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KONISHI et al.(10) **Pub. No.: US 2014/0020882 A1**(43) **Pub. Date: Jan. 23, 2014**(54) **HEAT SINK FOR LED LIGHTING**(30) **Foreign Application Priority Data**(71) Applicant: **KABUSHIKI KAISHA KOBE SEIKO**
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SHO (Kobe Steel, Ltd.), Kobe-shi (JP)(51) **Int. Cl.**
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CPC **F28F 3/00** (2013.01)
USPC **165/185**(21) Appl. No.: **14/034,696**(22) Filed: **Sep. 24, 2013****Related U.S. Application Data**(63) Continuation of application No. PCT/JP2012/057691,
filed on Mar. 26, 2012.(57) **ABSTRACT**

A heat sink for LED lighting formed of an aluminum material includes: a mounting face part having an LED element mounted on a surface thereof; a first fin part extending in a direction perpendicular to the mounting face part; and a second fin part extending in a direction perpendicular to the mounting face part and extending in a direction intersecting the first fin part.

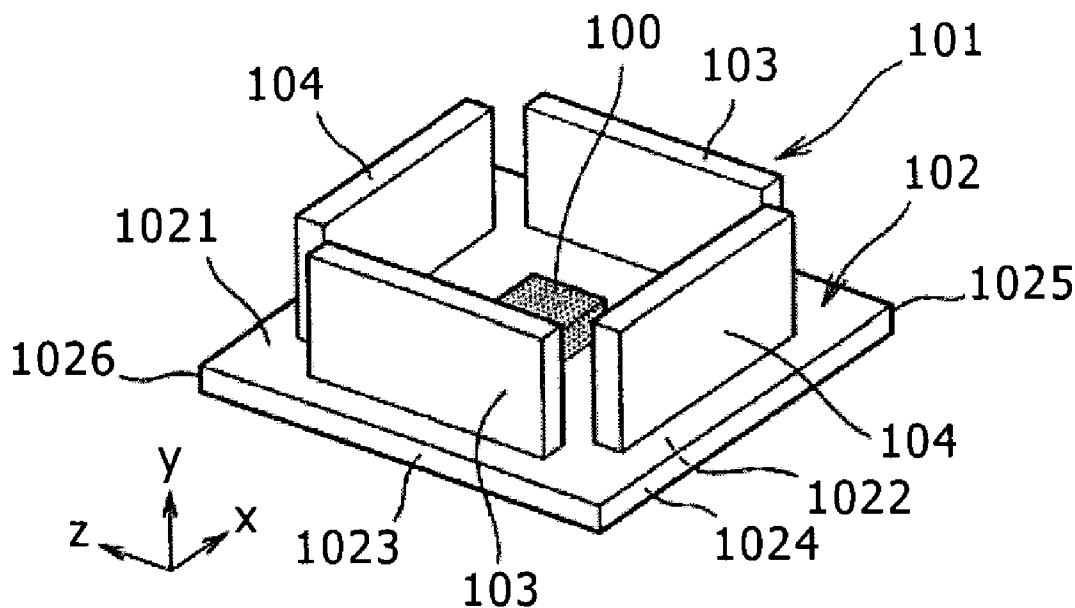


FIG. 1

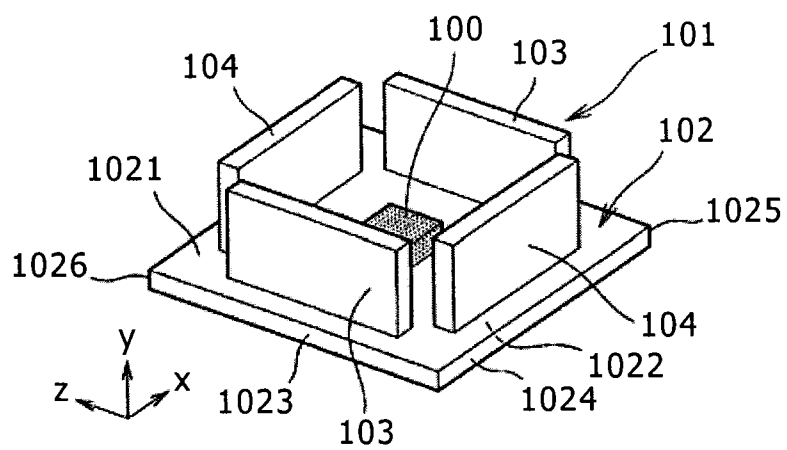


FIG. 2

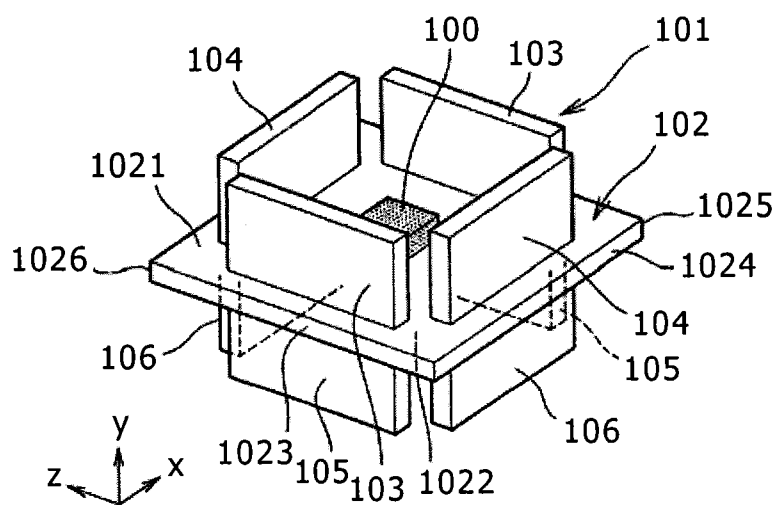


FIG. 3

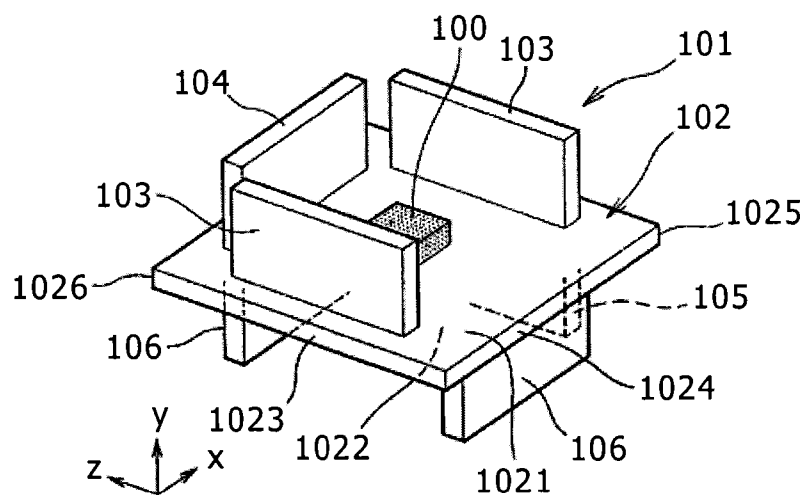
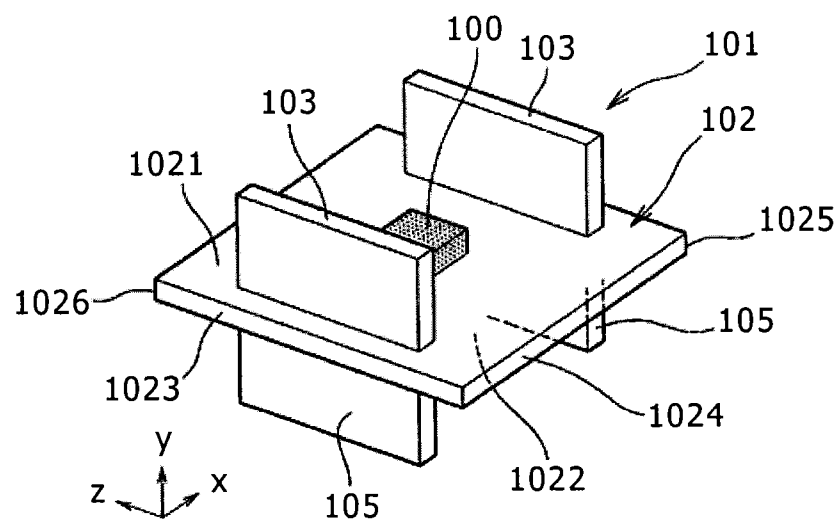


FIG. 4



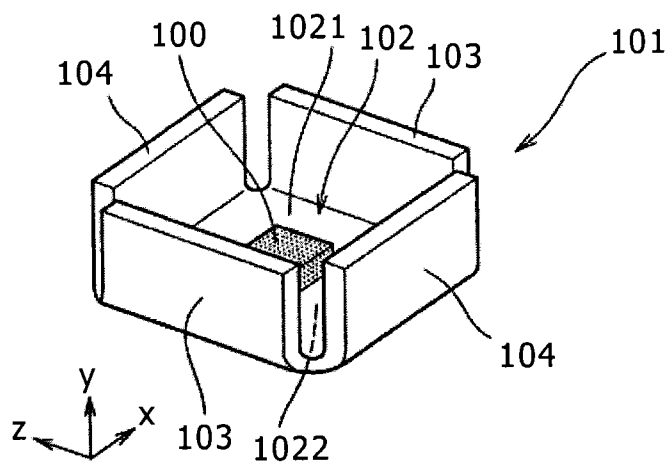


FIG. 7

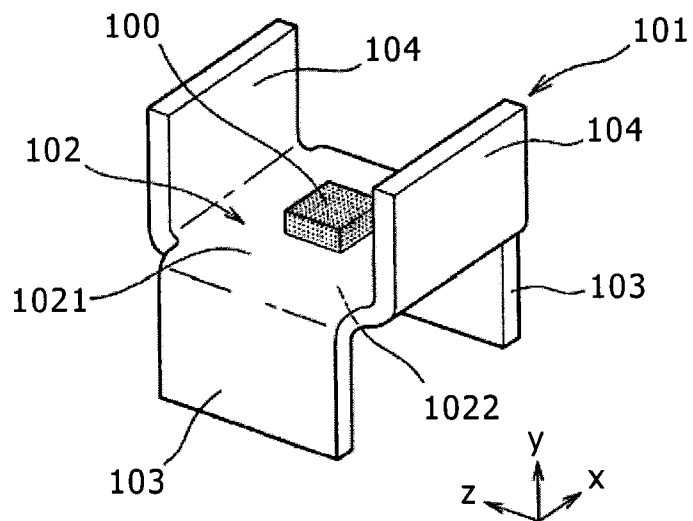


FIG. 8

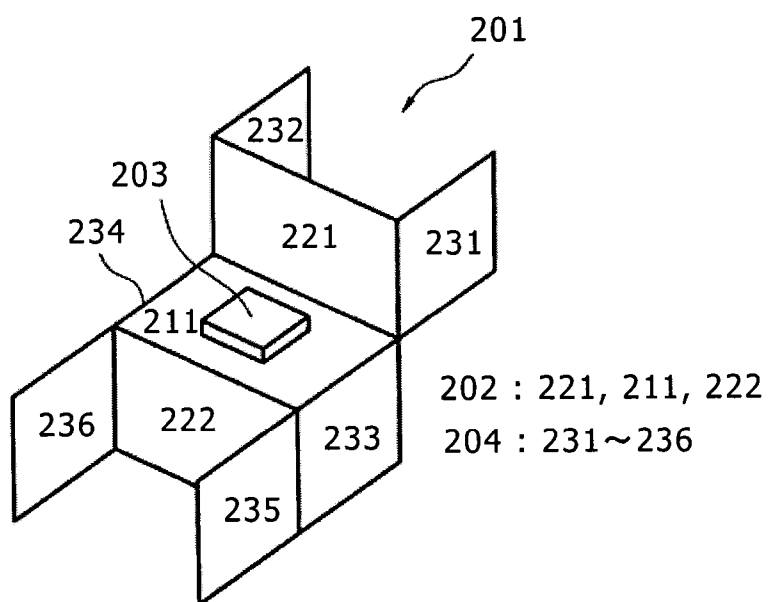


FIG. 9

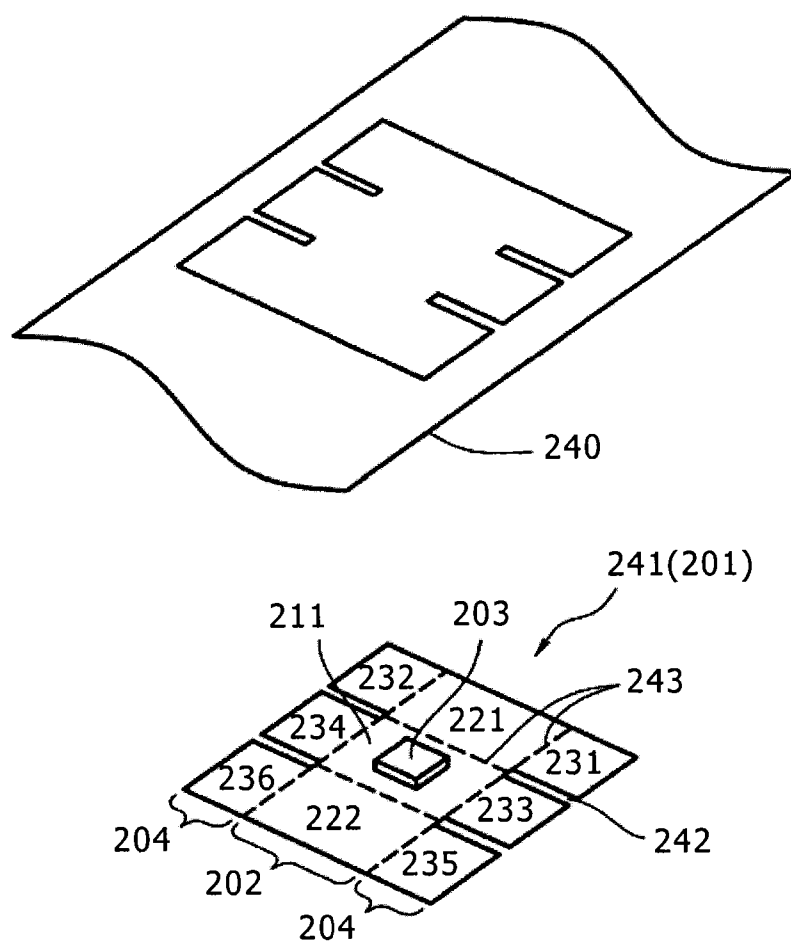


FIG. 10

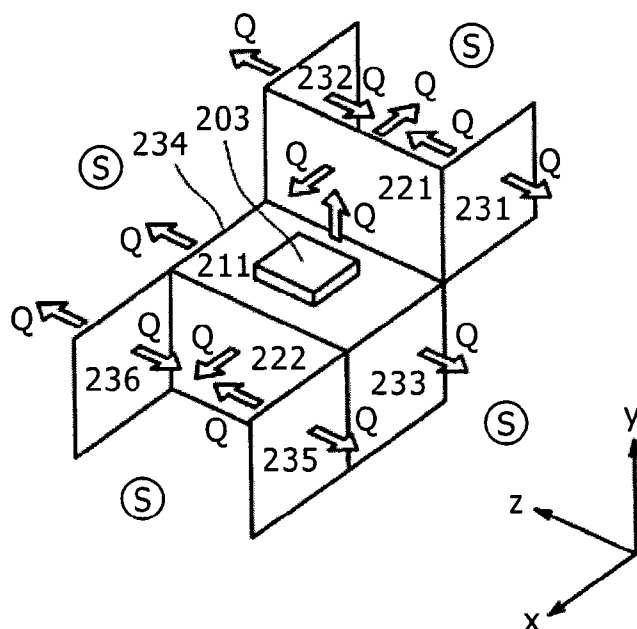
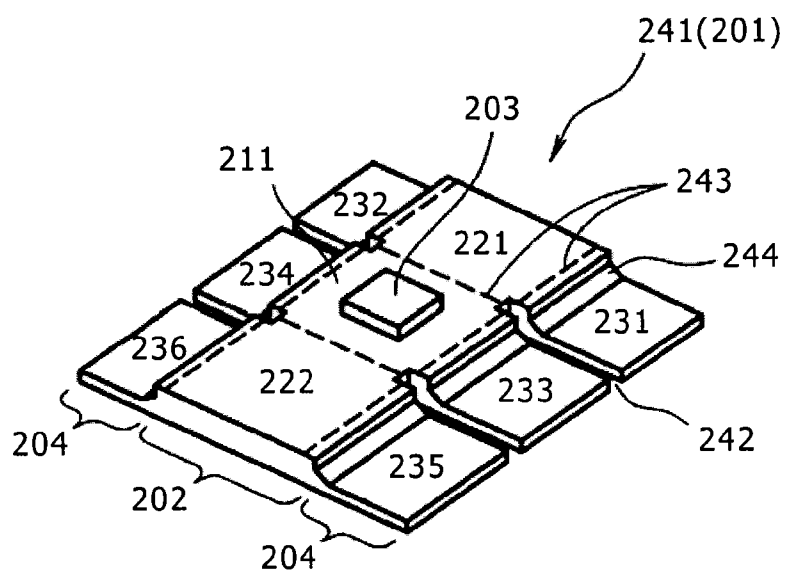


FIG. 11



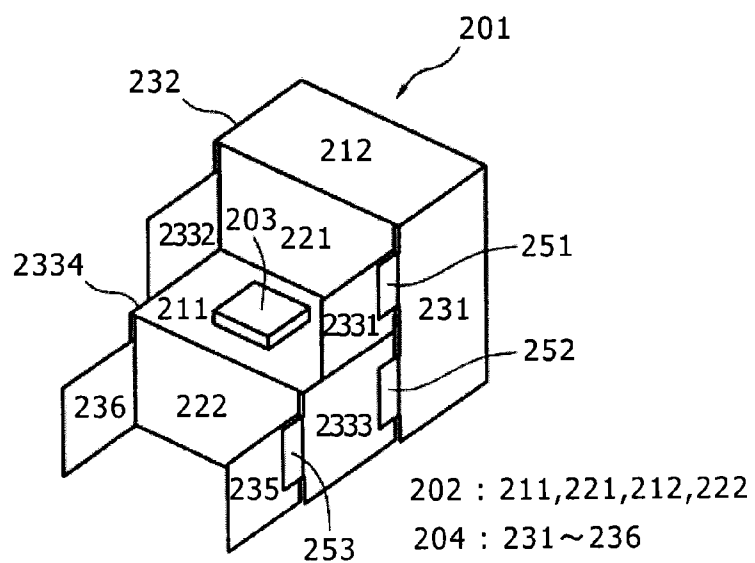


FIG. 14

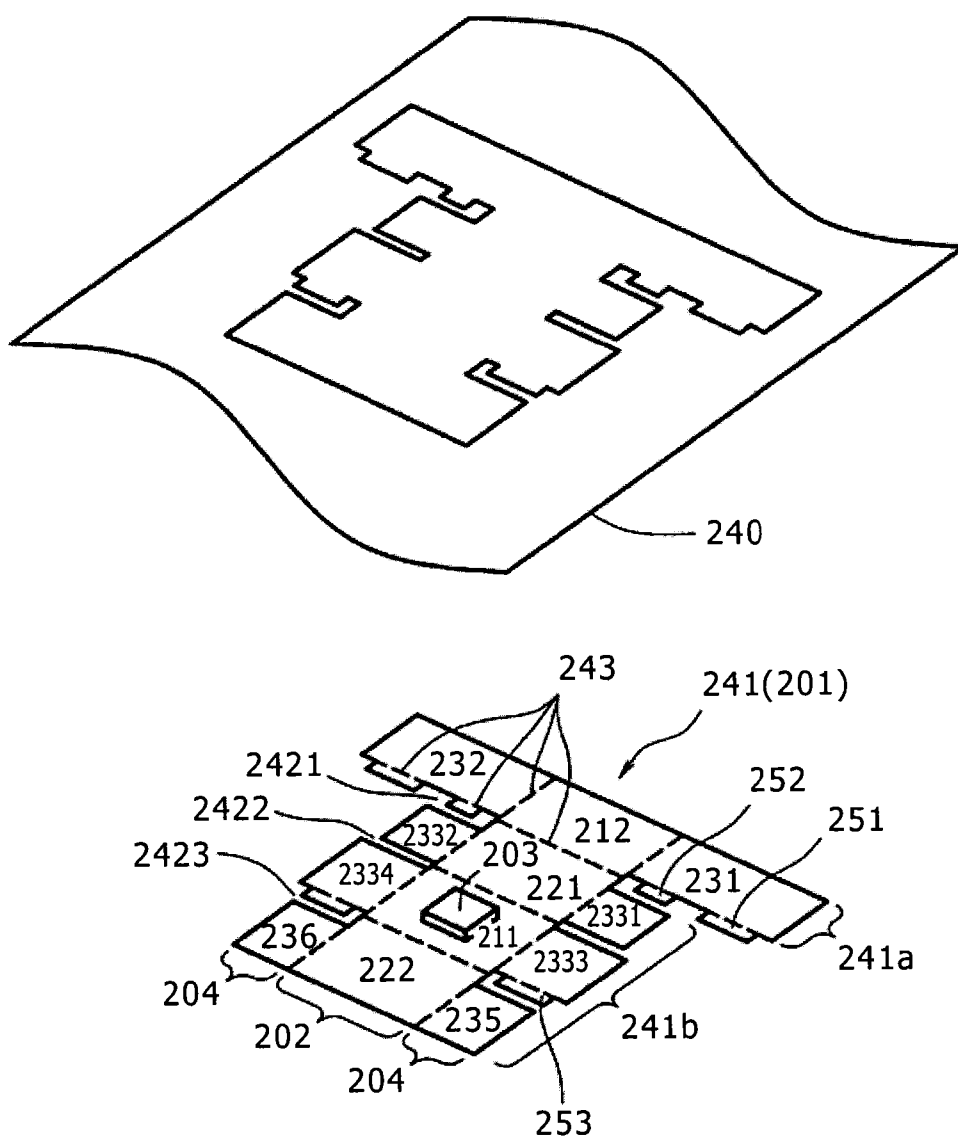


FIG. 15

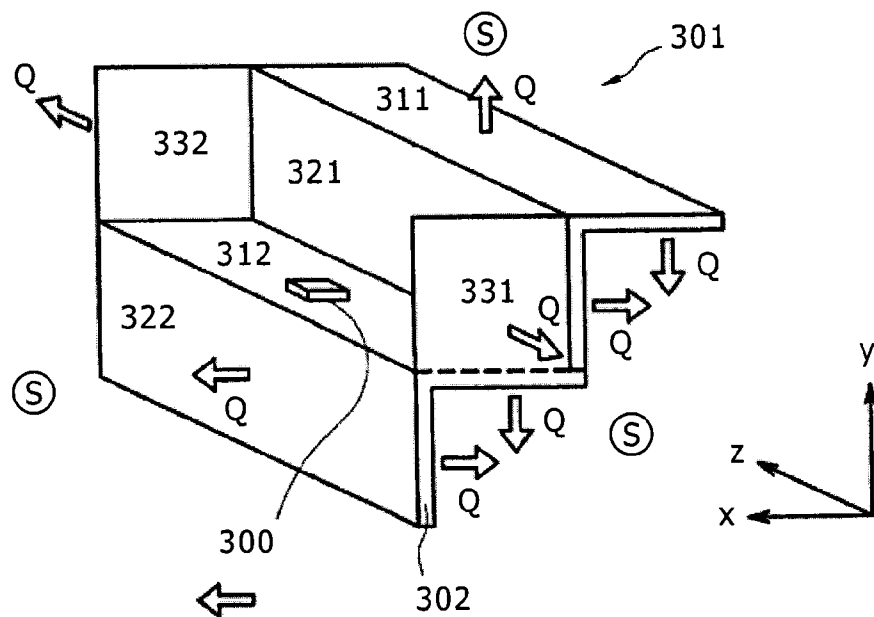


FIG. 16

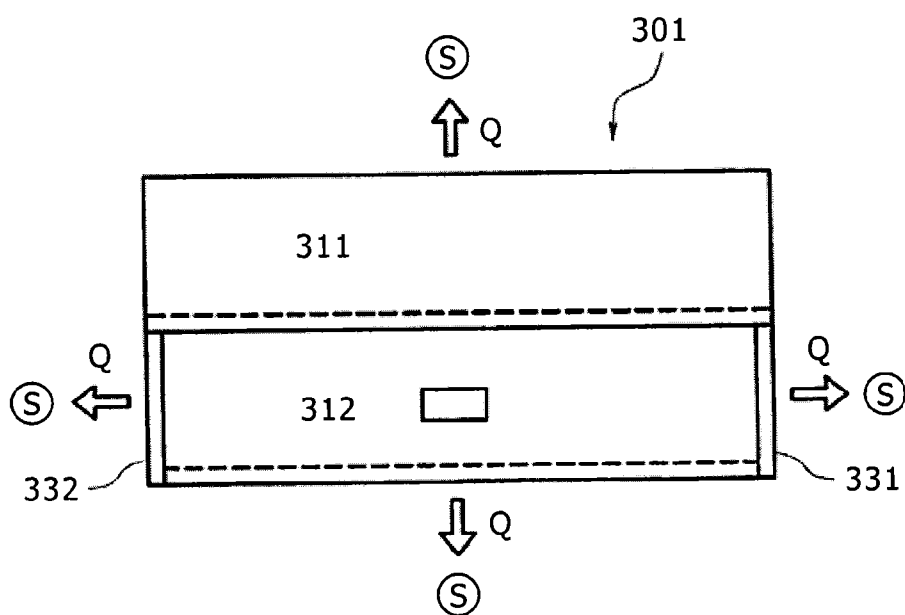


FIG. 17

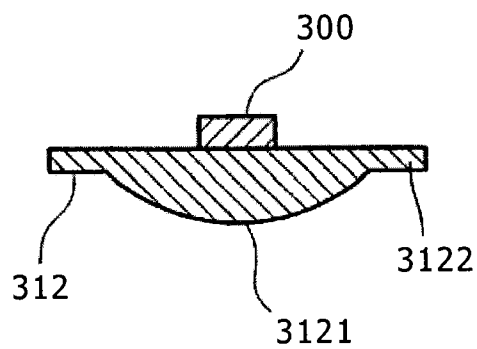


FIG. 18

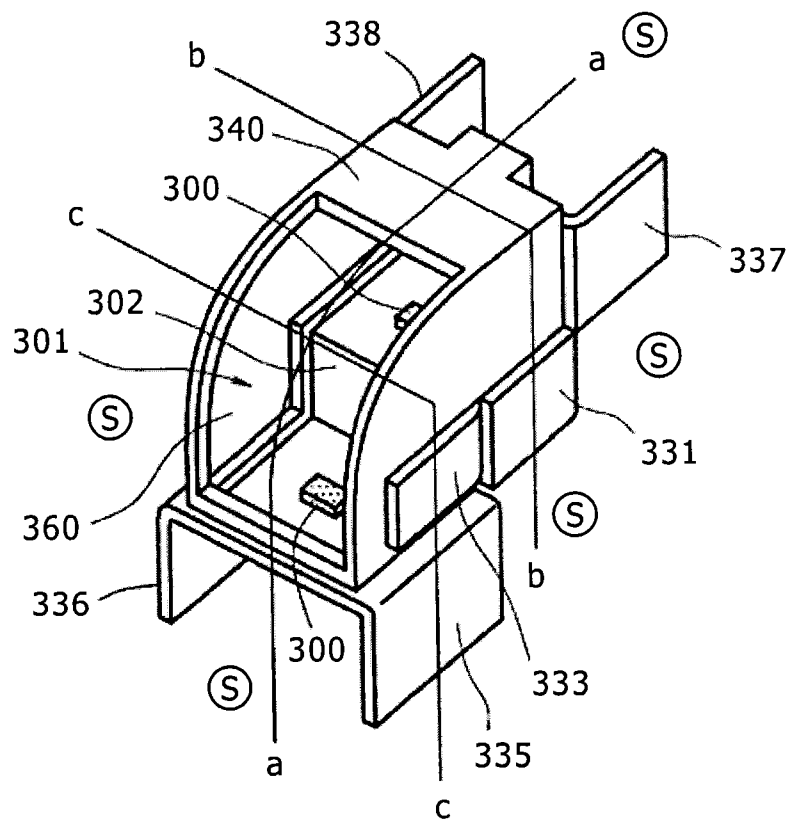
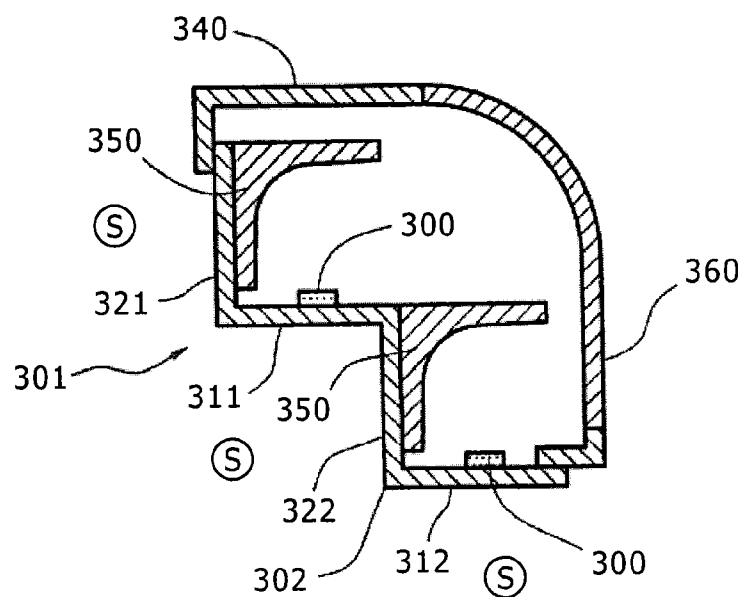
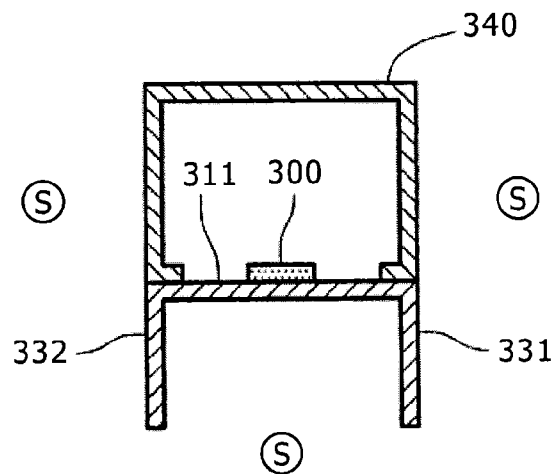


