United States Patent	12392561
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Machida; Yoshihiro

Loop-type heat pipe

Abstract

An evaporator includes a first metal layer having a first inner surface and a first outer surface, a second metal layer having a second inner surface and a second outer surface, and a porous body provided between the first outer surface and the second outer surface. The porous body includes a first bottomed hole provided in the first inner surface, a second bottomed hole provided in the second inner surface, a first fine pore, wherein the first bottomed hole and the second bottomed hole partially communicate with each other through the first fine pore, a first groove portion provided in the first inner surface and configured to communicate with the first bottomed hole, and a second groove portion provided in the second inner surface and configured to communicate with the second bottomed hole. The first outer surface and the second outer surface serve as an outer surface of the evaporator.

Inventors: **Machida; Yoshihiro (Nagano, JP)**

Applicant: **SHINKO ELECTRIC INDUSTRIES CO., LTD.** (Nagano, JP)

Family ID: **1000008765380**

Assignee: **SHINKO ELECTRIC INDUSTRIES CO., LTD. (Nagano, JP)**

Appl. No.: **18/479337**

Filed: **October 02, 2023**

Prior Publication Data

Document Identifier	Publication Date
US 20240110752 A1	Apr. 04, 2024

Foreign Application Priority Data

JP	2022-159594	Oct. 03, 2022

Publication Classification

Int. Cl.: **F28D15/00** (20060101); **F28D15/02** (20060101); **F28D15/04** (20060101)

U.S. Cl.:

CPC **F28D15/0266** (20130101); **F28D15/043** (20130101);

Field of Classification Search

CPC: F28D (15/043); F28D (15/0266)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2018/0058767	12/2017	Machida et al.	N/A	N/A
2019/0013257	12/2018	Kurashima	N/A	N/A
2019/0242652	12/2018	Machida	N/A	N/A
2020/0025458	12/2019	Takahashi et al.	N/A	N/A
2020/0404802	12/2019	Takahashi et al.	N/A	N/A
2022/0107136	12/2021	Takahashi et al.	N/A	N/A
2023/0358481	12/2022	Takahashi et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
3 575 727	12/2018	EP	N/A
2018-036012	12/2017	JP	N/A
2019-135434	12/2018	JP	N/A
2019-196896	12/2018	JP	N/A

OTHER PUBLICATIONS

Extended European Search Report issued on Feb. 7, 2024, Application No. EP 23 20 0921, 8 pages. cited by applicant

---

Primary Examiner: Ruby; Travis

Attorney, Agent or Firm: Rankin, Hill & Clark LLP

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) This application claims priority from Japanese Patent Application No. 2022-159594 filed on Oct. 3, 2022, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

(2) The present invention relates to a loop-type heat pipe.

BACKGROUND ART

(3) In the related art, a heat pipe configured to transport heat by using a phase change of a working fluid is suggested as a device configured to cool a heat-generating component of a semiconductor device (for example, a CPU or the like) mounted on an electronic device (for example, refer to JP2018-036012A and JP2019-135434A).
(4) As an example of the heat pipe, known is a loop-type heat pipe including an evaporator configured to vaporize a working fluid by heat of a heat-generating component and a condenser configured to cool and condense the vaporized working fluid, in which the evaporator and the condenser are connected by a liquid pipe and a vapor pipe that form a loop-shaped flow channel. In the loop-type heat pipe, the working fluid flows in one direction in the loop-shaped flow channel.
SUMMARY OF INVENTION
(5) For the loop-type heat pipe described above, further thinning is desired.
(6) Certain embodiment provides a loop-type heat pipe comprising: an evaporator configured to vaporize a working fluid; a condenser configured to condense the working fluid; a liquid pipe configured to connect the evaporator and the condenser to each other; a vapor pipe configured to connect the evaporator and the condenser to each other; and a loop-shaped flow channel provided in each of the evaporator, the condenser, the liquid pipe, and the vapor pipe, and through which the working fluid flows, wherein at least one of the evaporator, the condenser, the liquid pipe, and the vapor pipe comprises: a first metal layer having a first inner surface and a first outer surface, a second metal layer having a second inner surface bonded to the first inner surface and a second outer surface, and a porous body provided between the first outer surface and the second outer surface, and wherein the porous body comprises: a first bottomed hole provided in the first inner surface, a second bottomed hole provided in the second inner surface, a first fine pore, wherein the first bottomed hole and the second bottomed hole partially communicate with each other through the first fine pore, a first groove portion provided in the first inner surface and configured to communicate with the first bottomed hole, and a second groove portion provided in the second inner surface and configured to communicate with the second bottomed hole, wherein the first outer surface and the second outer surface serve as an outer surface of the at least one of the evaporator, the condenser, the liquid pipe, and the vapor pipe.
(7) According to one aspect of the present invention, it is possible to obtain an effect capable of thinning.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a schematic plan view showing a loop-type heat pipe of one embodiment.
(2) FIG. **2** is a schematic plan view showing a part of the loop-type heat pipe of one embodiment.
(3) FIG. **3** is a schematic cross-sectional view (a cross-sectional view taken along a line **3-3** in FIGS. **2** and **4**) showing an evaporator of one embodiment.
(4) FIG. **4** is an enlarged plan view showing a part of a porous body of the evaporator of one embodiment.
(5) FIG. **5** is a schematic cross-sectional view (a cross-sectional view taken along a line **5-5** in FIGS. **2** and **4**) showing the evaporator of one embodiment.
(6) FIG. **6** is a schematic cross-sectional view (a cross-sectional view taken along a line **6-6** in FIG. **4**) showing the evaporator of one embodiment.
(7) FIG. **7** is a schematic cross-sectional view (a cross-sectional view taken along a line **7-7** in FIG. **4**) showing the evaporator of one embodiment.
(8) FIG. **8** is a schematic cross-sectional view (a cross-sectional view taken along a line **8-8** in FIG. **1**) showing a vapor pipe of one embodiment.
(9) FIG. **9** is a schematic cross-sectional view (a cross-sectional view taken along a line **9-9** in FIG.

1) showing a condenser of one embodiment.
(10) FIG. **10** is a schematic cross-sectional view (a cross-sectional view taken along a line **10-10** in FIG. **1**) showing a liquid pipe of one embodiment.
(11) FIGS. **11**A and **11**B are schematic cross-sectional views showing a method of manufacturing a loop-type heat pipe of one embodiment.
(12) FIGS. **12**A and **12**B are schematic cross-sectional views showing the method of manufacturing a loop-type heat pipe of one embodiment.
(13) FIGS. **13**A and **13**B are schematic cross-sectional views showing the method of manufacturing a loop-type heat pipe of one embodiment.
(14) FIGS. **14**A and **14**B are schematic cross-sectional views showing the method of manufacturing a loop-type heat pipe of one embodiment.
(15) FIGS. **15**A and **15**B are schematic cross-sectional views showing the method of manufacturing a loop-type heat pipe of one embodiment.
(16) FIGS. **16**A and **16**B are schematic cross-sectional views showing the method of manufacturing a loop-type heat pipe of one embodiment.

