effect for the solid-liquid diffusion reaction and good bonding for the first metal layers **120**. The material of the intermediate metal layer **110** includes nickel or a nickel-phosphorous alloy. Referring to FIG. **2**B and FIG. **2**C, after the bonding is complete, an intermetal layer **150** is formed between the metal patch **100** and the high-power element **10**, and another intermetal layer **150** is also formed between the metal patch **100** and the substrate **20**. It should be mentioned that, the above is also exemplified by completely consuming the first metal layers **120** and the second metal layers **130** after bonding. In other embodiments, the first metal layer **120** can also not be completely consumed and exist between the intermetal layer **150** and the intermediate metal layer **110**, which is not repeated herein.

[0021] In the manufacture, the metal patch **100** can be performed via electroplating and evaporation. In the case of manufacturing the metal patch **100** of FIG. **2**A, the intermediate metal layer **110** is used as the substrate, the first metal layers **120** are plated on both sides, and lastly the second metal layers are plated to complete the manufacture. The manufacturing method of the metal patch **100** of FIG. **1**A is similar, and can be done by only plating the barrier layers **114** on both sides using the base layer **112** of the intermediate metal layer **110** as the substrate before the first metal layers **120** are plated.

[0022] Referring to FIG. **3**A, in comparison to the metal patch **100** of the embodiment of FIG. **1**A, the metal patch **100** shown in FIG. **3**A further includes two wetting layers **140**. The wetting layers **140** are respectively disposed on the second metal layers **130**, such that the intermediate metal layer **110**, the first metal layers **120**, and the second metal layers **130** are located between the wetting layers **140**. Specifically, the metal patch **100** is a sandwich structure including, in the order of outside to inside, the wetting layers **140**, the second metal layers **130**, the first metal layers **120**, and the intermediate metal layer **110**. In the present embodiment, the material of each of the wetting layers **140** includes inorganic chloride, such as zinc chloride. A small amount of the zinc chloride solution having a concentration of, for instance, 0.1% to 1% can be coated on the surface of each of the second metal layers **130** using drop coating or thermal evaporation, and then the moisture of the zinc chloride solution is heated and evaporated or co-evaporated with the second metal layers **130**. As a result, a very thin zinc chloride layer (i.e., the wetting layer **140**) is formed on the surface of each of the second metal layers **130**. Moreover, referring to FIG. **3**B and FIG. **3**C, after the bonding is complete, an intermetal layer **150** is formed between the metal patch **100** and the high-power element **10**, and another intermetal layer **150** is also formed between the metal patch **100** and the substrate **20**. It should mentioned that, in the bonding process, the wetting layers **140** can increase the wettability of the second metal layers **130** of the metal patch **100** respectively with the high-power element **10** and the substrate **20**, so as to increase the bonding strength between the metal patch **100** and the high-power element **10** and the bonding strength between the metal patch **100** and the substrate **20**. Moreover, in the material selected for the wetting layers **140**, a portion of metal ions thereof may also participate in the solid-liquid diffusion reaction in the bonding process, such that the intermetal layer **150** formed in the bonding process contains an alloy formed by the metal ions of the wetting layers **140**. In the case that zinc chloride is selected for the wetting layers **140** in the present embodiment, the composition of the bonded intermetal layer **150** is an alloy containing zinc and formed by the material selected for the first metal layers **120** and the second metal layers **130**.

[0023] Referring to FIG. **4**A, in comparison to the metal patch **100** of the embodiment of FIG. **3**A, the intermediate metal layer **110** of the metal patch **100** shown in FIG. **4**A is a single-layer structure. In the present embodiment, the material of the intermediate metal layer **110** includes nickel or a nickel-phosphorous alloy. Moreover, referring to FIG. **4**B and FIG. **4**C, after the bonding is complete, an intermetal layer **150** is formed between the metal patch **100** and the high-power element **10**, and another intermetal layer **150** is also formed between the metal patch **100** and the substrate **20**. Similarly, in the present embodiment, the wettability of the metal patch **100** with the high-power element **10** and the substrate **20** is also increased by adopting the wetting layers **140** so as to increase bonding strength.

[0024] Referring further to FIG. **3**A, a method of drop coating is adopted to coat a 1% zinc chloride solution on the surface of the second metal layers **130** (such as indium-tin alloy layers having a composition ratio of 52:48), and then the moisture of the zinc chloride solution is heated and evaporated to form a very thin zinc chloride layer (i.e., the wetting layer **140**) on the surface of each of the second metal layers **130**. Then, referring further to FIG. **3**B and FIG. **3**C, low-temperature bonding is performed to bond the metal patch **100** to the high-power element **10** and the substrate **20** (such as copper substrate). After bonding is complete under such conditions, according to US military thrust value MIL-STD-883 TEST METHOD 2019 DIE SHEAR STRENGTH specifications, the relationship of bonding strength between the metal patch **100** and the high-power element **10** against time and thrust can be obtained as shown in FIG. **5**, and the relationship of bonding strength between the metal patch **100** and the substrate **20** against time and thrust can be obtained, as shown in FIG. **6**. In FIG. **5**, the maximum thrust value of the bonding strength between the metal patch **100** and the high-power element **10** reaches 15 kg. In FIG. **6**, the maximum thrust value of the bonding strength between the metal patch **100** and the substrate **20** reaches 85 kg. In other words, the bonding of using the metal patch **100** in the present embodiment to bond the high-power element **10** and the substrate **20** is good in both cases.