FIG. 19



a-a SECTION

FIG. 20



b-b SECTION

FIG. 21

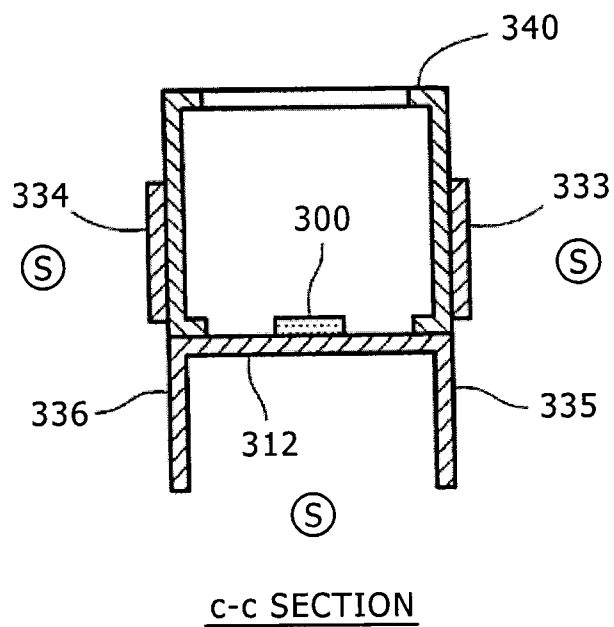


FIG. 22

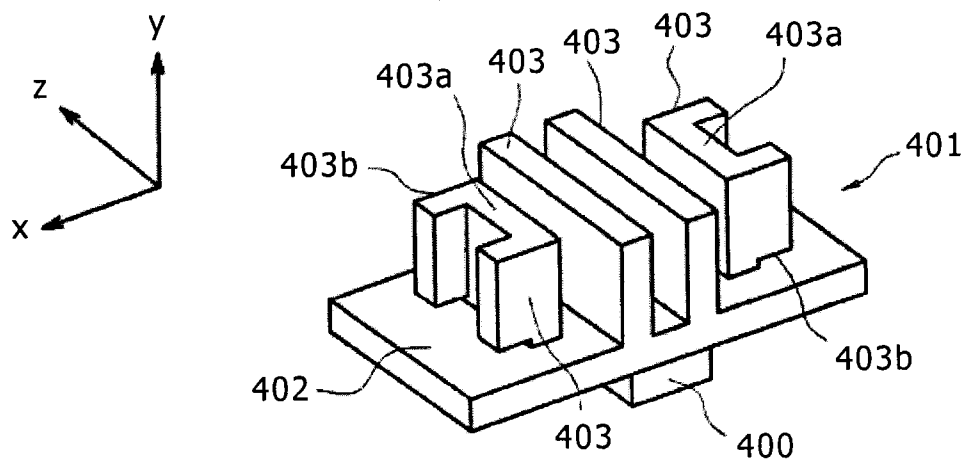


FIG. 23

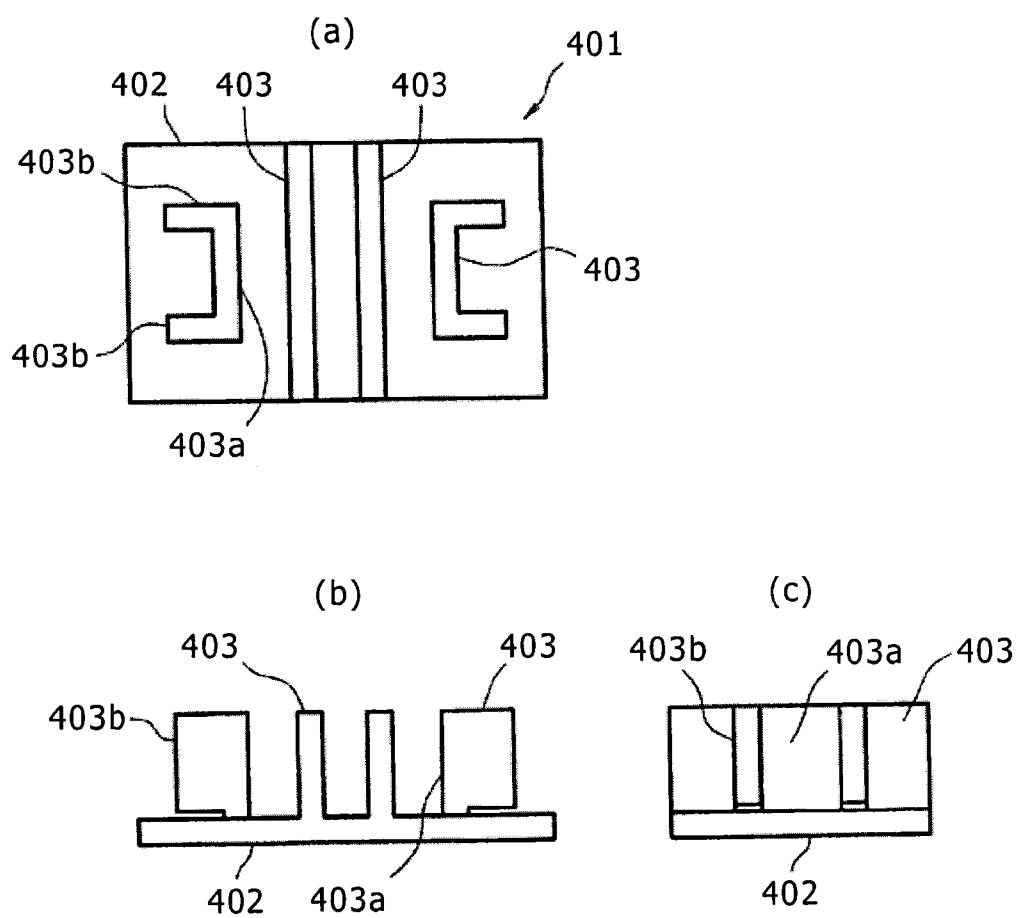


FIG. 24

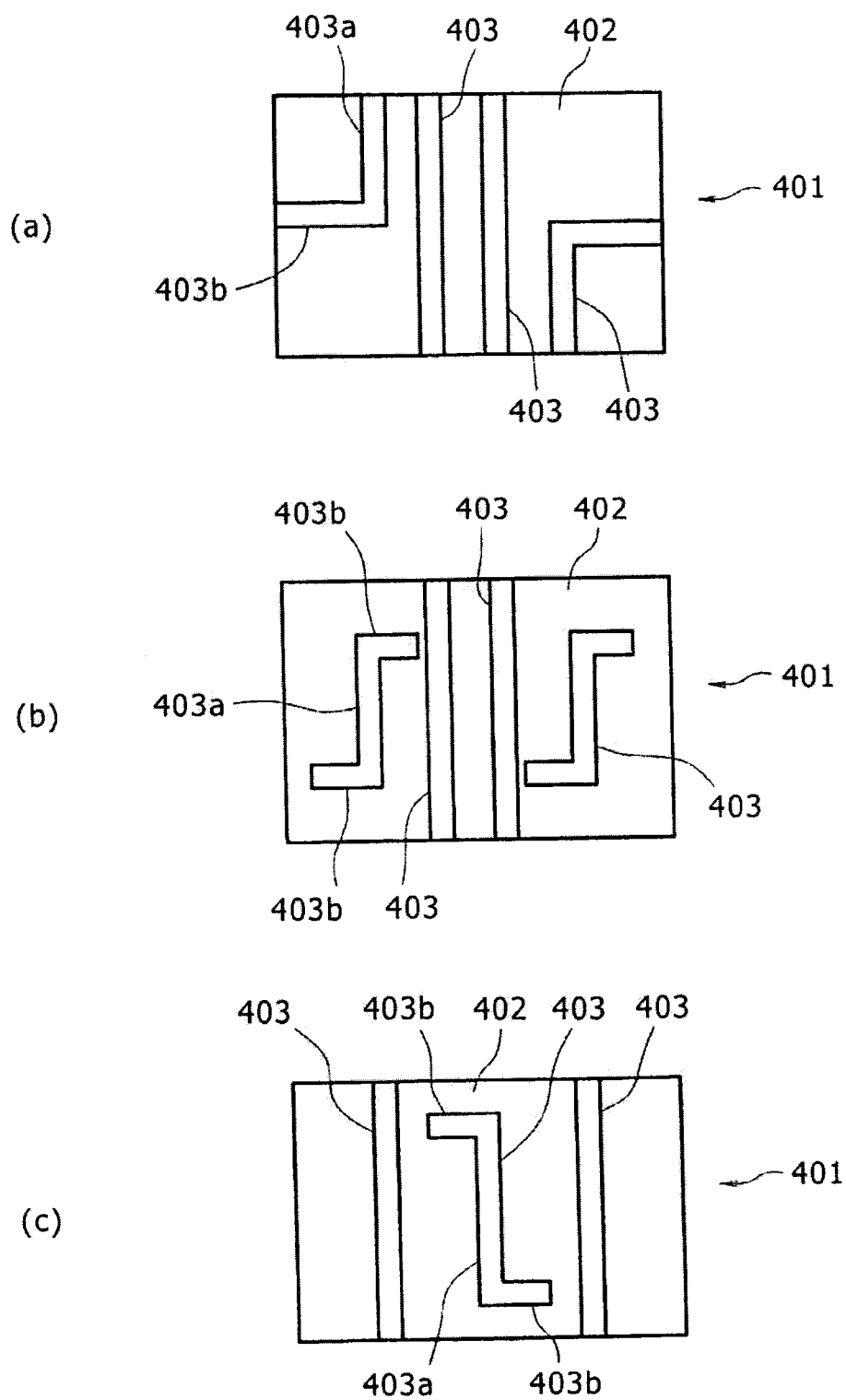


FIG. 25

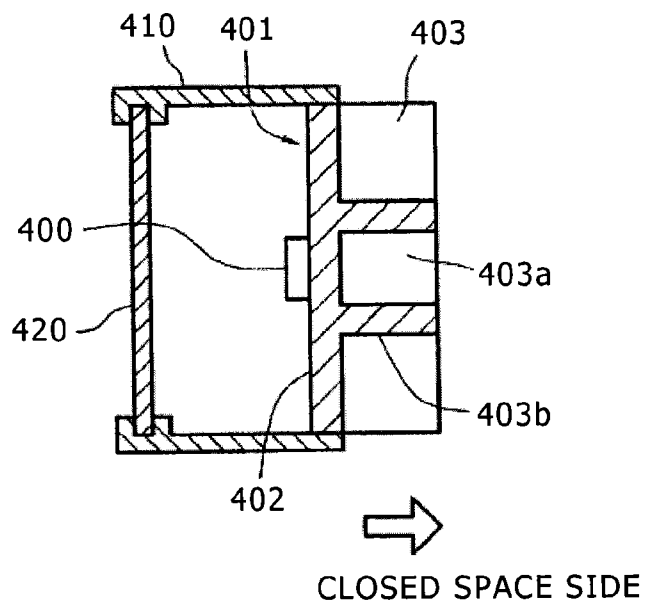


FIG. 26

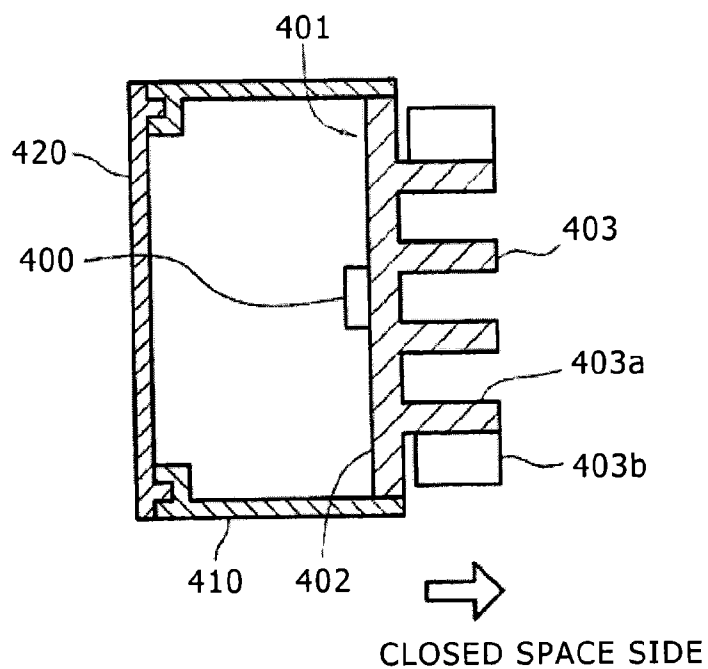


FIG. 27

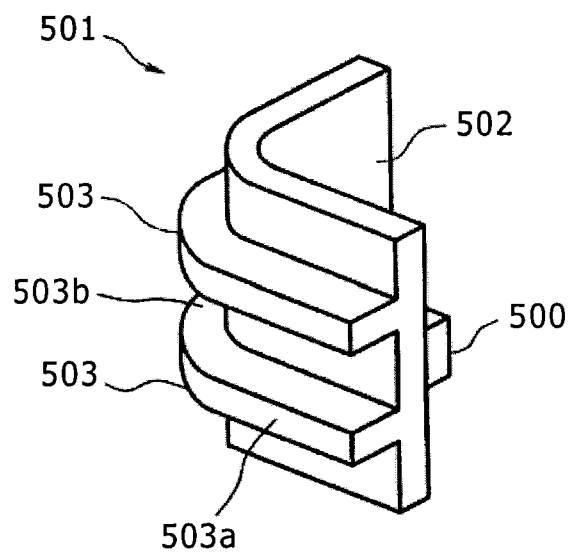


FIG. 28

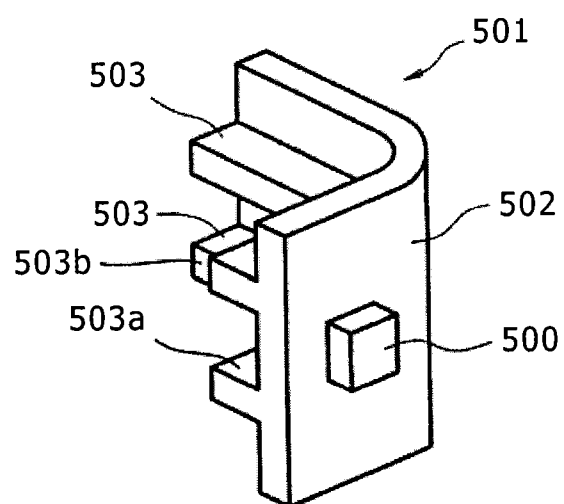


FIG. 29

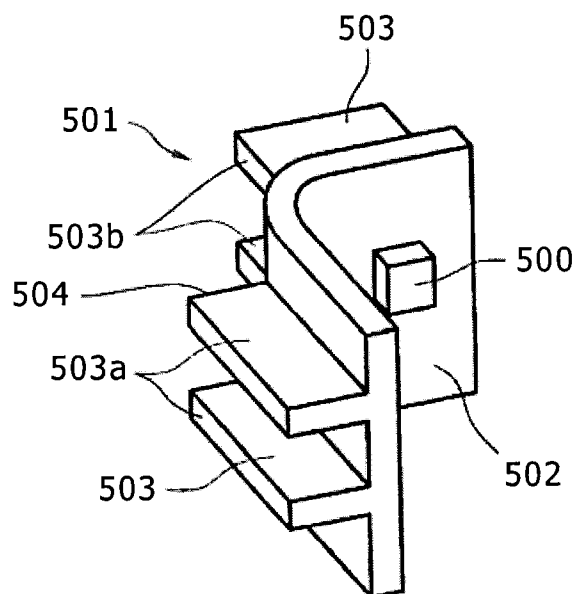


FIG. 30

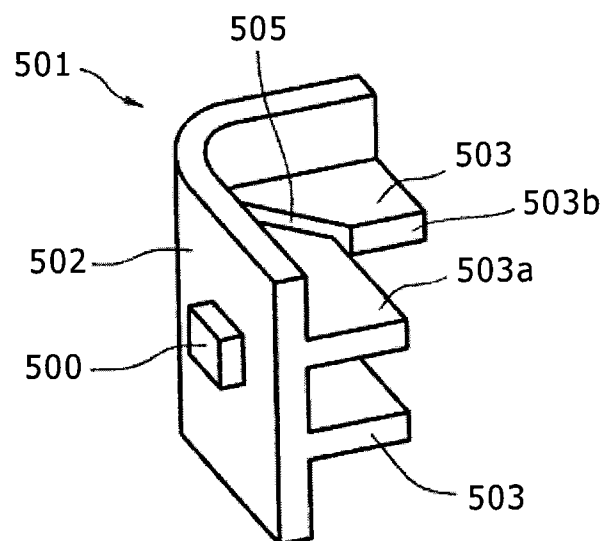


FIG. 31

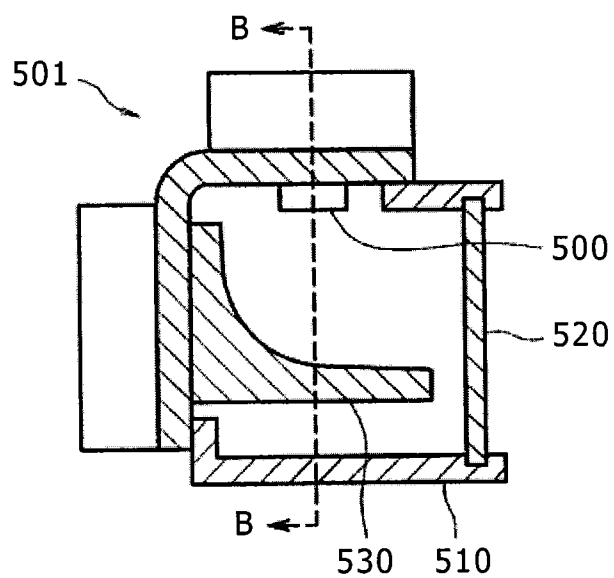
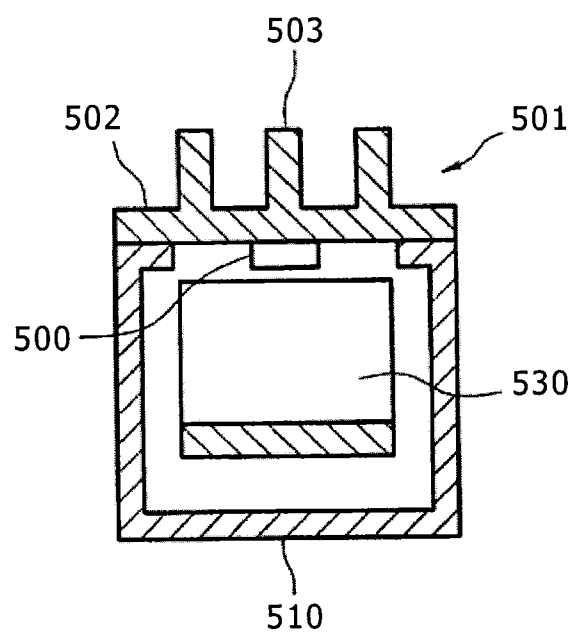


FIG. 32



A cross-sectional view of a semiconductor device 500. The device features a substrate 501 with a central opening 510. A layer 530 is formed on the substrate 501, surrounding the opening 510. A layer 502 is formed on the layer 530, and a layer 503 is formed on the layer 502. The layers 502 and 503 are formed in a pattern that fills the opening 510 and extends to the edges of the substrate 501.