DESCRIPTION OF EMBODIMENTS

(17) Hereinafter, one embodiment will be described with reference to the accompanying drawings.
(18) Note that, for convenience, in the accompanying drawings, a characteristic part is enlarged so as to easily understand the feature, and the dimension ratios of the respective constitutional elements may be different in the respective drawings. Further, in the cross-sectional views, hatching of some members is shown in a satin form and hatching of some members is omitted, so as to easily understand a sectional structure of each member. In the respective drawings, XYZ axes orthogonal to one another are shown. In descriptions below, for convenience, a direction extending along the X-axis is referred to as ‘X-axis direction’, a direction extending along the Y-axis is referred to as ‘Y-axis direction’, and a direction extending along the Z-axis is referred to as ‘Z-axis direction’. Note that, in the present specification, ‘in a plan view’ means seeing a target object from a vertical direction (Z-axis direction, here) in FIG. **3** and the like, and ‘a planar shape’ means a shape of the target object seen from the vertical direction in FIG. **3** and the like.
(19) (Overall Configuration of Loop-type Heat Pipe **20**)
(20) A loop-type heat pipe **20** shown in FIG. **1** is accommodated in a mobile electronic device M**1** such as a smart phone and a tablet terminal, for example. The loop-type heat pipe **20** includes an evaporator **21**, a vapor pipe **22**, a condenser **23**, and a liquid pipe **24**.
(21) The evaporator **21** and the condenser **23** are connected by the vapor pipe **22** and the liquid pipe **24**. The evaporator **21** has a function of vaporizing a working fluid C to generate vapor Cv. The vapor Cv generated in the evaporator **21** is sent to the condenser **23** via the vapor pipe **22**. The condenser **23** has a function of condensing the vapor Cv of the working fluid C. The condensed working fluid C is sent to the evaporator **21** via the liquid pipe **24**. The vapor pipe **22** and the liquid pipe **24** form a loop-shaped flow channel **25** through which the working fluid C or the vapor Cv is caused to flow.
(22) The vapor pipe **22** is formed into, for example, a long tubular body. The liquid pipe **24** is formed into, for example, a long tubular body. In the present embodiment, the vapor pipe **22** and the liquid pipe **24** are the same in dimension (i.e., length) in a length direction, for example. Note that the length of the vapor pipe **22** and the length of the liquid pipe **24** may be different from each other. For example, the length of the vapor pipe **22** may be shorter than the length of the liquid pipe **24**. Here, in the present specification, the ‘length direction’ of the evaporator **21**, the vapor pipe **22**, the condenser **23** and the liquid pipe **24** is a direction that coincides with a direction (refer to an arrow in the drawing) in which the working fluid C or vapor Cv in each member flows. In addition, in the present specification, the ‘same’ includes not only a case in which comparison targets are exactly the same but also a case in which there is a slight difference between the comparison targets due to influences of dimensional tolerances and the like.

(23) (Configuration of Evaporator **21**)
(24) The evaporator **21** is fixed in close contact with a heat-generating component (not shown). The working fluid C in the evaporator **21** is vaporized by heat generated in the heat-generating component, and accordingly, vapor Cv is generated. Note that a thermal interface material (TIM) may also be interposed between the evaporator **21** and the heat-generating component. The TIM reduces contact thermal resistance between the heat-generating component and the evaporator **21** to cause heat to be conducted smoothly from the heat-generating component to the evaporator **21**.
(25) (Configuration of Vapor Pipe **22**)
(26) The vapor pipe **22** has, for example, a pair of pipe walls **22***w* provided on opposite sides in a width direction orthogonal to the length direction of the vapor pipe **22**, in a plan view, and a flow channel **22***r* provided between the pair of pipe walls **22***w*. The flow channel **22***r* communicates with an internal space of the evaporator **21**. The flow channel **22***r* is a part of the loop-shaped flow channel **25**. The vapor Cv generated in the evaporator **21** is guided to the condenser **23** via the vapor pipe **22**.
(27) (Configuration of Condenser **23**)
(28) The condenser **23** has, for example, a heat dissipation plate **23***p* whose area has been increased for heat dissipation, and a flow channel **23***r* provided inside the heat dissipation plate **23***p*. The flow channel **23***r* communicates with the flow channel **22***r*. The flow channel **23***r* is a part of the loop-shaped flow channel **25**. The condenser **23** has pipe walls **23***w* provided on opposite sides in the width direction orthogonal to the length direction of the flow path **23***r*, in a plan view. The vapor Cv guided via the vapor pipe **22** is condensed in the condenser **33**.
(29) (Configuration of Liquid Pipe **24**)
(30) The liquid pipe **24** has, for example, a pair of pipe walls **24***w* provided on opposite sides in the width direction orthogonal to the length direction of the liquid pipe **24**, in a plan view, and a flow channel **24***r* provided between the pair of pipe walls **24***w*. The flow channel **24***r* communicates with the flow channel **23***r* of the condenser **23**, and communicates with the internal space of the evaporator **21**. The flow channel **24***r* is a part of the loop-shaped flow channel **25**.
(31) The liquid pipe **24** has, for example, a pair of porous bodies **24***s* and a flow channel **28** provided between the pair of porous bodies **24***s*. Each of the porous bodies **24***s* extends from the condenser **23** to the vicinity of the evaporator **21** along the length direction of the liquid pipe **24**, for example. Each of the porous bodies **24***s* guides the working fluid C condensed in the condenser **23** to the evaporator **21** by capillary force generated in the porous body **24***s*.
(32) In the loop-type heat pipe **20**, the heat generated in the heat-generating component is moved to the condenser **23** and radiated in the condenser **23**. Thereby, the heat-generating component is cooled, and the temperature rise of the heat-generating component is suppressed.
(33) Here, as the working fluid C, a fluid having a high vapor pressure and a high latent heat of vaporization is preferably used. By using such a working fluid C, it is possible to effectively cool the heat-generating component by the latent heat of vaporization. As the working fluid C, ammonia, water, freon, alcohol, acetone and the like can be used, for example.
(34) (Specific Structure of Evaporator **21**)
(35) As shown in FIG. **2**, the evaporator **21** has, for example, pipe walls **21***w* and porous bodies **21***s*. The pipe walls **21***w* are provided at opposite ends in the width direction (here, X-axis direction) of the evaporator **21**, for example. The pipe walls **21***w* are provided at opposite ends in the length direction (here, Y-axis direction) of the evaporator **21**, for example.
(36) The porous body **21***s* has a connecting portion **26** and a plurality of projections **27**. The connecting portion **26** is provided, for example, at a part, which is closest to the liquid pipe **24**, of the internal space of the evaporator **21**, in a plan view. The connecting portion **26** is formed to extend in the width direction (here, X-axis direction) of the evaporator **21**, for example. A surface of the connecting portion **26** on the liquid pipe **24** side has a part in contact with the pipe walls **21***w* and a remaining part in contact with a space S**1**, for example. A surface of the connecting part **26**

on the vapor pipe **22** side has a part connecting to the projections **27** and a remaining part in contact with a space S**2**. Each of the projections **27** protrudes from the connecting portion **26** toward the vapor pipe **22** in a plan view, for example. Each of the projections **27** is formed to extend along the length direction (here, Y-axis direction) of the evaporator **21**, for example. The plurality of projections **27** are provided spaced at intervals in the width direction of the evaporator **21** in a plan view, for example. The space S**2** is provided between two projections **27** adjacent to each other in the X-axis direction. An end portion of each projection **27** on the vapor pipe **22** side is provided spaced from the pipe walls **21***w* of the evaporator **21**. In other words, the space S**2** is provided between the end portion of each projection **27** on the vapor pipe **22** side and the pipe wall **21***w*. In the plurality of projections **27**, the end portions on the vapor pipe **22** side are not connected to each other.

(37) In this way, the porous body **21***s* of the present embodiment is formed in a comb-tooth shape having the connecting portion **26** and the plurality of projections **27** in a plan view. The number of comb-teeth of the porous body **21***s* can be changed as appropriate. Note that when a contact area between the projection **27** and the space S**2** is increased, the working fluid C is easily vaporized, and the pressure loss can be reduced.

(38) In the internal space of the evaporator **21**, the space S**2** is formed in a region where the porous body **21***s* is not provided. The space S**2** communicates with the flow channel **22***r* of the vapor pipe **22**.

(39) When the working fluid C is guided to the evaporator **21** from the liquid pipe **24** side, the working fluid C penetrates into the porous body **21***s*. The working fluid C penetrating into the porous body **21***s* in the evaporator **21** is vaporized by heat generated in the heat-generating component fixed to the evaporator **21** to produce vapor Cv. The vapor Cv passes through the space S**2** in the evaporator **21** and flows to the vapor pipe **22**.

(40) As shown in FIG. **3**, the evaporator **21** has a structure in which two layers of a first metal layer **31** and a second metal layer **32** are stacked. In other words, the evaporator **21** is constituted by only the first metal layer **31** and the second metal layer **32** serving as a pair of outer metal layers.

