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(54) **ALUMINUM-COPPER CLAD MEMBER, METHOD OF MANUFACTURING THE SAME, AND HEAT SINK**

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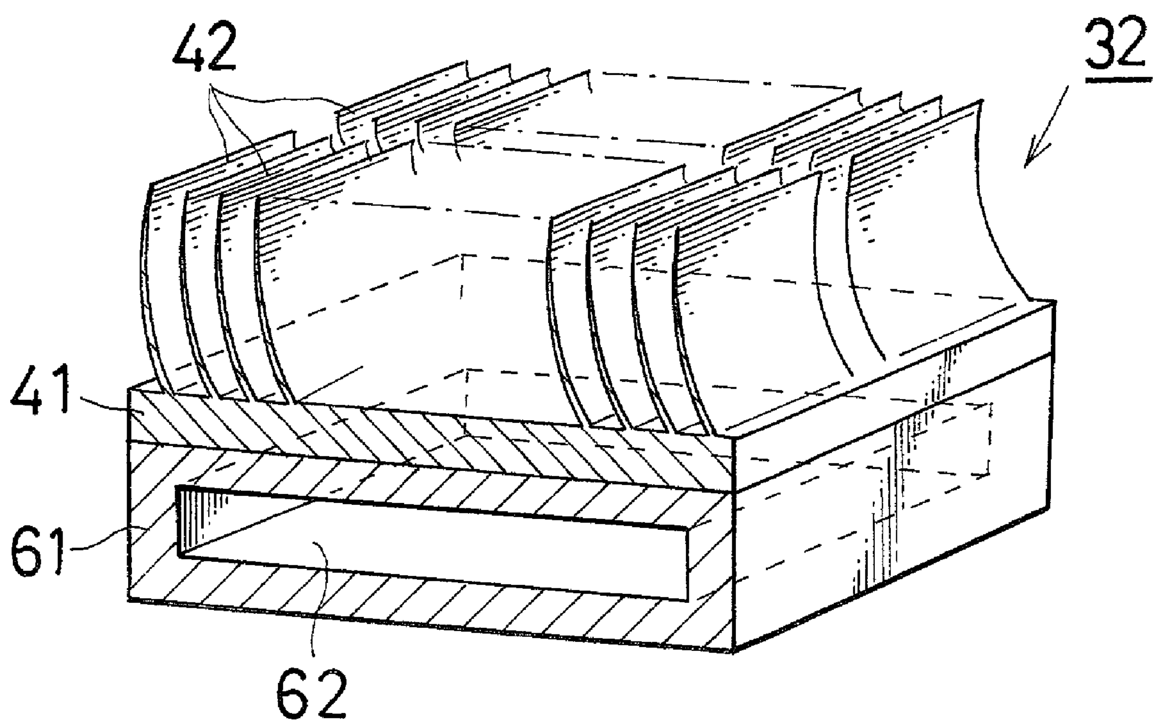
(57) **ABSTRACT**

An aluminum-copper clad member includes an aluminum-base member, a copper-base member and an insertion member made of pure aluminum or JIS A1xxx series aluminum alloy. The aluminum-base member and the copper-base member are clad via the insertion member. A heat sink includes a heat radiation portion made of aluminum-base material and provided with a plurality of tongue-like fins formed by skiving a surface layer of one side of the heat radiation portion and a thermal diffusion portion made of copper-base material and joined to the other side of the heat radiation portion via an insertion member made of pure aluminum or JIS A1xxx series aluminum alloy.