FIG. 35

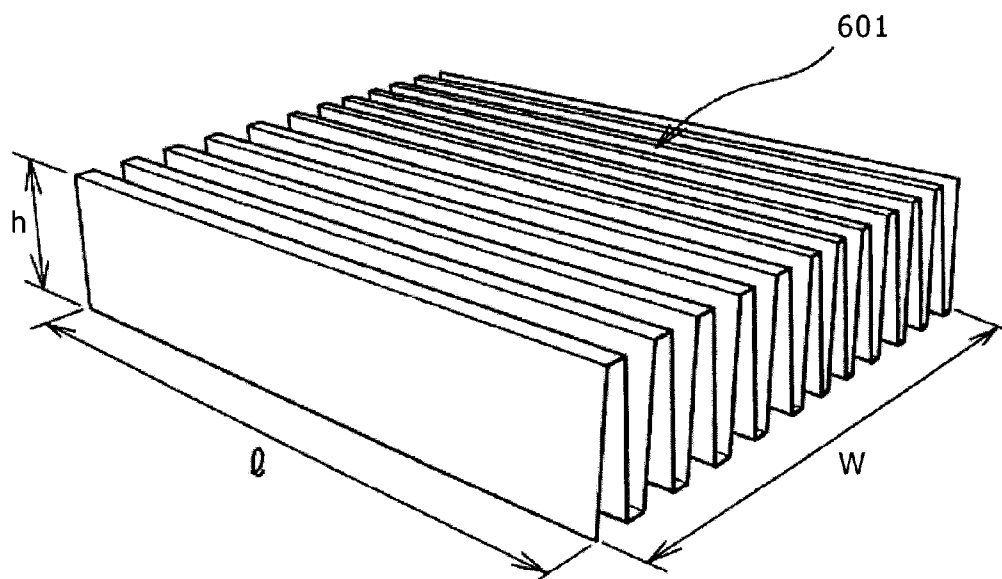


FIG. 36

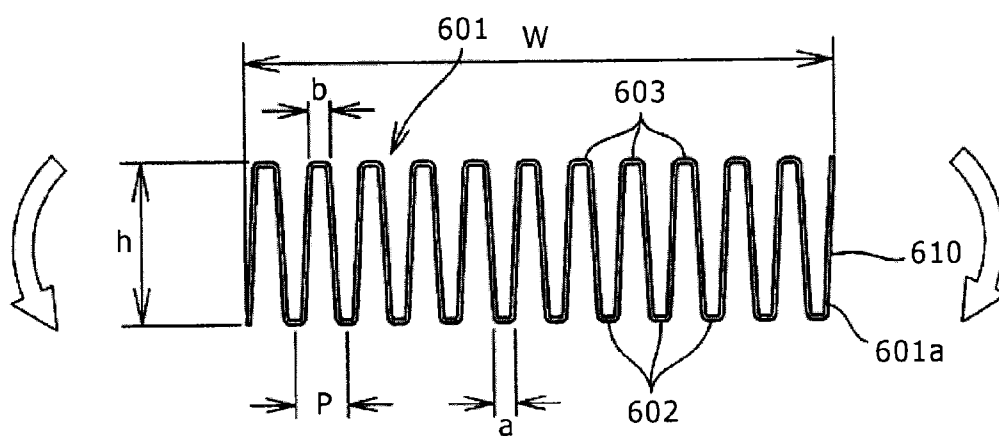


FIG. 37

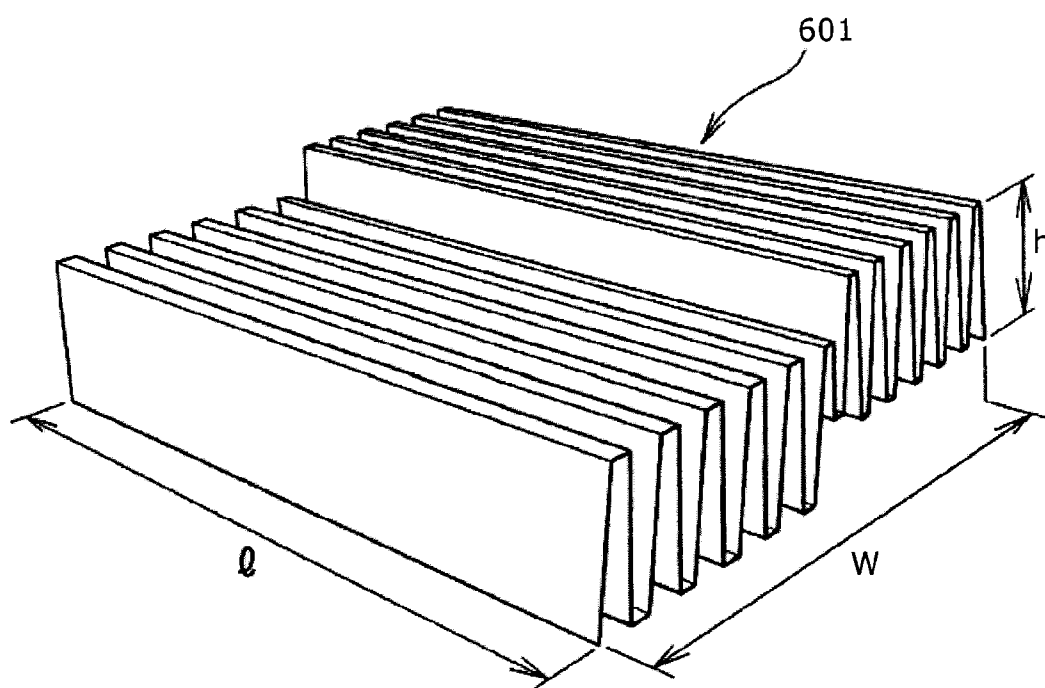


FIG. 38

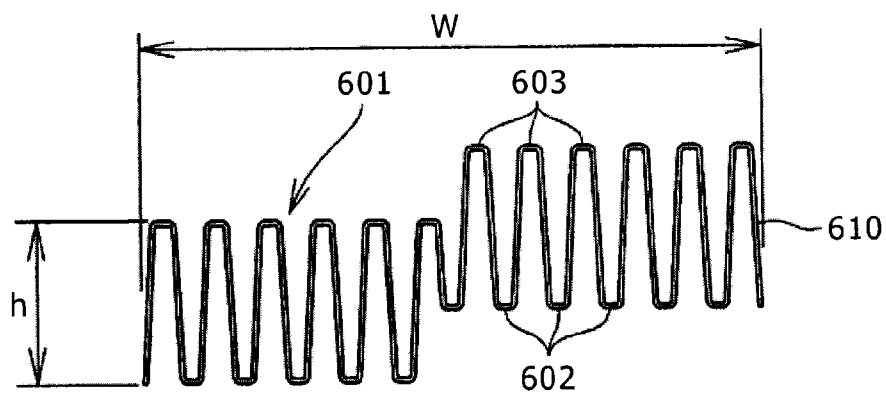


FIG. 39

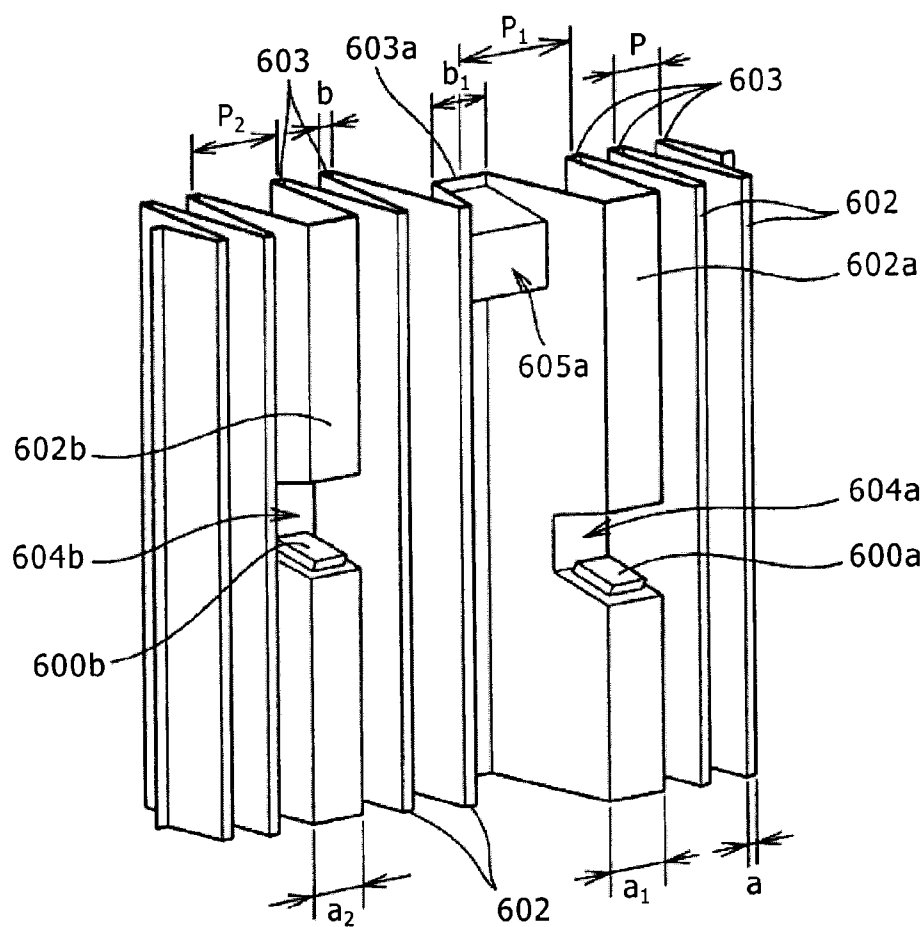


FIG. 40

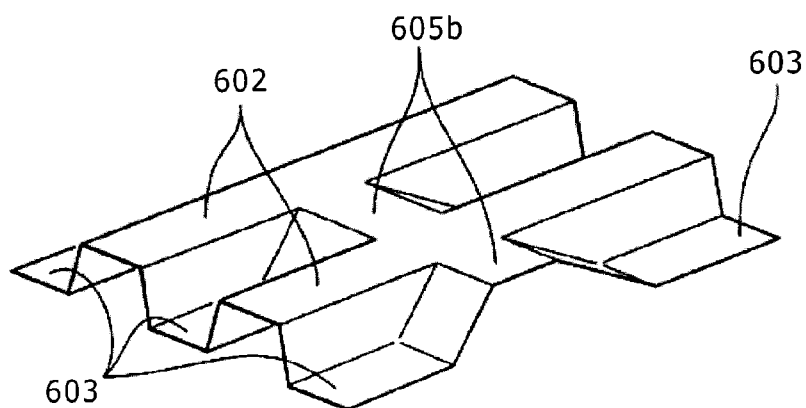


FIG. 41

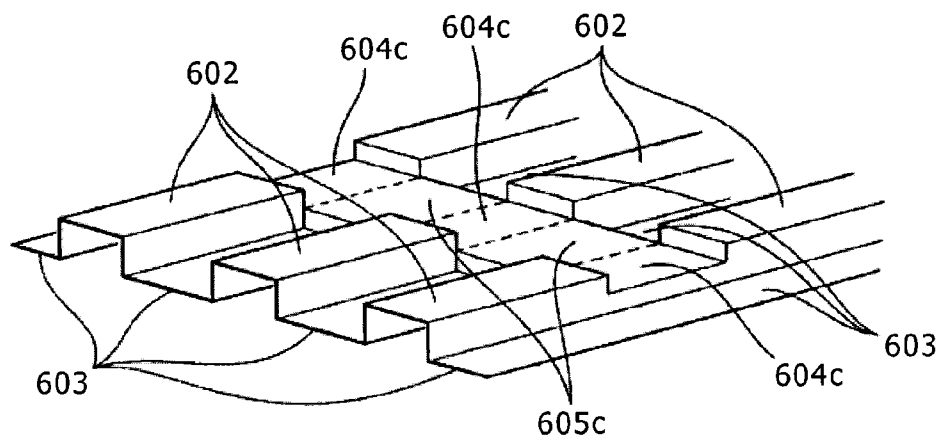


FIG. 42

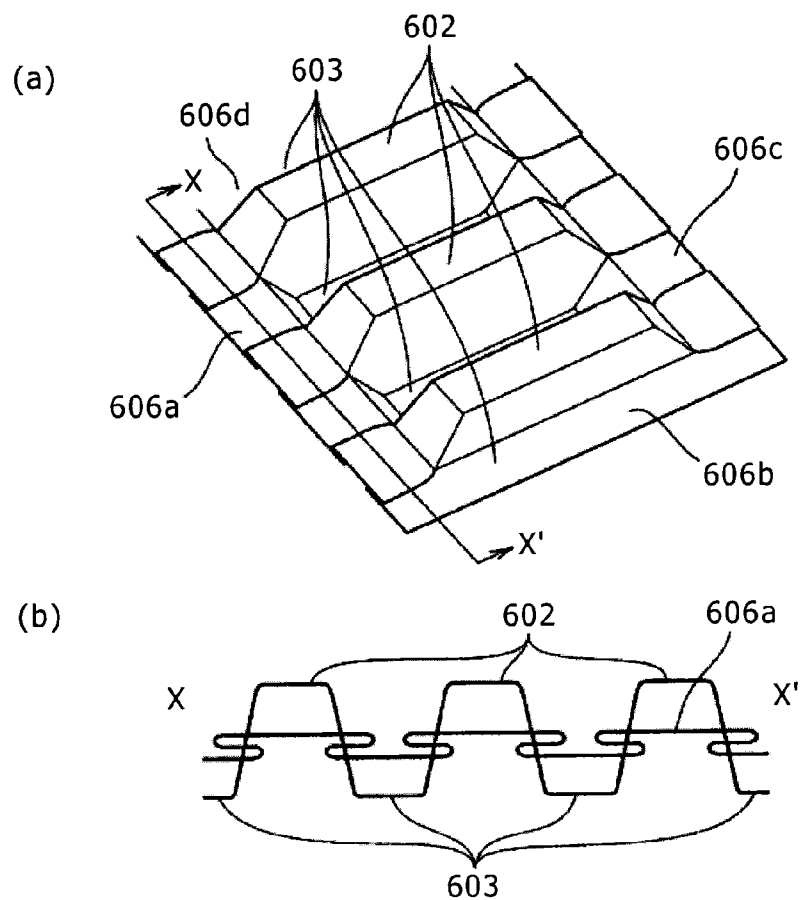


FIG. 43

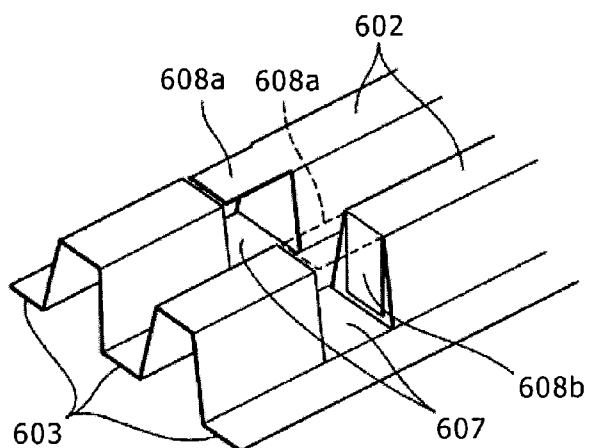


FIG. 44

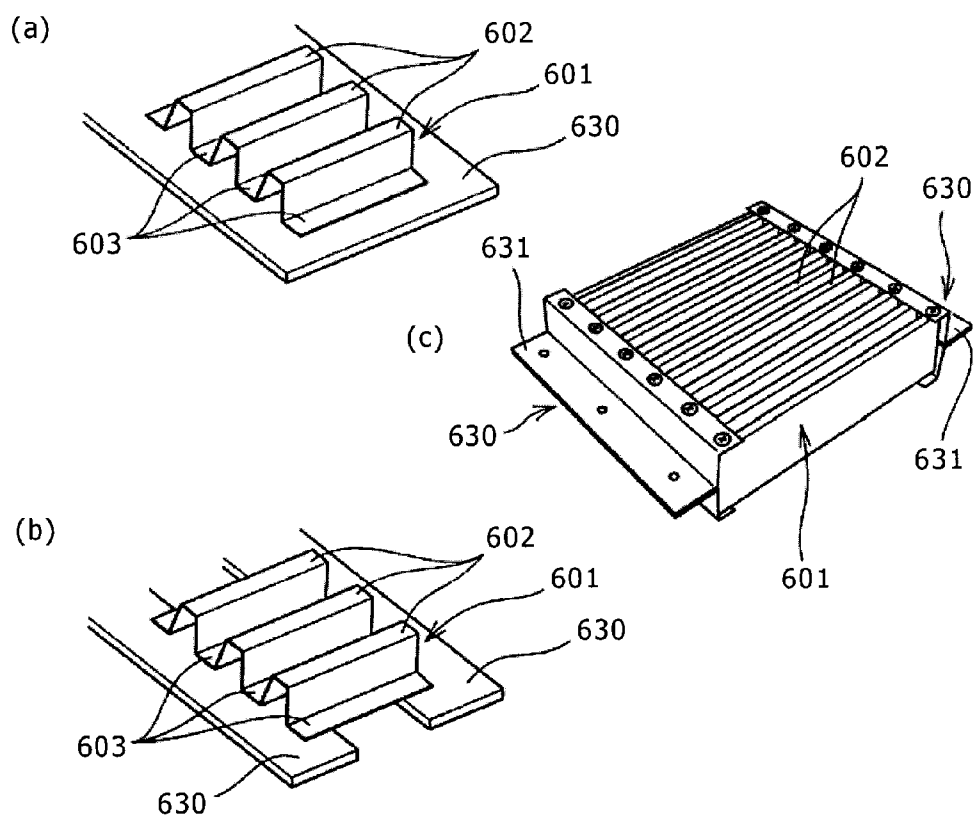


FIG. 45

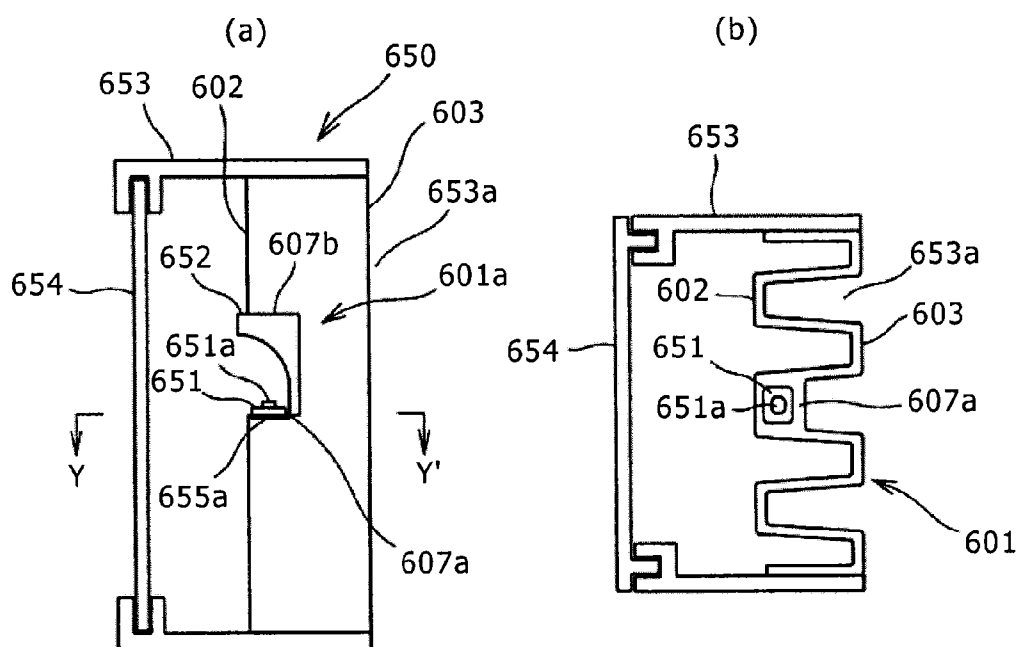


FIG. 46

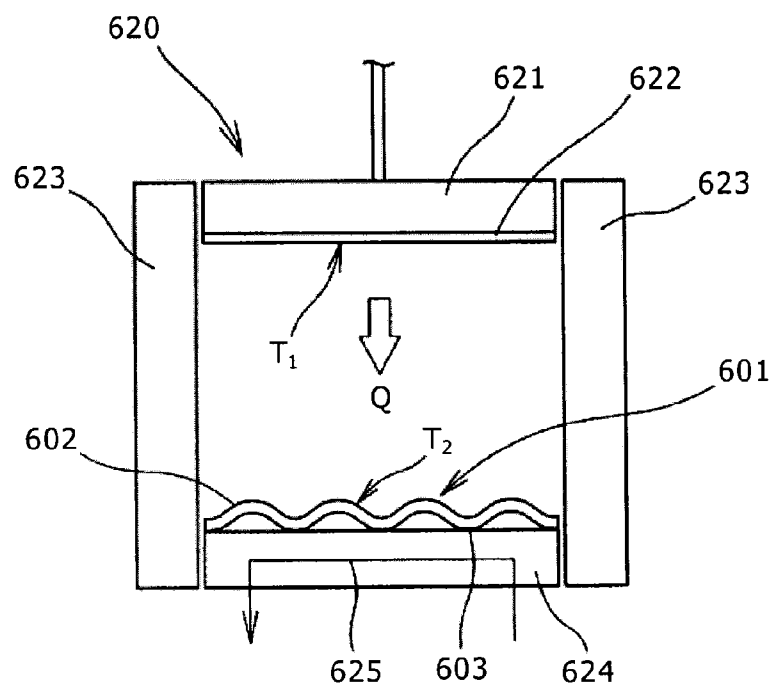


FIG. 47

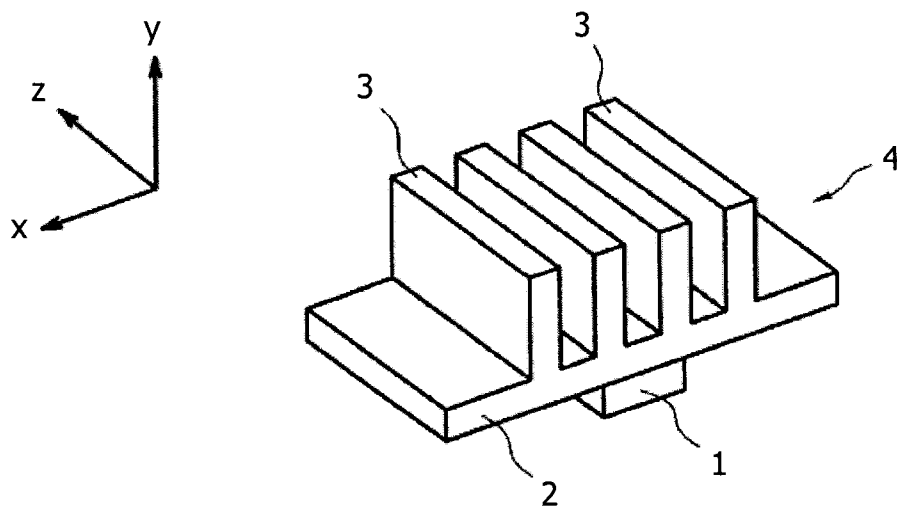


FIG. 48

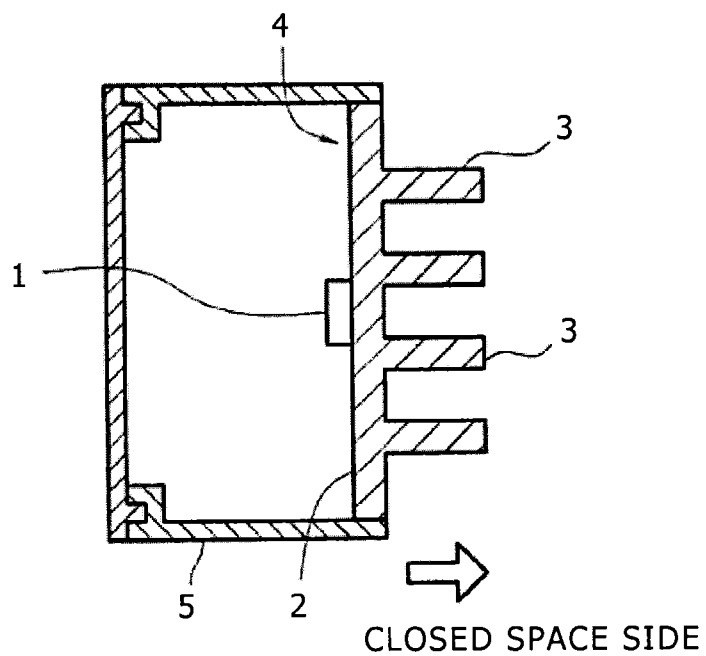


FIG. 49

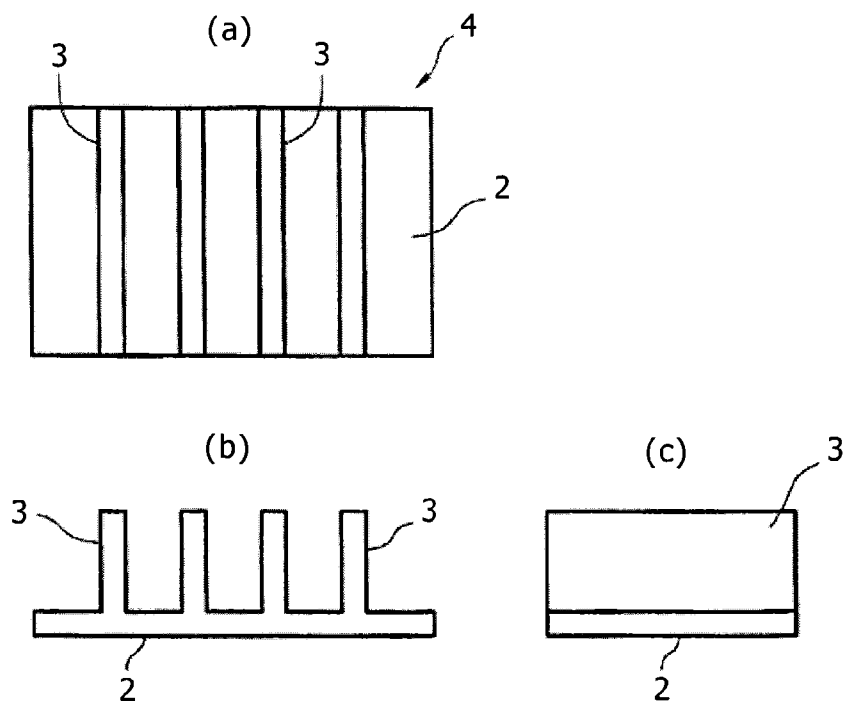
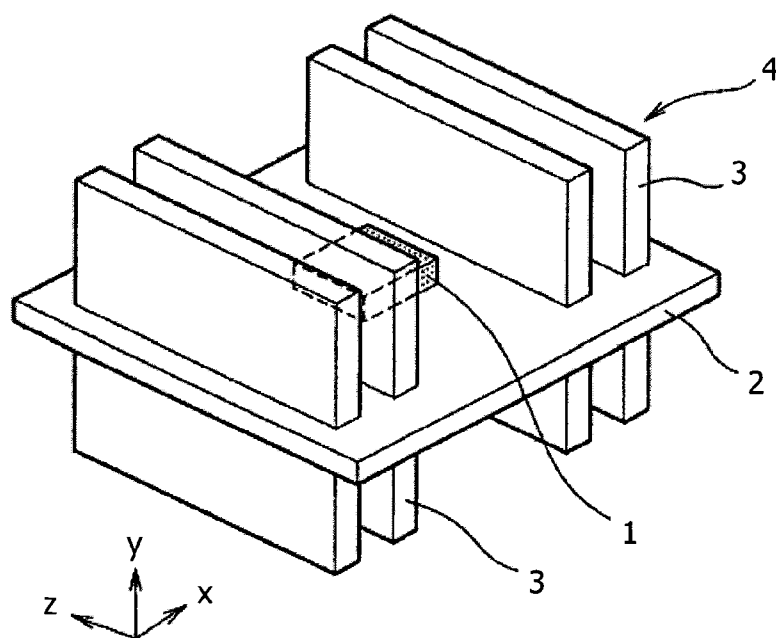


FIG. 50



HEAT SINK FOR LED LIGHTING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of International Patent Application No. PCT/JP2012/057691, filed Mar. 26, 2012, the disclosure of which is incorporated herein by reference in its entirety. This application claims priority to Japanese Patent Application No. 2011-080432, filed Mar. 31, 2011, Japanese Patent Application No. 2011-066326, filed Mar. 24, 2011, Japanese Patent Application No. 2011-066327, filed Mar. 24, 2011, Japanese Patent Application No. 2011-280062, filed Dec. 21, 2011, and Japanese Patent Application No. 2012-065237, filed Mar. 22, 2012, the disclosures of which are incorporated herein by reference in their entireties.

BACKGROUND

[0002] The present invention relates to a heat sink for LED lighting in which LED lighting having a light emitting diode (LED) element as a light emitting source dissipates heat generated at the time of emitting light into a surrounding space.

[0003] Lighting having a light emitting diode (LED) element as a light emitting source is low in power consumption and is long in life and hence gradually begins to prevail in the market. Among the lighting, it is a vehicle-mounted LED lighting such as a headlight of an automobile that especially gets much attention in recent years, and it has been started to replace embedded lighting in buildings and other fields with the LED lighting as an application of the vehicle-mounted LED.

[0004] However, the LED element of the light emitting source of the LED has the following problems: the LED element is very weak against heat; and when temperature is higher than an allowable temperature, the LED element is reduced in light emitting efficiency and has its life affected. In order to solve these problems, the heat generated when the LED element emits light needs to be dissipated into a space surrounding the LED element and hence the LED lighting is provided with a large heat sink.

[0005] An aluminum die-cast heat sink using aluminum or aluminum alloy as a raw material has been widely used as a heat sink for LED lighting. In patent literatures 1 to 4 have been disclosed heat sinks having typical constructions of these heat sinks. Each of these heat sinks has a base plate part having an LED light source arranged and fixed on a front side thereof and a plurality of fin parts arranged in parallel to each other on the back side of the base plate part in such a way as to protrude separately from each other and uses the base plate part and the fin parts as heat dissipating surfaces and hence can acquire a large heat dissipating area, which makes it possible to think that the heat sink has a given heat dissipation capability.

[0006] However, in a case where a heat sink **4** for LED lighting that has a base plate part **2** having an LED light source **1** arranged and fixed on a front side thereof and a plurality of fin parts **3** in parallel to each other on the back side of the base plate part **2** in such a way as to protrude separately from each other, as shown in FIG. **47**, is used for dissipating heat generated by a vehicle-mounted lighting such as a headlight of an automobile and by an embedded lighting of a building, the heat sink **4** is fixed, as shown in FIG. **48**, in the state where the base plate part **2** constructs a back part of a housing **5** of a case

of the LED lighting. In the case where the heat sink **4** is fixed in the vehicle body of an automobile or the wall surface or the ceiling of a building in the state where the heat sink **4** is built in the housing **5**, the fin parts **3** are protruded in a closed space on the back side of the LED lighting in which the convection of air is not caused.

[0007] In this way, in the case where the heat sink **4** is used in the state where the fin parts **3** of the heat sink **4** are protruded into the closed space on the back side, heat dissipation from the heat sink **4** becomes heat dissipation into the closed space in which the convection of air is not caused. Hence, the heat sink **4** having the plurality of fin parts arranged in parallel to each other cannot dissipate heat efficiently.

[0008] That is, heat dissipation from a heat sink in a closed space is mainly done not by convection but by radiation. For this reason, it can be thought that increasing all projected areas in an x-axis direction, a y-axis direction, and a z-axis direction, that is, in three directions of the heat sink is more effective for enhancing a heat dissipation capability than providing the heat sink with a plurality of fin parts to simply increase their surface areas.

[0009] Patent literature 1: JP-A No. 2007-172932

[0010] Patent literature 2: JP-A No. 2007-193960

[0011] Patent literature 3: JP-A No. 2009-277535

[0012] Patent literature 4: JP-A No. 2010-278350

SUMMARY

[0013] An object of the present invention is to provide a heat sink for LED lighting that can efficiently dissipate heat even in a closed space.

[0014] In order to solve the problems, a heat sink for LED lighting according to the present invention is a heat sink for LED lighting formed of an aluminum material and is constructed of: a mounting face part having an LED element mounted on a surface thereof; a first fin part extending in a direction perpendicular to the mounting face part; and a second fin part extending in a direction perpendicular to the mounting face part and extending in a direction intersecting the first fin part.

[0015] In this heat sink for LED lighting, the first fin part and the second fin part extend in a direction perpendicular to the mounting face part mounted with the LED element and the first fin part extends in a direction intersecting the second fin part. Hence, the heat sink for LED lighting can increase all projected areas in three dimensional directions of an x-axis direction, a y-axis direction, and a z-axis direction. Therefore, even when the heat sink dissipates heat in a closed space in which the convection of air is hardly caused, the heat sink can efficiently dissipates heat.

[0016] In the heat sink for LED lighting according to the present invention, it is preferable that: the mounting face part has the first fin part or/and the second fin part formed integrally with any one or both of top and bottom faces thereof, each of the first fin part and the second fin part being shaped like a plate; the respective fin parts are formed in such a way as to erect outward and separately from each other; and the number of the fin parts extending in a same direction is two or less at an arbitrary section perpendicular to any one of the top and bottom faces of the mounting face part.

[0017] In this case, it is preferable that the respective fin parts are formed at positions between which the LED element is mounted.

[0018] Further, it is preferable that the first fin part and the second fin part are formed by a total of 2 to 8.

[0019] In this way, the object of the present invention can be achieved without complicating the shape and structure of the heat sink, especially, the shape and structure of the fin part for dissipating heat and without increasing the number of fin parts. On the contrary, the object of the present invention can be achieved by simplifying the shape and structure of the fin part and by decreasing the number of fin parts. Further, in the present invention, the base plate and the heat dissipating fins of the heat sink are integrally formed, so that the face of the base plate and the faces of the heat dissipating fins are continuous with each other and hence the path of heat conduction by the surfaces or materials of these parts is continuously formed. Hence, since there is no impediment such as a slit for cutting the path of heat conduction, the path of heat condition in the heat sink is not cut and heat from the LED element can be transferred to the respective parts constructing the heat sink. Therefore, an extremely high heat dissipation capability of the heat sink can be ensured.

[0020] Further, in the heat sink for LED lighting according to the present invention, it is preferable that the mounting face part and the first fin part are formed in a continuous stepped shape.

[0021] In this case, it is preferable that the mounting face part, the first fin part, and the second fin part are integrally formed by bending a blank of aluminum material.

[0022] Further, it is preferable that the first fin part has the second fin part further formed on an end portion thereof, the second fin part extending in a direction intersecting the first fin part.

[0023] Still further, it is preferable that the mounting face part or/and the first fin part is/are larger in thickness than the second fin part.

[0024] Still further, it is preferable that the second fin parts, or the second fin part and the mounting face part or/and the first fin part are overlaid on each other.

[0025] Still further, it is preferable that a portion at which the LED element is mounted of the mounting face part is partially increased in thickness.

[0026] The heat sink for LED lighting constructed in this way is a heat sink which is formed of an aluminum material and has a simple structure, so that the heat sink can be comparatively easily manufactured by bending a blank acquired by punching and cutting a rolled plate such as sheet or coil or an extruded plate and is lightweight. Hence, the heat sink for LED lighting according to the present invention is most suitable for a heat sink for LED lighting for a vehicle.

[0027] Further, in the heat sink for LED lighting according to the present invention, it is preferable that the mounting face part has the LED element arranged and fixed on a front side thereof and has a plurality of the first fin parts formed on a back side thereof in such a way as to protrude separately from each other and in parallel to each other, and that of the first fin parts, at least one first fin part has a portion thereof bent at a right angle, whereby the portion is made the second fin part, and that the second fin part has a heat dissipating surface in a direction which is perpendicular to a heat dissipating surface of the first fin part and to a heat dissipating surface of the mounting face part, respectively.

[0028] The heat sink for LED lighting constructed in this way can be manufactured from an aluminum material by a comparatively simple working method such as cutting and bending and the number of parts constructing the heat sink is not increased.

[0029] In the heat sink for LED lighting according to the present invention, it is preferable that the mounting face part has the LED element arranged and fixed on a front side thereof and has a plurality of the first fin parts formed on a back side thereof in such a way as to protrude separately from each other and in parallel to each other, and that the mounting face part is bent in a direction perpendicular to a longitudinal direction of the first fin part and hence is formed in a shape of a letter L, and that the second fin part is formed by bending the mounting face part in this manner.

[0030] In this way, the heat sink for LED lighting can be manufactured from an aluminum material by the use of a comparatively simple working method such as slitting and bending and the number of parts constructing the heat sink is not increased. In addition, the heat sink for LED lighting can be fixed even in a narrow limited space and in an indented space, which hence makes it possible to ensure a sufficient amount of heat dissipation from LED lighting even in such a limited space.

[0031] In this case, it is preferable that the first fin part is protruded to an outside of the mounting face part bent in the shape of the letter L and has a linear slit formed in a bent portion thereof at the time of bending and hence is divided, the slit reaching an outside surface of the mounting face part.

[0032] In this way, the heat sink for LED lighting can be fixed even in a concave corner of a narrow limited space, and when the base plate part is bent, it is not caused that the fin part has an effect on bending, and an amount of protrusion of the fin part does not need to be made small, which hence further makes it possible to further ensure a sufficient amount of heat dissipation from LED lighting.

[0033] Alternatively, it is preferable that the first fin part is protruded to an inside of the mounting face part bent in the shape of the letter L and has a slit formed in a bent portion thereof at the time of bending and hence is divided, the slit reaching an inside surface of the mounting face part and being formed in a shape of a letter V having an angle of 90 degrees or more.

[0034] In this way, the heat sink for LED lighting can be fixed even in a narrow limited space and can ensure a sufficient heat dissipating space by the surface areas of the base plate part and the fin parts, which hence makes it possible to further ensure a sufficient amount of heat dissipation from LED lighting. Further, the heat sink for LED lighting can be fixed even in a convex corner of a limited indented space. Still further, it is not caused that when the base plate part is bent, the fin part has an effect on the bending, and an amount of protrusion of the fin part does not need to be made small, which hence makes it possible to still further ensure a sufficient amount of heat dissipation from LED lighting.

[0035] Further, in the heat sink for LED lighting according to the present invention, it is preferable that the first fin part and the second fin part are formed in a shape of continuous wavy heat dissipating fins by corrugating and have a part thereof pressed into a stepped part, the stepped part constructing the mounting face part.

[0036] In this case, before the corrugating, the first fin part and the second fin part have their surfaces previously subjected to pre-coating having an emissivity ϵ of 0.7 or more.

[0037] According to the heat sink for LED lighting constructed in this way, by forming the whole shape of the heat dissipating fins of the continuous wavy shapes by corrugating, it is possible to form many thin fins at comparatively

narrow intervals and hence to increase a heat transfer area and to enhance a heat dissipation capability.

[0038] Further, by using an aluminum alloy thin plate as a raw material, as a treatment for enhancing a heat dissipation capability, it is possible to previously apply pre-coating to the aluminum alloy thin plate as the raw material before corrugating. This makes it possible to omit or shorten processes that are necessary for a conventional heat sink manufactured by an aluminum alloy die casting, for example, a process of buffing the surface of a die casting, a cleaning process, a degreasing process, and a surface treatment process for enhancing the emissivity of a surface and hence to significantly reduce the manufacturing cost of the heat sink.

[0039] Still further, when a raw material plate is corrugated, the part on which the LED element is fixed and the stepped part such as a depression and a protrusion for reinforcing rigidity can be formed by a series of corrugating processes including a forming process of the whole shape of the heat dissipating fins of continuous wavy shapes and a crushing process following the forming process. At this time, it is possible to design and form a portion to become the stepped part partially in a larger width than the width of the fin. Hence, it is possible to integrally manufacture a heat sink, which ensures an LED element mounting area and has many fins to ensure a heat dissipation capability, from the same raw material plate. The heat sink for LED lighting of the present invention can increase all projected areas in the three dimensional directions of the x-axis direction, the y-axis direction, and the z-axis direction and hence can efficiently dissipate heat even in a closed space in which the convection of air is not caused.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

[0041] FIG. 1 is a perspective view showing a heat sink for LED lighting of a first embodiment according to the present invention.

[0042] FIG. 2 is a perspective view showing a first modified example of the heat sink of the first embodiment.

[0043] FIG. 3 is a perspective view showing a second modified example of the heat sink of the first embodiment.

[0044] FIG. 4 is a perspective view showing a third modified example of the heat sink of the first embodiment.

[0045] FIG. 5 is a perspective view showing a fourth modified example of the heat sink of the first embodiment.

[0046] FIG. 6 is a perspective view showing a fifth modified example of the heat sink of the first embodiment.

[0047] FIG. 7 is a perspective view showing a sixth modified example of the heat sink of the first embodiment.

[0048] FIG. 8 is a perspective view showing a heat sink for LED lighting of a second embodiment according to the present invention.

[0049] FIG. 9 illustrates a method for manufacturing the heat sink for LED lighting of the second embodiment and is perspective views, one of which shows a plate-shaped aluminum material made of a coil material and a blank, and the other of which shows a mode of a blank after coining.

[0050] FIG. 10 is a perspective view illustrating the principle and function of heat dissipation in the heat sink for LED lighting of the second embodiment.

[0051] FIG. 11 is a perspective view of such a mode of a blank after coining that illustrates a method for manufacturing a heat sink for LED lighting of a first modified example of the second embodiment, the first modified example being common in a whole shape to the second embodiment.

[0052] FIG. 12 is a perspective view of such a mode of a blank after coining that illustrates a method for manufacturing a heat sink for LED lighting of a second modified example of the second embodiment, the second modified example being common in a whole shape to the second embodiment.

[0053] FIG. 13 is a perspective view that shows a heat sink for LED lighting of a third modified example of the second embodiment, the third modified example being different in a whole shape from the second embodiment.

[0054] FIG. 14 illustrates a method for manufacturing the heat sink for LED lighting of the third modified example of the second embodiment and is perspective views, one of which shows a plate-shaped aluminum material made of a coil material and a blank, and the other of which shows a mode of a blank after coining.

[0055] FIG. 15 is a perspective view showing a heat sink for LED lighting of a third embodiment according to the present invention.

[0056] FIG. 16 is a plan view of FIG. 15.

[0057] FIG. 17 is a side section view of an aluminum plate showing an example of a case in which an aluminum plate (horizontal plane part) of an LED element mounting part in the heat sink for LED lighting of the third embodiment is made partially larger in thickness.

[0058] FIG. 18 is a perspective view showing a setting state in a case where the heat sink for LED lighting of the third embodiment is applied to a headlight of an automobile.

[0059] FIG. 19 is a section view taken on a line a-a in FIG. 18.

[0060] FIG. 20 is a section view taken on a line b-b in FIG. 18.

[0061] FIG. 21 is a section view taken on a line c-c in FIG. 18.

[0062] FIG. 22 is a perspective view showing a heat sink for LED lighting of a fourth embodiment according to the present invention.