(41) The first metal layer **31** and the second metal layer **32** are, for example, copper (Cu) layers having excellent thermal conductivity. The first metal layer **31** and the second metal layer **32** are directly bonded to each other by solid-phase bonding such as diffusion bonding, pressure welding, friction pressure welding or ultrasonic bonding. Note that, in FIG. **3** and subsequent drawings, the first metal layer **31** and the second metal layer **32** are distinguished from each other by a solid line for easy understanding. For example, when the first metal layer **31** and the second metal layer **32** are integrated by diffusion bonding, an interface between the first metal layer **31** and the second metal layer **32** may disappear, so a boundary therebetween may be unclear. As used herein, the solid-phase bonding is a method in which bonding target objects are not melted into each other but softened by heat in a solid-phase (solid) state, and then plastically deformed by further heat to be bonded to each other. Note that each of the first metal layer **31** and the second metal layer **32** is not limited to the copper layer, but may also be formed of a stainless steel layer, an aluminum layer, a magnesium alloy layer or the like. Further, for the first metal layer **31** and the second metal layer **32**, different materials may be used. A thickness of each of the first metal layer **31** and the second metal layer **32** can be set, for example, within a range of about 50 μm to 200 μm. Note that the thickness of the first metal layer **31** and the thickness of the second metal layer **32** may be different from each other, for example.

(42) (Configuration of First Metal Layer **31** and Second Metal Layer **32**)

(43) The first metal layer **31** is stacked on an upper surface of the second metal layer **32**. The first metal layer **31** has a first inner surface **31**A (here, lower surface) that is bonded to the second metal layer **32**, and a first outer surface **31**B (here, upper surface) that is provided on an opposite side to the first inner surface **31**A in a thickness direction (here, Z-axis direction) of the first metal layer **31**. The first outer surface **31**B becomes an outer surface of the evaporator **21**. The first metal layer

31 has, for example, a first wall portion **31***w*, a first porous body **31***s*, and a first concave portion **71**.

(44) The second metal layer **32** has a second inner surface **32**A (here, upper surface) that is bonded to the first inner surface **31**A, and a second outer surface **32**B (here, lower surface) that is provided on an opposite side to the second inner surface **32**A in the thickness direction (here, Z-axis direction) of the second metal layer **32**. The second outer surface **32**B becomes an outer surface of the evaporator **21**. The second metal layer **32** has, for example, a second wall portion **32***w*, a second porous body **32***s*, and a second concave portion **72**. The second wall portion **32***w* is provided at a position overlapping the first wall portion **31***w* in a plan view. The second porous body **32***s* is provided at a position partially overlapping the first porous body **31***s* in a plan view. The second concave portion **72** is provided at a position overlapping the first concave portion **71** in a plan view.

(45) The pipe wall **21***w* is constituted by the first wall portion **31***w* of the first metal layer **31** and the second wall portion **32***w* of the second metal layer **32**. In the pipe wall **21***w*, the first inner surface **31**A of the first wall portion **31***w* and the second inner surface **32**A of the second wall portion **32***w* are bonded to each other. No hole or groove is formed in each of the first wall portion **31***w* and the second wall portion **32***w*, for example. The porous body **21***s* is constituted by the first porous body **31***s* of the first metal layer **31** and the second porous body **32***s* of the second metal layer **32**. The porous body **21***s* is provided between the first outer surface **31**B and the second outer surface **32**B. The space S**2** provided inside the evaporator **21** is constituted by the first concave portion **71** of the first metal layer **31** and the second concave portion **72** of the second metal layer **32**.

(46) (Specific Configuration of Porous Body **21***s*)

(47) As shown in FIGS. **4** and **5**, the first porous body **31***s* has a plurality of first bottomed holes **41**, and first groove portions **42** each communicating two or more bottomed holes **41**. The second porous body **32***s* has a plurality of second bottomed holes **51**, and second groove portions **52** each communicating two or more bottomed holes **51**. The porous body **21***s* has first fine pores **61** formed as the first bottomed holes **41** and the second bottomed holes **51** partially communicate with each other, and second fine pores **62** formed as the first groove portions **42** and the second groove portions partially communicate with each other. Note that FIG. **4** is an enlarged plan view of a portion of the porous body **21***s*, specifically, a portion surrounded by the dashed-dotted line in FIG. **2**. In addition, in FIG. **4**, for convenience, the first bottomed holes **41** and the first groove portions **42** provided in the first metal layer **31** are shown by solid lines, and the second bottomed holes **51** and the second groove portions **51** provided in the second metal layer **32** are shown by broken lines.

(48) As shown in FIG. **5**, the first bottomed hole **41** is formed recessed from the first inner surface **31**A of the first metal layer **31** to a central portion in the thickness direction of the first metal layer **31**. A depth **41**D of the first bottomed hole **41** can be set, for example, within a range of about 20 μm to 100 μm. The first groove portion **42** is formed recessed from the first inner surface **31**A of the first metal layer **31** toward the central portion in the thickness direction of the first metal layer **31**. A depth **42**D of the first groove portion **42** is smaller than the depth **41**D of the first bottomed hole **41**. The depth **42**D of the first groove portion **42** is preferably within a range of 0.5 times or greater and less than 0.8 times the depth **41**D of the first bottomed hole **41**, for example. Here, when the depth **42**D of the first groove portion **42** is set to a depth of less than 0.5 times the depth **41**D of the first bottomed hole **41**, the first groove portion **42** is crushed upon bonding of the first metal layer **31** and the second metal layer **32**, so a possibility that the first groove portion **42** will not function as a moving path for the working fluid C increases. In addition, when the depth **42**D of the first groove portion **42** is set to a depth 0.8 times or greater than the depth **41**D of the first bottomed hole **41**, the capillary force generated in the first groove portion **42** is reduced. The depth **42**D of the first groove portion **42** can be set, for example, within a range of about 10 μm to 70 μm.

(49) The second bottomed hole **51** is formed recessed from the second inner surface **32**A of the

second metal layer **32** to a central portion in the thickness direction of the second metal layer **32**. A depth **51**D of the second bottomed hole **51** can be set, for example, within a range of about 20 μm to 100 μm. The second groove portion **52** is formed recessed from the second inner surface **32**A of the second metal layer **32** toward the central portion in the thickness direction of the second metal layer **32**. The depth **52**D of the second groove portion **52** is smaller than the depth **51**D of the second bottomed hole **51**. The depth **52**D of the second groove portion **52** is preferably within a range of 0.5 to 0.8 times the depth **51**D of the second bottomed hole **51**, for example. Here, when the depth **52**D of the second groove portion **52** is set to a depth less than 0.5 times the depth **51**D of the second bottomed hole **51**, the second groove portion **52** is crushed upon bonding of the first metal layer **31** and the second metal layer **32**, so a possibility that the second groove portion **52** will not function as a moving path for the working fluid C increases. In addition, when the depth **52**D of the second groove portion **52** is set to a depth of 0.8 times or greater than the depth **51**D of the second bottomed hole **51**, the capillary force generated in the second groove portion **52** is reduced. The depth **52**D of the second groove portion **52** can be set, for example, within a range of about 10 μm to 70 μm.

(50) An inner surface of the first bottomed hole **41** is formed, for example, in a shape of a continuous arc from an opening side, i.e., the first inner surface **31**A side of the first metal layer **31** to a bottom surface side. An inner surface of the second bottomed hole **51** is formed, for example, in a shape of a continuous arc from an opening side, i.e., the second inner surface **32**A side of the second metal layer **32** to a bottom surface side. The inner surfaces of the first bottomed hole **41** and the second bottomed hole **51** are each formed as a curved surface curved in an arc shape in a cross sectional view. The bottom surfaces of the first bottomed hole **41** and the second bottomed hole **51** are each formed as a curved surface curved in an arc shape in a cross sectional view. The bottom surface of the first bottomed hole **41** is formed to be continuous with the inner surface of the first bottomed hole **41**, for example. A radius of curvature of the bottom surface of the first bottomed hole **41** may be the same as a radius of curvature of the inner surface of the first bottomed hole **41** or may be different from a radius of curvature of the inner surface of the first bottomed hole **41**. The bottom surface of the second bottomed hole **51** is formed to be continuous with the inner surface of the second bottomed hole **51**, for example. A radius of curvature of the bottom surface of the second bottomed hole **51** may be the same as a radius of curvature of the inner surface of the second bottomed hole **51** or may be different from a radius of curvature of the inner surface of the second bottomed hole **51**.