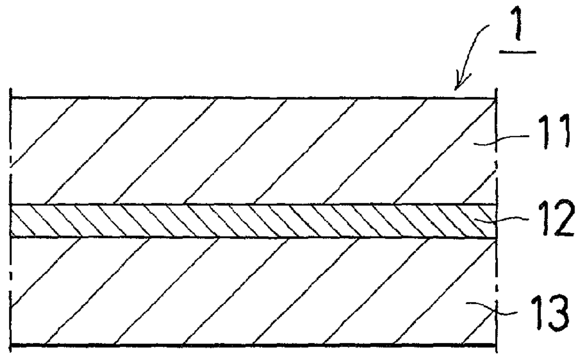



FIG.1

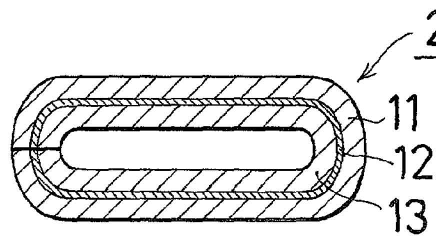



FIG.2

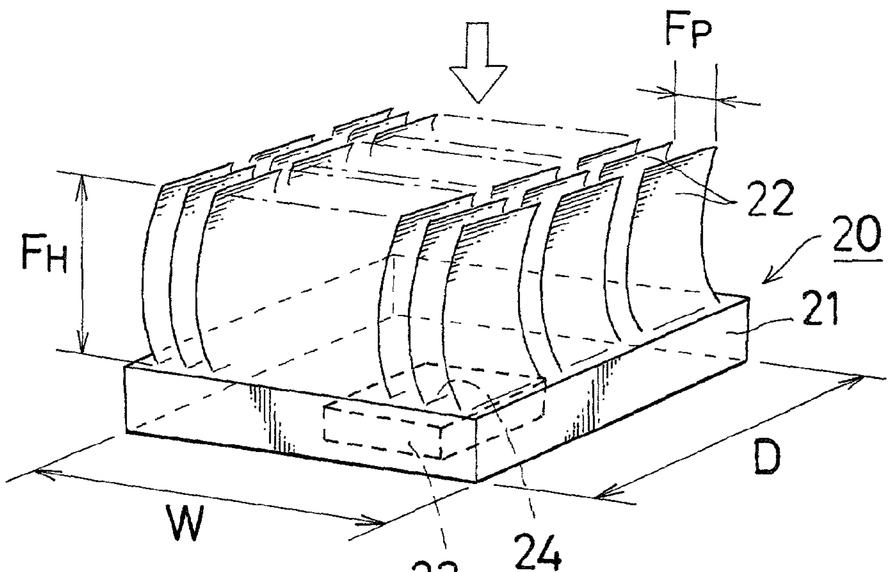



FIG.3

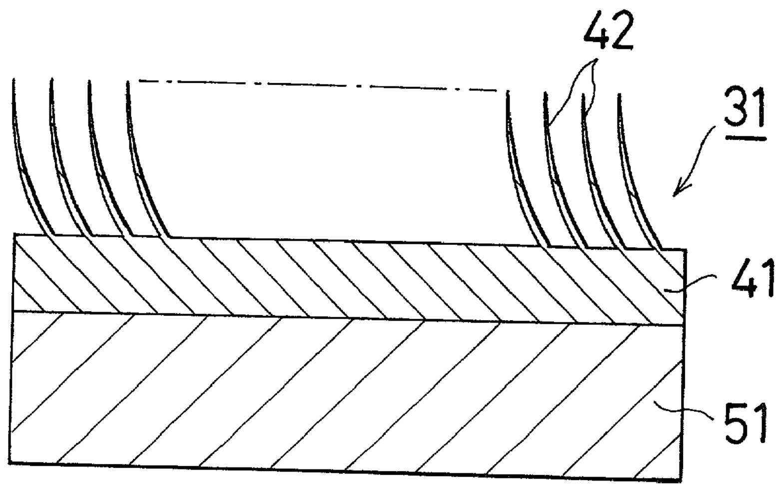



FIG. 4

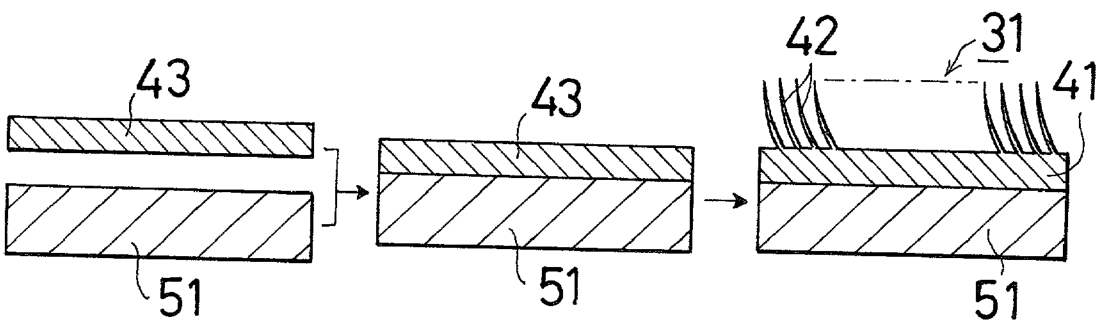



FIG. 5

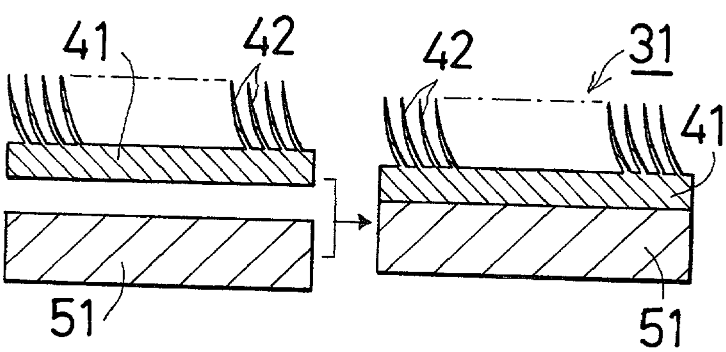



FIG. 6

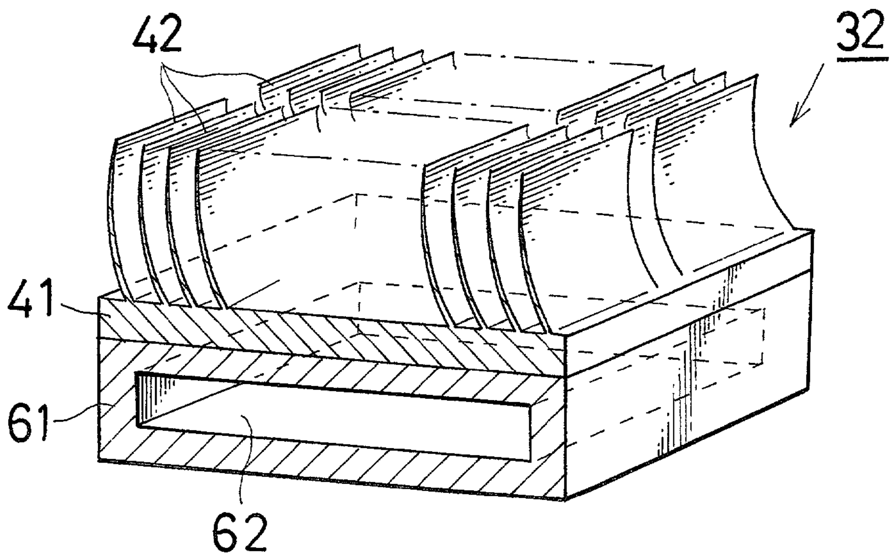



FIG. 7

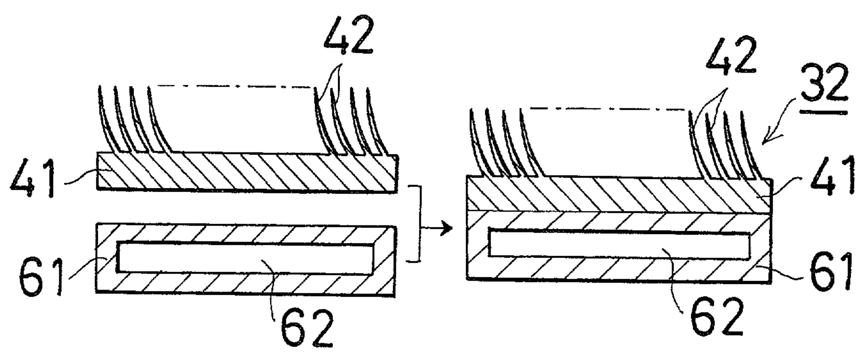



FIG. 8

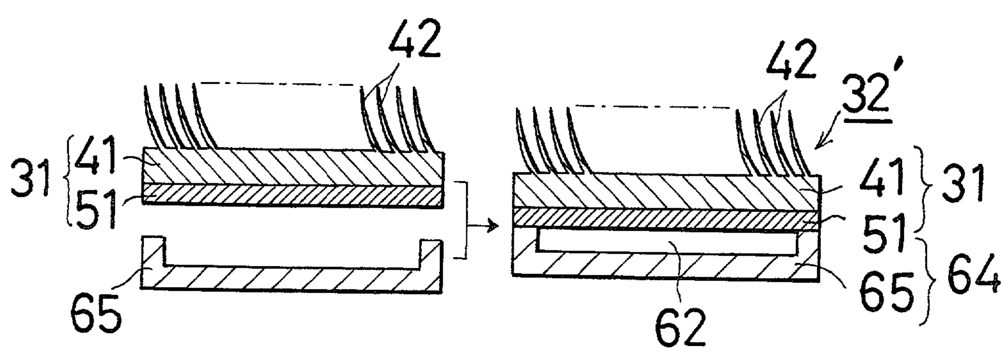



FIG. 9

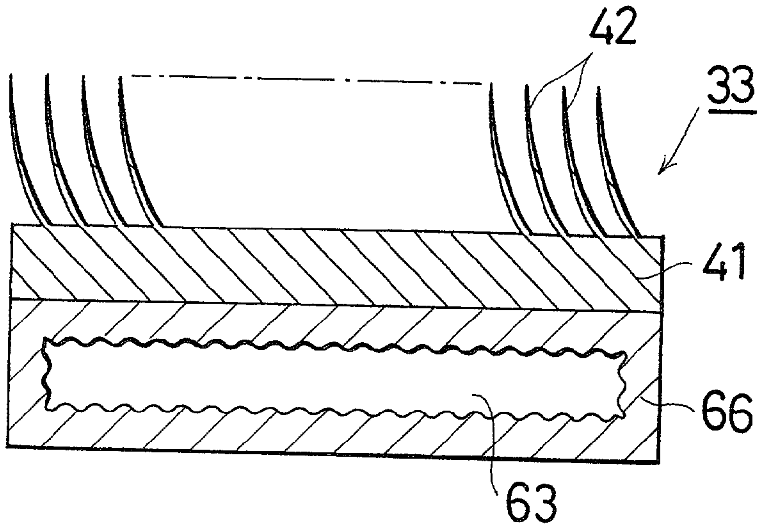

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FIG.10

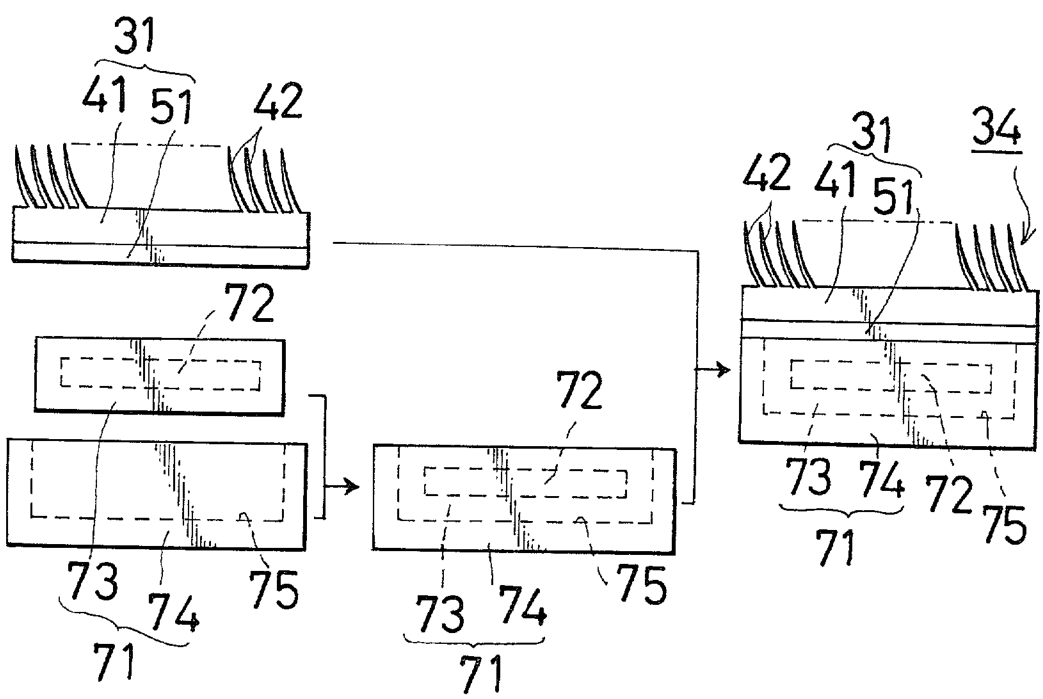
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FIG.11

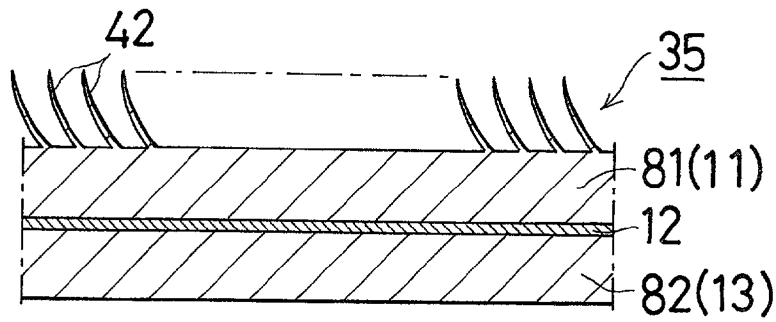


FIG. 12

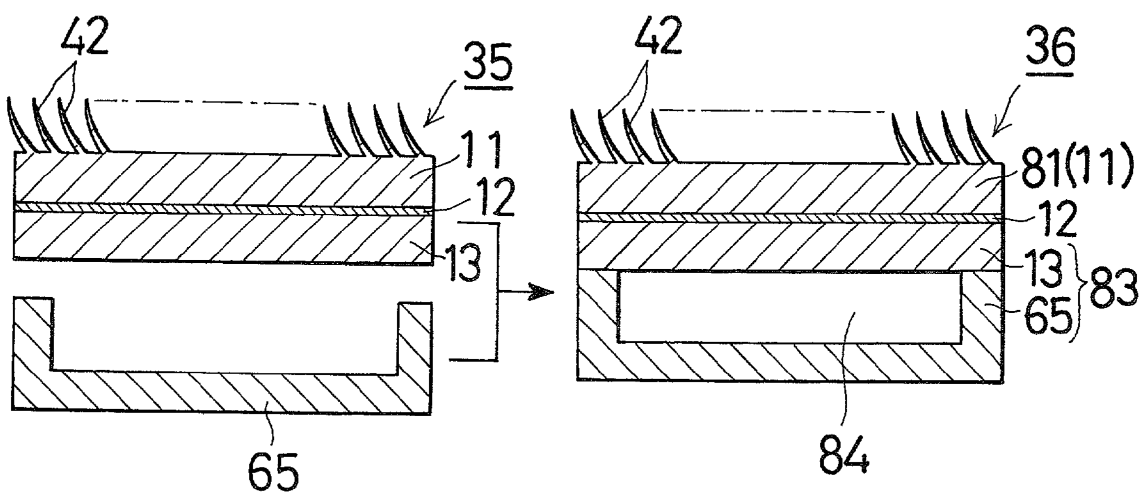


FIG. 13

# ALUMINUM-COPPER CLAD MEMBER, METHOD OF MANUFACTURING THE SAME, AND HEAT SINK

## BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to an aluminum-copper clad member suitably used as, for example, a heat exchanger, a radiator, a heat pipe and a heat sink, and also relates to a manufacturing method thereof. Furthermore, the present invention relates to a heat sink, and more specifically to, a heat sink suitably used for cooling exothermic devices installed in various electric apparatuses.

[0003] 2. Description of Related Art

[0004] Heat exchangers, radiators, heat pipes and heat sinks are widely used in the industrial fields of electric devices, communication apparatuses and transport apparatuses such as automobiles and airplanes. They are required to be not only excellent in heat transfer performance but also light in weight and small in size. Thus, various improvements have been made from the view points of materials and configurations.

[0005] As for the view point of materials, in place of copper-base material which is excellent in heat transfer performance and thermal diffusion performance but defective in weight, aluminum-base material, which is light in weight and excellent in heat transfer performance ranked next to copper, is widely used.