[0063] FIGS. 23(a), 23(b) and 23(c) show a heat sink for LED lighting of the fourth embodiment. FIG. 23(a) is a plan view and FIG. 23(b) is a front view and FIG. 23(c) is a side view.

[0064] FIGS. 24(a), 24(b) and 24(c) show plan views showing modified examples of the heat sink for LED lighting of the fourth embodiment.

[0065] FIG. 25 is a lateral section view showing a usage state in which the heat sink for LED lighting of the fourth embodiment is built in LED lighting as a part of housing.

[0066] FIG. 26 is a vertical section view showing a usage state in which the heat sink for LED lighting of the fourth embodiment is built in LED lighting as a part of housing.

[0067] FIG. 27 is a perspective view showing a heat sink for LED lighting of a fifth embodiment according to the present invention.

[0068] FIG. 28 is a perspective view showing a heat sink for LED lighting of a first modified example of the fifth embodiment.

[0069] FIG. 29 is a perspective view showing a heat sink for LED lighting of a second modified example of the fifth embodiment.

[0070] FIG. 30 is a perspective view showing a heat sink for LED lighting of a third modified example of the fifth embodiment.

[0071] FIG. 31 is a lateral section view showing a usage state in which the heat sink for LED lighting of the fifth embodiment shown in FIG. 29 is built in LED lighting as a part of a housing.

[0072] FIG. 32 is a section view taken along a line B-B in FIG. 31.

[0073] FIG. 33 is a lateral section view showing a usage state in which the heat sink for LED lighting of the fifth embodiment shown in FIG. 30 is built in LED lighting as a part of a housing.

[0074] FIG. 34 is a section view taken along a line B-B in FIG. 33.

[0075] FIG. 35 is a perspective view showing a heat sink for LED lighting of a sixth embodiment according to the present invention.

[0076] FIG. 36 is a plan view of FIG. 35.

[0077] FIG. 37 is a perspective view showing a heat sink for LED lighting of a first modified example of the sixth embodiment.

[0078] FIG. 38 is a plan view of a FIG. 37.

[0079] FIG. 39 is a perspective view showing a heat sink for LED lighting of a second modified example of the sixth embodiment.

[0080] FIG. 40 is a perspective view showing a heat sink for LED lighting of a third modified example of the sixth embodiment.

[0081] FIG. 41 is a perspective view showing a heat sink for LED lighting of a fourth modified example of the sixth embodiment.

[0082] FIGS. 42(a) and 42(b) show a heat sink for LED lighting of a fifth modified example of the sixth embodiment, and FIG. 42(a) is a perspective view and FIG. 42(b) is a section view taken on a line X-X' in FIG. 42(a).

[0083] FIG. 43 is a perspective view showing a heat sink for LED lighting of a sixth modified example of the sixth embodiment.

[0084] FIGS. 44(a), 44(b), and 44(c) are perspective views showing the heat sinks for LED lighting of a seventh modified example of the sixth embodiment.

[0085] FIGS. 45(a) and 45(b) illustrate a mode in which the heat sink of the sixth embodiment is mounted in a vehicle-mounted LED lamp.

[0086] FIG. 46 illustrates an outline of an emissivity measurement device.

[0087] FIG. 47 is a perspective view showing a conventional heat sink for LED lighting.

[0088] FIG. 48 is a longitudinal section view showing a usage state in which the conventional heat sink for LED lighting is built in LED lighting as a part of a housing.

[0089] FIGS. 49(a), 49(b), and 49(c) show the conventional heat sink for LED lighting, and FIG. 49(a) is a plan view and FIG. 49(b) is a front view and FIG. 49(c) is a side view.

[0090] FIG. 50 is a perspective view showing a mode of a heat sink so as to make a comparison.

[0091] 100—LED element

[0092] 101—heat sink for LED lighting

[0093] 102—base plate (mounting face part)

[0094] 103, 105—heat dissipating fin (first fin part)

[0095] 104, 106—heat dissipating fin (second fin part)

[0096] 201—heat sink for LED lighting

[0097] 211, 212—horizontal plane part (mounting face part)

[0098] 221, 222—vertical front part (first fin part)

[0099] 231-236, 2331-2334—vertical side part (second fin part)

[0100] 300—LED element

[0101] 301—heat sink for LED lighting

[0102] 311, 312—horizontal plane part (mounting face part)

[0103] 321, 322—vertical front part (first fin part)

[0104] 331-338—vertical side part (second fin part)

[0105] 400—LED light source (LED element)

[0106] 401—heat sink for LED lighting

[0107] 402—base plate part (mounting face part)

[0108] 403—fin part (first fin part)

[0109] 403a—fin main body (first fin part)

[0110] 403b—fin bent piece (second fin part)

[0111] 500—LED light source (LED element)

[0112] 501—heat sink for LED lighting

[0113] 502—base plate part (mounting face part)

[0114] 503—fin part

[0115] 503a—first fin part

[0116] 503b—second fin part

[0117] 601—heat sink for LED lighting

[0118] 600, 600a, 600b—element

[0119] 602, 603—wavy shape (first fin part and second fin part)

[0120] 604a, 604b—stepped part (mounting face part)

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0121] Hereinafter, the present invention will be further described in detail on the basis of embodiments shown in the accompanying drawings.

First Embodiment

[0122] FIG. 1 shows a heat sink 101 for LED lighting of a first embodiment. The heat sink 101 for LED lighting is characterized in that: a base plate 102 having an LED element 100 mounted on any one of top and bottom faces 1021, 1022 thereof has plate-shaped heat dissipating fins 103, 104 integrally formed on any one or both of the top and bottom faces 1021, 1022 thereof; the heat dissipating fins 103, 104 are formed in such a way as to erect to the outside from any one of the top and bottom faces 1021, 1022 of the base plate 102 and to be separate from each other; and the number of the heat dissipating fins 103, 104 extending in the same direction are two or less in an arbitrary section perpendicular to any one of the top and bottom faces 1021, 1022 of the base plate 102. Of these parts, the base plate 102 constructs a mounting face part of the present invention, and the heat dissipating fin 103 constructs a first fin part of the present invention, and the heat dissipating fin 104 constructs a second fin part of the present invention.

[0123] Specifically, a first embodiment of the heat sink 101 for LED lighting of the present invention will be shown by a perspective view in FIG. 1, and a first modified example to a sixth modified example of the first embodiment of the heat sink 101 for LED lighting of the present invention will be shown in FIGS. 2 to 7.

[0124] Basic Structure of a Heat Sink:

[0125] First, there will be described a basic structure common to the heat sink 101 for LED lighting of the first

embodiment of the present invention in FIGS. 1 to 7. In these FIGS. 1 to 7, the heat sink 101 for LED lighting of the present invention commonly has the plate-shaped base plate 102 having the LED element 100 mounted thereon. The base plate 102 has two top and bottom faces 1021, 1022 in a y direction (up and down direction) in each drawing, and these faces 1021, 1022 extend in an x direction and in a z direction in each drawing. The plate-shaped base plate 102 has the LED element 100 mounted on any one of these two top and bottom faces 1021, 1022, thereby supporting the LED element 100. In FIGS. 1 to 7, for the sake of convenience, a face on a top side in each drawing is referred to as a mounting face 1021 of the LED element 100 and the LED element 100 is mounted in a central portion of the mounting face 1021. The other face on an under side in each drawing is referred to as the bottom face 1022 for the sake of convenience.

[0126] Further, the top and bottom faces 1021, 1022 of the base plate 102 have the plate-shaped heat dissipating fins 103 to 106 which extend in the y direction (the up and down direction) in each drawing in such a way as to protrude perpendicularly to any one or both of the top and bottom faces 1021, 1022 (direction in which the face extends=perpendicular to the x direction and the z direction in each drawing). These plate-shaped heat dissipating fins 103 to 106 are erected on the top and bottom faces 1021, 1022 of the base plate 102 in such a way as to direct to the outside. However, in the plate-shaped heat dissipating fins 103 to 106, their plate-shaped heat dissipation side surfaces do not necessarily need to be perpendicular to the top and bottom faces 1021, 1022 of the base plate 102 at an angle of 90 degrees as shown in FIGS. 1 to 7. For example, the plate-shaped heat dissipating fins 103 to 106 may be erected in such a way that the plate-shaped heat dissipating side surfaces are inclined to the outside with respect to the top and bottom faces 1021, 1022 of the base plate 102 at an angle smaller than 90 degrees or larger than 90 degrees. However, in any case, these plate-shaped heat dissipating fins 103 to 106 are formed integrally and continuously with the base plate 102 in terms of material. In other words, at least the plate-shaped top and bottom faces of the plate-shaped heat dissipating fins 103 to 106 are formed in such a way as not to be separate from but to be continuous with the top and bottom faces 1021, 1022 of the base plate 102.

[0127] For this reason, there are formed continuous heat transfer surfaces in which heat from the LED element 100 is continuously transferred to the bottom face 1022, the side faces surrounding the heat dissipating fins 103 to 106, and faces in a thickness direction via the face (surface) 1021, on which the LED element is mounted, of the base plate 102. Further, there are formed also continuous heat dissipating surfaces for continuously radiating heat from these continuous heat transfer surfaces.

[0128] In this regard, as to the shape of the base plate 102, a rectangular (or square) plate shape or planar shape is shown in FIGS. 1 to 7. However, as to the shape of the base plate 102, a planar shape such as a circular shape, a triangular shape, a polygonal shape, or an indefinite shape, or a three dimensional shape such as a cylindrical shape, a rectangular cylindrical shape, or a stepped shape can be arbitrarily selected according to the usage of the heat sink 101 for LED lighting.

[0129] Feature of Heat Dissipating Fin:

[0130] The above-mentioned basic structure of the heat sink 101 for LED lighting 101 of the present invention, when glanced, seems to be not much different from the structure of

a conventional heat sink 4 shown in FIG. 47. However, the basic structure of the heat sink 101 for LED lighting of the present invention is much different from the structure of the conventional heat sink 4 in that ingenuity for dissipating heat from the LED element 100 mainly by heat radiation, which is required in a narrow space or a closed space of a housing for vehicle-mounted lighting, is exercised in the arrangement of the plate-shaped heat dissipating fins 103 to 106.

[0131] First, in the heat sink for LED lighting 101 of the present invention 1, on the premise of the basic structure of the heat sink, the plate-shaped heat dissipating fins 103 to 106, preferably, a total of 2 to 8 heat dissipating fins to be mounted on the two faces 1021, 1022 of the base plate 102, are formed continuously and integrally with the faces 1021, 1022 of the base plate 102 and separately from each other.

[0132] Of these heat dissipating fins 103 to 106, the number of the fins extending in the same direction (including a parallel state) is made two or less in an arbitrary section perpendicular to the two faces 1021, 1022 of the base plate 102, in other words, two or less in any section of the heat sink 101 which is cut at an arbitrary section perpendicular to the two faces 1021, 1022 of the base plate 102.

[0133] Meaning of Specification of Direction in which Heat Dissipating Fin Extends:

[0134] Here, the meaning of “extending in the same direction”, which is described in the present invention, naturally includes a parallel state and includes not only a parallel state in the strict sense of the word but also a state in which angles in which the plate-shaped side faces of the heat dissipating fins extend are slightly different from each other. An object of the present invention is to eliminate the excessive overlap of the heat dissipating fins in any direction of the three dimensional directions of the heat sink, to reduce the waste of material, and to achieve high performance in heat radiation efficiency. Hence, even if the angles in which the plate-shaped side faces of the heat dissipating fins extend are slightly different from each other within a range not to impair the object and the effect of the invention, it is possible to regard the plate-shaped side faces of the heat dissipating fins as extending in the same direction. This is because even if the angles in which the plate-shaped side faces of the heat dissipating fins extend are slightly different from each other or are not different from each other because the plate-shaped side faces are strictly parallel to each other, there is not much difference in that the heat dissipating fins extend in the same direction and overlap each other, which is to be specified in the present invention.

[0135] As to the degree of this difference in the angle, in the case where an angle formed by the directions in which the plate-shaped side faces of the heat dissipating fins extend is 30 degrees or less, the heat dissipating fins are regarded as extending in the same direction. On the contrary, in the case where the angle formed by the directions in which the plate-shaped side faces of the heat dissipating fins extend is more than 30 degrees, the heat dissipating fins are not regarded as extending in the same direction.

[0136] In FIGS. 1 to 7 which will be described later, as a mode in which two heat dissipating fins extend in the same direction across the LED element 100, the two heat dissipating fins are arranged in such a way as to be parallel to each other and to surround the perimeter of the LED element 100 in a rectangular shape and to make the heat dissipating fins adjacent to each other perpendicular to each other (intersect each other at right angles). However, in the present invention,

the heat dissipating fins are not necessarily arranged in this way but may be arranged separately from each other on a circumference or an arc, in which the LED element 100 is set at a center, in such a way as to surround the perimeter of the LED element 100, for example, in the arrangement of dominos in domino toppling in which the angles of the plate-shaped side faces are changed in sequence.

[0137] In addition, it is because of preventing the heat dissipating fins from overlapping each other excessively with respect to a certain direction in a three-dimensional space “that the number of the heat dissipating fins extending in the same direction is specified to be two or less in an arbitrary section perpendicular to the two faces 1021, 1022 of the base plate 102 (at any section of the heat sink cut at the section in this direction). In this regard, as will be described later, even in the case of one heat dissipating fin, there is a case where the one heat dissipating fin has a plurality of plate-shaped heat dissipating surfaces (heat dissipating side surfaces) extending in different directions, for example, a case of a heat dissipating fin formed in the shape of a letter L or C. Not only for a plate-shaped heat dissipating fin but also for a heat dissipating fin of a shape having a plurality of heat dissipating surfaces which are different from each other in an extending direction or in a shape, for example, each of straight portions in which a planar shape is formed in the shape of a letter L or C is regarded as a single heat dissipating fin and the number of the heat dissipating fins in the same direction (the degree of overlapping of the heat dissipating fins) are estimated. In this way of estimation, the number of the heat dissipating fins extending in the same direction in an arbitrary section perpendicular to either of the top face and the bottom faces of the base plate 102 is made two or less, whereby the heat dissipating fins or the heat dissipating side surfaces of the heat dissipating fins can be prevented from overlapping each other in the same direction. That is, the above-mentioned specification is provided for the following purpose: regardless of whether or not the heat dissipating surfaces are of the same heat dissipating fin, the number of the heat dissipating surfaces (heat dissipating side surfaces) of the heat dissipating fins is regarded as the number of the heat dissipating fins and is specified to be two or less so as to prevent the heat dissipating surfaces of the heat dissipating fins from overlapping each other excessively in the same direction regardless of the positions of the two faces 1021, 1022 of the base plate 102.

[0138] In this point, in the case where the number of the heat dissipating fins extending in the same direction is temporarily specified to be “two or less even in either of faces 1021, 1022 of the base plate 102” as another expression different from the above-mentioned specification, the absolute number of the heat dissipating fins will be specified. For this reason, in this case, the number of the heat dissipating surfaces in different directions of the heat dissipating fin shaped like a letter L or C is not regarded as the number of heat dissipating fins, which presents the possibility that the heat dissipating surfaces of the heat dissipating fins will overlap each other excessively depending on the positions of the two faces 1021, 1022 of the base plate 102. Hence, as described above, “the number of the heat dissipating fins is specified to be two or less in an arbitrary section perpendicular to the two faces 1021, 1022 of the base plate 102 (in any section of the heat sink cut at a section in this direction)”.

[0139] As to the shape of the plate-shaped heat dissipating fins 103 to 106, examples are shown in FIGS. 1 to 7 in which the whole shape or the plate-shaped side face is a rectangle

(square). However, the shape is not limited to this rectangle but a planar shape or a three-dimensional shape can be selected. For example, in the case where a plurality of plate-shaped heat dissipating surfaces (heat dissipating side surfaces) are extended in different directions (which form, for example, 90 degrees or more), the heat dissipating fins 103 to 106 may be formed in the shape of a letter L in which the heat dissipating fins 103, 104 or 105, 106, which are adjacent to each other, are integrated with each other, or may be formed in the shape of a letter C in which the heat dissipating fins 103, 104, 103, or 105, 106, 105, which are adjacent to each other, are integrated with each other. If manufactured, the heat dissipating fins 103 to 106 may have not only these plate-shaped heat dissipating surfaces (heat dissipating side surfaces) but also an arc-shaped or a curved heat dissipating surfaces (heat dissipating side surfaces) or a whole shape. Further, the heat dissipating fins 103 to 106 extending in the outward direction may be made different in the shape of a section in a thickness direction or in a thickness at height positions, that is, may be formed in the shape of a letter L or in a stepped shape. In addition, the heat dissipating fins 103 to 106 may also have the heat dissipating surfaces selectively formed in a planar shape such as a circular shape, a triangular shape, a polygonal shape, or an indefinite shape.

[0140] Hereinafter, specific embodiments of the present invention shown in FIGS. 1 to 7 will be described, and the meaning of specifying the number and the arrangement of the plate-shaped heat dissipating fins 103 to 106 of the present invention will be described. That is, the meaning of specifying the number of the plate-shaped heat dissipating fins 103 to 106 to be preferably 2 to 8 in total will be also described. Further, the meaning of specifying the number of the fins extending in the same direction of these heat dissipating fins 103 to 106 to be two or less even in any section of the heat sink 101 cut at an arbitrary section in a direction perpendicular to either of the faces 1021, 1022 of the base plate 102 will be also described.

[0141] First Embodiment Shown in FIG. 1:

[0142] In the plate-shaped heat dissipating fins 103, 104 shown in FIG. 1, a total of four plate-shaped heat dissipating fins are formed on the side of the LED element mounting face 1021 of the base plate 102 in such a way that their respective plate-shaped side faces are integral and continuous with the face 1021 of the base plate 102, the LED element mounting face 1021 supporting the LED element 100. The heat dissipating fin is not formed on the other side of the bottom face 1022 but only the plate-shaped bottom face 1022 exists.

[0143] In the heat dissipating fins 103, 104 formed on the side of the LED element mounting face 1021, two of them are formed side by side in parallel to each other symmetrically across the LED element 100 as a mode in which the heat dissipating fins 103, 103 on the left and right sides in the drawing and the heat dissipating fins 104, 104 on the up and down sides in the drawing extend in the same direction, respectively. That is, the plate-shaped heat dissipating fins 103, 103 (or 104, 104) opposed to each other are formed on the top surface side of the LED element mounting face 1021 at positions between which the LED element 100 is mounted. Of these heat dissipating fins 103, 104, the number of the heat dissipating fins extending in the same direction is specified to be two or less even in an arbitrary section perpendicular to the faces 1021, 1022 of the base plate 102 (even in any section of the heat sink 101 cut at a section in this direction).

[0144] The heat dissipating fins 103, 104, that is, the heat dissipating fins adjacent to each other are formed and arranged in such a way as to be perpendicular to each other (to intersect each other at right angles) and surround a rectangular perimeter in which the LED element 100 is sandwiched (the LED element 100 is arranged at the center), and the respective plate-shaped side faces of the heat dissipating fins 103, 104, which are large in thermal emissivity, are directed to the x direction and to the z direction, respectively. The LED element mounting face 1021 and the other bottom face 1022, which are large in thermal emissivity, of the base plate 102 are directed to the y direction.

[0145] In addition, the respective faces 1023, 1024, 1025, 1026 (1023, 1024, 1025, 1026 are on the left side, on the lower side, on the right side, and on the upper side in the drawing, respectively) in the thickness direction of the square perimeter of the base plate 102 are comparatively smaller in area than the respective faces 1021, 1022 but are directed to the x direction and the z direction, respectively, and become the heat radiating surfaces in these directions. This is ditto for the respective faces (top faces, faces of both end portions) in the thickness direction of the respective heat dissipating fins 103, 104: that is, the respective faces are comparatively smaller in area than the plate-shaped side faces but are larger in the number of the faces; and in the top faces and the faces of both end portions, a total of four faces are directed to each of the x, y, z directions and become the heat radiating surfaces in these directions.

[0146] Hence, although of the plate-shaped side surfaces of the heat dissipating fins 103, 104, a pair of two side faces opposed to each other on the side in which the LED element 100 is mounted overlap each other, the heat dissipating surfaces of the heat dissipating fins do not overlap each other excessively in any direction of the x, y, and z directions, which results in eliminating the waste of material. For this reason, a high heat radiation efficiency can be acquired by the synergistic effect of the effect of forming the continuous heat transfer faces to which the heat of the LED element 100 is continuously transferred to the bottom face 1022, the side faces surrounding the respective heat dissipating fins 103, 104, and the faces in the thickness direction thereof via the mounting face 1021 of the base plate 102 and the effect of forming the continuous heat dissipating surfaces for continuously radiating heat from the continuous heat transfer faces.

[0147] The Number of the Heat Dissipating Fins:

[0148] In the case where the number of the heat dissipating fins extending in the same direction is further reduced to only two of a preferable limit even in an arbitrary section perpendicular to the faces 1021, 1022 of the base plate 102, only two of both of the heat dissipating fins 103, 103 on the left and right sides in FIG. 1, only two of both of the heat dissipating fins 104, 104 on the up and down sides in FIG. 1, or only two of any one of the heat dissipating fins 103 and any one of the heat dissipating fins 104 are left and the other heat dissipating fins are eliminated. In this case, both of the heat dissipating fins 103, 103 on the left and right sides in FIG. 1 may be left, or both of the heat dissipating fins 104, 104 on the up and down sides in FIG. 1 may be left, or two of either of the heat dissipating fins 103, 103 and either of the heat dissipating fins 104, 104 may be left.

[0149] In contrast to this, in the case where the number of the plate-shaped heat dissipating fins is increased, the heat dissipating surfaces of the heat dissipating fins overlap each other in any one of the three dimensional directions of the x,

y, z directions, which results in causing the waste of material and reducing the heat radiation efficiency of heat (heat dissipation efficiency) for a high spatial occupancy. Hence, the number of the heat dissipating fins to be mounted, that is, the number of the heat dissipating fins on two faces 1021, 1022 of the top and bottom faces of the base plate 102 is specified to be eight or less in total, preferably, within a range from two to eight. However, in FIGS. 1 to 7, in the case of the mode in which one of the dissipating fins 103 to 106 is only separated or divided into several parts or many small parts as they are in the directions in which the heat dissipating side surfaces extend, each of the separated or divided parts is not individually regarded as one heat dissipating fin but the separated or divided parts are collectively regarded as one heat dissipating fin.

[0150] A problem caused in the case where a total number of the plate-shaped heat dissipating fins is increased is caused similarly also in the case where the number of the heat dissipating fins extending in the same direction (in parallel to each other) is too large, as is the case with a comparative example shown in FIG. 50 in which the number of the heat dissipating fins is three or more in an arbitrary section perpendicular to the two top and bottom faces 1021, 1022 of the base plate 102 (three or more also in any section of the heat sink 101 cut by an arbitrary section in a direction perpendicular to the two top and bottom faces 1021, 1022 of the base plate 102). In the comparative example shown in FIG. 50, when four heat dissipating fins extending in parallel to each other are formed on each of the top and bottom faces 1021, 1022 of the base plate 102, the number of the heat dissipating fins formed on the top face 1021 is equal to the number of the heat dissipating fins arranged in parallel to each other of a conventional example shown in FIG. 47, and the heat dissipating surfaces of the heat dissipating fins overlap each other in any one of the three dimensional directions of the x, y, z directions. Hence, the waste of material is caused and the heat radiation efficiency is reduced for a high spatial occupancy.

[0151] First Modified Example of the First Embodiment Shown in FIG. 2:

[0152] Plate-shaped heat dissipating fins shown in FIG. 2 show a mode in which heat dissipating fins 105, 106 are mounted not only on one side of the LED mounting face (top face) 1021 of the base plate 102 as shown in FIG. 1 but also on the other bottom face 1022 side of the base plate 102. Specifically, in addition to four plate-shaped heat dissipating fins 103, 104 formed on one side of the LED mounting face 1021 of the base plate 102 shown in FIG. 1, two for each of heat dissipating fins 105, 106 are formed also on the side of the other bottom face 1022 symmetrically with respect to the LED mounting face 1021, that is, a total of eight (which is a preferable upper limit) of heat dissipating fins 103, 104, 105, 106 are formed on the top and bottom faces 1021, 1022 of the base plate 102.

[0153] The heat dissipating fins 105, 106 formed on the side of the bottom face 1022 are arranged absolutely similarly to and symmetrically in the up and down direction in the drawing with respect to the four plate-shaped heat dissipating fins 103, 104 formed on the side of the LED element mounting face 1021 of the base plate 102. That is, as a mode in which the heat dissipating fins extend in the same direction, two heat dissipating fins 105, 105 on the left and right sides of the drawing are formed side by side in parallel to each other and symmetrically to each other across the LED element 100, whereas two heat dissipating fins 106, 106 on the up and down

sides of the drawing are formed side by side in parallel to each other and symmetrically to each other across the LED element **100**. That is, also on the side of the bottom face **1022**, the plate-shaped heat dissipating fins **105**, **105** and **106**, **106** opposed to each other are formed at positions between which a position on the bottom face side, which corresponds to a position on the top face side at which the LED element **100** is mounted, is sandwiched in a similar manner in which the plate-shaped heat dissipating fins **103**, **103** and **104**, **104** on the top face side of the LED element mounting face **1021** are formed. In other words, the plate-shaped heat dissipating fins are formed at the positions between which the LED element **100** is sandwiched on both of the top and bottom faces of the base plate **102**. Of the heat dissipating fins **105**, **106**, the number of the heat dissipating fins extending in the same direction is specified to be two also in an arbitrary section perpendicular to the face **1022** of the base plate **102** (also at any section of the heat sink **101** cut at a section in this direction).

[0154] The heat dissipating fins **105**, **106** surround a rectangular perimeter in which a position of the bottom face **1022** corresponding to the position of the top face **1021** at which the LED element **100** is mounted is at the center in a manner in which the heat dissipating fins adjacent to each other are perpendicular to each other (intersect at right angles), and the respective plate-shaped side faces of the heat dissipating fins **105**, **106** having a large heat radiation efficiency are directed to the x direction and the z direction, respectively. The LED element mounting face **1021** and the other bottom face **1022**, each of which has a large heat radiation efficiency, of the base plate **102** are directed to the y direction.

[0155] In addition, not only the respective faces **1023**, **1024**, **1025**, **1026** in the thickness direction of the rectangular perimeter of the base plate **102** and the respective faces (top faces and faces of the end portions) in the thickness direction of the four plate-shaped heat dissipating fins **103**, **104** formed on the side of the LED mounting face **1021** of the base plate **102** but also the respective faces (bottom faces and faces of the end portions) in the thickness direction of the respective heat dissipating fins **105**, **106** on the side of the bottom face **1022** become the heat radiating surfaces. The respective faces in the thickness direction of the respective heat dissipating fins are comparatively small in area, but the number of faces of both of the top and bottom faces and the faces of the end portions becomes two times the number of those faces in FIG. 1 and a total of eight faces are directed to each of the x, y, z directions and become the heat radiating surfaces in these directions.

[0156] Hence, also in the case of FIG. 2, the heat dissipating surfaces of the heat dissipating fins do not overlap each other, especially, even in any direction of the three dimensional directions of these x, y, z directions, whereby the waste of material can be eliminated and a high heat radiation efficiency can be acquired for a low spatial occupancy.

[0157] Second, Third, and Fourth Modified Examples of the First Embodiment Shown in FIGS. 3, 4 and 5:

[0158] The plate-shaped heat dissipating fins of the modified examples shown in FIGS. 3, 4, and 5 show modes in which heat dissipating fins on either of one side of the base plate **102**, that is, the LED element mounting face **1021** or the other side of the base plate **102**, that is, the bottom face **1022** are omitted from the case shown in FIG. 2 in which the number of the heat dissipating fins is the upper limit.

[0159] In the second modified example shown in FIG. 3, as compared with the arrangement of the heat dissipating fins shown in FIG. 2, on the side of the LED element mounting face **1021** of the base plate **102**, one heat dissipating fin on the lower side in the drawing of two heat dissipating fins **104** is omitted, that is, the number of the heat dissipating fins is reduced to three. Also on the other side of the bottom face **1022**, the heat dissipating fins are arranged asymmetrically in the up and down direction in the drawing, that is, one heat dissipating fin on the left side in the drawing of two heat dissipating fins **105** is omitted and hence the number of heat dissipating fins is reduced to three. In other words, a total of six heat dissipating fins are formed.

[0160] In the third modified example shown in FIG. 4, as compared with the arrangement of the heat dissipating fins shown in FIG. 2, on the side of the LED element mounting face **1021** of the base plate **102**, two heat dissipating fins **104**, **104** on the upper and lower sides in the drawing are omitted, that is, only two heat dissipating fins **103**, **103** on the left and right sides in the drawing are formed. Also on the other bottom face **1022** side, the symmetric arrangement of the heat dissipating fins in the up and down direction in the drawing is kept and hence two heat dissipating fins **106**, **106** on the upper and lower sides in the drawing are omitted and the heat dissipating fins **105**, **105** on the left and right sides in the drawing are mounted. In other words, a total of four heat dissipating fins are mounted.

[0161] The fourth modified example shown in FIG. 5 is the same as FIG. 4 in that as compared with the arrangement of the heat dissipating fins shown in FIG. 2, on the LED element mounting face **1021** side of the base plate **102**, two heat dissipating fins **104**, **104** on the upper and lower sides in the drawing are omitted, that is, only two heat dissipating fins **103**, **103** on the left and right sides in the drawing are formed. As an asymmetric arrangement of the heat dissipating fins in the up and down direction in the drawing, on the other side of the bottom face **1022**, two heat dissipating fins **105**, **105** on the left and right sides in the drawing are omitted, that is, only two heat dissipating fins **106**, **106** on the upper and lower sides in the drawing are formed. In other words, a total of four heat dissipating fins are formed.

[0162] Fifth and Sixth Modified Examples of the First Embodiment Shown in FIGS. 6, 7:

[0163] A heat sink **101** for LED lighting shown in FIGS. 6, 7 shows an embodiment in which the base plate **102** (faces **1021**, **1022**) and plate-shaped heat dissipating fins **103** and **104** are integrally formed of a metal thin plate made of, for example, aluminum and having a given thickness.

[0164] In this case, the plate-shaped heat dissipating fins **103** and **104** are integrally formed of the same material by bending the base plate **102** in the y direction (in the up and down direction in the drawing), in which the respective heat dissipating surfaces extend, from the end portion sides of the base plate **102**. In the fifth modified example shown in FIG. 6, the heat dissipating fins **103**, **103** and **104**, **104** are bent respectively to the upper side in the drawing in such a way as to be opposed to each other. In the sixth modified example shown in FIG. 7, the heat dissipating fins **104**, **104** are bent to the upper side in the drawing in such a way as to be opposed to each other, whereas the heat dissipating fins **103**, **103** are bent to the lower side in the drawing in such a way as to be opposed to each other. As to the arrangement and the number of the plate-shaped heat dissipating fins **103** and **104**, FIG. 6

is the same as the case shown in FIG. 1 and FIG. 7 is the same as the case shown in FIG. 5. However, the heat dissipating fins **103**, **104** are formed by bending the end portions of the base plate **102** and hence the arrangement structures shown in FIG. 1 and FIG. 5 in which the heat dissipating fins **103**, **104** are positioned at the end portions of the base plate **102** are different from the arrangement structures shown in FIG. 6 and FIG. 7.