(51) The inner surface of each of the first bottomed hole **41** and the second bottomed hole **51** of the present embodiment is formed in a concave shape with a semi-circular or semi-elliptical cross section. As used herein, in the present specification, the 'semi-circular shape' includes not only a semi-circle obtained by bisecting a true circle, but also, for example, one having an arc longer or shorter than the semi-circle. In addition, in the present specification, the 'semi-elliptical shape' includes not only a semi-ellipse obtained by bisecting an ellipse, but also, for example, one having an arc longer or shorter than the semi-ellipse. Note that the inner surface of each of the first bottomed hole **41** and the second bottomed hole **51** may be formed to have a tapered shape that widens from the bottom surface side toward the opening side. Further, the bottom surface of the first bottomed hole **41** may be formed to be a plane parallel to the first inner surface **31**A of the first metal layer **31**, and the inner surface of the first bottomed hole **41** may be formed to extend perpendicularly to the bottom surface. The bottom surface of the second bottomed hole **51** may be formed to be a plane parallel to the second inner surface **32**A of the second metal layer **32**, and the inner surface of the second bottomed hole **51** may be formed to extend perpendicularly to the bottom surface.

(52) The planar shape of each of the first bottomed hole **41** and the second bottomed hole **51** may be formed to have any shape and any size. The planar shape of each of the first bottomed hole **41** and the second bottomed hole **51** may be formed into, for example, a circular shape, an elliptical

shape or a polygonal shape. The planar shape of the first bottomed hole **41** and the planar shape of the second bottomed hole **51** may be the same or different from each other. As shown in FIG. **4**, the planar shape of each of the first bottomed hole **41** and the second bottomed hole **51** of the present embodiment is a circular shape. A diameter of each of the first bottomed hole **41** and the second bottomed hole **51** may be set, for example, within a range of about 100 μm to 400 μm.
(53) The plurality of first bottomed holes **41** are aligned in a zigzag pattern, for example, in a plan view. For example, the plurality of first bottomed holes **41** are provided at predetermined intervals along the X-axis direction, and are provided at predetermined intervals along the Y-axis direction. However, the first bottomed holes **41** adjacent to each other in the X-axis direction are provided at positions shifted from each other in the Y-axis direction.
(54) The plurality of second bottomed holes **51** are aligned in a zigzag pattern, for example, in a plan view. For example, the plurality of second bottomed holes **52** are provided at predetermined intervals along the X-axis direction, and are provided at predetermined intervals along the Y-axis direction. However, the second bottomed holes **51** adjacent to each other in the X-axis direction are provided at positions shifted from each other in the Y-axis direction. In addition, each second bottomed hole **51** is provided at a position shifted from the first bottomed hole **41** in the Y-axis direction, for example.
(55) The first bottomed hole **41** and the second bottomed hole **51** partially overlap each other in a plan view. For example, an end portion of the first bottomed hole **41** and an end portion of the second bottomed hole **51** overlap each other in a plan view. As shown in FIGS. **3** and **4**, in a portion where the first bottomed hole **41** and the second bottomed hole **51** overlap in a plan view, the first bottomed hole **41** and the second bottomed hole **51** partially communicate with each other to form a first pore **61**. In addition, as shown in FIG. **5**, in a portion where the first bottomed hole **41** and the second bottomed hole **51** overlap in a plan view, in the XZ cross section, the semi-circular first bottomed hole and the semi-circular second bottomed hole **51** communicate with each other to form the first fine pore **61**.
(56) An inner surface of each of the first groove portion **42** and the second groove portion **52** is formed in a shape similar to the inner surface of each of the first bottomed hole **41** and the second bottomed hole **51**, for example. The inner surface of each of the first groove portion **42** and the second groove portion **52** of the present embodiment is formed in a concave shape with a semi-circular or semi-elliptical cross section. Note that the inner surface of each of the first groove portion **42** and the second groove portion **52** may be formed to have a tapered shape that widens from the bottom surface side toward the opening side. Further, the bottom surface of the first groove portion **42** may be formed to be a plane parallel to the first inner surface **31**A of the first metal layer **31**, and the inner surface of the first groove portion **42** may be formed to extend perpendicularly to the bottom surface. The bottom surface of the second groove portion **52** may be formed to be a plane parallel to the second inner surface **32**A of the second metal layer **32**, and the inner surface of the second groove portion **52** may be formed to extend perpendicularly to the bottom surface.
(57) As shown in FIG. **4**, each of first groove portions **42** is formed to communicate two first bottomed holes **41** adjacent to each other in the X-axis direction, for example. One end portion of each of the first groove portions **42** is connected to one first bottomed hole **41** of the two adjacent first bottomed holes **41**, and the other end portion of each of the first groove portions **42** is connected to the other first bottomed hole **41** of the two adjacent first bottomed holes **41**. Each of the second bottomed hole **52** is formed to communicate two second bottomed holes **51** adjacent to each other in the X-axis direction, for example. One end portion of each of the second groove portions **52** is connected to one second bottomed hole **51** of the two adjacent second bottomed holes **51**, and the other end portion of each of the second groove portions **52** is connected to the other second bottomed hole **51** of the two adjacent second bottomed holes **51**.
(58) The planar shape of each of the first groove portion **42** and the second groove portion **52** may

be formed to have any shape and any size. The planar shape of the first groove portion **42** may be formed to have any shape and any size, for example, as long as it has a structure capable of communicating a plurality of first bottomed holes **41**. The planar shape of the second groove portion **52** may be formed to have any shape and any size, for example, as long as it has a structure capable of communicating a plurality of second bottomed holes **51**. The planar shape of the first groove portion **42** and the planar shape of the second groove portion **52** may be the same or may be different from each other. The planar shape of each of the first groove portion **42** and the second groove portion **52** of the present embodiment is formed in a rectangular shape. The planar shape of each of the first groove portion **42** and the second groove portion **52** is formed in a rectangular shape extending along a direction intersecting both the X-axis direction and the Y-axis direction in the XY plane. A width of the first groove portion **42** is smaller than a width (diameter, here) of the first bottomed hole **41**, for example. A width of the second groove portion **52** is smaller than a width (diameter, here) of the second bottomed hole **51**, for example. The width of each of the first groove portion **42** and the second groove portion **52** may be set, for example, within a range of about 50 μm to 200 μm.

(59) Some of the plurality of first groove portions **42** extend along a first direction D**1** intersecting both the X-axis direction and the Y-axis direction, for example. Some of the plurality of first groove portions **42** extend along a second direction D**2** intersecting the first direction D**1** while intersecting both the X-axis direction and the Y-axis direction, for example. The plurality of first groove portions **42** extending along the first direction D**1** are formed to extend parallel to each other. The plurality of first groove portions **42** extending along the second direction D**2** are formed to extend parallel to each other.

(60) Some of the plurality of second groove portions **52** extend along the first direction D**1**, for example. Some of the plurality of second groove portions **52** extend along the second direction D**2**, for example. The plurality of second groove portions **52** extending along the first direction D**1** are formed to extend parallel to each other. The plurality of second groove portions **52** extending along the second direction D**2** are formed to extend parallel to each other.

(61) The first groove portion **42** and the second groove portion **52** are formed to intersect each other in a plan view. For example, each of the first groove portions **42** extending along the first direction D**1** is formed to intersect the second groove portion **52** extending along the second direction D**2** in a plan view. For example, each of the first groove portions **42** extending along the second direction D**2** is formed to intersect the second groove portion **52** extending along the first direction D**1** in a plan view. In a portion where the first groove portion **42** and the second groove portion **52** intersect each other in a plan view, the first groove portion **42** and the second groove portion **52** partially overlap each other in a plan view. For example, a central portion in the length direction of the first groove portion **42** and a central portion in the length direction of the second groove portion **52** overlap each other in a plan view.

(62) As shown in FIGS. **5** to **7**, in the portion where the first groove portion **42** and the second groove portion **52** overlap in a plan view, the first groove portion **42** and the second groove portion **52** partially communicate with each other to form a second fine pore **62**. As shown in FIG. **5**, in the portion where the first groove portion **42** and the second groove portion **52** overlap in a plan view, in the XZ cross section, the semi-circular first groove portion **42** and the semi-circular second groove portion **52** communicate with each other to form the second fine pore **62**. The second fine pore **62** is formed smaller than the first fine pore **61**, for example.