[0006] In an aluminum heat exchanger used in the field of electric device industries, various improvements including an increasing of the cooling area and the thickness of components are made in order to improve heat transfer performance thereof. However, since such an aluminum heat exchanger has been remarkably improved in size, weight and performance, it becomes difficult to further improve the heat transfer performance by increasing the cooling area and the thickness of components. Furthermore, in cases where water is used as operation fluid for heat pipes, there are such drawbacks that the heat pipe performance of aluminum heat exchanger deteriorates due to non-condensing gases generated therein.

[0007] From the view point of configuration, in a heat sink, for example, a number of thin-plate like fins are integrally formed on a heat radiation board to increase the heat radiation area. Such a heat sink, which is usually an aluminum extruded article, is advantageous to an electric device, such as a computer having a number of exothermic devices, for quickly discharging heat generated by the exothermic devices. In the heat sink of the aforementioned shape, in order to improve the heat radiation performance, it is important to increase the heat radiation area. In order to increase the heat radiation area, it is necessary to increase the number of fins, decrease the fin thickness, narrow the fin intervals and increase the fin height. It is, however, difficult to manufacture the heat sink of such a fin shape due to restrictions of extrusion technology.

[0008] Moreover, since improving the fin functions is not sufficient to enhance the heat radiation performance of the heat sink, it is necessary to improve the thermal diffusion function of the heat sink substrate to be attached to an exothermic device. The thermal diffusion function can be improved by increasing the thickness of the substrate. However, since the installation space of a heat sink is limited due to the miniaturization of the whole apparatus in which the heat sink is installed, an increased thickness of the substrate results in a decreased fin height, which in turn decreases the heat radiation area. Moreover, increasing the thickness of the substrate contradicts decreasing the weight of the apparatus.