[0165] Principle and Function of Heat Dissipation:

[0166] There will be described the principle (function) of heat dissipation in the case where this heat sink **101** of the present invention is set in a space in which the convection of air is not caused to thereby do the LED lighting. When the LED element **100** mounted on the LED mounting face **1021** is made to emit light, the heat (heat flux) Q emitted by the LED element **100** is transferred to the LED element mounting face **1021** of the base plate **102** through a mounting part (not shown) of a bottom portion of the LED element **100**. Subsequently, the heat Q transferred to the LED element mounting face **1021** is transferred (conducted) not only to the heat dissipating fins **103**, **104** on the side of the LED mounting face **1021** but also to the bottom face **1022** and the heat dissipating fins **105**, **106** on the side of the bottom face **1022** speedily (without delay) continuously with the respective heat dissipating surfaces described above and almost uniformly at a high level. For this reason, convection from the heat dissipating surfaces of these heat dissipating fins and, in particular, heat dissipation by radiation are performed uniformly at a given level or more, whereby the heat dissipation efficiency can be increased.

[0167] Here, as is specified by the present invention, in the heat dissipating fins **103** to **106**, the number of the heat dissipating fins extending in the same direction is specified to be two or less at an arbitrary section perpendicular to the faces **1021**, **1022** of the base plate **102** and hence the heat dissipating fins **103** to **106** do not overlap each other excessively in the same direction. Hence, the transferred heat Q is transmitted to the three dimensional directions of the x, y, z directions and is radiated speedily and efficiently to a closed space (heat dissipating space) around them from the surfaces of the LED element mounting face **1021** and the bottom face **1022** of the base plate **102** and the respective heat dissipating surfaces of the heat dissipating fins **103** to **106**. Hence, the heat emitted by the LED element **100** is dissipated in all directions of the three dimensional x, y, z directions at a high radiation efficiency in which the amount of heat dissipation is more than a given value. The reasons are as follows: although the heat sink **101** of the present invention is small in the number of the heat dissipating fins **103** to **106**, the heat sink **101** is large in a projected area in any direction of the x, y, z directions also in a closed heat dissipating space in a lighting device in which the efficiency of heat dissipation is controlled by heat radiation and in which the convection of air is little caused. The heat sink **101** of the present invention has an excellent characteristic such that although the heat sink **101** has a simple structure in which the number of the heat dissipating fins **103** to **106** is small, the heat sink **101** is excellent in the heat dissipation efficiency per unit heat dissipation area.

[0168] Here, in the case of heat dissipation by radiation, which is required in a narrow space or a closed space of a housing for a vehicle-mounted lighting device, the sizes of the projected areas in the x-axis, y-axis, z-axis directions (three dimensional directions) shown in the respective drawings influence the heat radiation efficiency of the vehicle-mounted

lighting device, that is, as the total of the projected areas becomes larger, the heat radiation efficiency becomes larger.

[0169] In this point, in a heat sink in a conventional example shown in FIG. 47 or a heat sink **4** of a comparative example, a projected area in the y direction becomes the total of the plane of a base plate part **2** and the upper planes of fin parts **3** and the fin parts **3** do not overlap each other, so that the waste of material is eliminated and the projected area is made large. However, the projected area in the z direction becomes the total of the side faces of the base plate part **2** and the side faces of the fin parts **3** and a projection plane is shaped like a comb and has many spaces and the projected area becomes a small area that is smaller than 50% of a total area acquired by multiplying the length of the base plate part **2** by the height of the fin part **3**. Further, a projected area in the x direction becomes the total of the front of the base plate part **2** and the front of the fin part **3**, and although four fin parts **3** are formed, these four fin parts overlap each other and hence the projected area of the fin parts **3** becomes equal to the projected area of one fin part **3**, which results in causing the waste of material and reducing the heat radiation efficiency per unit heat radiation area. That is, although many fins overlap each other and occupy the space in the x direction, the projected area is small and the heat radiation efficiency is low for a large spatial occupancy. In addition, since the number of the heat dissipating fins in the x direction is excessive, there is presented also the problem of increasing the waste of material and the weight of the heat sink.

[0170] In other words, in the conventional heat sink shown in FIG. 47 and the heat sink **4** of the comparative example, the heat radiation efficiency in any of the x, y, z directions (three dimensional directions) inevitably becomes low. As a result, the heat radiation efficiency in any direction of the three dimensional directions cannot be increased and hence an integrated heat radiation efficiency is decreased. Further, the number of the heat dissipating fins becomes excessive in the x direction or the like and hence the waste of material becomes large. In other words, these conventional techniques are common to each other in that a heat sink cannot be produced which is little in the waste of material and is high in the heat radiation efficiency in any direction of the three dimensional directions of the heat sink for a small spatial occupancy.

[0171] Incidentally, Japanese Patent Application Laid-Open No. 2010-146817 is the same in this point, and the heat radiation efficiency is low for a high spatial occupancy in the direction in which the heat dissipating parts of many ladle parts, each of which is shaped like a letter C, overlap each other and the waste of material is large, in particular, in the x direction in terms of the integrated heat radiation efficiency in three directions of the three dimensional directions. Further, the slit-shaped opening described above is greatly limited in width so as to ensure the size of a heat sink itself and an area on the heat dissipating part side and hence is inevitably made narrow, so that in the case where the heat sink is applied to a closed space, an improvement in the heat dissipation efficiency by the convection of air cannot be actually made as large as desired.

[0172] The heat sink of the present invention is most suitable in a usage (installation) state in which a heat dissipating space around the heat sink is closed and is small in volume and is little in the convection of air, that is, in a usage (installation) environment in which heat dissipation by the convection of air is hardly expected. In this usage environment, in

order to dissipate heat, heat dissipation by radiation needs to be made main. However, in the heat conventional heat sink structure in which heat dissipation performance is mainly enhanced by an increase in the convection of air which is made by increasing the surface areas of the heat dissipating surfaces of the heat dissipating fins or the like, the heat dissipation by the radiation becomes insufficient and hence heat dissipation cannot be efficiently achieved as a whole. In contrast to this, in the heat sink of the present invention, heat dissipation is mainly done by the radiation of heat from the heat dissipating surfaces of the heat dissipating side surfaces, so that the heat sink of the present invention can be said to be the most suitable heat sink for the usage (setting) environment in which heat dissipation by the convection of air can be hardly expected.

[0173] In addition, in the heat sink of the present invention, the respective heat dissipating surfaces including the LED element mounting face **1021** and the heat dissipating fins are of an integral structure in which each of the heat dissipating surfaces does not have a joint face between the LED element mounting face **1021** and the heat dissipating fin and hence do not cause a contact heat resistance caused in the case where the LED element mounting face **1021** and the heat dissipating fins are separately manufactured and then joined to each other. For this reason, heat conduction can be easily developed between the LED element mounting face **1021** and the respective heat dissipating fins, which results in markedly increasing the heat dissipation performance of the whole heat sink. Further, the structure of the heat sink **101** is a structure such that the heat dissipating fins are directed to all directions of the x, y, z directions of the three dimensional directions and hence has high rigidity. For this reason, even in the case of usage in which the heat sink suffers vibrations, for example, in the vehicle-mounted lighting device or the like, the heat sink can hold a shape without using a special reinforcing member and can achieve a maintenance-free heat sink and a long life.

[0174] Common Items of the First Embodiment Including the Respective Modified Examples:

[0175] The LED element mounting face **1021** and the bottom face **1022** of the base plate **102** and the respective heat dissipating surfaces of the heat dissipating fins **103** to **106**, which have been described above, may have a space, a slit, or a partial shape for fixing a component formed in a portion thereof, according to the usage of the heat sink **101** and to a member to which the heat sink **101** is fixed, by cutting out a portion of the face and the surfaces or by three-dimensionally forming a depressed part, a projected part, or a stepped part in the surfaces. In addition, the heat dissipating side surfaces may have a portion thereof omitted or changed in shape according to the need of fixing the component and the like.

[0176] The heat sink **101** of the present invention can achieve an excellent heat dissipation effect without complicating the shape and structure of the heat sink, in particular, the shape and structure of the heat dissipating fins and without increasing the number of the heat dissipating fins, on the contrary, by simplifying the structure and by decreasing the number of heat dissipating fins. As a result, various kinds of raw materials, various manufacturing methods, or various manufacturing processes can be selected and hence a heat sink easily manufactured at low cost can be provided. As the raw material can be selected from various kinds of raw materials, for example, aluminum (pure aluminum) or aluminum alloy, copper (pure copper) or copper alloy, a steel plate, resin,

or ceramics, and manufacturing methods or manufacturing processes such as drawing or bending of a plate, die casting or casting, forging, or extruding can be selected.

[0177] (Aluminum)

[0178] In this regard, aluminum (pure aluminum) or an aluminum alloy is desired as a raw material having strength, rigidity, lightness, corrosion resistance, heat transfer capability, heat dissipation capability, and workability which are characteristics require of the heat sink **101**. The aluminum (pure aluminum) or the aluminum alloy is especially large in heat transfer characteristics and heat dissipation characteristics required of the heat sink and pure aluminum of 1000 series specified by the AA standard or the JIS standards can be preferably used.

[0179] The plate thickness (thickness) of the base plate **102** and the thicknesses of the heat dissipating fins **103** to **106** or a plate thickness (thickness) in the case where a raw material is a metal thin plate can be preferably selected from a range from 0.4 mm to 4 mm in consideration of a reduction in weight, required strength and rigidity, and drawing (forming) capability of the heat sink. When the plate thickness is too thin, the required strength and rigidity or the drawing (forming) capability of the heat sink cannot be ensured. On the other hand, when the plate thickness is too thick, the reduction in weight of the heat sink is sacrificed.

[0180] (Surface Emissivity of Heat Dissipating Surface)

[0181] In order to make the heat sink of the present invention acquire high heat dissipation capability, the surface emissivity ϵ of the metal thin plate is desired to be 0.6 or more. For this reason, before drawing the metal thin plate, a pre-coating processing (coating) of paint of black, gray, or white, which is high in heat dissipation rate, may be applied to the entire surface of the metal thin plate of the raw material. Alternatively, after drawing the metal thin plate, a post-coating processing (coating) of the paint which is high in thermal emissivity may be applied to a drawn product. In this way, the amount of heat transfer by radiation as the heat sink can be increased. When the pre-coating processing is previously applied to the metal thin plate of the raw material before the drawing, the coating processing serves as a lubricant in the drawing.

[0182] The surface emissivity ϵ is the ratio of the heat radiation of an actual body to a theoretical value (heat radiation of a black body of an ideal heat radiator) and an actual surface emissivity E may be measured by the method described in Japanese Patent Application Laid-Open No. 2002-234460 or may be measured by the use of a portable thermal emissivity measuring device on the market.

[0183] (Mounting Heat Sink of Present Invention in Vehicle-Mounted Lamp)

[0184] The mounting of the heat sink of the present invention in a vehicle-mounted LED lamp or the like can be performed in the same way as the mounting of a heat sink generally used, which is also an advantage of the heat sink of the present invention. Usually, the vehicle-mounted LED lamp (lighting device for a vehicle) includes an LED substrate having an LED element as a light source mounted thereon, a reflector for reflecting light from the LED to the front in the direction in which light is emitted, a housing for wrapping the LED substrate and the reflector, an outer lens for closing the open front end of the housing and made of a transparent material, and a heat sink arranged in thermal contact with the LED substrate. The reflector is formed of a resin material and has a parabolic reflecting surface having a focal point near the

LED on the LED substrate. Here, the heat sink of the present invention is used as a heat sink arranged on the LED substrate or in thermal contact with the LED substrate. Even in this case, the heat sink of the present invention used for the vehicle-mounted LED lamp is greatly different from the conventional heat sink in the following point: that is, heat dissipation by the convection of air to which heat is transferred to air as in the case of the conventional heat sink is not main but heat dissipation by the thermal radiation of heat is main.

EXAMPLES

[0185] The heat sinks of the respective shapes of the fifth modified example (inventive example) shown in FIG. 6 corresponding to FIG. 1, the first modified example shown in FIG. 2, the conventional example shown in FIG. 47, and the comparative example shown in FIG. 50 were actually manufactured, and each of the heat sinks was mounted with an LED element and had electric current applied thereto to thereby emit light and the temperature of the LED element was measured. The measurement results will be shown in Table 1.

[0186] The heat sinks of the respective shapes of the first modified example shown in FIG. 2, the conventional example shown in FIG. 47, and the comparative example shown in FIG. 50 were manufactured by machining or cutting an extruded bar of aluminum of 1100 series of the JIS as a raw material. The heat sink of the inventive example shown in FIG. 6 corresponding to FIG. 1 was manufactured by press-forming the end portions of a cold-rolled plate made of aluminum of 1100 series of the JIS to bend the end portions into heat dissipating fins.

[0187] The rectangular shape of the base plate of each example was of the size of 100 mm (z direction)×100 mm (x direction)×thickness 2 mm, and the rectangular shape of the heat dissipating fin was of the size of 70 mm (length in the z direction of the plate-shaped side surface)×30 mm (height in the y direction of the plate-shaped side surface)×thickness 2 mm, which was common to the respective examples. The distance between the heat dissipating fins parallel to each other of the inventive example, that is, between 103 and 103 on the left and right sides and between 104 and 104 on the upper and lower sides was 80 mm or more (the distance from the center of the LED element was 35 mm or more). The distance between the heat dissipating fins in the conventional example and the comparative example was 10 mm. The base plate and the heat dissipating fins had cationic resin coating electrodeposited on the surfaces in the respective examples, the cationic resin coating being commercially available and black. When a surface thermal emissivity was measured for all examples by the use of a commercially available portable thermal emissivity measuring device developed by Japan Aerospace Exploration Agency, the surface thermal emissivity was 0.85 for all examples.

[0188] In all examples, the base plate was mounted with a commercially available LED element and then the LED element had an electric current of 3.7 V×0.85 A applied thereto from a direct current power supply to thereby emit light. At this time, the heat sink was set hermetically in a cylindrical wooden case simulating the closed space of a vehicle-mounted LED lamp in which the convection of air was not caused and having the size of 300 mm×300 mm×300 mm, and while monitoring the temperature of the LED element with a thermocouple, the LED element was made to emit light in the atmosphere set at a temperature of 20° C. After a given time passed, the temperature brought into a steady state in which

the temperature was neither increased nor decreased was measured. The temperature was measured five times for each of the examples and an average value of the measured temperatures was found and evaluated.

[0189] As shown in Table 1, in an inventive example 1 corresponding to the fifth modified example shown in FIG. 6 corresponding to FIG. 1 and an inventive example 2 corresponding to the first modified example shown in FIG. 2, even in the closed space of the vehicle-mounted LED lamp in which the convection of air is not caused, the temperature of the LED element in the steady state could be held at an extremely low temperature of 42° C. or less which is lower than 100° C. or less exemplified as the allowable temperature at which the light emission efficiency of the LED element is not decreased, so that it could be assured that the inventive examples 1,2 had an excellent heat dissipation performance (cooling performance) by the heat radiation. In this regard, naturally, the inventive example 2 shown in FIG. 2, which had the heat dissipating fins of eight of a preferable upper limit, was more excellent in heat dissipation performance but was larger in weight than the inventive example 1 shown in FIG. 6 which had four heat dissipating fins, so that there was not much difference in terms of heat dissipation efficiency between the inventive example 2 and the inventive example 1.

[0190] On the other hand, in the heat sinks of the conventional example 1 shown in FIG. 47, the conventional example 2 similar to the conventional example 1, and the comparative example shown in FIG. 50, the temperature of the LED element in the steady state was lower than 100° C. but was higher than the inventive examples, so that it could be assured that the heat sinks of the conventional examples 1, 2 and the comparative example were inferior to the inventive examples 1, 2 in the heat dissipation performance (cooling performance) by the heat radiation in the closed space of the vehicle-mounted LED lamp in which the convection of air was not caused. Here, in the bunch of tests, heat inputs from an engine, a heat exchanger, and various kinds of electric devices, which are thought when the heat sink is mounted in an actual vehicle, and a heat input from direct sunlight were not taken into account. For this reason, it is thought that the temperature of the LED element will be lower than the temperature of the LED element actually mounted in the vehicle (vehicle-mounted LED). However, the bunch of tests have sufficient accuracy and reproducibility in the performance comparison of the heat sinks.

[0191] The critical significance of the specifications, in particular, the number and the arrangement of the heat dissipating fins of the heat sink of the present invention can be supported by the facts described above.

TABLE 1

Category	Correspondence to FIG.	Number of heat dissipating fins of base plate	Arrangement of heat dissipating fins	Average temperature in steady state (° C.)
Inventive example 1	FIG. 1	4 only on one face	Perpendicular to each other	37
Inventive example 2	FIG. 2	a total of 8 on both faces	Perpendicular to each other	34
Conventional example 1	FIG. 47	4 only on one face	Parallel to each other	49
Conventional example 2	—	6 only on one face	Parallel to each other	47

TABLE 1-continued

Category	Correspondence to FIG.	Number of heat dissipating fins of base plate	Arrangement of heat dissipating fins	Average temperature in steady state (° C.)
Comparative example	FIG. 50	a total of 8 on both faces	Parallel to each other	43

[0192] As described above, in the heat sinks of the present invention, heat dissipation is done mainly by heat dissipation by heat radiation from the heat dissipating surfaces such as the heat dissipating side surfaces and the like, so that the heat sink of the present invention is most suitable for a narrow usage space (usage, setting environment) in which the convection of air is little caused (heat dissipation by the convection of air is hardly expected). For this reason, the heat sink of the present invention can be used as a heat dissipating component for a vehicular lighting device such as a vehicle-mounted LED lamp.

[0193] In various exemplary embodiments, a heat sink for LED lighting according to the present invention includes: a base plate; a first heat-dissipating fin; and a second heat-dissipating fin. In some such embodiments: the base plate, the first fin, and the second fin are formed integrally from aluminum or an aluminum alloy; the base plate comprises a first surface suitable for mounting an LED element and a second surface opposite from the first surface; the first fin extends from the first surface or the second surface of the base plate; the second fin extends from the first surface or the second surface of the base plate; no more than one additional heat-dissipating fin extends from the surface of the base plate from which the first fin extends and is parallel or substantially parallel to the first fin; and no more than one additional heat-dissipating fin extends from the surface of the base plate from which the second fin extends and is parallel or substantially parallel to the second fin.

[0194] In further exemplary embodiments, the heat sink according to the present invention includes: a third heat-dissipating fin; and a fourth heat-dissipating fin. In some such embodiments: the first fin is not parallel or substantially parallel to the second fin; the third fin is parallel or substantially parallel to the first fin; and the fourth fin is parallel or substantially parallel to the second fin.

[0195] In further exemplary embodiments, in the heat sink according to the present invention, each of the first fin, the second fin, the third fin, and the fourth fin extends from the first surface of the base plate.

[0196] In further exemplary embodiments, in the heat sink according to the present invention: the heat sink is formed by bending a blank of the aluminum or aluminum alloy; and each of the first fin, the second fin, the third fin, and the fourth fin is formed by bending the blank such that the base plate joins each of the first fin, the second fin, the third fin, and the fourth fin at a location of a respective bend.

[0197] In further exemplary embodiments, the heat sink according to the present invention includes: a fifth heat-dissipating fin; a sixth heat-dissipating fin; a seventh heat-dissipating fin; and an eighth heat-dissipating fin. In some such embodiments: each of the fifth fin, the sixth fin, the seventh fin, and the eighth fin extends from the second surface of the base plate; the fifth fin is not parallel or substantially parallel to the sixth fin; the seventh fin is parallel or substantially

parallel to the fifth fin; and the eighth fin is parallel or substantially parallel to the sixth fin.

[0198] In further exemplary embodiments, in the heat sink according to the present invention, each of the first fin, the second fin, the third fin, and the fourth fin extends from the second surface of the base plate.

[0199] In further exemplary embodiments, the heat sink according to the present invention includes: a third heat-dissipating fin; a fourth heat-dissipating fin; and a fifth heat-dissipating fin. In some such embodiments, each of the first fin, the third fin, and the fourth fin extends from the first surface of the base plate; each of the second fin and the fifth fin extends from the second surface of the base plate; the first fin is not parallel or substantially parallel to the second fin; the third fin is parallel or substantially parallel to the first fin; the fourth fin is not parallel or substantially parallel to the first fin; and the fifth fin is parallel or substantially parallel to the second fin.

[0200] In further exemplary embodiments, the heat sink according to the present invention includes: a third heat-dissipating fin; and a fourth heat-dissipating fin. In some such embodiments: each of the first fin and the third fin extends from the first surface of the base plate; each of the second fin and the fourth fin extends from the second surface of the base plate; the first fin is parallel or substantially parallel to the second fin; the third fin is parallel or substantially parallel to the first fin; and the fourth fin is parallel or substantially parallel to the second fin.

[0201] In further exemplary embodiments, in the heat sink according to the present invention: each of the first fin and the third fin extends from the first surface of the base plate; and each of the second fin and the fourth fin extends from the second surface of the base plate.

[0202] In further exemplary embodiments, in the heat sink according to the present invention: the heat sink is formed by bending a blank of the aluminum or aluminum alloy; and each of the first fin, the second fin, the third fin, and the fourth fin is formed by bending the blank such that the base plate joins each of the first fin, the second fin, the third fin, and the fourth fin at a location of a respective bend.

Second Embodiment

[0203] FIG. 8 shows a heat sink **201** for LED lighting of a second embodiment. The heat sink **201** for LED lighting is the heat sink **201** for LED lighting made of plate-shaped aluminum material and is integrally formed by bending a blank material **241** made of aluminum and is characterized by including a stepped base plate part **202** in which a horizontal plane part **211** and vertical front parts **221**, **222** are alternately continuous with each other and by an LED mounting part **203** formed on the surface of the horizontal plane part **211** and/or the vertical front parts **221**, **222** of the base plate part **202**. Of these parts, the horizontal plane part **211** constructs a mounting face part of the present invention and the vertical front parts **221**, **222** construct a first fin part of the present invention and vertical side surface parts **231** to **236** construct a second fin part of the present invention.

[0204] Specifically, the heat sink **201**, as shown in FIG. 8, is constructed of the base plate part **202** formed of a plate-shaped aluminum (including aluminum alloy) material having a given uniform thickness and having a stepped shape as a whole. That is, the base plate part **202** has a shape (structure) in which the horizontal plane part and the vertical plane parts are integrally formed at right angle, in more detail, the vertical

plane part **221**, the horizontal plane part **211** and the vertical plane part **222**, each of which has a same rectangular shape, are alternately formed continuously with each other in this order from the top portion of the stepped shape. The LED mounting part **203** is mounted in a bulging manner at the center of the surface of the horizontal plane part **211** of the base plate part.

[0205] The base plate part **202** of the heat sink **201** has a side plate part **204** further formed integrally with the end portions on both sides thereof, the side plate part **204** being vertical to the base plate part **202**. That is, the vertical front part **221** on the top of the base plate part **202** has a vertical side part **231** and a vertical side part **232** which are continuously arranged on both sides of and at right angles with the vertical front part **221** in such a way as to extend backward. Further, the horizontal plane part **211** of the base plate part **202** has a vertical side part **233** and a vertical side part **234** which are continuously arranged on both sides of and at right angles with the horizontal plane part **211** in such a way as to extend downward. Still further, the vertical front part **222** on the bottom of the base plate part **202** has a vertical side part **235** and a vertical side part **236** which are continuously arranged on both sides of and at right angles with the vertical front part **222** in such a way as to extend forward.

[0206] Depending on the whole size of the heat sink **201**, it is generally desired that the thickness of the base plate part **202** and the side plate part **204** constructing the heat sink **201** is 0.5 to 5 mm from the viewpoint of rigidity, heat dissipation capability, and weight reduction.

[0207] In this regard, although the aluminum material is not limited to a special kind of aluminum, it is desired to use pure aluminum of JIS 1000 series, aluminum alloy of JIS 3000 series, and aluminum alloy of JIS 5000 series, which are excellent in thermal conductivity and formability.

[0208] A method for manufacturing the heat sink **201** of the second embodiment will be described below on the basis of FIG. 9.

[0209] First, one blank **241** which corresponds to a plane shape of a development view matching the three dimensional shape of the heat sink **201** shown in FIG. 8 is acquired by punching a plate-shaped aluminum coil material **240** produced by rolling, as shown in an upper figure of FIG. 9. The blank **241**, as shown in a lower figure of FIG. 9, has a rectangular shape as a whole and has cutouts **242** at two portions respectively on both sides, that is, at a total of four portions. The cutouts **242** are made at positions at which the length of the blank **241** is trisected, and each of the cutouts **242** is made in the shape of a belt extending from an end on the long side of the blank **241** to the center of the blank **241**, and the cutouts **242** extend in parallel to each other. Here, in place of the aluminum coil material **240**, a sheet material produced by rolling may be used.

[0210] Next, the LED element mounting part **203**, which is formed in a rectangular parallelepiped bulged upward, is formed at the center position of the surface of the blank **241** by coining.

[0211] Next, the respective parts of the blank **241** are bent. In the lower figure of FIG. 9, the same reference numerals as the reference numerals corresponding to the names of the respective parts constructing the three-dimensional shape of the heat sink **201** shown in FIG. 8 are shown in respective sections of the plane of the blank **241**. The reference numeral **202** designates the base plate part and the reference numerals **204** designate the side plate parts. The broken lines are the

boundary lines of the respective continuous parts and show the bend lines (fold lines) when the blank **241** is bent.

[0212] First, a **221** face part of the blank **241** is bent up integrally with a **231** face part and a **232** face part at a right angle with a center on a bend line **243** of a boundary with a **211** face part, and a **222** face part is bent down integrally with a **235** face part and a **236** face part at a right angle with a center on the bend line **243** of a boundary with the **211** face part. In this way, there is formed the base plate part **202**, shown in FIG. 8, in which the vertical front part **221** of the top, the horizontal plane part **211** of the middle, and the vertical front part **222** of the bottom are continuous with each other in the stepped shape. Next, the **231** face part and the **232** face part are bent back (down in FIG. 9) at a right angle respectively with centers on the bend lines **243** of the boundaries with the **221** face part. In this way, the vertical side part **231** and the vertical side part **232** continuous with the vertical front part **221** shown in FIG. 8 are formed at the end portions on both sides of the vertical front part **221**. Next, the **235** face part and the **236** face part are bent forth (down in FIG. 9) at a right angle respectively with centers on the bend lines **243** of the boundaries with the **222** face part. In this way, the vertical side part **235** and the vertical side part **236** continuous with the vertical front part **222** shown in FIG. 8 are formed at the end portions on both sides of the vertical front part **222**. Still further, a **233** face part and a **234** face part are bent down at a right angle with centers on the bend lines **243** of the boundaries with the **211** face part. In this way, the vertical side part **233** and the vertical side part **234** continuous with the horizontal plane part **211** shown in FIG. 8 are formed at the end portions on both sides of the horizontal plane part **211**.

[0213] The manufacturing of the heat sink **201** for LED lighting of the embodiment shown in FIG. 8 is finished by bending the blank **241** in the manner described above. In this regard, the order of bending the respective parts in the bending process of the blank **241** for manufacturing the heat sink **201** of the present embodiment is not especially limited to the method described above. Even if the order of bending processes is interchanged as appropriate, the present heat sink **201** can be manufactured in the same way.

[0214] In this way, the heat sink **201** for LED lighting of the embodiment shown in FIG. 8 can be easily manufactured only by punching, coining, and bending the raw material of the aluminum plate produced by working such as rolling. Further, the heat sink **201** has the combined structure of the thin plate and hence is very light and has sufficient rigidity. Still further, as compared with a conventional heat sink manufactured by die casting, the heat sink **201** can be greatly reduced in the manufacturing cost.

[0215] Next, the principle and function of heat dissipation in the case where the heat sink **201** according to the present invention is set in a closed space in which the convection of air is not caused and where the LED lighting is done will be described with reference to FIG. 10 by taking the embodiment shown in FIG. 8 as an example. Here, the directions in which the heat *Q* is emitted from the respective parts are denoted by arrows and a surrounding closed space is denoted by *S*.

[0216] First, when the LED element mounted on the LED element mounting part **203** of the horizontal plane part **211** is made to emit light, heat generated by the LED element is transferred to the horizontal plane part **211** through the LED element mounting part **203**. Subsequently, the heat transferred to the horizontal plane part **211** is conducted to the

vertical front parts **221**, **222** and the vertical side parts **233**, **234**. Then, the heat Q conducted to the horizontal plane part **211** is radiated in directions at right angles with the horizontal plane part **211** (an arrow of the heat Q radiated from the bottom surface in the up and down direction in the drawing will be omitted), that is, into the surrounding closed space S (heat dissipation space) from the top and bottom surfaces of the horizontal plane part **211**. Further, the heat Q conducted to the vertical front parts **221**, **222** is radiated in directions at right angles with the vertical front parts **221**, **222** (arrows of the heat Q radiated from the bottom surfaces of the vertical front part **222** in the back and forth directions in the drawing will be omitted), that is, into the surrounding closed space S from the top and bottom surfaces of the vertical front parts **221**, **222**. Still further, the heat Q conducted to the vertical side parts **233**, **234** is radiated in directions at right angles with the vertical side parts **233**, **234** (arrows of the heat Q radiated from the bottom surfaces of the vertical side parts **233**, **234** in the left and right directions in the drawing will be omitted), that is, into the surrounding closed space S from the top and bottom surfaces of the vertical side parts **233**, **234**.

[0217] On the other hand, a part of the heat Q conducted to the vertical front part **221** is conducted to the vertical side parts **231**, **232** and is radiated in directions at right angles with the vertical side parts **231**, **232** (in the right and left directions in the drawing), that is, into the surrounding closed space S from the top and bottom surfaces of the vertical side parts **231**, **232**. Further, a part of the heat Q conducted to the vertical front part **222** is conducted to the vertical side parts **235**, **236** and is radiated in directions at right angles with the vertical side parts **235**, **236** (in the right and left directions in the drawing), that is, into the surrounding closed space S from the top and bottom surfaces of the vertical side parts **235**, **236**.

[0218] In this regard, in the vertical side parts **231** to **236**, the vertical side parts **231** and **232**, **233** and **234**, and **235** and **236** are opposite to each other, respectively, so that the vertical side parts **231** to **236** are smaller in heat dissipation by heat radiation than the horizontal plane part **211** and the vertical front parts **221**, **222**. This is because as follows: for example, when looking at the vertical side parts **231** and **232**, the heat Q from the top face (right face in the drawing) of the vertical side part **231** and the heat Q from the top face (left face in the drawing) of the vertical side part **232** are directly radiated in the directions at right angles with the vertical side parts **231**, **232**, that is, into the surrounding space S , thereby being sufficiently dissipated; on the other hand, the heat Q radiated in the direction at a right angle with the vertical side part **231** from the bottom face (left face in the drawing) of the vertical side part **231** and the heat Q radiated in the direction at a right angle with the vertical side part **232** from the bottom face (right face in the drawing) of the vertical side part **232** pass each other; so that the vertical side parts **231**, **232** absorb the heats Q each other and hence inhibit heat dissipation to the surrounding space S .