(63) As shown in FIGS. **4** and **5**, the first inner surface **31**A between the first bottomed holes **41** on two rows adjacent to each other in the X-axis direction is formed with only the first groove portion **42**. In other words, the first inner surface **31**A between the first bottomed holes **41** on two rows adjacent to each other in the X-axis direction is formed with no concave portion other than the first groove portion **42**. That is, the first inner surface **31**A between the first bottomed holes **41** on two rows adjacent to each other in the X-axis direction is formed in a plane on a portion other than the

first groove portion **42**. Further, the second inner surface **32**A between the second bottomed holes **51** on two rows adjacent to each other in the X-axis direction is formed with only the second groove portion **52**. In other words, the second inner surface **32**A between the second bottomed holes **51** on two rows adjacent to each other in the X-axis direction is formed in a plane on a portion other than the second groove portion **52**. As shown in FIG. **5**, in a portion, in which the first groove portion **42** and the second groove portion **52** are not formed, between the first bottomed holes **41** on two rows adjacent to each other in the X-axis direction, the first inner surface **31**A and the second inner surface **32**A are directly bonded to each other.

(64) As shown in FIG. **6**, in a first cross section obtained by cutting the porous body **21***s* in the XZ plane along the first direction D**1** passing through the center in the width direction of the first groove portion **42**, the first bottomed hole **41** and the first groove portion **42** are continuously formed along the first direction D**1** in the first inner surface **31**A of the first metal layer **31**. Further, in the first cross section, the second inner surface **32**A of the second metal layer **32** is partially formed with only the second groove portion **52**. For example, the second inner surface **32**A in the first cross section is formed with the second groove portion **52** at a position overlapping the central portion in the length direction (here, first direction D**1**) of the first groove portion **42** in a plan view, and is formed in a plane on a portion other than the second groove portion **52**. In this way, the second groove portion **52** extending along the second direction D**2** partially communicates with only a part in the length direction of the first groove portion **42** extending along the first direction D**1**, so that the second fine pore **62** is formed. Further, a boundary portion **43** between the first bottomed hole **41** and the first groove portion **42** is not in contact with the second inner surface **32**A of the second metal layer **32**. A space is provided between the boundary portion **43** and the second inner surface **32**A of the second metal layer **32**. Note that although not shown, in a cross section obtained by cutting the porous body **21***s* in the XZ plane along the second direction D**2** passing through the center in the width direction of the first groove portion **42**, the first metal layer **31** and the second metal layer **32** have a cross-sectional structure similar to that shown in FIG. **6**.

(65) As shown in FIG. **7**, in a second cross section obtained by cutting the porous body **21***s* in the XZ plane along the first direction D**1** passing through the center in the width direction of the second groove portion **52**, the second bottomed hole **51** and the second groove portion **52** are continuously formed along the first direction D**1** in the second inner surface **32**A of the second metal layer **32**. Further, in the second cross section, the first inner surface **31**A of the first metal layer **31** is partially formed with only the first groove portion **42**. For example, the first inner surface **31**A in the second cross section is formed with the first groove portion **42** at a position overlapping the central portion in the length direction of the second groove portion **52** in a plan view, and is formed in a plane on a portion other than the first groove portion **42**. In this way, the first groove portion **42** extending along the second direction D**2** partially communicates with only a part in the length direction of the second groove portion **52** extending along the first direction D**1**, so that the second fine pore **62** is formed. Further, a boundary portion **53** between the second bottomed hole **51** and the second groove portion **52** is not in contact with the first inner surface **31**A of the first metal layer **31**. A space is provided between the boundary portion **53** and the first inner surface **31**A of the first metal layer **31**. Note that although not shown, in a cross section obtained by cutting the porous body **21***s* in the XZ plane along the second direction D**2** passing through the center in the width direction of the second groove portion **52**, the first metal layer **31** and the second metal layer **32** have a cross-sectional structure similar to that shown in FIG. **7**.

(66) As shown in FIG. **4**, the first groove portion **42** is formed not to overlap the second bottomed hole **51** in a plan view, for example. That is, the first groove portion **42** is formed not to directly communicate with the second bottomed hole **51**. The second groove portion **52** is formed not to overlap the first bottomed hole **41** in a plan view, for example. That is, the second groove portion **52** is formed not to directly communicate with the first bottomed hole **41**.

(67) As shown in FIGS. **3** to **7**, the first bottomed hole **41**, the first groove portion **42**, the second

bottomed hole **51**, the second groove portion **52**, the first fine pore **61**, and the second fine pore **62** communicate with one another. A space formed as the first bottomed hole **41**, the first groove portion **42**, the second bottomed hole **51**, the second groove portion **52**, the first fine pore **61**, and the second fine pore **62** communicate with one another expands three-dimensionally. The first bottomed hole **41**, the first groove portion **42**, the second bottomed hole **51**, the second groove portion **52**, the first fine pore **61** and the second fine pore **62**, i.e., the flow channel of the porous body **21***s* functions as a flow channel through which the liquid working fluid C (refer to FIG. **1**) flows.

(68) (Specific Configuration of Space S**2**)

(69) As shown in FIG. **3**, the space S**2** is formed as the first concave portion **71** of the first metal layer **31** and the second concave portion **72** of the second metal layer **32** communicate with each other. For example, the first concave portion **71** and the second concave portion **72** are formed to completely overlap each other in a plan view. That is, the entirety of the first concave portion **71** is formed to overlap the entirety of the second concave portion **72** in a plan view.

(70) The first concave portion **71** is formed recessed from the first inner surface **31**A of the first metal layer **31** to the central portion in the thickness direction of the first metal layer **31**. A depth **71**D of the first concave portion **71** is greater than the depth **41**D of the first bottomed hole **41**, for example. The depth **71**D of the first concave portion **71** is, for example, a depth ranging from 1.1 to 1.3 times the depth **41**D of the first bottomed hole **41**. The depth **71**D of the first concave hole **71** can be set, for example, within a range of about 25 μm to 130 μm.

(71) The second concave portion **72** is formed recessed from the second inner surface **32**A of the second metal layer **32** to the central portion in the thickness direction of the second metal layer **32**. A depth **72**D of the second concave portion **72** is greater than the depth **51**D of the second bottomed hole **51**, for example. The depth **72**D of the second concave portion **72** is, for example, a depth ranging from 1.1 to 1.3 times the depth **51**D of the second bottomed hole **51**. The depth **72**D of the second concave portion **72** can be set, for example, within a range of about 25 μm to 130 μm.

(72) The inner surface of each of the first concave portion **71** and the second concave portion **72** may be formed to have any shape. The inner surface of each of the first concave portion **71** and the second concave portion **72** of the present embodiment is formed in a concave shape with a rectangular cross section. Note that the inner surface of each of the first concave portion **71** and the second concave portion **72** may be formed to have a tapered shape that widens from the bottom surface side toward the opening side. In addition, the inner surface of each of the first concave portion **71** and the second concave portion **72** may be formed in a concave shape with a semi-circular or semi-elliptical cross section.

(73) The space S**2** communicates with the flow channel of the porous body **21***s*, for example. For example, the first concave portion **71** communicates with the first bottomed hole **41** or the first groove portion **42**. For example, the second concave portion **72** communicates with the second bottomed hole **51** or the second groove portion **52**. Note that the first groove portion **42** that communicates with the first concave portion **71** is formed to communicate the first bottomed hole **41** and the first concave portion **71** each other. The second groove portion **52** that communicates with the second concave portion **72** is formed to communicate the second bottomed hole **51** and the second concave portion **72** each other.