## SUMMARY OF THE INVENTION

[0009] It is an object of the present invention to provide an aluminum-copper clad member which is excellent in heat radiation performance and suitably used for a heat sink or the like.

[0010] It is another object of the present invention to provide a method of manufacturing the aluminum-copper clad member.

[0011] It is still another object of the present invention to provide a heat sink which is capable of improving the heat radiation performance without increasing the size and/or weight.

[0012] According to one aspect of the present invention, an aluminum-copper clad member comprises an aluminum-base member, a copper-base member and an insertion member made of pure aluminum or Japanese Industrial Standard (hereinafter referred to as "JIS") JIS A1xxx series aluminum alloy, wherein the aluminum-base member and the copper-base member are clad via the insertion member. According to the aluminum-copper clad member, since the aluminum-base member and the copper-base member are clad via the insertion member made of pure aluminum or JIS A1xxx series aluminum alloy which is easily clad to the copper-base member even in a cold rolling, oxidization of the copper-base member and generation of compounds between different materials can be decreased, resulting in high joining strength.

[0013] It is preferable that the copper-base member is made of oxygen free copper or phosphorus processed deoxidized copper. In this case, the generation of oxides is effectively restrained, resulting in excellent joining strength of the clad member.

[0014] In the aforementioned aluminum-copper clad member, since the clad member has lightness of aluminum and heat transfer performance, thermal diffusion performance and corrosion resistance of copper, when used as heat exchanger material, it is possible to realize a heat transfer performance exceeding that of aluminum while restraining the weight increase as compared to a copper heat sink. Moreover, corrosion resistance equivalent to copper can be obtained by applying the aforementioned clad member such that the copper-base member constitutes an easy-to-corrode portion.

[0015] According to another aspect of the present invention, a method of manufacturing an aluminum-copper clad member includes the steps of: joining an insertion member made of pure aluminum or JIS A1xxx series aluminum alloy to a copper-base member by a cold rolling to obtain a joined two members; joining an aluminum-base member to the insertion member by a cold rolling or a hot rolling to obtain a joined three members; and heat treating the joined two members before joining the aluminum-base member to the insertion member by a cold rolling or a hot rolling, or heat treating the joined three members after joining the aluminum-base member to the insertion member by a cold rolling or a hot rolling.

**[0016]** According to this method, even if the joining of the copper-base member and the insertion member to be directly connected thereto is performed by a cold rolling, high joining strength therebetween can be obtained, resulting in excellent joining of the copper-base member and the aluminum-base member. Moreover, since the aforementioned clad member is obtained through rolling steps, it is possible to manufacture the aluminum-copper clad member having a wide width and a long length. Therefore, a heat exchanger member, which requires lightness, good heat transfer performance, good corrosion resistance and large surface area, can be manufactured.

**[0017]** In the aforementioned method, it is preferable that a roll-working rate of the insertion member is set to 30% or more. Furthermore, it is preferable that a roll-working rate of the aluminum-base member is set to 40% or more. In cases where the roll-working rate of the insertion member is set to 30% or more, and/or the roll-working rate of the aluminum-base member is set to 40% or more, excellent joining strength can be obtained.

**[0018]** Furthermore, it is preferable that the heat treating is performed at from 200° C. to 400° C. This also enhances the joining strength.

**[0019]** According to still another aspect of the present invention, a heat sink includes a heat radiation portion made of aluminum-base material and provided with a plurality of tongue-like fins formed by skiving a surface layer of one side of the heat radiation portion; and a thermal diffusion portion made of copper-base material and joined to the other side of the heat radiation portion in a closely fitted manner.

**[0020]** In the aforementioned heat sink, since it includes a heat radiation portion made of aluminum-base material and provided with a plurality of tongue-like fins formed by skiving a surface layer of one side of the heat radiation portion and a thermal diffusion portion made of copper-base material and joined to the other side of the heat radiation portion in a closely fitted manner, when used as heat exchanger material, it is possible to realize a heat transfer performance exceeding that of aluminum while restraining the weight increase as compared to a copper heat sink. Especially, since the thermal diffusion portion in contact with the heat radiation portion is made of a copper-base member, an excellent cooling effect can be obtained without increasing the volume of the heat sink while maintaining the conventional fin height. Therefore, the heat sink is suitably used as a heat sink in the electric device having a limited installation space.

**[0021]** In the aforementioned heat sink, it is preferable that the thermal diffusion portion is a flat plate. In this case, the heat sink can be manufactured easily.

**[0022]** Furthermore, it is preferable that the thermal diffusion portion includes a heat exchanging medium chamber inside thereof and that the heat exchanging medium chamber is provided with wicks formed on an inner wall thereof. In cases where the thermal diffusion portion includes the heat exchanging medium chamber inside thereof, the heat sink can be used as a heat pipe and the thermal diffusion performance and heat radiation performance can be further improved.

**[0023]** Furthermore, since the thermal diffusion portion is formed by corrosion resistant copper-base material, it is possible to use water as heat exchange medium.

**[0024]** In cases where the heat exchanging medium chamber is provided with wicks formed on an inner wall thereof, since the circulation of heat exchange medium is enhanced within the chamber due to the capillary phenomenon, the thermal diffusion performance and the heat radiation performance can be further improved.

**[0025]** According to still yet another aspect of the present invention, a heat sink includes a heat radiation portion made of aluminum-base material and provided with a plurality of tongue-like fins formed by skiving a surface layer of one side of the heat radiation portion; and a thermal diffusion portion made of copper-base material and joined to the other side of the heat radiation portion via an insertion member made of pure aluminum or JIS A1xxx series aluminum alloy. In this heat sink, oxidization of the copper-base member and generation of the compounds between the different materials are restrained at the time of junction, resulting in high joining strength. Moreover, this heat sink also has outstanding lightness, heat transfer performance, thermal diffusion performance and corrosion resistance.

**[0026]** In the aforementioned heat sink, it is preferable that the thermal diffusion portion is a flat plate. In this case, the heat sink can be manufactured easily. Furthermore, it is preferable that the thermal diffusion portion includes a heat exchanging medium chamber inside thereof and that the heat exchanging medium chamber is provided with wicks formed on an inner wall thereof. In cases where the thermal diffusion portion includes the heat exchanging medium chamber inside thereof, the heat sink can be used as a heat pipe and the thermal diffusion performance and heat radiation performance can be further improved.

**[0027]** Furthermore, since the thermal diffusion portion is formed by corrosion-resistant copper-base material, it is possible to use water as heat exchange medium.

**[0028]** In cases where the heat exchanging medium chamber is provided with wicks formed on an inner wall thereof, since the circulation of heat exchange medium is enhanced within the chamber due to the capillary phenomenon, the thermal diffusion performance and the heat radiation performance can be further improved.