[0219] In this way, the heat sink **201** shown in FIG. 8 is formed of the stepped base plate part **202** in which the horizontal plane part **211** and the vertical front parts **221**, **222** are continuously formed one after the other and has the vertical side parts **231** to **236** on both side ends of the base plate part **202**. Hence, it can be understood that since the heat sink **201** shown in FIG. 8 has very large projected areas in the x , y , z directions, that is, in the three dimensional directions, the heat sink **201** has a high heat radiation efficiency and an excellent heat dissipation capability even in the closed heat dissipation

space in which the heat dissipation efficiency is subjected mainly to heat radiation and in which the convection of air is hardly caused.

[0220] Next, a first modified example of the second embodiment will be described which is common to the second embodiment shown in FIG. 8 in the whole shape. The heat sink itself of the first modified example of the second embodiment, although not illustrated, is different from the second embodiment shown in FIG. 8 only in the thicknesses of the stepped base plate part **202** (horizontal plane part **211**, the vertical front part **221** and the vertical front part **222**) shown in FIG. 8 and the vertical side parts (**231**, **232**, **233**, **234**, **235**, **236**) formed on the end portions on both sides of the base plate part **202** and is absolutely same as the second embodiment shown in FIG. 8 in the other portions.

[0221] The first modified example of the second embodiment will be specifically described with reference to FIG. 11 showing the shape of a blank after a coining process.

[0222] A blank **241** is a blank which has a rectangular shape as a whole and which has two cutouts respectively on both side portions thereof, that is, a total of four cutouts **242** and which includes a base plate part **202** formed in the center portion and having a thick thickness and side parts **204** formed on both sides and having a thin thickness, that is, a blank whose thickness is varied in a width direction.

[0223] When describing a method for manufacturing the blank **241**, two kinds of plate-shaped aluminum coil materials produced by rolling and having different thicknesses are prepared, and one thick plate and one thin plate which are acquired by punching or cutting the respective plate-shaped aluminum coil materials are welded to each other, thereby being integrated. A reference numeral **244** designates welded bead portions. Then, cutouts **242** extending in parallel to each other in the shape of a belt from an end side to a center side in a given length are made in the integrated aluminum plate at the positions at which the length is trisected.

[0224] By bending the blank **241** in the manner described in the second embodiment, a heat sink **201** according to the first modified example of the second embodiment can be easily manufactured. The heat sink **201** according to the first modified example of the second embodiment has the same three-dimensional shape as shown in FIG. 8 but is characterized in that the thickness of the base plate part **202** constructing a stepped shape (that is, the vertical front part **221**, the horizontal plane part **211**, and the vertical front part **222**) is larger than the thickness of the side plate part **204** (that is, vertical side parts **231**, **232**, **233**, **234**, **235**, and **236**). Specifically, it is desired that the thickness of the base plate part **202** is 0.5 to 5 mm and the thickness of the side part **204** is 0.25 to 2.5 mm.

[0225] According to the first modified example of the second example, as compared with the second embodiment shown in FIG. 8, the rigidity of the stepped base plate part **202** of the backbone of the heat sink **201** can be further increased and at the same time the thermal conductivity can be held higher, whereby the heat dissipation capability can be further improved.

[0226] Next, a second modified example of the second embodiment which is common to the second embodiment shown in FIG. 8 in the whole shape will be specifically described with reference to FIG. 12 showing the shape of a blank subjected to the coining process in the same way as described above. The blank **241** has a rectangular shape as a whole and has two cutouts respectively on both sides, that is, a total of four cutouts and includes a thick base plate part **202**

in the center and thin side parts **204** on both sides, so that the blank **241** is the same as the blank described above in the shape of the blank. However, the blank **241** is different from the above-mentioned integrated blank made by welding two kinds of plate-shaped aluminum coil materials having different thicknesses.

[0227] That is, the blank **241** is formed of an aluminum extruded material having the thick base plate part **202** in the center and the thin side parts **204** on both sides. The blank **241** can be manufactured by extruding an aluminum material by the use of a die corresponding to this sectional shape and then by forming the cutouts **242**. Further, by bending the blank **241** in the manner described in the second embodiment, the heat sink **201** according to the second modified example of the second embodiment can be manufactured in the same way.

[0228] The heat sink **201** of the second modified example of the second embodiment, as compared with the second embodiment shown in FIG. 8, can further increase the rigidity of the stepped base plate part **202** of the backbone of the heat sink **201** and at the same time can hold the thermal conductivity higher and can further enhance the heat dissipation capability. In addition, the blank **241**, which is uniform in quality and is different in thickness in the width direction, can be manufactured not by the punching process and the welding process but by the extruding process, so that the process of manufacturing the heat sink **201** can be further simplified as compared with the process shown in FIG. 9.

[0229] The heat sink shown in FIG. 8 is a mode showing a basic whole shape and the second embodiment is not limited to this mode. For example, although the heat sink shown in FIG. 8 has a one-stepped shape constructed of three plane parts of the upper and lower vertical front parts **221**, **222** and the horizontal plane part **211** formed between the vertical front parts **221**, **222**, in order to further increase the projected area to the heat dissipation space, the upper and lower vertical front parts and the horizontal plane part may be constructed of four or more plane parts and the number of steps may be increased to two or more. Further, in the heat sink shown in FIG. 8, all of the horizontal plane part **211** and the vertical front parts **221**, **222** constructing the stepped shape are formed in the same oblong shape (rectangular shape) having an equal length and an equal width. However, the horizontal plane part **211** and the vertical front parts **221**, **222** may be formed in different rectangular shapes connected one after the other, the different rectangular shapes being different from each other in length and width. In other words, the horizontal plane part **211** and the vertical front parts **221**, **222** may be formed of different shapes in which the respective steps are different in width, depth, and height. Further, the horizontal plane part **211** and the vertical front parts **221**, **222** may be formed of irregular shapes in which the respective steps are shifted in the width direction (in the left and right directions).

[0230] Further, in FIG. 8 is shown the heat sink having the vertical front part **221**, the horizontal plane part **211**, and the vertical front part **222** which have the vertical side parts **231**, **232**, the vertical side parts **233**, **234**, and the vertical side parts **235**, **236**, respectively. However, of these vertical side parts, all or one side parts of the vertical side parts **231**, **232**, and the vertical side parts **235**, **236** on both sides of the vertical side parts **221**, **222** may be omitted.

[0231] Next, a third modified example of the second embodiment which is different from the second embodiment shown in FIG. 8 in the whole shape will be described with reference to FIG. 13.

[0232] Here, a heat sink for LED lighting of the third modified example of the second embodiment is constructed of a base plate part **202** which is formed of a plate-shaped aluminum (including aluminum alloy) having a given uniform thickness and which is formed in the stepped shape as a whole, as is the case with the second embodiment shown in FIG. 8. A first different point from the second embodiment shown in FIG. 8 is that the base plate part **202** further has a horizontal plane part **212** arranged continuously backward on the top of the vertical front part **221** at a right angle with the vertical front part **221**, in other words, is formed in a two-stepped shape.

[0233] Next, the heat sink of the third modified example of the second embodiment is greatly different from the heat sink shown in FIG. 8 in the structure of the side plate parts **204** formed at both side ends of the base plate part **202**. A horizontal plane part **212** has vertical side parts **231** and **232** arranged continuously on both side ends thereof, the vertical side parts **231** and **232** extending downward to the lowest ends (lowest end position of the vertical front part **222**) at right angle with the horizontal plane part **212**. Further, the vertical front part **221** has vertical side parts **2331** and **2332** arranged continuously on both side ends thereof, the vertical side parts **2331** and **2332** extending forward to the middle of a full width (two thirds of the full width) of the horizontal plane part **211** at right angle with the horizontal plane part **211**. Still further, the horizontal plane part **211** has vertical side parts **2333** and **2334** arranged continuously on both side ends thereof, the vertical side parts **2333** and **2334** extending downward at right angles with the horizontal plane part **211**.

[0234] Still further, the vertical side parts **231** and **232** have overlapping flange parts **251** and **252** arranged at upper and lower positions thereof, respectively, the overlapping flange parts **251** and **252** protruding forward and covering portions of the surfaces of the vertical side parts **2331**, **2332**, and **2333**, **2334** (rear side portions) in such a way as to be in outer contact with the surfaces. Further, the vertical side parts **2333** and **2334** have overlapping flange parts **253**, **253** arranged at center positions thereof, respectively, the overlapping flange parts **253**, **253** protruding forward and covering portions of the surfaces of the vertical side parts **235**, **236** (rear side portions) respectively in such a way as to be in outer contact with the surfaces.

[0235] A method for manufacturing the heat sink **201** of the third modified example of the second embodiment will be described below on the basis of FIG. 14.

[0236] First, one blank **241** which corresponds to a plane shape of a development view matching the three-dimensional shape of the heat sink **201** shown in FIG. 13 is acquired by punching a plate-shaped aluminum coil material **240** produced by rolling is punched as shown in an upper figure of FIG. 14. The blank **241**, as shown in a lower figure of FIG. 14, has a shape of a letter T as a whole and has a total of six cutouts **2421** to **2423** in the perimeter thereof. That is, the blank **241** has cutouts **2421** at one position respectively on both lower sides (both near sides in the drawing) of a head part **241a** thereof and has cutouts **2422**, **2433** at two positions respectively on both sides of a body part **241b**. The cutout **2421** is formed in the shape of a two-stepped key, the cutout **2422** is formed in the shape of a belt, and the cutout **2433** is formed in the shape of a one-stepped key.

[0237] Next, an LED element mounting part 203, which is formed in a rectangular parallelepiped and is bulged upward, is formed at the center position of the surface of the blank 241 by the coining process.

[0238] Next, the respective parts of the blank 241 are bent. In the lower figure of FIG. 14, the same reference numerals as the reference numerals corresponding to the names of the respective parts constructing the three-dimensional shape of the heat sink 201 shown in FIG. 13 are shown in respective partitions of the plane of the blank 241. The reference numeral 202 designates the base plate part and the reference numeral 204 designates the side plate part. The broken lines are the boundary lines of the respective continuous parts and show the bend lines (fold lines) when the blank 241 is bent.

[0239] First, a 221 face part of the blank 241 is bent up with a 2331 face part, a 2332 face part, a 212 face part, a 231 face part, and a 232 face part at a right angle with a center on the bend line 243 of a boundary with a 211 face part. Further, a 222 face part is bent down integrally with a 235 face part and a 236 face part at a right angle with a center on the bend line 243 of a boundary with the 211 face part. Still further, the 212 face part is bent down (down in FIG. 14) integrally with the 231 face part and the 232 face part at a right angle with a center on the bend line 243 of a boundary with the 221 face part. In this way, the base plate part 202 is formed in which the horizontal plane part 212, the vertical front part 221, the horizontal plane part 211, and the vertical front part 222 are continuously formed one after the other in this order in the stepped shape from the top in FIG. 13.

[0240] After the stepped base plate part 202 is formed, the 235 face part and the 236 face part are bent forth (up in FIG. 14) with a center on the bend line 243 of a boundary with the 235 face part and with a center on the bend line 243 of a boundary with the 236 face part, respectively, whereby the vertical side part 235 and the vertical side part 236 which are continuous with the vertical front part 222 shown in FIG. 13 are formed on both side ends of the vertical front part 222. Next, a 2333 face part and a 2334 face part are bent down with a center on the bend line 243 of a boundary with the 211 face part and with a center on the bend line 243 of a boundary with the 211 face part, respectively, whereby the vertical side part 2333 and the vertical side part 2334 which are continuous with the horizontal plane part 211 shown in FIG. 13 are formed on both side ends of the horizontal plane part 211.

[0241] By forming the blank 241 in this way, the overlapping flange parts 253 of the 2333 face part and the 2334 face part overlap the surfaces of the 235 face part and the 236 face part and are bonded to the surfaces, respectively. That is, as shown in FIG. 13, the overlapping flange parts 253 of the vertical side part 2333 and the vertical side parts 2334 cover portions (rear portions) of the vertical side part 235 and the vertical side part 236 and are bonded to the portions, respectively, whereby these portions are formed in a double structure.

[0242] Next, the 2331 face part and the 2332 face part are bent forth (up in FIG. 14) at a right angle with a center on the bend line 243 of a boundary with the 221 face part and with a center on the bend line 243 of a boundary with the 221 face part, respectively, whereby the vertical side part 2331 and the vertical side part 2332 which are continuous with the vertical front part 221 shown in FIG. 13 are formed on both side ends of the vertical front part 221.

[0243] Subsequently, the 231 face part and the 232 face part are bent down at a right angle with a center on the bending line

243 of a boundary with the 212 face part and with a center on the bending line 243 of a boundary with the 212 face part, respectively, whereby the vertical side part 231 and the vertical side part 232 which are continuous with the horizontal plane part 212 shown in FIG. 13 are formed on both side ends of the horizontal plane part 212.

[0244] By forming the blank 241 in this way, the overlapping flange parts 251 of the 231 face part and the 232 face part are overlaid on the 2331 face part and the 2332 face part in contact with the surfaces thereof, whereas the overlapping flange parts 252 of the 231 face part and the 232 face part are overlaid on the 2333 face part and the 2334 face part in contact with the surfaces thereof. In other words, as shown in FIG. 13, the upper overlapping flange parts 251 of the vertical side part 231 and the vertical side part 232 cover portions (rear portions) of the vertical side part 2331 and the vertical side part 2332 and are overlaid on the portions, whereas the lower overlapping flange portions 252 of the vertical side part 231 and the vertical side part 232 cover portions (rear portions) of the vertical side part 2333 and the vertical side part 2334 and are overlaid on the portions. In this way, all of these flange parts are formed in the double structure.

[0245] By bending the blank 241 in the above-mentioned way, the manufacturing of the heat sink 201 for LED lighting of the third modified example of the second embodiment shown in FIG. 13 is finished. The order of working processes of the respective parts in the bending process of the blank 241 for manufacturing the heat sink 201 is not especially limited to the method described above, as is the case with the second embodiment shown in FIG. 8. However, in the case of the third modified example of the second embodiment is more complicated than the heat sink shown in FIG. 8, so that in order to prevent the respective parts from interfering with each other at the time of bending the respective parts, it is necessary to pay attention to the order of working processes: for example, a vertical side part having the overlapping flange part is bent after a vertical side part to be bonded thereto is bent.

[0246] According to the third modified example of the second embodiment, as compared with the heat sink of the second embodiment shown in FIG. 8, a heat sink of the third modified example is additionally provided with the horizontal plane part 212, the vertical side parts 231 and 232, and the vertical side part 2331 and 2332 or is increased in the area of the parts, thereby being increased in the projected areas in the three dimensional directions. Hence, the heat sink of the third modified example has a higher heat radiation efficiency and a more excellent heat dissipation capability. Further, the heat sink of the third example of the second embodiment has a structure such that the overlapping flange parts 251 to 253 are formed on the vertical side parts 231 and 233, and 2333 and 2334, respectively, and are overlaid on the vertical side part 2331 and 2332, 2333 and 2334, and 235 and 236, respectively, and are bonded and connected to them. Hence, the heat sink of the third example of the second embodiment has the heat generated from the LED element speedily conducted to the ends of the remote vertical side parts (fins) and radiated therefrom and hence can produce a still higher heat dissipation capability. Still further, the heat sink of the third example of the second embodiment has the vertical side parts overlaid and formed in a double-plate structure and hence can increase rigidity as compared with a one-plate structure shown in FIG. 8 and hence can enhance strength, durability, and stability.

[0247] In this regard, the third modified example of the second embodiment is an example in which the vertical side parts are overlaid on each other via the overlapping flange parts. However, not only this structure but also a structure such that the vertical side parts and the horizontal plane parts and/or the vertical front parts of the base plate part 202 are overlaid on each other can be also employed.

[0248] Further, in the double structure parts of the vertical side parts in the third modified example of the second embodiment, the double materials may be integrally bonded to each other by the use of a bonding method such as screw fastening, rivet fastening, swage fastening, welding, or soldering, whereby the rigidity of the heat sink can be greatly increased.

[0249] In various exemplary embodiments, the heat sink for LED lighting according to the present invention includes: a base plate; a first heat-dissipating fin; and a second heat-dissipating fin. In some such embodiments: the base plate, the first fin, and the second fin are formed integrally from aluminum or an aluminum alloy; the base plate comprises a first surface suitable for mounting an LED element and a second surface opposite from the first surface; the first fin comprises a first surface and a second surface opposite from the first surface; the first fin extends from the first surface or the second surface of the base plate; and the second fin extends from the first surface or the second surface of the first fin.

[0250] In further exemplary embodiments, the heat sink according to the present invention includes: a third heat-dissipating fin; a fourth heat-dissipating fin; a fifth heat-dissipating fin; a sixth heat-dissipating fin; a seventh heat-dissipating fin; and an eighth heat-dissipating fin. In some such embodiments: the first fin extends from the first surface of the base plate; the second fin extends from the second surface of the first fin; the third fin extends from the second surface of the first fin; the fourth fin extends from the second surface of the base plate; the fifth fin extends from the second surface of the base plate; the sixth fin comprises a first surface and a second surface opposite from the first surface; the sixth fin extends from the second surface of the base plate; the seventh fin extends from the first surface of the sixth fin; and the eighth fin extends from the first surface of the sixth fin.

[0251] In further exemplary embodiments, in the heat sink according to the present invention: the heat sink is formed by bending a blank of the aluminum or aluminum alloy; each of the first fin, the fourth fin, the fifth fin, and the sixth fin is formed by bending the blank such that the base plate joins each of the first fin, the fourth fin, the fifth fin, and the sixth fin at a location of a respective bend; each of the second fin and the third fin is formed by bending the blank such that the first fin joins each of the second fin and the third at a location of a respective bend; and each of the seventh fin and the eighth fin is formed by bending the blank such that the sixth fin joins each of the seventh fin and the eighth fin at a location of a respective bend.

[0252] In further exemplary embodiments, in the heat sink according to the present invention, the blank comprises a thick portion corresponding to the base plate, the first fin, and the sixth fin and a thin portion corresponding to corresponding to the second fin, the third fin, the fourth fin, the fifth fin, the seventh fin, and the eighth fin.

[0253] In further exemplary embodiments, in the heat sink according to the present invention, the blank is prepared by welding sheets of the aluminum or aluminum alloy.

[0254] In further exemplary embodiments, in the heat sink according to the present invention, the blank is prepared by coining.

[0255] In further exemplary embodiments, the heat sink according to the present invention includes: a third heat-dissipating fin; a fourth heat-dissipating fin; a fifth heat-dissipating fin; a sixth heat-dissipating fin; a seventh heat-dissipating fin; an eighth heat-dissipating fin; a ninth heat-dissipating fin; a tenth heat-dissipating fin; and an eleventh heat-dissipating fin. In some such embodiments: the first fin extends from the first surface of the base plate; the second fin comprises a first surface and a second surface opposite from the first surface; the second fin extends from the second surface of the first fin; the third fin extends from the first surface of the first fin; the fourth fin extends from the first surface of the first fin; the fifth fin extends from the second surface of the surface of the second fin; the sixth fin extends from the second surface of the surface of the second fin; the seventh fin extends from the second surface of the base plate; the eighth fin extends from the second surface of the base plate; the ninth fin comprises a first surface and a second surface opposite from the first surface; the ninth fin extends from the second surface of the base plate; the tenth fin extends from the first surface of the ninth fin; and the eleventh fin extends from the first surface of the ninth fin.

[0256] In further exemplary embodiments, in the heat sink according to the present invention: a portion of the fifth fin overlaps and contacts a portion of the fourth fin; a portion of the fifth fin overlaps and contacts a portion of the seventh fin; a portion of the sixth fin overlaps and contacts a portion of the third fin; a portion of the sixth fin overlaps and contacts a portion of the eighth fin; a portion of the seventh fin overlaps and contacts a portion of the eleventh fin; and a portion of the eighth fin overlaps and contacts a portion of the tenth fin.

[0257] In further exemplary embodiments, in the heat sink according to the present invention: the heat sink is formed by bending a blank of the aluminum or aluminum alloy; each of the first fin, the seventh fin, the eighth fin, and the ninth fin is formed by bending the blank such that the base plate joins each of the first fin, the seventh fin, the eighth fin, and the ninth fin at a location of a respective bend; each of the second fin, the third fin, and the fourth fin is formed by bending the blank such that the first fin joins each of the second fin, the third fin, and the fourth fin at a location of a respective bend; each of the fifth fin and the sixth fin is formed by bending the blank such that the second fin joins each of the fifth fin and the sixth fin at a location of a respective bend; and each of the tenth fin and the eleventh fin is formed by bending the blank such that the ninth fin joins each of the tenth fin and the eleventh fin at a location of a respective bend.

Third Embodiment

[0258] FIG. 15 shows a heat sink 301 for LED lighting of a third embodiment. The heat sink 301 for LED lighting is the heat sink 301 for LED lighting formed of an aluminum plate 302 and is characterized by including a stepped shape such that horizontal plan parts 311, 312 and vertical front parts 321, 322 are continuously formed one after the other and in that an LED element 300 is mounted on the surface of the horizontal plane part and/or the vertical front part. Of these parts, the horizontal plane part 312 constructs a mounting face part of the present invention and the vertical front parts

321, 322 construct a first fin part of the present invention and vertical side parts **331** to **338** to be described later construct a second fin part.

[0259] Specifically, the heat sink **301** of the third embodiment, as shown in FIG. 15, is formed of an aluminum (including aluminum alloy) plate **302** having a given thickness and has a stepped shape as a whole. That is, in the case of the heat sink **301** shown in FIG. 15, the heat sink **301** is formed of the aluminum plate **302** and has a whole basis shape formed in a two-stepped shape. In other words, in the case of the heat sink **301** shown in FIG. 15, the heat sink **301** is formed in the two-stepped shape and is formed in a shape (structure) in which horizontal plane parts and vertical front parts, which meet each other at a right angle, are continuously formed one after the other from the top portion of a step in the order of a horizontal plane part **311**, a vertical front part **321**, a horizontal plane part **312**, and a vertical front part **322**.

[0260] Each of the horizontal plane parts **311, 312** and the vertical front parts **321, 322** is a rectangle having a long side of the same length of the width of the aluminum plate **302** forming the stepped shape and a short side of a width acquired by dividing the length of the aluminum plate **302** into equal quarters.

[0261] A reference numeral **300** designates an LED element mounted on the center of the horizontal plane part **312**.

[0262] Of the horizontal plane parts and the vertical front parts, the horizontal plane part **312** and the vertical front part **321** have vertical side parts **331, 332** arranged on both side ends at a right angle with them, that is, vertically with them. Each of the vertical side parts **331, 332** is a square having a side of the length of the horizontal plane parts **311, 312** and the vertical front parts **321, 322**.

[0263] Next, the principle and function of heat dissipation in the case where the heat sink **301** having such a stepped shape is set in a space in which the convection of air is not caused and where LED lighting is done will be described. When the LED element **300** mounted on the horizontal plane part **312** is made to emit light, the heat generated by the LED element **300** is conducted to the horizontal plane part **312** through a part having the LED element **300** mounted thereon. Subsequently, the heat conducted to the horizontal plane part **312** is conducted to the vertical front part **321**, the vertical front part **322**, and the vertical side parts **331, 332**. In this way, the heat conducted to the horizontal plane part **312** is conducted to the two or more vertical front parts or the vertical side parts which are continuous with the horizontal plane part **312**. Then, the heat Q conducted to the horizontal plane part **312** is radiated at right angles with the horizontal plane part **312** (up and down directions in FIG. 15) into the surrounding closed space (heat dissipation space) S from the whole top and bottom surfaces of the horizontal plane part **312**, and the heat Q conducted to the vertical front part **321** is radiated at a right angle with the vertical front part **321** (left and right directions in FIG. 15) into the surrounding closed space S from the whole top and bottom surfaces of the vertical front part **321**, and the heat Q conducted to the vertical side parts **331, 332** is radiated at right angles with the vertical side parts **331, 332** (right and left directions in FIG. 16) into the surrounding closed space S from the whole surfaces of the vertical side parts **331, 332**. Here, the heat is dissipated respectively in the left and right directions from the side (left surface in FIG. 15) facing the LED element **300** of the vertical side part **331** and the side (right surface in FIG. 15) facing the LED element **300** of the vertical side part **332**, but the heat dissipation

to the left from the vertical side part **331** is absorbed by the right surface of the vertical side part **332** and the heat dissipated to the right from the vertical side part **332** is absorbed by the left surface of the vertical side part **331** and hence the heat dissipation by radiation from these both surfaces is a little.

[0264] Further, a portion of the heat Q conducted to the vertical front part **321** is conducted to the horizontal plane part **311** and is radiated at right angles with the horizontal plane part **311** (up and down directions in FIG. 15) into the surrounding closed space S from the whole top and bottom surfaces of the horizontal plane part **311**. Here, the heat conducted to the horizontal plane part **312**, the vertical front part **321**, the vertical plane part **322**, the horizontal plane part **311**, and the vertical side parts **331** and **332** is conducted from a high heat level to a low heat level.

[0265] In this way, the heat sink having the stepped shape shown in FIG. 15 and further having the vertical side parts on both sides of the horizontal plane part and the vertical front part constructing the stepped shape has a very large projected area in the x, y, z directions, that is, three dimensional directions. Hence, it can be understood that the heat sink has a high heat radiation efficiency and an excellent heat dissipation capability even in the closed heat dissipation space in which the efficiency of heat dissipation is subjected to radiation and in which the convection of air is not caused. The heat sink is excellent in heat dissipation efficiency per unit heat dissipation area and is formed in a simple structure. Still further, since the heat sink has two or more vertical front parts and vertical side parts which are continuous from the horizontal plane part **312** mounted with the LED element, the heat generated by the LED element is conducted in many directions from the LED mounting surface and hence is speedily dissipated to accelerate heat radiation from the respective surfaces. Hence, the heat sink has an excellent heat dissipation capability.

[0266] Next, a method for manufacturing a heat sink formed in a shape shown in FIG. 15 will be described.

[0267] First, a pure aluminum plate or an aluminum alloy plate (which is simply referred to as an aluminum plate in the present invention) having a given thickness is produced from a raw material of pure aluminum or aluminum alloy by rolling or the like. The aluminum plate produced has a length L of four times a short side of the rectangle of the horizontal plane part **311** (which is the same as the horizontal plane part **312**, and vertical front parts **321** and **322**) shown in FIG. 15 and a width W acquired by adding two times a side of a square of the vertical side part **331** (which is the same as the vertical side part **332**) to a long side of the rectangle of the horizontal plane part **311**.

[0268] Next, of four rectangles acquired by dividing the aluminum plate, which is produced by the rolling and has a size of $L \times W$, into four equal quarters in the length direction, three rectangles of the first, second, and fourth quarters except for the third quarter from an end have both side portions thereof cut off by a length corresponding to a side of the square of the vertical side part **331** (which is the same as the vertical side part **332**). By cutting the aluminum plate in this way, an aluminum plate **302** can be acquired which has three rectangles having a width (long side) corresponding to the horizontal plane part **311** and the vertical front parts **321** and **322** and one rectangle having a long width (total width)

acquired by adding a side of the vertical side part 331 and a side of the vertical side part 332 to a width of the horizontal plane part 312.

[0269] In the aluminum plate 302, a short-width rectangular part which is to be the horizontal plane part 311 is bent at a right angle with a rectangular part which is to be the vertical front part 321 with a center on a boundary with the rectangular part which is to be the vertical front part 321; next, a same rectangular part which is to be the horizontal plane part 312 is further bent on a side opposite to the horizontal plane part 311 at a right angle with the rectangular part which is to be the vertical front part 321 with a center on a boundary with the rectangular part which is to be the vertical front part 321; subsequently, a same rectangular part which is to be the vertical front part 322 is still further bent on a side opposite to a same rectangular part of the vertical front part 321, which is bent, at a right angle with the same rectangular part of the horizontal plane part 312 with a center on a boundary with the same rectangular part of the horizontal plane part 312. In this way, a stepped shape of a base shape can be formed.

[0270] Then, finally, square parts of the vertical side part 331 and the vertical side part 332 which are positioned on both sides in a width direction of a long-width rectangular part which is to be (the horizontal plane part 312+the vertical side part 331+the vertical side part 332) is bent to the side of the face of the vertical front part 321 at a right angle with the rectangular part of the horizontal plane part 312 with a center on a boundary with the horizontal plane part 312, respectively. In this way, the heat sink 301 of the present invention shown in FIG. 15 can be easily manufactured from the raw material of the aluminum plate 302 by the use of comparatively easy working processes of cutting and bending.

[0271] A method for manufacturing the aluminum plate 302 has been described by taking the rolling method as an example. However, not only the rolling method but also other working method such as an extruding method can be used.

[0272] The heat sink 301 shown in FIG. 15 is an embodiment showing a basic whole shape and the third embodiment is not limited to this embodiment. For example, the heat sink shown in FIG. 15 has a two-stepped shape but the heat sink may have three or more steps so as to increase a projected area to the heat dissipation space. Further, in the heat sink shown in FIG. 15, the horizontal plane parts 311, 312 and the vertical front parts 321, 322 constructing the two-stepped shape are formed in the same rectangles each of which has the same length and the same width. However, the heat sink may be formed of rectangles which are different from each other in length and width and which are continuous one after the other, in other words, may be formed in the shape in which steps are different from each other in width, depth, and height. Further, the heat sink may be formed in an irregular shape in which steps are shifted in the width direction (left and right directions).

[0273] Further, in FIG. 15 is shown the heat sink having the vertical side parts 331, 332 on both sides of the horizontal plane part 312 and the vertical front part 321. However, the vertical side parts 331, 332 are not necessarily formed on both sides of the stepped shape but may be formed only on one side. Further, the vertical side parts 331, 332 are not formed limitedly on one side or both sides of the horizontal plane part 312 and the vertical front part 321 but may be formed on one side or both sides of the horizontal plane part 312 and the vertical front part 322 and on one side or both sides of the horizontal plane part 311 and the vertical front part 321. Still

further, the vertical side parts may be vertically arranged on both side ends (or one side end) of any one of the horizontal plane parts and the vertical front parts, that is, may be vertically protruded up from the both side ends of the horizontal plane part 311 shown in FIG. 15 and may be vertically protruded forth from the both side ends of the vertical front part 322.

[0274] Still further, the vertical side parts 331, 332 shown in FIG. 15, as described above, are formed by bending the rectangular aluminum plate including (the horizontal plane part 312+the vertical side part 331+the vertical side part 332) in the same direction at right angles and are integral and continuous with the horizontal plane part 312. Hence, the vertical side parts 331, 332 can be easily formed by cutting and bending the aluminum plate, which is preferable, but may be formed by previously preparing separate plates of the vertical side parts 331, 332 and by welding the separate plates to both end portions of the vertical front part 321 forming a stepped main body in a state where the separate parts are arranged vertically on both side ends of the vertical front part 321.