(74) (Configuration of Vapor Pipe **22**)

(75) As shown in FIG. **8**, the vapor pipe **22** is formed by stacking two layers of the first metal layer **31** and the second metal layer **32**, like the evaporator **21**. In the vapor pipe **22**, the first concave portion **71** provided in the first inner surface **31**A of the first metal layer **31** and the second concave portion **72** provided in the second inner surface **32**A of the second metal layer **32** communicate with each other to form the flow channel **22***r*. The vapor pipe **22** has the pair of pipe walls **22***w* provided on opposite sides in the width direction (here, Y-axis direction) orthogonal to the length direction (here, X-axis direction) of the vapor pipe **22**. Each of the pipe walls **22***w* is not formed

with a hole or a groove. Note that the flow channel **22***r* is provided between the pair of pipe walls **22***w*.
(76) (Configuration of Condenser **23**)
(77) As shown in FIG. **9**, the condenser **23** is formed by stacking two layers of the first metal layer **31** and the second metal layer **32**, like the evaporator **21**. In the condenser **23**, the first concave portion **71** provided in the first inner surface **31**A of the first metal layer **31** and the second concave portion **72** provided in the second inner surface **32**A of the second metal layer **32** communicate with each other to form the flow channel **23***r*. The condenser **23** has the pair of pipe walls **23***w* provided on opposite sides in the width direction (here, X-axis direction) orthogonal to the length direction (here, Y-axis direction) of the condenser **23**. Each of the pipe walls **23***w* is not formed with a hole or a groove. Note that the flow channel **23***r* is provided between the pair of pipe walls **23***w*.
(78) (Configuration of Liquid Pipe **24**)
(79) As shown in FIG. **10**, the liquid pipe **24** is formed by stacking two layers of the first metal layer **31** and the second metal layer **32**, like the evaporator **21**. The liquid pipe **24** includes the pair of pipe walls **24***w* provided at opposite ends in the width direction (here, X-axis direction) of the liquid pipe **24**, the flow channel **28** provided between the pair of pipe walls **24***w*, the pair of porous bodies **24***s* provided on opposite sides of the flow channel **28** in the width direction of the liquid pipe **24**. In the liquid pipe **24**, the first concave portion **71** provided in the first inner surface **31**A of the first metal layer **31** and the second concave portion **72** provided in the second inner surface **32**A of the second metal layer **32** communicate with each other to form the flow channel **28**. By providing the flow channel **28** in the liquid pipe **24**, a storage amount of the working fluid C in the liquid pipe **24** can be increased.
(80) Each of the porous bodies **24***s* is integrally formed continuous with the wall **24***w*, for example. Each of the porous bodies **24***s* has a structure similar to that of the porous body **21***s* shown in FIGS. **3** to **7**, for example. Each of the porous bodies **24***s* has the first bottomed hole **41** provided in the first inner surface **31**A of the first metal layer **31**, the second bottomed hole **51** provided in the second inner surface **32**A of the second metal layer **32**, and the first fine pore **61** formed as the first bottomed hole **41** and the second bottomed hole **51** partially communicate with each other. Although not shown, each of the porous bodies **24***s* has the first groove portion **42** (refer to FIG. **5**), the second groove portion **52** (refer to FIG. **5**), and the second fine pore (refer to FIG. **5**) formed as the first groove portion **42** and the second groove portion **52** partially communicate with each other. The flow channel (i.e., the first bottomed hole **41**, the first groove portion **42**, the second bottomed hole **51**, the second groove portion **52**, the first fine pore **61** and the second fine pore **62**) of each of the porous bodies **24***s* functions as the flow channel **24***r* through which the liquid working fluid C (refer to FIG. **1**) flows. In the liquid pipe **14** of the present embodiment, the flow channel **24***r* is constituted by the flow channel and the flow channel **24***r* of each of the porous bodies **24***s*.
(81) Although not shown, the liquid pipe **24** is provided with an injection port for injecting the working fluid C (refer to FIG. **1**). However, the injection port is closed by a sealing member, so that an inside of the loop-type heat pipe **20** is kept airtight.
(82) (Method of Manufacturing Loop-Type Heat Pipe **20**)
(83) Next, a method of manufacturing the loop-type heat pipe **20** will be described with reference to FIGS. **11**A to **16**B. Note that, each of FIGS. **11**A, **12**A, **13**A, **14**A, **15**A and **16**A shows a cross-sectional structure at a position corresponding to a line **3-3** in FIG. **2**, and each of FIGS. **11**B, **12**B, **13**B, **14**B, **15**B and **16**B shows a cross-sectional structure at a position corresponding to a line **5-5** in FIG. **2**. In addition, FIGS. **11**A, **12**A, **13**A, **14**A, **15**A and **16**A, and FIGS. **11**B, **12**B, **13**B, **14**B, **15**B and **16**B show processes that are performed simultaneously, although cutting positions differ from each other.
(84) First, in a process shown in FIGS. **11**A and **11**B, a flat plate-shaped metal sheet **80** is prepared.

The metal sheet **80** is a member that finally becomes the first metal layer **31** (refer to FIG. **3**). The metal sheet **80** has a first inner surface **31**A and a first outer surface **31**B. The metal sheet **80** is made of, for example, copper, stainless steel, aluminum, a magnesium alloy, or the like. A thickness of the metal sheet **80** may be set, for example, within a range of about 50 μm to 200 μm.

(85) Subsequently, a first resist layer **81** is formed on the first inner surface **31**A of the metal sheet **80**, and a second resist layer **82** is formed on the first outer surface **31**B of the metal sheet **80**. The first resist layer **81** is formed to cover the entire surface of the first inner surface **31**A of the metal sheet **80**. The second resist layer **82** is formed to cover the entire surface of the first outer surface **31**B of the metal sheet **80**. As the first resist layer **81** and the second resist layer **82**, for example, a photosensitive dry film resist or the like may be used.

(86) Next, in a process shown in FIGS. **12**A and **12**B, the first resist layer **81** is patterned to form openings **81**X, **81**Y and **81**Z, which selectively expose the first inner surface **31**A of the metal sheet **80**, in the first resist layer **81**. For example, the first resist layer **81** is exposed and developed to form the openings **81**X, **81**Y and **81**Z in the first resist layer **81**. The opening **81**X shown in FIGS. **12**A and **12**B is formed to correspond to the first bottomed hole **41** shown in FIG. **3**. The opening **81**Y shown in FIG. **12**B is formed to correspond to the first groove portion **42** shown in FIG. **5**. The opening **81**Z shown in FIG. **12**A is formed to correspond to the first concave portion **71** shown in FIG. **3**. Here, a width of the opening **81**Y is formed smaller than a width of the opening **81**X. In addition, the width of the opening **81**X is formed smaller than a width of the opening **81**Z. Note that the openings **81**X, **81**Y and **81**Z are formed simultaneously in the same process, for example.

(87) Subsequently, in a process shown in FIGS. **13**A and **13**B, the metal sheet **80** exposed in the openings **81**X, **81**Y and **81**Z is etched from the first inner surface **31**A side of the metal sheet **80**. Thereby, a first bottomed hole **41**, a first groove portion **42**, and a first concave portion **71** are simultaneously formed in the first inner surface **31**A of the metal sheet **80**. Specifically, as shown in FIGS. **13**A and **13**B, the metal sheet **80** exposed from the opening **81**X is etched from the first inner surface **31**A side, so that the first bottomed hole **41** is formed. As shown in FIG. **13**B, the metal sheet **80** exposed from the opening **81**Y is etched from the first inner surface **31**A side, so that the first groove portion **42** is formed. As shown in FIG. **13**A, the metal sheet **80** exposed from the opening **81**Z is etched from the first inner surface **31**A side, so that the first concave portion **71** is formed. The first bottomed hole **41**, first groove portion **42** and first concave portion **71** may be formed by, for example, wet etching the metal sheet **80** by using the first resist layer **81** and the second resist layer **82** as etching masks. When copper is used as the material of the metal sheet **80**, a ferric chloride aqueous solution or a copper chloride aqueous solution may be used as an etching solution.

(88) Next, the first resist layer **81** and the second resist layer **82** are peeled off by a stripping solution. Thereby, as shown in FIGS. **14**A and **14**B, a first metal layer **31** having the first bottomed hole **41**, the first groove portion **42** and the first concave portion **71** in the first inner surface **31**A can be formed.

(89) Next, in a process shown in FIGS. **15**A and **15**B, a second metal layer **32** having a second bottomed hole **51**, a second groove portion **52** and a second concave portion **72** in the second inner surface **32**A is formed by a method similar to the processes shown in FIGS. **11** to **14**. Subsequently, the first metal layer **31** is arranged above the second metal layer **32** so that the first inner surface **31**A and the second inner surface **32**A face each other.