**[0029]** Other objects and the features of the present invention will be apparent from the following detailed description of the invention with reference to the attached drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0030]** The present invention will be more fully described and better understood from the following description, taken with the appended drawings, in which:

**[0031]** **FIG. 1** is a cross sectional view of an aluminum-copper clad member according to the present invention;

**[0032]** **FIG. 2** is a cross sectional view of a cooling tube made of the aluminum-copper clad member shown in **FIG. 1**;

[0033] **FIG. 3** is a perspective view showing a test heat sink;

[0034] **FIG. 4** is a cross sectional view showing an example A of a heat sink according to the present invention;

[0035] **FIG. 5** is an explanatory view showing the manufacturing process of the heat sink of the example A;

[0036] **FIG. 6** is an explanatory view showing another manufacturing processes of the heat sink of the example A;

[0037] **FIG. 7** is a perspective view showing an example B of a heat sink according to the present invention;

[0038] **FIG. 8** is an explanatory view showing the manufacturing process of the heat sink of the example B;

[0039] **FIG. 9** is an explanatory view showing another manufacturing processes of the heat sink of the example B;

[0040] **FIG. 10** is a cross sectional view showing an example C of a heat sink according to the present invention;

[0041] **FIG. 11** is a cross sectional view showing an elevation view and manufacturing process of an example D of a heat sink according to the present invention;

[0042] **FIG. 12** is a cross sectional view showing an example E of a heat sink according to the present invention; and

[0043] **FIG. 13** is a cross sectional view showing an example F of a heat sink according to the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0044] Aluminum—Copper Clad Member

[0045] As shown in **FIG. 1**, the aluminum—copper clad member **1** according to the present invention includes an aluminum-base member **11**, a copper-base member **13** and an insertion member **12**. The insertion member **12** is made of pure aluminum or JIS A1xxx series aluminum alloy and interposed between the copper-base member **13** and the aluminum-base member **11**.

[0046] The composition of the aforementioned aluminum-base member **11** is not specifically limited. As the aluminum-base member **11**, for example, high-grade pure aluminum, aluminum or its aluminum alloy of JIS A1xxx series, Al—Cu series alloy of JIS A2xxx series, Al—Mn series alloy of JIS A3xxx series, Al—Si series alloy of JIS A4xxx series, Al—Mg series alloy of JIS A5xxx series, Al—Si—Mg series alloy of JIS A6xxx series, Al—Zn—Mg—Cu series alloy and Al—Zn—Mg series alloy of JIS A7xxx series, etc., can be used widely.

[0047] The composition of the aforementioned copper-base member **13** is not specifically limited. It is recommended to use oxygen free copper or phosphorus processed deoxidized copper as the copper-base member because they can restrain generation of oxides or compounds with aluminum.

[0048] As for the insertion member **12**, it is necessary to use pure aluminum which is easily joined by a cold rolling to the copper-base member **13** as different metal material, or JIS A1xxx series aluminum alloy with few added elements. It is specifically recommended that the insertion member **12** is made of a high-grade pure aluminum of 99.90% purity, or an aluminum alloy of purity more than that of JIS A1050 alloy among JIS A1xxx series aluminum alloys.

[0049] By using the aforementioned insertion member **12**, the insertion member can be joined by a cold rolling with high joining strength. Generally, between the aluminum-base member **11** and the copper-base member **13**, thermal resistance arises due to the difference in thermal conductivity. However, the thermal resistance can be reduced by interposing pure aluminum or JIS A1xxx series aluminum alloy having higher thermal conductivity among aluminum-base materials as the aforementioned insertion member **12**.

[0050] Method of Manufacturing the Aluminum—Copper Clad Member

[0051] The aforementioned aluminum—copper clad member **1** is manufactured by, for example, the following method.

[0052] First, the insertion member **12** is joined to the copper-base member **13** by a cold rolling. Since the insertion member **12** is made of pure aluminum or JIS A1xxx series aluminum alloy, it is small in modification resistance and excellent in joining performance to the copper-base member **13** by a cold rolling. Moreover, since the insertion member **12** is joined to the copper-base member **13** by a cold rolling, oxidization of the copper-base member **13** and the generation of compounds with the ingredients of the insertion member **12** are restrained. Thus, the causes for deteriorating the joining strength can be eliminated. Although the cold roll-working rate is desirable to be 30% or more in order to obtain sufficient joining strength, when it exceeds 70%, there is a possibility that the materials may break due to the work hardening. More preferably, the roll-working rate is from 40% to 70%.

[0053] Next, the aluminum-base member **11** is joined to the insertion member **12** by a cold rolling or a hot rolling. In this rolling, since the surface of the copper-base member **13** is already covered with the insertion member **12** to be intercepted from atmosphere, a hot rolling or a cold rolling may be performed. In order to securely adhere the aluminum-base member **11** to the insertion member **12**, the roll-working rate is preferably set to 40% or more depending on the required final thickness. In cases of performing a hot rolling, it is preferable that the rolling temperature is set to from 100 to 350° C. and that the hot rolling is performed immediately after reaching the target temperature so as not to grow compound phase at the interface between the copper-base member **13** and the insertion member **12**. In this rolling, since both the insertion member **12** and the aluminum-base member **11** are aluminum, they are firmly joined each other, which results in a secure joining of the aluminum-base member **11** and the copper-base member **13** via the insertion member **12**.

[0054] In the aforementioned series of joining steps, the joined two members are heat treated before joining the aluminum-base member **11** to the insertion member **12** to securely join the copper-base member **13** and the insertion member **12**. Alternatively, after joining the aluminum-base member **11** on the insertion member **12**, the joined three members are heat treated to securely joining the aluminum-base member **11**, the insertion member **12** and the copper-base member **13**. In order to suppress the growth of compounds at the interface between the copper-base member **13** and the insertion member **12** and to obtain high joining strength therebetween, it is preferable to perform the aforementioned heat treatment within the temperature range of from 200 to 400° C. It is preferable to perform the aforementioned heat treatment at the temperature of from 220 to 300° C. Moreover, it is preferable to perform the heat treatment within one hour so as not to grow compounds. When the thickness of the compounds layer is controlled to 10 $\mu$m or less by adjusting the heat treatment conditions, a further improved joining condition can be obtained.

[**0055**] It is possible to manufacture a securely joined aluminum—copper clad member by heat treating the joined two members before joining the aluminum-base member **11** to the insertion member **12**, or the joined three members after joining the aluminum-base member **11** to the insertion member **12**. However, in cases where the aluminum-base member **11** is joined on the insertion member **12** by a cold rolling, the heat treatment is preferably subjected to the joined three members after joining the aluminum-base member **11** to the insertion member **12**.

[**0056**] Since the aforementioned aluminum—copper clad member **1** according to the present invention has lightness of aluminum and heat transfer performance, thermal diffusion performance and corrosion resistance of copper, the clad member can be suitably used as heat exchanger materials.

[**0057**] For example, the aluminum—copper clad member **1** can be manufactured into a heat exchanging tube **2** as shown in **FIG. 2**. In this heat exchanging tube **2**, when the copper-base member **13** is located inside the tube, refrigerant contacts the copper-base member **13** which is excellent in corrosion resistant. This enhances not only the heat transfer performance but also the corrosion resistance. Moreover, the aluminum—copper clad member **1** can also be manufactured into a heat sink with a plurality of tongue-like fins which will be detailed.

## EXAMPLE

[**0058**] The aluminum—copper clad member and the method of manufacturing the clad member according to the present invention will be detailed below.

[**0059**] As the aforementioned copper-base member **13**, an oxygen free copper board and a phosphorus processed deoxidized copper board, each of which is 8 mm in thickness, 100 mm in width and 150 mm in length, were prepared.

[**0060**] As the aforementioned insertion member **12**, three kinds of 99.999% purity aluminum plates 94 mm width and 150 mm length with different thickness, i.e., 0.1 mm thickness, 0.5 mm thickness and 1.0 mm thickness, were prepared.

[**0061**] As the aforementioned aluminum-base member **11**, JIS A1100 or JIS A6063 aluminum plate 100 mm width and 200 mm length with different thickness, i.e., 2.0 mm thickness, 5.0 mm thickness, 10.0 mm thickness and 15.0 mm thickness, were prepared.