[0025] Based on the above, in the invention, the metal patch can be made beforehand and then connected to the high-power element and the substrate, and therefore a bonding layer (such as a solder layer or a metal layer) does not need to be formed on the high-power element and the substrate beforehand. Moreover, the material of the second metal layers of the metal patch adopts an indium-tin alloy, and therefore the metal patch can be bonded at a lower temperature. After the bonding is complete, the bonding interface (i.e., intermetal layer) between the metal patch and the high-power element has higher temperature tolerance, and the bonding interface (i.e., intermetal layer) between the metal patch and the substrate also has higher temperature tolerance. Therefore, for the bonding of the high-power element and the substrate, the metal patch has the characteristics of "low-temperature bonding" and "high-temperature usage". Moreover, the metal patch can also include two wetting layers respectively disposed on the second metal layers, and therefore in the bonding process, the wetting layers can increase the wettability of the second metal layers of the metal patch respectively with the high-power element and the substrate, so as to increase the bonding strength between the metal patch and the high-power element and the bonding strength between the metal patch and the substrate.

[0026] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the disclosed embodiments without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A metal patch, comprising:

an intermediate metal layer;

two first metal layers respectively disposed on two opposite surfaces of the intermediate metal layer, wherein the intermediate metal layer is located between the first metal layers, and a melting point of each of the first metal layers is greater than 800° C.; and

two second metal layers respectively disposed on the first metal layers, wherein the intermediate metal layer and the first metal layers are located between the second metal layers, a material of each of the second metal layers comprises an indium-tin alloy, and each of the first metal layers and the corresponding second metal layer are capable of generating an intermetal via a solid-liquid diffusion reaction.

2. The metal patch of claim **1**, wherein the intermediate metal layer comprises:

a base layer; and

two barrier layers respectively disposed on two opposite surfaces of the base layer, wherein the base layer is located between the barrier layers.

3. The metal patch of claim **2**, wherein a material of the base layer comprises copper.

4. The metal patch of claim **2**, wherein a thickness of the base layer is 10 micrometers to 50 micrometers.

5. The metal patch of claim **2**, wherein a material of each of the barrier layers comprises nickel, a nickel-phosphorus alloy, titanium, or chromium.

6. The metal patch of claim **1**, wherein a material of the intermediate metal layer comprises nickel or a nickel-phosphorous alloy.

7. The metal patch of claim **1**, wherein a material of each of the first metal layers comprises silver or gold.

8. The metal patch of claim **1**, wherein each of the second metal layers contains 5% to 55% of tin.

9. The metal patch of claim **1**, wherein an indium-tin percentage of each of the second metal layers is 52:48.

10. The metal patch of claim **1**, wherein a melting point range of each of the second metal layers is 118° to 150° C.

11. The metal patch of claim **1**, wherein the first metal layer and the corresponding second metal layer are capable of generating an intermetal having a melting point greater than 400° C. via solid-liquid diffusion.

12. The metal patch of claim **1**, further comprising:

two wetting layers respectively disposed on the second metal layers, wherein the intermediate metal layer, the first metal layers, and the second metal layers are located between the wetting layers.

13. The metal patch of claim **12**, wherein a material of each of the wetting layers comprises inorganic chloride.

14. The metal patch of claim **12**, wherein a material of each of the wetting layers comprises zinc chloride.

15. A manufacturing method of a metal patch for manufacturing the metal patch of claim **1**, wherein the manufacturing method of the metal patch contains the following steps: plating the first metal layer on both sides by using the intermediate metal layer as a substrate, and then plating the second metal layer.

16. The method of claim **15**, wherein before the first metal layer is plated, a barrier layer is plated on both sides by using a base layer of the intermediate metal layer as the substrate.

17. The method of claim **15**, further comprising coating a zinc chloride solution on a surface of the second metal layers, and then heating and evaporating a moisture of the zinc chloride solution.

18. The method of claim **17**, wherein a concentration range of the zinc chloride solution is 0.1% to 1%.

19. A bonding method using a metal patch, suitable for connecting a high-power element and a substrate, wherein the metal patch adopts the metal patch of claim **1**, and the bonding method comprises:

positioning the metal patch between the high-power element and the substrate, such that the metal patch is in contact with the high-power element and the substrate;

performing a preliminary bonding on a contact surface of the metal patch respectively with the high-power element and the substrate at a preliminary bonding temperature higher than a melting point of each of the second metal layers to generate an intermetal thin film at each of the contact surfaces;

performing a solid-liquid diffusion reaction on the preliminarily bonded metal patch, high-power element, and substrate at a bonding temperature higher than a melting point of each of the second metal layers to react a material of each of the first metal layers and the corresponding second metal layer in contact therewith into an intermetal via solid-liquid diffusion until each of the second metal layers is completely consumed.

20. The method of claim **19**, wherein the preliminary bonding temperature is 150° C. or 180° C.

21. The method of claim **19**, wherein a reaction time of the preliminary bonding is less than 10 seconds.

22. The method of claim **19**, wherein the bonding temperature is 150° C. or 180° C.

23. The method of claim **19**, wherein a reaction time of the solid-liquid diffusion reaction is greater than or equal to 0.5 hours.

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