[0275] Further, in the heat sink shown in FIG. 15, the thickness of the aluminum plate forming the respective parts 311, 321, 312, 322 is constant, but it is effective to partially increase the thickness of the horizontal plane part 312 mounted with the LED element 300. FIG. 17 shows this example and is a section view of a part of the horizontal plane part 312 on which the LED element 300 is mounted.

[0276] Here, the thickness of the horizontal plane part 312 except for the part having the LED element 300 mounted thereon is the same as the thickness of the other parts 321, 312, 322, and the part having the LED element 300 mounted thereon has a thicker part 3121 formed on the bottom side thereof in such a way as to bulge downward. In this way, by increasing the thickness of the part having the LED element 300 mounted thereon of the horizontal plane part 312, a large amount of heat generated by the horizontal plane part 312 at the time of lighting is speedily conducted to a surrounding thin part 3122 and is radiated into the upper and lower heat dissipation space from the whole top and bottom surfaces of the horizontal plane part 312 and at the same time is conducted also to the respective face parts 321, 322, 331, 332 adjacent to and continuous with the horizontal plane part 312 and is radiated also from these parts. Hence, the heat sink can further enhance the heat dissipation efficiency and can be easily manufactured in the case where the heat sink is formed in such a shape.

[0277] A setting state in the case where the above-mentioned heat sink 301 for an LED light is applied to a headlight for an automobile will be described with reference to FIG. 18 to FIG. 21. FIG. 18 is a perspective view to show a state where the heat sink 301 is set in the headlight, FIG. 19 is a section view taken along a line a-a in FIG. 18, FIG. 20 is a section view taken along a line b-b in FIG. 18, and FIG. 21 is a section view taken along a line c-c in FIG. 18.

[0278] Here, the heat sink 301 is formed of the aluminum plate 302 and has a stepped (two-stepped) shape constructed of the vertical front part 321, the horizontal plane part 311, the vertical front part 322, and the horizontal plane part 312 in this order from the top and has the vertical side parts 331, 332 on both side ends of the horizontal plane part 311 and the vertical front part 322 and has the vertical side parts 333, 334 on both side ends of the horizontal plane part 312 and the vertical front part 322 and has the vertical side parts 333, 334 on both side ends of the horizontal plane part 312 and the

vertical front part 322. Further, the heat sink 301 has the vertical side parts 335, 336 extended (protruded) down on both side ends of the horizontal plane part 312 and has vertical side parts 337, 338 extended (protruded) back on both side ends of the vertical front part 321. Here, the vertical side parts 331, 332 are made by bending down extensions of the horizontal plane part 311 at a right angle and are flush with the side surfaces of a housing 340, the extensions being extended to both sides of the horizontal part 311, whereas the vertical side parts 333, 334 are made by bending forth extensions of the vertical front part 322 at a right angle and are arranged in the state where the parts are overlaid on the outside surfaces of the housing 340, the extensions being extended to both sides of the vertical front part 322. The vertical side parts 335, 336 are formed by bending down extensions of the horizontal plane part 312 at a right angle, the extensions being extended to both sides of the horizontal plane part 312. The vertical side parts 337, 338 are formed by bending back extensions of the vertical plane part 321 at a right angle, the extensions being extended to both sides of the vertical plane part 321.

[0279] A reference numeral 300 designates an LED element of a light emitting source and the LED elements 300 are mounted on the upper faces of the horizontal plane parts 311, 312. A reference numeral 350 designates reflectors (which is omitted in FIG. 18) set on the insides of the vertical front parts 321, 322, and a reference numeral 360 designates an outer lens.

[0280] The heat sink 301 is set in the housing 340 formed in the shape of a frame body, whose both sides have top ends formed nearly in the shape of an arc and have bottom ends formed in the stepped shape and whose front portion has a curved opening corresponding to the shape of the arc, in the state where the housing 340 is disposed on the heat sink 301 formed in the stepped shape. The vertical side parts 335, 336 and 337, 338 of the heat sink 301 integrated with the housing 340 are fixed and supported by a fixing part (not shown) of a vehicle body. In the curved opening of the housing 340 is fitted an outer lens 360 formed in the same shape as the curved opening and of transparent glass.

[0281] The respective outside surfaces of the vertical front part 321, the horizontal plane part 311, the vertical front part 322, and the horizontal plane part 312 of the heat sink 301 are opposed to the closed space S in a vehicle body and the inside surfaces and outside surfaces of the vertical side parts 331, 332 and 335, 336, and 337, 338 of the heat sink are also opposed to the closed space S.

[0282] In the case where the LED element 300 is made to emit light and to do illumination as the headlight of the automobile in this setting state, the heat generated when the LED element 300 emits light is dissipated by radiation to the surrounding closed space (heat dissipation space) S opposite to these parts from the outside surfaces of these face parts 311, 312, 321, and 322 constructing the stepped shape and from the inside surfaces and outside surfaces of the vertical side parts 331 to 338 on both side ends of these face parts. The heat is dissipated by the heat sink having a heat dissipating surface of a very large projected area in the three dimensional directions of the x, y, and z directions and having a high heat radiation efficiency and hence can be dissipated very effectively to a narrow space in which the convection of air is hardly caused.

[0283] In various exemplary embodiments, the heat sink for LED lighting according to the present invention includes: a base plate; a first heat-dissipating fin; and a second heat-

dissipating fin. In some such embodiments: the base plate, the first fin, and the second fin are formed integrally from aluminum or an aluminum alloy; the base plate comprises a first surface suitable for mounting an LED element and a second surface opposite from the first surface; the first fin comprises a first surface and a second surface opposite from the first surface; the first fin extends from the first surface or the second surface of the base plate; and the second fin extends from the first surface or the second surface of the first fin.

[0284] In further exemplary embodiments, the heat sink according to the present invention includes: a third heat-dissipating fin; a fourth heat-dissipating fin; and a fifth heat-dissipating fin. In some such embodiments: the first fin extends from the first surface of the base plate; the second fin extends from the second surface of the first fin; the third fin extends from the first surface of the base plate; the fourth fin extends from the first surface of the base plate; and the fifth fin extends from the second surface of the base plate.

[0285] In further exemplary embodiments, in the heat sink according to the present invention: the heat sink is formed by bending a blank of the aluminum or aluminum alloy; each of the first fin, the fourth fin, the fifth fin, and the sixth fin is formed by bending the blank such that the base plate joins each of the first fin, the fourth fin, the fifth fin, and the sixth fin at a location of a respective bend; each of the second fin and the third fin is formed by bending the blank such that the first fin joins each of the second fin and the third at a location of a respective bend; and each of the seventh fin and the eighth fin is formed by bending the blank such that the sixth fin joins each of the seventh fin and the eighth fin at a location of a respective bend.

Fourth Embodiment

[0286] FIG. 22 shows a heat sink 401 for LED lighting of a fourth embodiment. The heat sink 401 for LED lighting is a heat sink for LED lighting formed of an aluminum extrusion material and is constructed of: a base plate part 402 having an LED light source 400 arranged and fixed on a front side thereof; and a plurality of fin parts 403 arranged on the back side of the base plate part 402 in such a way as to protrude in parallel to each other and separately from each other. The heat sink 401 is characterized in that: of the respective fin parts 403, at least one fin part 403 has a portion thereof bent at a right angle from a fin main body 403a, whereby the portion is made the fin bent piece 403b; and the fin bent piece 403b has a heat dissipating surface in a direction which is perpendicular to a heat dissipating surface of the fin main body 403a and to a heat dissipating surface of the base plate part 402. Of these parts, the base plate part 402 constructs a mounting face part of the present invention and the fin part 403 and the fin main body 403a construct a first fin part of the present invention and the fin bent piece 403b constructs a second fin part of the present invention.

[0287] Specifically, the heat sink 401 for LED lighting of the fourth embodiment (hereinafter simply referred to as the heat sink 401 in some cases) is manufactured by applying a comparatively simple working such as cutting and bending to an aluminum extrusion material made by extruding an aluminum material which is excellent in thermal conductivity and formability, such as pure aluminum of JIS 1000 series and an aluminum alloy of JIS 6000 series. Further, the heat sink 401 may be manufactured by the use of other aluminum alloy material such as an aluminum alloy material of JIS 5000 series. A manufacturing method will be described later.

[0288] As shown in FIG. 22, the heat sink 401 of the fourth embodiment is constructed of: for example, the base plate part 402 having the LED light source 400 arranged and fixed on the front side thereof (shown on the lower side in FIG. 22); and the plurality of fin parts 403 arranged on the back side of the base plate part 402 in such a way as to protrude in parallel to each other and separately from each other. Of these fin parts 403, at least one fin part 403 has a portion thereof bent at a right angle from the fin main body 403a, whereby the portion is made the fin bent piece 403b. Here, the LED light source 400 is formed by mounting a plurality of light emitting diode (LED) elements on a substrate based on an aluminum alloy.

[0289] The fin bent piece 403b has the heat dissipating surface in the direction which is perpendicular to the heat dissipating surface of the fin main body 403a and to the heat dissipating surface of the base plate part 402. That is, the heat dissipating surface of the base plate part 402, the heat dissipating surface of the fin main body 403a, and the heat dissipating surface of the fin bent piece 403b are directed in different directions (y-axis direction, x-axis direction, z-axis direction) which are perpendicular to each other.

[0290] A plan view, a front view, and a side view of the heat sink 401 of the fourth embodiment will be shown in FIG. 23, whereas a plan view, a front view, and a side view of a conventional heat sink 4 will be shown in FIG. 49. It can be understood that in the heat sink 401 shown in FIG. 23, a sufficient projected area can be ensured in the plan view, the front view, and the side view, but it is clear that in the heat sink 4 shown in FIG. 49, a sufficient projected area cannot be ensured only in the front view.

[0291] In the fourth embodiment shown in FIG. 22, four fin parts 403 are formed in parallel to each other on the back side of the base plate part 402 in such a way as to protrude separately from each other, and of these four fin parts 403, two fin parts 403 on both sides have both end portions thereof bent at a right angle from the fin main body 403a toward both side edges of the base plate part 402, respectively, whereby the both end portions are made the fin bent pieces 403b.

[0292] The number and shape of these fin parts 403 do not need to be the same as those of the embodiment shown in FIG. 22. It is only necessary that the number of the fin parts 403 is plural, that is, at least two or more, and in the case where the number of the fin parts 403 is three or more, the fin parts 403 having the fin bent piece 403b formed thereon do not need to be two fin parts 402 on both sides. For example, as shown in FIG. 24(c), the fin bent piece 403b can be formed on the fin part 403 at the center. In FIG. 24 will be shown modified examples of the heat sink 401, the modified examples being formed in various shapes.

[0293] Next, a method for manufacturing the heat sink 401 for LED lighting of the fourth embodiment will be simply described. As described above, the heat sink 401 for LED lighting according to the present invention is manufactured from the aluminum extrusion material formed by extruding a metal material, which is excellent in thermal conductivity and formability, such as pure aluminum of JIS 1000 series and aluminum alloy of JIS 6000 series.

[0294] For example, in the case where the heat sink 401 shown in FIG. 22 is manufactured, first, an aluminum extrusion material (of the same shape as a conventional heat sink for LED lighting shown in FIG. 47) produced by the use of an extrusion process is prepared, and slits of a given depth are made in lower ends of both sides (portions in contact with the base plate part 402) of the fin parts 403 on both sides of the

aluminum extrusion material, in other words, slits each having a given depth are made at a total of four lower edges of the fin parts 403 on both sides from both side ends. Next, the portions having the slits made therein of the fin parts 403 are bent at a right angle in both side-edge directions (outward directions) of the base plate part 402, whereby the fin bent parts 403b are formed. Here, a middle portion, which does not have a slit made in lower edge thereof and is not bent, of the fin part 403 becomes the fin main body 403a.

[0295] The heat sink 401 for LED lighting described above is used as the heat sink 401 for vehicle-mounted lighting such as a headlight of an automobile or an embedded lighting of a building. In FIG. 25 and FIG. 26 will be shown a usage state in which the heat sink 401 for LED lighting of the fourth embodiment is used as a heat sink for LED lighting of a headlight of an automobile. The heat sink 401, as shown in FIG. 25 and FIG. 26, is mounted in the state where the base plate part 402 constructs a back part of a housing 410 of a case for LED lighting, that is, a part of the housing 410. In the case where the heat sink 401 is mounted in the state where the heat sink 401 is set in the housing 410, the fin parts 403 are protruded into a closed space which is located on the back side of the LED lighting and in which the convection of air is not caused. Here, a reference numeral 420 designates an outer lens fixed to a front of the LED lighting and having transparency.

[0296] In this way, in the case the heat sink 401 for LED lighting of the fourth embodiment is used as the heat sink for LED lighting in a state where the fin parts 403 of the heat sink 401 is protruded into the closed space, the heat generated when the LED light source emits light is dissipated from the heat sink 401 into the closed space in which the convection of air is not caused. The heat sink 401 for LED lighting according to the present invention, as shown in the plan view, the front view, and the side view of FIG. 23, can ensure sufficient projected areas in all directions of the x-axis direction, the y-axis direction, and the z-axis direction, so that the heat can be efficiently dissipated even in this closed space.

[0297] In various exemplary embodiments, the heat sink for LED lighting according to the present invention includes: a base plate; a first heat-dissipating fin; a second heat-dissipating fin; and a third heat-dissipating fin. In some such embodiments: the base plate, the first fin, the second fin, and the third fin are formed integrally from aluminum or an aluminum alloy; the base plate comprises a first surface suitable for mounting an LED element and a second surface opposite from the first surface; the first fin extends from the second surface of the base plate; the second fin comprises a first surface and a second surface opposite from the first surface; the second fin extends from the second surface of the base plate; and the third fin extends from the first surface or the second surface of the second fin.

[0298] In further exemplary embodiments, the heat sink according to the present invention includes: a fourth heat-dissipating fin; a fifth heat-dissipating fin; a sixth heat-dissipating fin; a seventh heat-dissipating fin; and an eighth heat-dissipating fin. In some such embodiments: the third fin extends from the first surface of the second fin; the fourth fin extends from the first surface of the second fin; the fifth fin extends from the second surface of the base plate; the sixth fin comprises a first surface and a second surface opposite from the first surface; the sixth fin extends from the second surface

of the base plate; the seventh fin extends from the first surface of the sixth fin; and the eighth fin extends from the first surface of the sixth fin.

[0299] In further exemplary embodiments, the heat sink according to the present invention includes: a fourth heat-dissipating fin; a fifth heat-dissipating fin; and a sixth heat-dissipating fin. In some such embodiments: the fourth fin extends from the second surface of the base plate; the fifth fin comprises a first surface and a second surface opposite from the first surface; and the sixth fin extends from the first surface or the second surface of the fifth fin.

[0300] In further exemplary embodiments, the heat sink according to the present invention includes: a fourth heat-dissipating fin; a fifth heat-dissipating fin; a sixth heat-dissipating fin; a seventh heat-dissipating fin; and an eighth heat-dissipating fin. In some such embodiments: the third fin extends from the first surface of the second fin; the fourth fin extends from the second surface of the second fin; the fifth fin extends from the second surface of the base plate; the sixth fin comprises a first surface and a second surface opposite from the first surface; the sixth fin extends from the second surface of the base plate; the seventh fin extends from the first surface of the sixth fin; and the eighth fin extends from the second surface of the sixth fin.

[0301] In further exemplary embodiments, the heat sink according to the present invention includes: a fourth heat-dissipating fin; and a fifth heat-dissipating fin. In some such embodiments: the third fin extends from the first surface of the second fin; the fourth fin extends from the second surface of the second fin; and the fifth fin extends from the second surface of the base plate.

Fifth Embodiment

[0302] FIG. 27 shows a heat sink 501 for LED lighting of a fifth embodiment. The heat sink 501 for LED lighting is a heat sink 501 for LED lighting formed of an aluminum extrusion material and is constructed of: a base plate part 502 having an LED light source 500 arranged and fixed on a front side thereof; and a plurality of fin parts 503 arranged in parallel to each other on the back side of the base plate part 502 in such a way as to protrude separately from each other. The heat sink 501 for LED lighting of the fifth embodiment is characterized in that the base plate part 502 is bent in a direction perpendicular to the longitudinal direction of the fin part 503, that is, is formed in the shape of a letter L. Of these parts, the base plate part 502 constructs a mounting face part of the present invention, and a side 503a extending in one direction of the fin part 503 construct a first fin part of the present invention, and a side 503b extending in other direction of the fin part 503 constructs a second fin part of the present invention.

[0303] Specifically, the heat sink 501 for LED lighting of the fifth embodiment (hereinafter simply referred to as the heat sink 501 in some cases) is manufactured by applying a comparatively simple working such as cutting and bending to an aluminum extrusion material made by extruding an aluminum material, which is excellent in thermal conductivity and formability, such as pure aluminum of JIS 1000 series and aluminum alloy of JIS 6000 series. Further, the heat sink 501 for LED lighting may be manufactured by the use of other aluminum alloy material such as aluminum alloy material of JIS 5000 series.

[0304] As shown in FIG. 27, the heat sink 501 of the fifth embodiment is constructed of: the base plate part 502 having the LED light source 500 arranged and fixed on the front side

thereof (face on a right concave corner part in FIG. 27); and the plurality of fin parts 503 arranged in parallel to each other on the back side of the base plate part 502 in such a way as to protrude separately from each other.

[0305] The base plate part 502 is a plate so-called shaped like a letter L, the plate being bent in a direction perpendicular to the longitudinal direction of the fin parts 503 arranged in parallel to each other. As the base plate part 502 is bent in this manner, there is formed the fin part 503 having a first fin part 503a, which extends in a direction perpendicular to the base plate part 502, and a second fin part 503b, which extends in the direction perpendicular to the base plate part 502 and in a direction intersecting the first fin part 503a. In the present embodiment, the fin part 503 is bent outside along with the base plate part 502 and hence a bent part of the fin part 503 is pulled and extended, which hence is likely to have an effect on the bending of the base plate part 502. Hence, the dimension of protrusion of the fin part 503 needs to be short not to interfere with the bending of the base plate part 502.

[0306] Here, the LED light source 500 is made, for example, by mounting a plurality of light emitting diode (LED) elements on a substrate based on an aluminum alloy.

[0307] FIG. 28 shows a first modified example of the heat sink 501 of the fifth embodiment. This heat sink 501, like the heat sink 501 shown in FIG. 27, is also constructed of: the base plate part 502 having the LED light source 500 arranged and fixed on the front side thereof (face on a right convex corner part in FIG. 28); and the plurality of fin parts 503 arranged in parallel to each other on the back side of the base plate part 502 in such a way as to protrude separately from each other.

[0308] The base plate part 502 is a plate so-called shaped like a letter L, the plate being bent in a direction perpendicular to the longitudinal direction of the fin parts 503 arranged in parallel to each other. In the present embodiment, the fin parts 503 are bent to the inside along with the base plate part 502 and hence the bent parts of the fin parts 503 are compressed, which hence is likely to have an effect on the bending of the base plate part 502. Hence, the fin parts 503 need to be short in the dimension of protrusion not to interfere with the bending of the base plate part 502.

[0309] FIG. 29 shows a second modified example of the heat sink 501 of the fifth embodiment. This heat sink 501, like the heat sink 501 shown in FIG. 27, is also constructed of: the base plate part 502 having the LED light source 500 arranged and fixed on the front side thereof (face on a right concave corner part in FIG. 29); and the plurality of fin parts 503 arranged in parallel to each other on the back side of the base plate part 502 in such a way as to protrude separately from each other.

[0310] The base plate part 502 is a plate so-called shaped like a letter L, the plate being bent in a direction perpendicular to the longitudinal direction of the fin parts 503 arranged in parallel to each other. In the present embodiment, the fin parts 503 are bent to the outside along with the base plate part 502 and, if the fin parts 503 are bent as they are, the fin parts 503 have an effect on the bending of the base plate part 502, so that before bending the base plate part 502, a linear slit 504 reaching the outside surface of the base plate part 502 is formed in a portion to be bent of each fin part 503. Since the base plate part 502 is bent after the slit is formed in each fin part 503 in this manner, as is the case with the embodiment shown in FIG. 27, the fin part 503 does not need to be especially short in the dimension of protrusion and hence heat can be dissipated

from the LED lighting more efficiently than in the embodiment shown in FIG. 27. Further, each of the fin parts 503 is divided into one first fin part 503a and the other second fin part 503b by the slit 504.

[0311] FIG. 30 shows a third modified example of the heat sink 501 of the fifth embodiment. This heat sink 501, like the heat sink 501 shown in FIG. 28, is also constructed of the base plate part 502 having the LED light source 500 arranged and fixed on the front side (face on a left convex corner side in FIG. 30) and the plurality of fin parts 503 arranged in parallel to each other on the back side of the base plate part 502 in such a way as to protrude separately from each other.

[0312] The base plate part 502 is a plate so-called shaped like a letter L, the plate being bent in a direction perpendicular to the longitudinal direction of the fin parts 503 arranged in parallel to each other. In the present embodiment, the fin parts 503 are bent to the inside along with the base plate part 502 and, if the fin parts 503 are bent as they are, the fin parts 503 have an effect on the bending of the base plate part 502, so that before bending the base plate part 502, a slit 505 is formed in a portion to be bent of each of the fin parts 503, the slit 505 reaching the outside surface of the base plate part 502 and being shaped like a letter V of an angle of 90 degrees or more. Since the slit 505 shaped like a letter V is formed in each of the fin parts 503 in this manner and then the base plate part 502 is bent, the fin parts 503 do not need to be especially short in the dimension of protrusion as is the case with the embodiment shown in FIG. 28, so that the heat can be dissipated more efficiently from the LED lighting than in the embodiment shown in FIG. 28. Further, each of the fin parts 503 is divided into one first part 503a and the other second fin part 503b by the slit 505.

[0313] The heat sink 501 for LED lighting is used as a heat sink 501 for vehicle-mounted lighting such as the headlight of an automobile and the embedded lighting of a building. FIG. 31 and FIG. 32 show a usage state in which the heat sink 501 of the embodiment shown in FIG. 29 is used as the heat sink 501 for LED lighting of the headlight of an automobile, respectively, whereas FIG. 33 and FIG. 34 show a usage state in which the heat sink 501 of the embodiment shown in FIG. 30 is used as the heat sink 501 for LED lighting of the headlight of an automobile, respectively.

[0314] In this regard, the heat sink 501 shown in FIG. 27 is the same in the usage state as the heat sink 501 shown in FIG. 29, whereas the heat sink 501 shown in FIG. 28 is the same in the usage state as the heat sink 501 shown in FIG. 30, so that their descriptions will be omitted.

[0315] The heat sink 501 shown in FIG. 29, as shown in FIG. 31 and FIG. 32, is fixed to a concave corner of the LED lighting in a state where the base plate 502 shaped like a letter L constructs a portion of the housing 510 of the case of the LED lighting. In this way, when the heat sink 501 having the base plate part 502 shaped like a letter L shown in FIG. 29 is used (ditto for the case where the heat sink 501 shown in FIG. 27 is used), the heat sink 501 can be set even in a narrow limited space in which a conventional plate-shaped base plate part 2 shown in FIG. 47 cannot be set.

[0316] Here, a reference numeral 520 designates an outer lens fixed to the front of the LED lighting and having transparency, whereas a reference numeral 530 designates a reflector for making light emitted from the LED light source 500 reflect to the outer lens 520.

[0317] The heat sink 501 shown in FIG. 30, as shown in FIG. 33 and FIG. 34, is fixed in a state where one part of the

base plate part 502 shaped like a letter L constructs a part of the housing 510 of the case of the LED lighting. In this way, when the heat sink 501 having the base plate part 502 shaped like a letter L shown in FIG. 30 is used (ditto for the case where the heat sink 501 shown in FIG. 28 is used), the heat sink 501 can be set even in a narrow limited space in which the conventional plate-shaped base plate part 2 shown in FIG. 47 cannot be set.

[0318] When the heat sink 501 is fixed in a state where one part of the base plate part 502 constructs a part of the housing 510 of the LED lighting, there is brought about a state in which the other part of the base plate part 502 is protruded to the outside from the LED lighting (in the case of the automobile, inner space in a bonnet) as is the case with the fin parts 503. However, sufficient heat dissipating area can be ensured by the surface area of the base plate part 502 shaped like a letter L and by the surface area of the fin parts 503, so that a sufficient amount of heat can be dissipated.

[0319] Here, although a usage state is not shown especially, the heat sinks 501 shown in FIG. 28 and FIG. 30 can be fixed even in a convex indented corner which is limited in space.

[0320] In various exemplary embodiments, the heat sink for LED lighting according to the present invention includes: a bent planar base plate; a first heat-dissipating fin; and a second heat-dissipating fin. In some such embodiments: the base plate, the first fin, and the second fin are formed integrally from aluminum or an aluminum alloy; the base plate comprises an inner surface and an outer surface opposite from the inner surface; the first fin extends from the inner surface or the outer surface of the base plate; and the second fin extends from the same surface of the base plate as the first fin.

[0321] In further exemplary embodiments, in the heat sink according to the present invention: the inner surface of the base plate is suitable for mounting an LED element; the first fin and the second fin extend from the outer surface; the base plate comprises a first planar region and a second planar region that are joined by a bent region; the first fin extends from the outer surface of the base plate in the first planar region, the second planar region, and the bent region; and the second fin extends from the outer surface of the base plate in the first planar region, the second planar region, and the bent region.

[0322] In further exemplary embodiments, in the heat sink according to the present invention: the outer surface of the base plate is suitable for mounting an LED element; the first fin and the second fin extend from the inner surface; the base plate comprises a first planar region and a second planar region that are joined by a bent region; the first fin extends from the inner surface of the base plate in the first planar region, the second planar region, and the bent region; and the second fin extends from the inner surface of the base plate in the first planar region, the second planar region, and the bent region.

[0323] In further exemplary embodiments, the heat sink according to the present invention includes: a third heat-dissipating fin; and a fourth heat-dissipating fin. In some such embodiments, the inner surface of the base plate is suitable for mounting an LED element; the first fin, the second fin, the third fin, and the fourth fin extend from the outer surface; the base plate comprises a first planar region and a second planar region that are joined by a bent region; the first fin and the second fin extend from the outer surface of the base plate in

the first planar region; and the second fin and the fourth fin extend from the outer surface of the base plate in the second planar region.

[0324] In further exemplary embodiments, the heat sink according to the present invention includes: a third heat-dissipating fin; and a fourth heat-dissipating fin. In some such embodiments: the outer surface of the base plate is suitable for mounting an LED element; the first fin, the second fin, the third fin, and the fourth fin extend from the inner surface; the base plate comprises a first planar region and a second planar region that are joined by a bent region; the first fin and the second fin extend from the inner surface of the base plate in the first planar region; and the second fin and the fourth fin extend from the inner surface of the base plate in the second planar region.

Sixth Embodiment

[0325] FIG. 35 shows a heat sink 601 for LED lighting of a sixth embodiment. The heat sink 601 for LED lighting is firstly characterized in that an aluminum alloy thin plate is formed in the heat dissipating fin shape of continuous wavy shapes 602, 603 by corrugating. Further, the heat sink 601 is secondly characterized in that the aluminum alloy thin plate previously has a pre-coating applied to the surface thereof before it is corrugated, the pre-coating having an emissivity ϵ of 0.7 or more. Still further, the heat sink 601 is thirdly characterized in that the wavy shapes 602, 603 have stepped parts 604 to 607 which are formed by crushing parts of the wavy shapes 602, 603. Of these parts, the stepped parts 604 to 607 construct a mounting face part of the present invention and the wavy shapes 602, 603 construct the first and the second fin parts of the present invention.

[0326] FIG. 35 is a perspective view showing the heat sink 601 of the sixth embodiment and FIG. 36 is a plan view of FIG. 35. Further, FIG. 37 is a perspective view showing a heat sink 601 of a first modified example of the sixth embodiment and FIG. 38 is a plan view of FIG. 37.

[0327] These FIG. 35 to FIG. 38 show the heat sink 601 manufactured by forming a heat dissipating fin shape in which wavy shapes 602, 603 are continuously formed by corrugating an aluminum alloy thin plate 601a of a raw material having a pre-coating film 610 applied previously to the surface thereof by pre-coating a black paint. Here, corrugating, as anyone knows, means forming a flat plate or a smooth pipe into a wavy shape. The pre-coating film 610 of the black paint is a very thin surface coating and hence is designated only by a number of 610. The aluminum alloy thin plate 601a has the pre-coating film 610 applied to the whole surface (both surfaces) or a necessary portion of surface (including one surface).

[0328] In the heat sink 601 shown in FIG. 35 to FIG. 38, the wavy shapes 602, 603 are continuous with one after the other. However, in the wavy shapes 602, 603 shown in FIG. 37 and FIG. 41, the heat sink 601 has a step formed in a center portion in the longitudinal direction (in the left and right direction in the drawing) of the heat sink 601, and the left and right wavy shapes are different from each other in the level of the wavy shape with a boundary at the center portion. By forming the step like this in accordance with the design of space or the condition of space of the heat sink 601 in the vehicle-mounted LED lamp, the whole shape of the continuous wavy shapes 602, 603 can be formed by corrugating not only in a uniform shape such as a rectangle shown in FIG. 35 and FIG. 36 but in an irregular shape shown in FIG. 37 and FIG. 41.

[0329] Wavy Shape of Heat Dissipating Fin:

[0330] In FIG. 35 to FIG. 38, the heat dissipating fins=wavy shapes 602, 603 having the same width and the same height are continuously repeated at the same pitches one after the other. Here, the wavy shapes 602, 603 are convex parts and concave parts which are continuous with each other and which are different from each other by 180 degrees in the direction of a convex part and a concave part, to be more precise, elements or units of the wavy shapes continuous with each other, and are simply referred to as wavy shapes 602, 603 in the present specification.

[0331] Here, a width a of the wavy shape 602, a width b of the wavy shape 603, a pitch p of the wavy shapes 602, 602 or the wavy shapes 603, 603, a width w and a height h of the wavy shapes 602, 603 (heat sink 601), and a length l of the continuous wavy shapes 602, 603 (heat sink 601) are designed so as to be tailored to the specifications of the vehicle-mounted LED lamp to which the heat sink 601 is set and to satisfy the required heat dissipation characteristics of the heat sink 601.

[0332] When usage ranges of them are described by an example from the specifications of the LED lamp mounted in an ordinary passenger car, the width a of the wavy shape 602 and the width b of the wavy shape 603 are 1 to 20 mm, the pitch p of the wavy shapes 602, 602 or the wavy shapes 603, 603 is 4 to 40 mm, the width w and the height h of the wavy shapes 602, 603 (heat sink 601) are 50 to 250 mm and 10 to 60 mm, respectively, and the length l of the continuous wavy shapes 602, 603 (heat sink 601) is 30 to 250 mm. Further, limit values in the design of these wavy shapes 602, 603 are specified also from the forming limit of the wavy shape when the aluminum alloy thin plate 601a of the raw material is corrugated. That is, in the case where the design values of these wavy shapes 602, 603 are too small or too large, it is impossible to corrugate the aluminum alloy thin plate.