(90) Subsequently, in a process shown in FIGS. **16**A and **16**B, the stacked first metal layer **31** and second metal layer **32** are pressed while heating the same at a predetermined temperature (e.g., about 900° C.). Thereby, the first metal layer **31** and the second metal layer **32** are bonded by solid-phase bonding. In this case, the first inner surface **31**A (here, lower surface) of the first wall portion **31***w* and the second inner surface **32**A (here, upper surface) of the second wall portion **32***w* are directly bonded. In addition, the first inner surface **31**A, in which the first bottomed hole **41** and the first groove portion **42** are not formed, of the first porous body **31***s* and the second inner surface

32A, in which the second bottomed hole **51** and the second groove portion **52** are not formed, of the second porous body **32***s* are directly bonded.

(91) By the processes described above, a structure in which the first metal layer **31** and the second metal layer **32** are stacked is formed. Then, the loop-type heat pipe **20** having the evaporator **21**, the vapor pipe **22**, the condenser **23**, and the liquid pipe **24** shown in FIG. **1** is formed. Thereafter, for example, after exhausting the inside of the liquid pipe **24** by using a vacuum pump or the like, the working fluid C is injected into the liquid pipe **24** from an injection port (not shown), and then the injection port is sealed.

(92) Subsequently, operational effects of the present embodiment are described. (1) The loop-type heat pipe **20** is formed by only the two metal layers of the first metal layer **31** and the second metal layer **32**. This makes it possible to reduce a thickness of the loop-type heat pipe **20**, as compared with a case in which three or more metal layers are stacked. In addition, since an amount of metal layers used can be reduced, as compared with the case in which three or more metal layers are stacked, the manufacturing cost of the loop-type heat pipe **20** can be reduced. (2) When three or more metal layers are bonded, unevenness may arise in a bonded state among the respective metal layers. In contrast, since the loop-type heat pipe **20** of the present embodiment is constituted by only two metal layers, i.e., the first metal layer **31** and the second metal layer **32**, the stability of the bonding between the first metal layer **31** and the second metal layer **32** can be improved. (3) The first inner surface **31**A of the first metal layer **31** is formed with the first bottomed hole **41** and the first groove portion **42**, and the second inner surface **32**A of the second metal layer **32** is formed with the second bottomed hole **51** and the second groove portion **52**. Further, the first fine pore **61** is formed by partially communicating the first bottomed hole **41** and the second bottomed hole **51** each other. Thereby, the three-dimensional flow channel functioning as the porous body **21***s* can be formed by only the first metal layer **31** and the second metal layer **32** as the outer metal layers, without providing an inner metal layer. The condensed working fluid C can be favorably moved three-dimensionally by the capillary force generated in the porous body **21***s*. (4) The porous body **21***s* has the first bottomed hole **41**, the first groove portion **42**, the second bottomed hole **51**, the second groove portion **52**, and the first fine pore **61**. Further, the porous body **21***s* has the second fine pores **62** formed by partially communicating the first groove portions **42** and the second groove portions **52** each other. In this configuration, the first bottomed hole **41**, the first groove portion **42**, the second bottomed hole **51**, the second groove portion **52**, the first fine pore **61**, and the second fine pore **62** communicate with one another. Then, the space which is formed by the first bottomed hole **41**, the first groove portion **42**, the second bottomed hole **51**, the second groove portion **52**, the first fine pore **61**, and the second fine pore **62** communicating with one another, i.e., the flow channel of the porous body **21***s* can be favorably formed to expand three-dimensionally. In addition, by providing the second fine pores **62**, it is possible to increase the number of three-dimensionally communicating portions in the flow channel of the porous body **21***s*, so that the liquid working fluid C can be favorably moved three-dimensionally in the flow channel of the porous body **21***s*. (5) Further, since the second fine pore **62** is formed by partially communicating the first groove portion **42** and the second groove portion **52** each other, the second fine pore **62** is formed smaller, as compared with a case in which the entirety of the first groove portion **42** and the entirety of the second groove portion **52** communicate with each other. As a result, since the capillary force generated in the second fine pores **62** can be increased, the liquid working fluid C can be favorably moved three-dimensionally in the flow channel of the porous body **21***s*. (6) The first bottomed hole **41** is formed deeper than the first groove portion **42**, and the second bottomed hole **51** is formed deeper than the second groove portion **52**. In other words, the first groove portion **42** is formed shallower than the first bottomed hole **41**, and the second grooved portion **52** is formed shallower than the second bottomed hole **51**. Further, the width of the first groove portion **42** is smaller than the width of the first bottomed hole **41**, and the width of the second groove portion **52** is smaller than the width of the second bottomed hole **51**. As a result, since the capillary

force generated in the first groove portion **42** and the second groove portion **52** can be increased, the liquid working fluid C can be favorably moved three-dimensionally in the flow channel of the porous body **21***s*. (7) If the respective depths **42**D and **52**D of the first groove portion **42** and the second groove portion **52** are shallow, the possibility that the first groove portion **42** and the second groove portion **52** will be crushed upon bonding of the first metal layer **31** and the second metal layer **32** increases. If the first groove portion **42** and the second groove portion **52** are crushed, the adjacent first bottomed holes **41** cannot communicate with each other and the adjacent second bottomed holes **51** cannot communicate with each other. In contrast, in the present embodiment, the depth **42**D of the first groove portion **42** is set to a depth within the range of 0.5 times or greater and less than 0.8 times the depth **41**D of the first bottomed hole **41**, and the depth **52**D of the second groove portion **52** is set to a depth within the range of 0.5 times or greater and less than 0.8 times the depth **51**D of the second bottomed hole **51**. That is, each of the first groove portion **42** and the second groove portion **52** is formed shallower than the first bottomed hole **41** and the second bottomed hole **51**, but is also formed deep to some extent. According to this configuration, while increasing the capillary force generated in the first groove portion **42** and the second groove portion **52**, the first groove portion **42** and the second groove portion **52** can be favorably suppressed from being crushed when bonding the first metal layer **31** and the second metal layer **32**. Thereby, in a state in which the first metal layer **31** and the second metal layer **32** are bonded, the first groove portion **42** communicating the adjacent first bottomed holes **51** each other and the second groove portion **52** communicating the adjacent second bottomed holes **51** each other can be favorably maintained. As a result, the three-dimensional flow channel of the porous body **21***s* can be favorably maintained in the state where the first metal layer **31** and the second metal layer **32** are bonded. (8) The first concave portion **71** is formed in the first inner surface **31**A of the first metal layer **31**, and the second concave portion **72** is formed in the second inner surface **32**A of the second metal layer **32**. Further, by communicating the first concave portion **71** and the second concave portion **72** each other, the space S**2** in which the vaporized working fluid C (namely, vapor Cv) moves is formed. Thereby, the space S**2** serving as the movement space for the gaseous working fluid C can be formed with only the first metal layer **31** and the second metal layer **32** as the outer metal layers, without providing an inner metal layer. (9) The first resist layer **81** having the openings **81**X and **81**Y for selectively exposing the first inner surface **31**A of the metal sheet **80** is formed, and the metal sheet **80** exposed from the openings **81**X and **81**Y is etched from the first inner surface **31**A side. Thereby, the first bottomed hole **41** and the first groove portion **42** are simultaneously formed in the first inner surface **31**A of the first metal layer **31**. For this reason, as compared with a case in which the first bottomed hole **41** and the first groove portion **42** are formed in separate processes, the number of the manufacturing processes can be reduced. Further, both the first bottomed hole **41** and the first groove portion **42** can be formed using one first resist layer **81** as an etching mask. (10) The first resist layer **81** having the openings **81**X, **81**Y and **81**Z in the first inner surface **31**A of the metal sheet **80** is formed, and the metal sheet **80** exposed from the openings **81**X, **81**Y and **81**Z is etched from the first inner surface **31**A side. Thereby, the first bottomed hole **41**, the first groove portion **42**, and the first concave portion **71** are simultaneously formed in the first inner surface **31**A of the first metal layer **31**. For this reason, as compared with a case where the first bottomed hole **41**, the first groove portion **42**, and the first concave portion **71** are formed in separate processes, the number of the manufacturing processes can be reduced.