[**0062**] The combination of the aforementioned members are shown in Table 1.

[**0063**] In manufacturing the clad member, the insertion member **12** was placed on the copper-base member **13**, and then they are subjected to a cold rolling at the roll-working rate shown in Table 1 to join them.

[**0064**] Subsequently, the joined members **12** and **13** according to the example Nos. 1-13 were held for 1 hour at the temperature shown in Table 1 to perform a middle heat treatment. On the other hand, the joined members according to the examples of the inventive example Nos. 14-17 were proceeded to the following process without being subjected to the middle heat treatment.

[**0065**] Next, the aluminum-base member **11** shown in Table 1 was put on the insertion member **12** of the aforementioned joined member and subjected to a cold rolling or a hot rolling at 500° C. at the roll-working rate shown in Table 1 to join them.

[**0066**] Furthermore, as for the example Nos. 14-17 to which the middle heat treatment was not executed, they were held at the temperature shown in Table 1 for 1 hour to perform a final heat treatment.

[**0067**] The examples Nos. 1-13 to which the middle heat treatment was executed, were not subjected to the final heat treatment.

[**0068**] On the other hand, as for the clad member according to the comparative example Nos. 1-4 with no insertion member, the clad members were manufactured by performing a hot rolling an aluminum-base member and a copper-base member at the temperature and the roll-working rate shown in Table 1.

[**0069**] The joining rate and the joining strength of these clad members were evaluated. The joining rate was evaluated by an ultrasonic inspection. The joining rate (%) was calculated as follows: the joining rate (%)=(non-joined area/measured area)×100. The joining strength was evaluated by falling the test piece onto an iron floor 20 times from the height of 1.5 m, and cracks or destructions of the test piece was examined. These evaluation results are shown in Table 1.

TABLE 1

(Manufacturing conditions and Evaluation)

| Clad member No. | | Cupper-base member | Insertion member (Pure Al) Thickness(mm) | Cold roll-working rate(%) | Middle heat treatment (° C.) | Aluminum-base member Material/Thickness (mm) | Hot/Cold roll-working rate (%) | Final heat treatment (° C.) | Joining rate (%) | Joining strength |
|---|---|---|---|---|---|---|---|---|---|---|
| Example | 1 | Oxygen free copper | 0.1 | 42 | 250 | A1100/2.0 | Heat/58 | — | 100 | No crack |
| | 2 | Oxygen free copper | 0.5 | 45 | 300 | A1100/5.0 | Heat/58 | — | 100 | No crack |
| | 3 | Phosphorus processed deoxidized copper | 0.5 | 55 | 350 | A6063/10.0 | Cold/50 | — | 100 | No crack |

TABLE 1-continued

(Manufacturing conditions and Evaluation)

| Clad member No. | | Cupper-base member | Insertion member (Pure Al) Thickness(mm) | Cold roll-working rate(%) | Middle heat treatment (° C.) | Aluminum-base member Material/Thickness (mm) | Hot/Cold roll-working rate (%) | Final heat treatment (° C.) | Joining rate (%) | Joining strength |
|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | Oxygen free copper | 0.5 | 59 | 400 | A1100/10.0 | Heat/45 | — | 100 | No crack |
| | 5 | Phosphorus processed deoxidized copper | 1.0 | 65 | 300 | A6063/10.0 | Cold/58 | — | 100 | No crack |
| | 6 | Oxygen free copper | 1.0 | 68 | 350 | A1100/2.0 | Cold/58 | — | 100 | No crack |
| | 7 | Phosphorus processed deoxidized copper | 1.0 | 68 | 400 | A6063/10.0 | Heat/55 | — | 100 | No crack |
| | 8 | Phosphorus processed deoxidized copper | 1.0 | 68 | 200 | A6063/10.0 | Heat/53 | — | 100 | No crack |
| | 9 | Oxygen free copper | 0.5 | 65 | 250 | A6063/15.0 | Cold/50 | — | 100 | No crack |
| | 10 | Phosphorus processed deoxidized copper | 0.5 | 65 | 350 | A6063/150 | Cold/50 | — | 100 | No crack |
| | 11 | Oxygen free copper | 0.5 | 65 | 350 | A6063/15.0 | Heat/58 | — | 100 | No crack |
| | 12 | Phosphorus processed deoxidized copper | 0.5 | 65 | 400 | A1100/5.0 | Heat/58 | — | 100 | No crack |
| | 13 | Oxygen free copper | 10 | 60 | 350 | A6063/10.0 | Heat/50 | — | 100 | No crack |
| | 14 | Oxygen free copper | 1.0 | 68 | — | A1100/2.0 | Cold/58 | 350 | 100 | No crack |
| | 15 | Phosphorus processed deoxidized copper | 1.0 | 65 | — | A6063/100 | Cold/58 | 300 | 100 | No crack |
| | 16 | Oxygen free copper | 0.5 | 65 | — | A6063/15.0 | Cold/50 | 350 | 100 | No crack |
| | 17 | Phosphorus processed deoxidized copper | 0.5 | 55 | — | A6063/10.0 | Cold/50 | 300 | 100 | No crack |
| Comparative example | 1 | Oxygen free copper | No insertion member | | | A1100/10.0 | Heat/49 | | 50 | Destroyed |
| | 2 | Oxygen free copper | | | | A6063/100 | Heat/58 | | 60 | Cracks |
| | 3 | Phosphorus processed deoxidized copper | | | | A6063/10.0 | Heat/59 | | 70 | Destroyed |
| | 4 | Phosphorus processed deoxidized copper | | | | A1100/10.0 | Heat/58 | | 95 | Cracks |

**[0070]** Furthermore, the heat transfer performance of the test heat sink **20** shown in **FIG. 3** manufactured by the aluminum—copper clad members according to the example Nos. 2, 8 and 16 and the non-clad aluminum alloy member having the same thickness as the aforementioned clad members, were compared and evaluated.

**[0071]** The aforementioned test heat sink **20** was prepared by cutting out the aforementioned clad member into a plate of 80 mm width (W) and 60 mm depth (D) and forming three rows of tongue-like fins **22** of 30 mm height (FH) at the fin pitch (FP) of 2 mm. The copper-base member side constitutes a plate-like base portion **21**. As for the test heat sink **20** made of the non-clad aluminum alloy member, the test heat sink **20** was prepared by cutting out the aforementioned non-clad aluminum alloy member into the same size as the aforementioned clad member and forming the same tongue-like fins **22** as in the aforementioned clad member on one surface. The other side constitutes a plate-like base portion **21**.

**[0072]** As shown in **FIG. 3, a** heat source **23** was attached to the rear central portion of the base portion **21** of each test heat sink **20** in a close-fitted manner. Then, the test heat sink **20** was heated by the heat source **23** and, at the same time, cooled by blowing air of 2 m/sec wind velocity onto the test heat sink from the upper side of the fins. In this state, the temperature of the right above portion **24** of the heat source **23**, the temperature of the cooling air, and the input heat quantity (w) of the heat source **23** were measured respectively, and the thermal resistance (R) of each test heat sink was calculated by the following formula (f1) for evaluating the heat transfer performance

$$R=(Te-Tair)/Q \qquad \text{(f1)}$$

**[0073]** wherein R is a thermal resistance (° C./w) of the heat sink, Te is a temperature (° C.) at the right above portion **24** of the heat source **23**, Tair is a temperature (° C.) of the cooling air, Q is an input heat quantity(w) of the heat source **23**.