[0333] Pre-Coating:

[0334] In FIG. 35 to FIG. 38, the aluminum alloy thin plate 601a of the raw material has a pre-coating (pre-coating film) 610 applied to the whole surface thereof, the pre-coating being performed by a black paint having an emissivity ϵ of 0.7 or more and a large amount of heat dissipation. This pre-coating 610 can increase the amount of heat transfer or the amount of heat dissipation by radiation as the heat dissipating fins=wavy shapes 602, 603 (heat sink 601).

[0335] Further, the pre-coating serves as a lubricant agent at the time of corrugating the aluminum alloy thin plate 601a of the raw material and hence has an effect on improving the formability of the heat dissipating fins=wavy shapes 602, 603. Hence, in the present invention, before corrugating the aluminum alloy thin plate 601a, the pre-coating of the black paint is previously applied to the aluminum alloy thin plate 601a.

[0336] The emissivity ϵ of the pre-coating (pre-coated film) 610 applied to the surface of the aluminum alloy thin plate 601a of the raw material is made 0.7 or more so as to increase the thermal emissivity of the heat dissipating fins=wavy shapes 602, 603. In the case where the emissivity is less than 0.7, the aluminum alloy thin plate 601a of the raw material having the pre-coating applied thereto has the effect of lubrication but is reduced in the amount of heat transfer or the amount of heat dissipation by radiation and is not much different from a bare aluminum alloy thin plate 601a not having any coating applied thereto.

[0337] This emissivity ϵ is the rate of heat radiation of an actual body to a theoretical value (heat radiation of a black body of an ideal thermal radiator) and the emissivity ϵ may be actually measured by a method described in Japanese Patent Application Laid-open No. 2002-234460 or by the use of a portable emissivity measurement device developed by Japan Aerospace Exploration Agency. The method described in the Japanese Patent Publication will be described below. The emissivity ϵ is measured by the use of an emissivity measurement device shown in FIG. 46. In FIG. 46, an emissivity measurement device 620 is basically constructed of: an electric heater 621 whose bottom surface is covered with a black paint layer 620, a cooling bed 624 arranged at a given distance below the electric heater 621, and a heat insulating layer 623 for surrounding the electric heater 621 and the cooling bed 624. A heat sink 601 is placed on the cooling bed 624 with an outer surface of a wavy shape 602 on the top, and the temperature and the amount of temperature increase (amount of heat transfer $Q1$) of the heat sink 601 to a given amount of heat Q radiated from the electric heater 621 are measured from electric power applied to the electric heater 621 or the amount of temperature increase (amount of cooling water and increase in temperature) of cooling water 625 in the cooling bed 624. Then, an emissivity ϵ , specified by the present invention, of the outer surface of the wavy shape 602 of the heat sink 601 is calculated from the following mathematical equation 1.

[Mathematical equation 1]

$$Q1 = \alpha(T_1^4 - T_2^4) / (1/\epsilon_1 + 1/\epsilon_2 - 1) \quad \text{Equation 1}$$

where $Q1$ =amount of heat transfer of an Al alloy heat sink 601, α =Stefan-Boltzmann constant $5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$, T_1 =temperature of black paint layer 622, T_2 =temperature of heat sink 601, ϵ_1 =emissivity of black paint layer 622=0.9, and ϵ_2 =emissivity of outer surface of wavy shape 602 of heat sink 601.

[0338] Forming of Stepped Part:

[0339] In the present invention, as a preferable mode, by crushing the portions of the heat dissipating fins=the wavy shapes 602, 603, stepped parts (steps, depressions and projections) are formed in the wavy shapes 602, 603. The stepped parts become component fixing parts and element fixing parts (mounting face parts) when the heat sink 601 is mounted as a heat sink for a vehicle-mounted LED lamp. Further, these stepped parts provide depressed and projected shapes for increasing rigidity as the heat sink against an external force (bending moment) around an axis vertical to the surface of paper, for example, as shown by arrows on the left and right sides of the heat sink 601 shown in FIG. 36.

[0340] A heat sink 601 of a second modified example of the sixth embodiment shown in FIG. 39 is the same in the basic shape in which the wavy shapes 602, 603 are alternately continuous with each other as the heat sink 601 shown in FIG. 35 and FIG. 36. However, in the heat sink 601 of the second modified example, of the wavy shapes 602, 603, a wavy shape 602a, a wavy shape 603a adjacent to the wavy shapes 602a, and a wavy shape 602b separated by several pitches from the wavy shape 602a are respectively formed in larger widths $a1$, $b1$, and $a2$ than the widths a , b of the other standard wavy shapes 602, 603. In addition, the wavy shapes 602a, 602b, and 603a are crushed in portions, thereby having the stepped parts (depressed parts) 604a, 604b formed therein. Components and elements 600a, 600b as the heat sink for vehicle-mounted LED lamp are fixed on the stepped parts 604a, 604b. The wide

wavy shape and stepped part or the width are appropriately selected according to the number, the dimension, the shape, the position of the necessary components and elements 600a, 600b to be mounted, or the degree of reinforcement such as rigidity. Here, specifically, the components and the elements 600a, 600b are an LED board for supplying an LED element with electric power and an LED element mounted on the LED board. In this regard, in this modified example, the stepped parts 604a, 604b construct a mounting face part of the present invention and the wavy shapes 602a, 602b having larger widths $a1$, $a2$ construct a first fin part of the present invention and a part connecting the wavy shapes 602a, 603a constructs a second fin part of the present invention.

[0341] These stepped parts, including stepped parts to be described later, can be formed by crushing portions, in which these stepped parts in the wavy shapes are to be formed, by the use of a die without using other off-line process after forming the wavy shapes 602, 603 by corrugating, but these stepped parts can be formed by a forming process accompanying the corrugating process in a series of corrugating processes.

[0342] The other modes of a reinforcing example like this will be shown in FIG. 40 to FIG. 43 in which the heat sink is placed laterally. In this regard, the heat sink 601 shown in these drawings are the same in the basic shape, in which the wavy shapes 602, 603 are alternately continuous with each other, as the heat sink shown in FIG. 35 and FIG. 36.

[0343] In a third modified example of the sixth embodiment shown in FIG. 40, of the wavy shapes 602, 603, each wavy shape 603 has a protruded part like a stepped part 605b formed at a height (level) equal to a face of the wavy shape 602 at a middle position (center position in this case). That is, the heat sink 601 including the wavy shapes 602, 603 has the stepped parts 605b formed continuously in the lateral direction of the wavy shape, thereby being reinforced and enhanced in the rigidity. The position, the number, and the height of the stepped part 605b can be selected as required. The stepped part 605b is formed by partially pressing up a portion, in which the stepped part 605b in the wavy shape 603 is to be formed, in the direction of the wavy part 602 after forming the wavy shapes 602, 603 by corrugating.

[0344] In a fourth modified example of the sixth embodiment shown in FIG. 41, protruded parts like stepped parts 605c are formed at middle positions (center positions in this case) of the respective wavy shapes 603 and depressed parts like stepped parts 604c are formed at middle positions (center positions in this case) of the respective wavy shapes 602 are formed in such a way that the stepped parts 605c and 604c are continuous with each other. In this way, the heat sink 601 is reinforced. In this regard, the protruded parts of the stepped parts 605c and the depressed parts of the stepped parts 604c are formed at the same height (level) and continuously with each other in the lateral direction of the wavy shape to thereby reinforce the heat sink 601. The position, the number, and the height of the stepped parts 605c and the stepped parts 604c are selected as required. These stepped parts 605c, 604c are formed by partially pressing up portions, in which the stepped parts 605c in the wavy shapes 603 are to be formed, in the direction of the wavy shape 602 and by partially crushing (pressing down) portions, in which the stepped parts 604c in the wavy shapes 602 are to be formed, in the direction of the wavy shape 603 after forming the wavy shapes 602, 603 by corrugating.

[0345] In a fifth modified example of the sixth embodiment shown in FIG. 42(a), flat flanges like the stepped parts 606a,

606b, **606c**, and **606d** are formed at the peripheral edge portions (four sides) of the wavy shapes **602**, **603** (heat sink **601**). These stepped parts are formed by crushing (pressing down) the wavy shapes **602** and crushing (pressing up) the wavy shapes **603** at the peripheral edge portions (four sides) as shown in FIG. **42(b)**, which is a section view taken on a line X-X' in FIG. **42**, after forming the wavy shapes **602**, **603** by corrugating. It is because the heat sink **601** is easily fixed in the housing that these ribs or flanges are formed.

[0346] In a sixth modified example of the sixth embodiment shown in FIG. **43**, there is formed a depressed part like a stepped part **607** in which the wavy shape **602** is cut out at a middle position (center position in this case). At this time, the top (upper side) of the wavy shape **602** is not cut away but is left as a square cut piece **608a** and the cut piece **608a** is bent at a right angle as shown by **608b**. It is because the element **600** and the necessary components are fixed without using the stepped parts that these cut pieces **608a**, **608b** are formed.

[0347] FIGS. **44(a)**, **44(b)**, and **44(c)** are seventh modified examples of the sixth embodiment and show examples in which a reinforcing bracket **630** is attached to the bottom faces of the wavy shapes **602**, **603** (heat sink **601**). FIG. **44(a)** shows an example in which an integral bracket **630** is attached to the whole bottom faces of the wavy shapes **602**, **603** (heat sink **601**) and FIG. **44(b)** shows an example in which two divided brackets **630** are attached to the bottom faces of the wavy shapes **602**, **603** (heat sink **601**), respectively. FIG. **44(c)** shows a case in which brackets **630** each having a section nearly shaped like a letter C are fixed to both ends of the wavy shapes **602**, **603** (heat sink **601**), the bracket **630** having a flange part **631** used for fixing the other component. Here, in FIGS. **44(a)**, **44(b)**, and **44(c)**, an aluminum alloy or a resin material can be used as the material of the brackets **630**, **631**.

[0348] Fixing Heat Sink in Vehicle-Mounted LED Lamp:

[0349] FIGS. **45(a)** and **45(b)** show a mode of fixing a heat sink in a vehicle-mounted LED lamp. FIG. **45(a)** shows a longitudinal section of an LED lamp, and FIG. **45(b)** is a view when a section taken on a line Y-Y' in FIG. **45(a)** is viewed from the top. In FIGS. **45(a)** and **45(b)**, a vehicle-mounted LED lamp (vehicular lamp) **650** includes: an LED substrate **651** mounted with an LED **651a** as a light source; a reflector **652** for reflecting light from the LED **651a** forward in the direction in which the light is emitted; a housing **653** for wrapping the LED substrate **651** and the reflector **652**; an outer lens **654** that closes an open front end of the housing **653** and that is made of a transparent material; and a heat sink **601** arranged in thermal contact with the LED substrate **651**.

[0350] Here, the heat sink **601** having the continuous wavy shapes **602**, **603** formed as heat dissipating fins has stepped parts **607a**, **607b**. Further, the stepped part **607a** has the bottom face of the LED substrate **651** thermally connected to the top face thereof via a sheet-shaped heat conducting member **655a**. Still further, the stepped part **607b** has the top face of the reflector **652** connected to the bottom face thereof.

[0351] On the other hand, the LED substrate **651** is arranged in the center portion of the stepped part **607** of the heat sink **601** and has the LED **651a** mounted on the top thereof. The reflector **652** is formed of a resin material and has a parabolic reflecting surface having a focal point near the LED **651a** on the LED substrate **651**.

[0352] The housing **653** is opened on the front side (side in which the outer lens **654** is mounted). Further, the housing **653** has an opening **653a** on the back side (on the right side in

the drawing) and has the heat sink **601** fixed thereto in such a way that the heat sink **601** closes the opening **653a** on the back side.

[0353] According to the vehicle-mounted LED lamp **650** of this construction, the LED **651a** on the LED substrate **651** is driven to emit light and the light emitted from the LED **651a** is reflected by the reflector **652** and is radiated forward in the direction in which the light is radiated via the outer lens **654**. Here, heat generated from the LED **651a** is transferred to the heat sink **601** via heat conducting material **655a** from the LED substrate **651** and is dissipated to the outside of the housing **653** from the heat sink **601**. In this way, an increase in the temperature of the LED **651a** can be suppressed.

[0354] Aluminum Alloy as Raw Material:

[0355] An aluminum alloy plate as a raw material used for the heat sink of the present invention is a thin plate having a thickness from 2 mm to 0.4 mm, and it is most important that the aluminum alloy plate can be formed into the shape of the heat sink **601** and is excellent in corrugating workability. In addition, in terms of the required characteristics of the heat sink such that heat sink needs to be excellent in heat transfer and corrosion resistance, pure aluminum of 1000 series is preferably selected which has as little amount of alloy element as possible and which is specified or included by the AA standard or the JIS standards. In this regard, in the present invention, an aluminum plate made of pure aluminum is also expressed by an aluminum alloy plate. However, in terms of strength to ensure the rigidity, an aluminum alloy material selected from the 3000 series specified or included by the AA standard or the JIS standards is selected as required. These aluminum alloy plates are manufactured in normal manufacturing processes including casting (DC casting and continuous casting), homogenized heat treatment, hot rolling, process annealing, cold rolling, and thermal refining such as solution heat treatment and quenching heat treatment.

[0356] According to the present invention, a heat sink manufactured at high productivity can be provided by using an aluminum alloy plate as a raw material and by corrugating the aluminum alloy plate into the whole shape of heat dissipating fins formed in a continuous wavy shape. For this reason, the heat sink manufactured by the present invention is most suitable for a heat sink for a vehicle-mounted LED lamp.

[0357] In various exemplary embodiments, the heat sink for LED lighting according to the present invention includes a corrugated sheet of aluminum or an aluminum alloy. In some such embodiments, at least one ridge of the corrugated sheet comprises a depression comprising a surface suitable for mounting an LED element.

[0358] In further exemplary embodiments, in the heat sink according to the present invention: the corrugated sheet comprises a lower step portion and a higher step portion; and the lower step portion and the higher step portion are not coplanar.

[0359] In further exemplary embodiments, in the heat sink according to the present invention: the corrugated sheet comprises a narrow pitch portion and a wide pitch portion; and a pitch of ridges of the corrugated sheet in the narrow pitch portion is less than a pitch of ridges of the corrugated sheet in the wide pitch portion.

[0360] In further exemplary embodiments, in the heat sink according to the present invention, the corrugated sheet comprises a raised portion extending transverse to ridges of corrugated sheet.

[0361] In further exemplary embodiments, in the heat sink according to the present invention, the corrugated sheet comprises a depressed portion extending transverse to ridges of corrugated sheet.

[0362] In further exemplary embodiments, in the heat sink according to the present invention, at least one portion of the corrugated sheet is not corrugated.

[0363] In various exemplary embodiments, heat sinks according to the present invention include one or more base plates and one or more heat-dissipating fins. Although the base plates and fins are not limited to strictly planar shapes, the base plates and fins may be generally planar and/or may include multiple generally planar portions (e.g., a bent planar structure including two generally planar portions joined at a bent portions). Further, even if the base plates and fins are not strictly planar, they may be said to define planes. Thus, the arrangement of base plates and fins with respect to each other may be defined with reference to the planes defined by such base plates and fins (e.g., the first fin is parallel to the second fin, the first fin is perpendicular to the base plate, the first fin defines a plane that intersects a plane defined by the second fin, etc.). Further, the arrangement of base plates and fins with respect to each other may be defined with reference to angles at which the base plates and fins (or planes defined by the base plates and fins) intersect (e.g., an angle between the first fin and the base plate is 45 degrees, the first fin defines a plane that intersects a plane defined by the second fin at an angle of 45 degrees, etc.). Base plates and fins may be arranged at angles of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, and/or 85 degrees, with respect to each other, as well as any subranges of angles therein.

[0364] A base plate or fin may be said to extend from a surface of another base plate or fin. For example, in the case that a generally planar fin extends from a surface of a generally planar base plate, an edge of the fin may be joined with the surface of the base plate. Such joint may be located at any location on the surface of the base plate. If the fin extends perpendicularly from a central location on the surface of the base plate, the joint between the fin and the base plate may be T-shaped when viewed from an end. If the fin extends perpendicularly from an edge of the surface of the base plate, the joint between the fin and the base plate may be L-shaped when viewed from an end.

[0365] In various exemplary embodiments, a fin may be a single unitary body. In alternative embodiments, a fin may be comprised of multiple coplanar or substantially coplanar fins.

[0366] In the above detailed description, reference was made by way of non-limiting example to preferred embodiments of the invention. Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

1-16. (canceled)

17. A heat sink for LED lighting, comprising:

a base plate;

a first heat-dissipating fin; and

a second heat-dissipating fin;

wherein:

the base plate, the first fin, and the second fin are formed integrally from aluminum or an aluminum alloy;

the base plate comprises a first surface suitable for mounting an LED element and a second surface opposite from the first surface;

the first fin extends from the first surface or the second surface of the base plate;

the second fin extends from the first surface or the second surface of the base plate;

no more than one additional heat-dissipating fin extends from the surface of the base plate from which the first fin extends and is parallel or substantially parallel to the first fin; and

no more than one additional heat-dissipating fin extends from the surface of the base plate from which the second fin extends and is parallel or substantially parallel to the second fin.

18. The heat sink of claim 17, comprising:

a third heat-dissipating fin; and

a fourth heat-dissipating fin;

wherein:

the first fin is not parallel or substantially parallel to the second fin;

the third fin is parallel or substantially parallel to the first fin; and

the fourth fin is parallel or substantially parallel to the second fin.

19. The heat sink of claim 18, wherein each of the first fin, the second fin, the third fin, and the fourth fin extends from the first surface of the base plate.

20. The heat sink of claim 19, wherein:

the heat sink is formed by bending a blank of the aluminum or aluminum alloy; and

each of the first fin, the second fin, the third fin, and the fourth fin is formed by bending the blank such that the base plate joins each of the first fin, the second fin, the third fin, and the fourth fin at a location of a respective bend.

21. The heat sink of claim 19, comprising:

a fifth heat-dissipating fin;

a sixth heat-dissipating fin;

a seventh heat-dissipating fin; and

an eighth heat-dissipating fin;

wherein:

each of the fifth fin, the sixth fin, the seventh fin, and the eighth fin extends from the second surface of the base plate;

the fifth fin is not parallel or substantially parallel to the sixth fin;

the seventh fin is parallel or substantially parallel to the fifth fin; and

the eighth fin is parallel or substantially parallel to the sixth fin.

22. The heat sink of claim 18, wherein each of the first fin, the second fin, the third fin, and the fourth fin extends from the second surface of the base plate.

23. The heat sink of claim 17, comprising:

a third heat-dissipating fin;

a fourth heat-dissipating fin; and

a fifth heat-dissipating fin;

wherein:

each of the first fin, the third fin, and the fourth fin extends from the first surface of the base plate;

each of the second fin and the fifth fin extends from the second surface of the base plate; the first fin is not parallel or substantially parallel to the second fin;

the third fin is parallel or substantially parallel to the first fin;

the fourth fin is not parallel or substantially parallel to the first fin; and
the fifth fin is parallel or substantially parallel to the second fin.

24. The heat sink of claim **17**, comprising:

a third heat-dissipating fin; and
a fourth heat-dissipating fin;

wherein:

each of the first fin and the third fin extends from the first surface of the base plate;

each of the second fin and the fourth fin extends from the second surface of the base plate;

the first fin is parallel or substantially parallel to the second fin

the third fin is parallel or substantially parallel to the first fin; and

the fourth fin is parallel or substantially parallel to the second fin.

25. The heat sink of claim **18**, wherein:

each of the first fin and the third fin extends from the first surface of the base plate; and

each of the second fin and the fourth fin extends from the second surface of the base plate.

26. The heat sink of claim **25**, wherein:

the heat sink is formed by bending a blank of the aluminum or aluminum alloy; and

each of the first fin, the second fin, the third fin, and the fourth fin is formed by bending the blank such that the base plate joins each of the first fin, the second fin, the third fin, and the fourth fin at a location of a respective bend.

27. A heat sink for LED lighting, comprising:

a base plate;

a first heat-dissipating fin; and

a second heat-dissipating fin;

wherein:

the base plate, the first fin, and the second fin are formed integrally from aluminum or an aluminum alloy;

the base plate comprises a first surface suitable for mounting an LED element and a second surface opposite from the first surface;

the first fin comprises a first surface and a second surface opposite from the first surface;

the first fin extends from the first surface or the second surface of the base plate; and

the second fin extends from the first surface or the second surface of the first fin.

28. The heat sink of claim **27**, comprising:

a third heat-dissipating fin;

a fourth heat-dissipating fin;

a fifth heat-dissipating fin;

a sixth heat-dissipating fin;

a seventh heat-dissipating fin; and

an eighth heat-dissipating fin;

wherein:

the first fin extends from the first surface of the base plate; the second fin extends from the second surface of the first fin;

the third fin extends from the second surface of the first fin; the fourth fin extends from the second surface of the base plate;

the fifth fin extends from the second surface of the base plate;

the sixth fin comprises a first surface and a second surface opposite from the first surface;

the sixth fin extends from the second surface of the base plate;

the seventh fin extends from the first surface of the sixth fin; and

the eighth fin extends from the first surface of the sixth fin.

29. The heat sink of claim **28**, wherein:

the heat sink is formed by bending a blank of the aluminum or aluminum alloy;

each of the first fin, the fourth fin, the fifth fin, and the sixth fin is formed by bending the blank such that the base plate joins each of the first fin, the fourth fin, the fifth fin, and the sixth fin at a location of a respective bend;

each of the second fin and the third fin is formed by bending the blank such that the first fin joins each of the second fin and the third at a location of a respective bend; and

each of the seventh fin and the eighth fin is formed by bending the blank such that the sixth fin joins each of the seventh fin and the eighth fin at a location of a respective bend.

30. The heat sink of claim **29**, wherein the blank comprises a thick portion corresponding to the base plate, the first fin, and the sixth fin and a thin portion corresponding to corresponding to the second fin, the third fin, the fourth fin, the fifth fin, the seventh fin, and the eighth fin.

31. The heat sink of claim **30**, wherein the blank is prepared by welding sheets of the aluminum or aluminum alloy.

32. The heat sink of claim **30**, wherein the blank is prepared by coining.

33. The heat sink of claim **27**, comprising:

a third heat-dissipating fin;

a fourth heat-dissipating fin;

a fifth heat-dissipating fin;

a sixth heat-dissipating fin;

a seventh heat-dissipating fin;

an eighth heat-dissipating fin;

a ninth heat-dissipating fin;

a tenth heat-dissipating fin; and

an eleventh heat-dissipating fin;

wherein:

the first fin extends from the first surface of the base plate;

the second fin comprises a first surface and a second surface opposite from the first surface;

the second fin extends from the second surface of the first fin;

the third fin extends from the first surface of the first fin;

the fourth fin extends from the first surface of the first fin;

the fifth fin extends from the second surface of the surface of the second fin;

the sixth fin extends from the second surface of the surface of the second fin;

the seventh fin extends from the second surface of the base plate;

the eighth fin extends from the second surface of the base plate;

the ninth fin comprises a first surface and a second surface opposite from the first surface;

the ninth fin extends from the second surface of the first fin;

the tenth fin extends from the first surface of the ninth fin; and

the eleventh fin extends from the first surface of the ninth fin.

34. The heat sink of claim **33**, wherein:

a portion of the fifth fin overlaps and contacts a portion of the fourth fin;
 a portion of the fifth fin overlaps and contacts a portion of the seventh fin;
 a portion of the sixth fin overlaps and contacts a portion of the third fin;
 a portion of the sixth fin overlaps and contacts a portion of the eighth fin;
 a portion of the seventh fin overlaps and contacts a portion of the eleventh fin; and
 a portion of the eighth fin overlaps and contacts a portion of the tenth fin.

35. The heat sink of claim **33**, wherein:

the heat sink is formed by bending a blank of the aluminum or aluminum alloy;

each of the first fin, the seventh fin, the eighth fin, and the ninth fin is formed by bending the blank such that the base plate joins each of the first fin, the seventh fin, the eighth fin, and the ninth fin at a location of a respective bend;

each of the second fin, the third fin, and the fourth fin is formed by bending the blank such that the first fin joins each of the second fin, the third fin, and the fourth fin at a location of a respective bend;

each of the fifth fin and the sixth fin is formed by bending the blank such that the second fin joins each of the fifth fin and the sixth fin at a location of a respective bend; and

each of the tenth fin and the eleventh fin is formed by bending the blank such that the ninth fin joins each of the tenth fin and the eleventh fin at a location of a respective bend.

36. The heat sink of claim **27**, comprising:

a third heat-dissipating fin;
 a fourth heat-dissipating fin; and
 a fifth heat-dissipating fin;

wherein:

the first fin extends from the first surface of the base plate;
 the second fin extends from the second surface of the first fin;

the third fin extends from the first surface of the base plate;
 the fourth fin extends from the first surface of the base plate; and

the fifth fin extends from the second surface of the base plate.

37. The heat sink of claim **28**, wherein:

the heat sink is formed by bending a blank of the aluminum or aluminum alloy;

each of the first fin, the fourth fin, the fifth fin, and the sixth fin is formed by bending the blank such that the base plate joins each of the first fin, the fourth fin, the fifth fin, and the sixth fin at a location of a respective bend;

each of the second fin and the third fin is formed by bending the blank such that the first fin joins each of the second fin and the third at a location of a respective bend; and

each of the seventh fin and the eighth fin is formed by bending the blank such that the sixth fin joins each of the seventh fin and the eighth fin at a location of a respective bend.

38. A heat sink for LED lighting, comprising:

a base plate;
 a first heat-dissipating fin;
 a second heat-dissipating fin; and
 a third heat-dissipating fin;

wherein:

the base plate, the first fin, the second fin, and the third fin are formed integrally from aluminum or an aluminum alloy;

the base plate comprises a first surface suitable for mounting an LED element and a second surface opposite from the first surface;

the first fin extends from the second surface of the base plate;

the second fin comprises a first surface and a second surface opposite from the first surface;

the second fin extends from the second surface of the base plate; and

the third fin extends from the first surface or the second surface of the second fin.

39. The heat sink of claim **38**, comprising:

a fourth heat-dissipating fin;
 a fifth heat-dissipating fin;
 a sixth heat-dissipating fin;
 a seventh heat-dissipating fin; and
 an eighth heat-dissipating fin;

wherein:

the third fin extends from the first surface of the second fin;
 the fourth fin extends from the first surface of the second fin;

the fifth fin extends from the second surface of the base plate;

the sixth fin comprises a first surface and a second surface opposite from the first surface;

the sixth fin extends from the second surface of the base plate;

the seventh fin extends from the first surface of the sixth fin; and

the eighth fin extends from the first surface of the sixth fin.

40. The heat sink of claim **38**, comprising:

a fourth heat-dissipating fin;
 a fifth heat-dissipating fin; and
 a sixth heat-dissipating fin;

wherein:

the fourth fin extends from the second surface of the base plate;

the fifth fin comprises a first surface and a second surface opposite from the first surface; and

the sixth fin extends from the first surface or the second surface of the fifth fin.

41. The heat sink of claim **38**, comprising:

a fourth heat-dissipating fin;
 a fifth heat-dissipating fin;
 a sixth heat-dissipating fin;
 a seventh heat-dissipating fin; and
 an eighth heat-dissipating fin;

wherein:

the third fin extends from the first surface of the second fin;
 the fourth fin extends from the second surface of the second fin;

the fifth fin extends from the second surface of the base plate;

the sixth fin comprises a first surface and a second surface opposite from the first surface;

the sixth fin extends from the second surface of the base plate;

the seventh fin extends from the first surface of the sixth fin; and

the eighth fin extends from the second surface of the sixth fin.

42. The heat sink of claim **38**, comprising:

a fourth heat-dissipating fin; and

a fifth heat-dissipating fin;

wherein:

the third fin extends from the first surface of the second fin;

the fourth fin extends from the second surface of the second fin; and

the fifth fin extends from the second surface of the base plate.

43. A heat sink for LED lighting, comprising:

a bent planar base plate;

a first heat-dissipating fin; and

a second heat-dissipating fin;

wherein:

the base plate, the first fin, and the second fin are formed integrally from aluminum or an aluminum alloy;

the base plate comprises an inner surface and an outer surface opposite from the inner surface;

the first fin extends from the inner surface or the outer surface of the base plate; and

the second fin extends from the same surface of the base plate as the first fin.

44. The heat sink of claim **43**, wherein:

the inner surface of the base plate is suitable for mounting an LED element;

the first fin and the second fin extend from the outer surface;

the base plate comprises a first planar region and a second planar region that are joined by a bent region;

the first fin extends from the outer surface of the base plate in the first planar region, the second planar region, and the bent region; and

the second fin extends from the outer surface of the base plate in the first planar region, the second planar region, and the bent region.

45. The heat sink of claim **43**, wherein:

the outer surface of the base plate is suitable for mounting an LED element;

the first fin and the second fin extend from the inner surface;

the base plate comprises a first planar region and a second planar region that are joined by a bent region;

the first fin extends from the inner surface of the base plate in the first planar region, the second planar region, and the bent region; and

the second fin extends from the inner surface of the base plate in the first planar region, the second planar region, and the bent region.

46. The heat sink of claim **43**, comprising:

a third heat-dissipating fin; and

a fourth heat-dissipating fin;

wherein:

the inner surface of the base plate is suitable for mounting an LED element;

the first fin, the second fin, the third fin, and the fourth fin extend from the outer surface;

the base plate comprises a first planar region and a second planar region that are joined by a bent region;

the first fin and the second fin extend from the outer surface of the base plate in the first planar region; and

the second fin and the fourth fin extend from the outer surface of the base plate in the second planar region.

47. The heat sink of claim **43**, comprising:

a third heat-dissipating fin; and

a fourth heat-dissipating fin;

wherein:

the outer surface of the base plate is suitable for mounting an LED element;

the first fin, the second fin, the third fin, and the fourth fin extend from the inner surface;

the base plate comprises a first planar region and a second planar region that are joined by a bent region;

the first fin and the second fin extend from the inner surface of the base plate in the first planar region; and

the second fin and the fourth fin extend from the inner surface of the base plate in the second planar region.

48. A heat sink for LED lighting, comprising a corrugated sheet of aluminum or an aluminum alloy, wherein at least one ridge of the corrugated sheet comprises a depression comprising a surface suitable for mounting an LED element.

49. The heat sink of claim **48**, wherein:

the corrugated sheet comprises a lower step portion and a higher step portion; and

the lower step portion and the higher step portion are not coplanar.

50. The heat sink of claim **48**, wherein:

the corrugated sheet comprises a narrow pitch portion and a wide pitch portion; and

a pitch of ridges of the corrugated sheet in the narrow pitch portion is less than a pitch of ridges of the corrugated sheet in the wide pitch portion.

51. The heat sink of claim **48**, wherein the corrugated sheet comprises a raised portion extending transverse to ridges of corrugated sheet.

52. The heat sink of claim **48**, wherein the corrugated sheet comprises a depressed portion extending transverse to ridges of corrugated sheet.

53. The heat sink of claim **48**, wherein at least one portion of the corrugated sheet is not corrugated.

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