Other Embodiments

(93) The above embodiment can be changed and implemented as follows. The above embodiment and the following modified embodiments can be implemented in combination with each other within a technically consistent range.

(94) In the above embodiment, the depth **71**D of the first concave portion **71** is formed deeper than the depth **41**D of the first bottomed hole **41**. However, the present invention is not limited thereto. For example, the depth **71**D of the first concave portion **71** may be formed to be the same as the

depth **41**D of the first bottomed hole **41**.
(95) In the above embodiment, the depth **72**D of the second concave portion **72** is formed deeper than the depth **51**D of the second bottomed hole **51**. However, the present invention is not limited thereto. For example, the depth **72**D of the second concave portion **72** may be formed to be the same as the depth **51**D of the second bottomed hole **51**.
(96) In the above embodiment, the depth **42**D of the first groove portion **42** is formed shallower than the depth **41**D of the first bottomed hole **41**. However, the present invention is not limited thereto. For example, the depth **42**D of the first groove portion **42** may be formed to be the same as the depth **41**D of the first bottomed hole **41**.
(97) In the above embodiment, the depth **52**D of the second groove portion **52** is formed shallower than the depth **51**D of the second bottomed hole **51**. However, the present invention is not limited thereto. For example, the depth **52**D of the second groove portion **52** may be formed to be the same as the depth **51**D of the second bottomed hole **51**.
(98) In the above embodiment, the depth **41**D of the first bottomed hole **41** and the depth **51**D of the second bottomed hole **51** may be different from each other.
(99) In the above embodiment, the depth **42**D of the first groove portion **42** and the depth **52**D of the second groove portion **52** may be different from each other.
(100) In the above embodiment, the depth **71**D of the first concave portion **71** and the depth **72**D of the second concave portion **72** may be different from each other.
(101) The alignment of the first bottomed hole **41** and the second bottomed hole **51** in the above embodiment may be changed as appropriate. For example, the alignment of the first bottomed hole **41** and the second bottomed hole **51** is not particularly limited as long as the first bottomed hole **41** and the second bottomed hole **51** are aligned to partially communicate with each other.
(102) In the above embodiment, the first groove portion **42** is formed not to overlap the second bottomed hole **51** in a plan view. However, the present invention is not limited thereto. For example, the first groove portion **42** may be formed to overlap a part of the second bottomed hole **51** in a plan view. In this case, the first groove portion **42** and the second bottomed hole **51** partially communicate with each other.
(103) In the above embodiment, the second groove portion **52** is formed not to overlap the first bottomed hole **41** in a plan view. However, the present invention is not limited thereto. For example, the second groove portion **52** may be formed to overlap a part of the first bottomed hole **41** in a plan view. In this case, the second groove portion **52** and the first bottomed hole **41** partially communicate with each other.
(104) In the above embodiment, the first groove portion **42** and the second groove portion **52** are formed such that the first groove portion **42** and the second groove portion **52** intersect in a plan view. However, the present invention is not limited thereto. For example, the first groove portion **42** and the second groove portion **52** may be formed such that the first groove portion **42** and the second groove portion **52** do not overlap each other in a plan view. In this case, the formation of the second fine pores **62** is omitted.
(105) The structure of the liquid pipe **24** in the above embodiment can be appropriately changed. For example, the arrangement of the flow channel **28** and the porous body **24***s* in the liquid pipe **24** may be appropriately changed. For example, the porous body **24***s* may be arranged at the center in the width direction of the liquid pipe **24**, and the flow channels **28** may be arranged on opposite sides of the porous body **24***s*. For example, the flow channel **28** in the liquid pipe **24** may be omitted.
(106) A porous body similar to the porous body **21***s* may be provided in the vapor pipe **22** in the above embodiment.
(107) A porous body similar to the porous body **21***s* may be provided in the condenser **23** in the above embodiment.
(108) This disclosure further encompasses various exemplary embodiments, for example, described

below. [1] A method of manufacturing a loop-type heat pipe comprising an evaporator configured to vaporize a working fluid, a condenser configured to condense the working fluid, a liquid pipe configured to connect the evaporator and the condenser, a vapor pipe configured to connect the evaporator and the condenser, and a loop-shaped flow channel provided in each of the evaporator, the condenser, the liquid pipe, and the vapor pipe, and through which the working fluid flows, the method comprising: forming a first metal layer having a first inner surface in which a first bottomed hole and a first groove portion communicating with the first bottomed hole are provided; forming a second metal layer having a second inner surface in which a second bottomed hole and a second groove portion communicating with the second bottomed hole are provided; and forming the evaporator by stacking the first metal layer and the second metal layer with the first inner surface and the second inner surface facing each other, wherein the forming of the first metal layer comprises: preparing a metal sheet having the first inner surface and a first outer surface, forming a first resist layer for covering the first inner surface of the metal sheet and forming a second resist layer for covering the first outer surface of the metal sheet, patterning the first resist layer to form a first opening and a second opening for selectively exposing the first inner surface of the metal sheet, in the first resist layer, and forming the first bottomed hole and the first groove portion in the first inner surface at the same time by etching, from the first inner surface side, the metal sheet exposed from the first opening and the second opening.

Claims

1. A loop-type heat pipe comprising: an evaporator configured to vaporize a working fluid; a condenser configured to condense the working fluid; a liquid pipe configured to connect the evaporator and the condenser to each other; a vapor pipe configured to connect the evaporator and the condenser to each other; and a loop-shaped flow channel provided in each of the evaporator, the condenser, the liquid pipe, and the vapor pipe, and through which the working fluid flows, wherein at least one of the evaporator, the condenser, the liquid pipe, and the vapor pipe comprises: a first metal layer having a first inner surface and a first outer surface, a second metal layer having a second inner surface bonded to the first inner surface and a second outer surface, and a porous body provided between the first outer surface and the second outer surface, wherein the porous body comprises: a first bottomed hole provided in the first inner surface, a second bottomed hole provided in the second inner surface, a first fine pore, wherein the first bottomed hole and the second bottomed hole partially communicate with each other through the first fine pore, a first groove portion provided in the first inner surface and configured to communicate with the first bottomed hole, and a second groove portion provided in the second inner surface and configured to communicate with the second bottomed hole, wherein the first outer surface and the second outer surface serve as an outer surface of the at least one of the evaporator, the condenser, the liquid pipe, and the vapor pipe.
2. The loop-type heat pipe according to claim 1, wherein the porous body has a second fine pore in which the first groove portion and the second groove portion partially communicate with each other through the second fine pore.
3. The loop-type heat pipe according to claim 2, wherein the first groove portion and the second groove portion intersect with each other in a plan view, and wherein the second fine pore is provided at a portion where the first groove portion and the second groove portion intersect in the plan view.
4. The loop-type heat pipe according to claim 1, wherein the first bottomed hole is deeper than the first groove portion, and wherein the second bottomed hole is deeper than the second groove portion.
5. The loop-type heat pipe according to claim 4, wherein a depth of the first groove portion is a depth within a range of 0.5 times or greater and less than 0.8 times a depth of the first bottomed

hole, and wherein a depth of the second groove portion is a depth within a range of 0.5 times or greater and less than 0.8 times a depth of the second bottomed hole.

6. The loop-type heat pipe according to claim 1, wherein a width of the first groove portion is smaller than a width of the first bottomed hole, and wherein a width of the second groove portion is smaller than a width of the second bottomed hole.

7. The loop-type heat pipe according to claim 1, wherein the evaporator comprises the first metal layer, the second metal layer and the porous body, wherein the evaporator has a space in which the vaporized working fluid moves, wherein the space is formed by a first concave portion provided in the first inner surface and a second concave portion provided in the second inner surface, and wherein the space is configured to communicate with a flow channel formed by the first bottomed hole, the second bottomed hole, the first fine pore, the first groove portion and the second groove portion of the porous body.

8. The loop-type heat pipe according to claim 7, wherein the first concave portion is deeper than the first bottomed hole, and wherein the second concave portion is deeper than the second bottomed hole.