**[0074]** The evaluated results are shown in Table 2.

TABLE 2

Thermal transfer performance of Al-Cu clad member and non-clad member

| Test No. | Test piece | Thermal resistance R(° C./W) |
|---|---|---|
| I | Clad member (Example No. 2) Oxygen free copper-A1100 Middle heat treatment | 0.510 |
| | A1100 member (non-clad) | 0.667 |
| II | clad member (Example No. 8) phosphorus processed deoxidized copper-A6063 Middle heat treatment | 0.534 |
| | A6063 (non-clad) | 0.682 |
| III | clad member (Example No. 16) Oxygen free copper-A6063 Final heat treatment | 0.528 |
| | A6063 member (non-clad) | 0.682 |

[0075] From the results shown in Table 1, as for the aluminum—copper clad member in which the insertion member was interposed, it is confirmed that different metal members are firmly joined at the whole surface thereof to have high joining strength. Moreover, from the results shown in Table 2, it is also confirmed that each aluminum—copper clad member is excellent in heat transfer performance exceeding the heat transfer performance of aluminum without causing deterioration of heat transfer performance due to the joined portions.

[0076] Heat Sink

[0077] FIGS. **4-11** show the examples A-D of heat sinks according to the present invention, each of which consists of a thermal-diffusion portion of aluminum-base material and a heat radiation portion of copper-base material.

[0078] Moreover, FIGS. **12-13** show examples E-F of heat sinks according to the present invention, each of which is made of the aforementioned aluminum—copper clad member **1**. Each of these heat sinks consists of a heat-radiation portion of aluminum-base material and a thermal diffusion portion of copper-base material joined to the heat-radiation portion via an insertion member. The shape and the manufacturing method of each heat sink will be explained as follows.

[0079] Embodiment A

[0080] The heat sink **31** shown in **FIG. 4** consists of a heat radiation portion **41** having a number of tongue-like fins **42** on one surface side thereof and a plate shaped thermal diffusion portion **51** joined to the other side of the heat radiation portion **41**.

[0081] As shown in **FIG. 5**, the heat sink **31** is manufactured by joining a plate-shaped aluminum-base member **43** and a plate-shaped copper-base member **51** and then forming tongue-like fins **42** on the aluminum plate **43**.

[0082] In the aforementioned manufacturing process, since both the members are flat plates, the joining method may be any one of well-known methods including a rolling method, a friction joining method, an ultrasonic joining method and a brazing method. Moreover, the tongue-like fins **42** may be formed by a well known method.

[0083] As shown in **FIG. 6**, the heat sink **31** can also be manufactured by forming tongue-like fins **42** on the aluminum plate to obtain a heat radiation portion **41**, and then joining the heat radiation portion **41** onto a copper-base plate **51**. In this case, the joining of the heat radiation portion **41** and the thermal diffusion portion **51** must be performed by a method other than a rolling method.

[0084] It is preferable that the thickness of the aluminum plate **43** before forming the tongue-like fins **42** is from 1 mm to 10 mm. If the fin height is less than 1 mm, the fin height becomes lower, resulting in decreased heat radiation performance. On the other hand, even if the fin height exceeds 10 mm, it does not contribute to form thinner and higher tongue-like fins **42**.

[0085] Moreover, it is preferable that the thickness of the plate-shaped copper-base member constituting a thermal diffusion portion **51** is from 1.5 mm to 8 mm so as to secure the excellent thermal diffusion performance as a plate-shaped thermal diffusion portion and to avoid excessive weight.

[0086] Embodiment B

[0087] The heat sink **32** shown in **FIG. 7** consists of a heat radiation portion **41** having a number of tongue-shaped fins **42** formed on one surface thereof and a thermal diffusion portion **61** joined to the other side of the heat radiation portion **41**. The thermal diffusion portion **61** has a hollow chamber **62** for heat exchanging medium. This heat sink **32** can be served as a heat pipe by vacuuming the chamber **62** and filling the vacuumed chamber with heat exchange medium such as water.

[0088] The heat sink **32** can be manufactured by joining the heat radiation portion **41** manufactured by forming the tongue-shaped fins **42** on the aluminum plate and the thermal diffusion portion **61** having a hollow portion, as shown in **FIG. 8**. Alternatively, the tongue-shaped fins **42** may be formed after joining the two members as shown in **FIG. 5**. Alternatively, as shown in **FIG. 9**, the similar heat exchanging chamber **32'** can be manufactured by joining a copper-base member **65** having a U-shaped cross-section to the heat sink **31** obtained by joining the plate-shaped thermal diffusion portion **51** and the heat radiation portion **41** as shown in **FIG. 4**. In this case, the plate-shaped thermal diffusion portion **51** and the copper-base member **65** of a U-shaped cross-section constitute the thermal diffusion portion **64**.

[0089] In this embodiment, the joining method of the heat radiation portion **41** and the thermal diffusion portion **61**, the joining method of the heat radiation portion **41** and the U-shaped member **65**, the forming method of the tongue-shaped fins **42**, and the size of the heat radiation portion **41** are the same as in the example A. Since the thermal diffusion portion **61** and **64** of the heat sink **32** and **32'** functions as a heat pipe, the thermal diffusion performance and the heat radiation performance of the thermal diffusion portion **61** and **64** will be increased. Therefore, the thickness of the thermal diffusion portion **61** and **64** may be thinner than that of the plate-shaped thermal diffusion portion **51**. The thickness is preferably from 1.2 mm to 5 mm. Since the thermal diffusion portion **61** is made of copper-base material, it is excellent in corrosion resistance, and water can be used as heat exchanging medium.

[0090] Embodiment C

[0091] **FIG. 10** shows a heat sink according to an embodiment C. This heat sink **33** has a thermal diffusion portion **66** which functions as a heat pipe like the heat sink **32** according to the embodiment B. However, this heat sink **33** is different from the aforementioned heat sink **32** in that wicks are formed in the inner wall of the heat exchanging medium chamber **63**. Thus, forming wicks by attaching a wire net or sintering copper powder to the inner wall of the heat exchanging medium chamber **63** enhances the circulation of the heat exchange medium within the chamber, resulting in improved performance of the heat pipe due to the capillary phenomenon, which improves the thermal diffusion performance and the heat radiation performance of the heat sink.

[0092] Embodiment D

[0093] **FIG. 11** shows a heat sink **34** having a heat pipe **73** embedded in the thermal diffusion portion **71**. In the heat pipe **73**, heat exchange medium **72** is enclosed.

[0094] In the heat sink **32** and **33** of the aforementioned embodiments B and C, the thermal diffusion portion **61** and

**66** itself constitutes a heat pipe. The heat pipe is formed by vacuuming air and introducing heat exchanging medium after the assembly of each members. Thus, the opening for vacuuming air or introducing heat exchanging medium is exposed to the outer surface of the heat sink.

[**0095**] On the other hand, in the heat sink **34** of this embodiment, after introducing heat exchange medium through an opening and closing the opening to complete a heat pipe **73**, the heat pipe **73** is assembled in the state that this heat pipe **73** is embedded in the thermal diffusion portion **71**, and then the tongue-shaped fins **42** are formed. Therefore, the heat pipe **73** is surrounded by the thermal diffusion portion **71** and cannot be seen from the outside.

[**0096**] The heat sink **34** can be manufactured by, for example, the process shown in **FIG. 11**.

[**0097**] That is, the completed heat pipe **73** is loaded into the dented portion **75** of the outer shell member **74**. The dented portion **75** has an inner shape corresponding to the outside shape of the heat pipe **73**. Therefore, the heat pipe **73** is closely fitted in the dented portion **75**. Thereafter, the outer shell member **74** in which the heat pipe **73** is loaded is joined, for example, to the heat sink **31** in which the plate-shaped thermal diffusion portion **51** and the heat radiation portion **41** as shown in **FIG. 6** are joined. This heat-pipe-embedded-type heat sink **34** has high reliability since the previous prepared reliable heat pipe is used.

[**0098**] Embodiment E

[**0099**] **FIG. 12** shows a heat sink including a heat radiation portion **81** on which tongue-shaped fins **42** are formed, a thermal diffusion portion **82** to be attached to a heating element and an insertion member **12** interposed between the heat radiation portion **81** and the thermal diffusion portion **82** to join them. This heat sink **35** is manufactured by forming tongue-shaped fins **42** on the surface of the aluminum-base member **11** of the previously manufactured aluminum—copper clad member **1**. The copper-base member **13** constitutes a plate-shaped thermal diffusion portion **82** as it is. The preferable thickness of each part before machining is the same as the embodiment A.

[**0100**] The heat sink **35** is excellent in thermal diffusion performance and light in weight like the embodiment A. Moreover, since the heat radiation portion **81** and the thermal diffusion portion **82**, which are different metal materials, are joined via the insertion member **12**, the joining strength is excellent.

[**0101**] Embodiment F

[**0102**] **FIG. 13** shows a heat sink **36** with a heat exchanging medium chamber **84** formed in the thermal diffusion portion **83**. In this heat sink **36**, the heat exchanging medium chamber **84** is formed by joining a copper-base member **65** of a U-shaped cross-section to the heat sink **35** of the embodiment E. The copper-base member **13** and the U-shaped member **65** in this clad member **1** constitutes a thermal diffusion portion **83**. The preferable thickness of each part before machining is the same as the embodiment B.

[**0103**] The heat sink **36** is excellent in thermal diffusion performance and light in weight like the embodiment B. Moreover, since the heat radiation portion **81** and the thermal diffusion portion **83**, which are different metal materials, are joined via the insertion member **12**, the joining strength is excellent.

[**0104**] Furthermore, in the heat sink **36**, wicks may be provided to the inner wall of the heat exchanging medium chamber **84** like the heat sink **33** shown in **FIG. 10**.

[**0105**] In the aforementioned heat sinks **31, 32, 32', 33, 34, 35** and **36**, the composition of the aluminum-base member constituting the heat radiation portion **41** and **81** is not specifically limited. For example, high-grade pure aluminum, aluminum or its aluminum alloy of JIS A1xxx series, Al—Cu series alloy of JIS A2xxx series, Al—Mn series alloy of JIS A3xxx series, Al—Si series alloy of JIS A4xxx series, Al—Mg series alloy of JIS A5xxx series, Al—Si—Mg series alloy of JIS A6xxx series, Al—Zn—Mg—Cu series alloy and Al—Zn—Mg series alloy of JIS A7xxx series, etc., can be used. Among the aforementioned materials, JIS A6xxx series alloy can be recommended in consideration of forming the tongue-shaped fins.

[**0106**] Moreover, the composition of the copper-base member constituting the thermal-diffusion portion **51, 61, 62, 65, 66, 71, 82** and **83** is not specifically limited. For example, tough pitch copper, oxygen-free copper or phosphorus processed deoxidized copper can be used. Among the aforementioned materials, oxygen free copper or phosphorus processed deoxidized copper can be recommended in consideration of controlling the generation of oxides or aluminum compounds when joining to the heat radiation portion **41** which is different in metal material.

[**0107**] Moreover, in the embodiments E-F, as the aforementioned insertion member **12**, it is recommended to use high-grade pure aluminum of 99.90% purity or more, and JIS A1050 alloy among JIS A1xxx series aluminum as in the insertion member in an aforementioned aluminum—copper clad member.

[**0108**] The present invention claims priorities based on Japanese Patent Applications Nos. 2000-66807 filed on Mar. 10, 2000 and 2000-66942 filed on Mar. 10, 2000, the content of which is incorporated hereinto by reference in its entirety.

[**0109**] The terms and expressions which have been employed herein are used as terms of description and not of limitation, and there is no intent, in the use of such terms and expressions, of excluding any of the equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

**1**. An aluminum—copper clad member, comprising:

an aluminum-base member;

a copper-base member; and

an insertion member made of pure aluminum or JIS A1xxx series aluminum alloy,

wherein said aluminum-base member and said copper-base member are clad via said insertion member.

**2**. The aluminum—copper clad member as recited in the claim 1, wherein said copper-base member is made of oxygen free copper or phosphorus processed deoxidized copper.

**3**. A method of manufacturing an aluminum—copper clad member, said method comprising the steps of:

joining an insertion member made of pure aluminum or JIS A1xxx series aluminum alloy to a copper-base member by a cold rolling to obtain a joined two members;

joining an aluminum-base member to said insertion member by a cold rolling or a hot rolling to obtain a joined three members; and

heat treating said joined two members before joining said aluminum-base member to said insertion member by a cold rolling or a hot rolling, or heat treating said joined three members after joining said aluminum-base member to said insertion member by a cold rolling or a hot rolling.

**4**. The method of manufacturing an aluminum—copper clad member as recited in claim 3, wherein a roll-working rate of said insertion member is set to 30% or more.

**5**. The method of manufacturing an aluminum—copper clad member as recited in claim 3, wherein a roll-working rate of said aluminum-base member is set to 40% or more.

**6**. The method of manufacturing an aluminum—copper clad member as recited in claim 4, wherein a roll-working rate of said aluminum-base member is set to 40% or more.

**7**. The method of manufacturing an aluminum—copper clad member as recited in claim 3, wherein said step of heat treating is performed at from 200 to 400° C.

**8**. The method of manufacturing an aluminum—copper clad member as recited in claim 4, wherein said step of heat treating is performed at from 200 to 400° C.

**9**. The method of manufacturing an aluminum—copper clad member as recited in claim 5, wherein said step of heat treating is performed at from 200 to 400° C.

**10**. A heat sink, comprising:

a heat radiation portion made of aluminum-base material and provided with a plurality of tongue-like fins formed by skiving a surface layer of one side of said heat radiation portion; and

a thermal diffusion portion made of copper-base material and joined to the other side of said heat radiation portion in a closely fitted manner.

**11**. The heat sink as recited in the claim 10, wherein said thermal diffusion portion is a flat plate.

**12**. The heat sink as recited in the claim 10, wherein said thermal diffusion portion includes a heat exchanging medium chamber inside thereof.

**13**. The heat sink as recited in the claim 12, wherein said heat exchanging medium chamber is provided with wicks formed on an inner wall thereof.

**14**. A heat sink, comprising:

a heat radiation portion made of aluminum-base material and provided with a plurality of tongue-like fins formed by skiving a surface layer of one side of said heat radiation portion; and

a thermal diffusion portion made of copper-base material and joined to the other side of said heat radiation portion via an insertion member made of pure aluminum or JIS A1xxx series aluminum alloy.

**15**. The heat sink as recited in the claim 14, wherein said thermal diffusion portion is a flat plate.

**16**. The heat sink as recited in the claim 14, wherein said thermal diffusion portion includes a heat exchanging medium chamber inside thereof.

**17**. The heat sink as recited in the claim 16, wherein said heat exchanging medium chamber is provided with wicks formed on an inner wall thereof.

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