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(54) **HEAT PIPE MADE OF COMPOSITE MATERIAL AND METHOD OF MANUFACTURING THE SAME**

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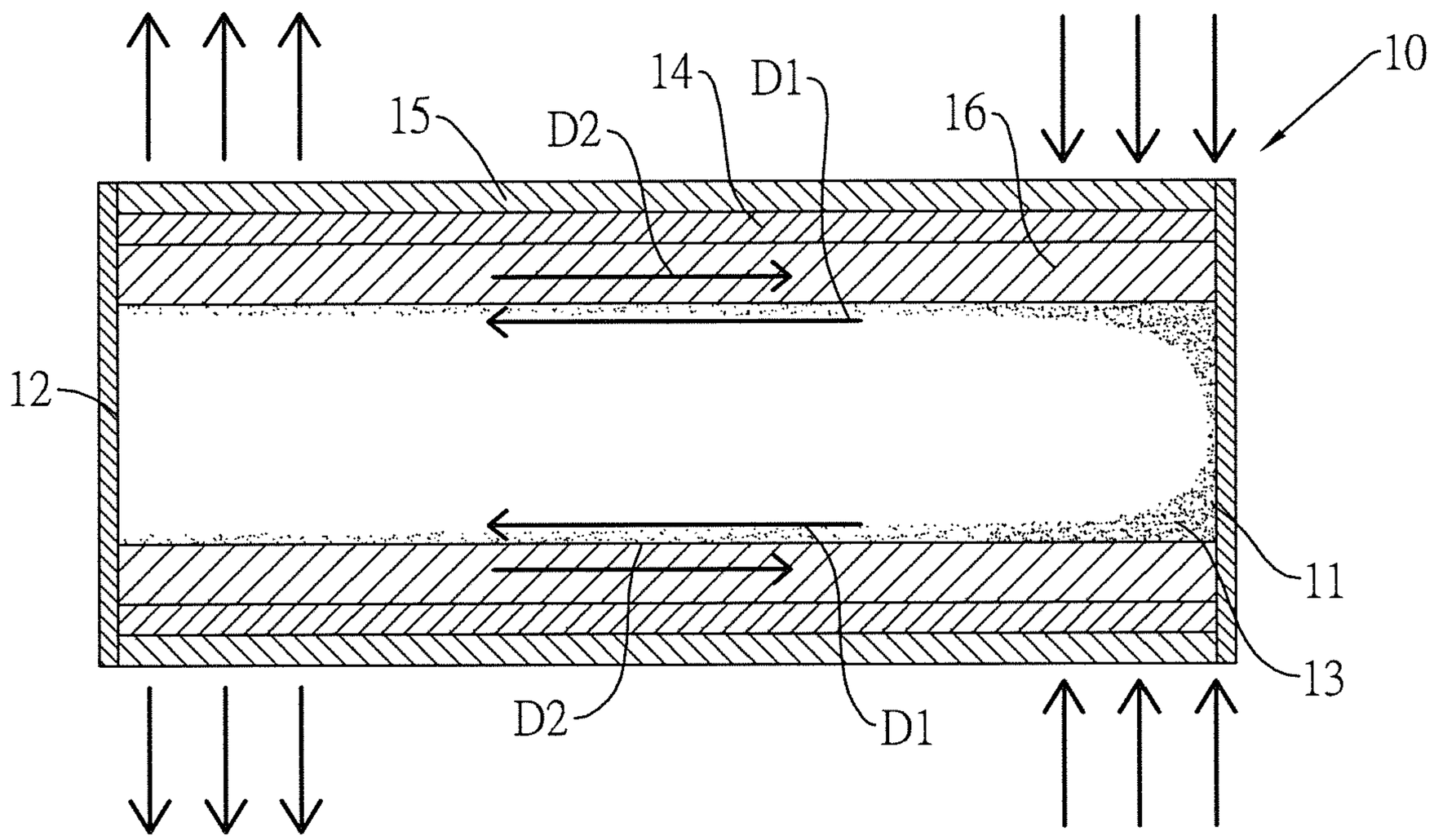
(57) **ABSTRACT**

The heat pipe made of composite material is a sealed hollow tube being a multilayer structure made of a composite material including copper and aluminum, is filled with water and has an inner surface, an evaporator end, a condenser end and a wick. The wick is attached to the inner surface of the tube. The invention provides a cost effective and lightweight heat pipe as it uses aluminum, which is cheap and light in weight. Also, the invention provides a high performance heat pipe system as it uses copper, which is highly thermally conductive. Therefore, the heat pipe is desirable for thermal management applications in a variety of products.



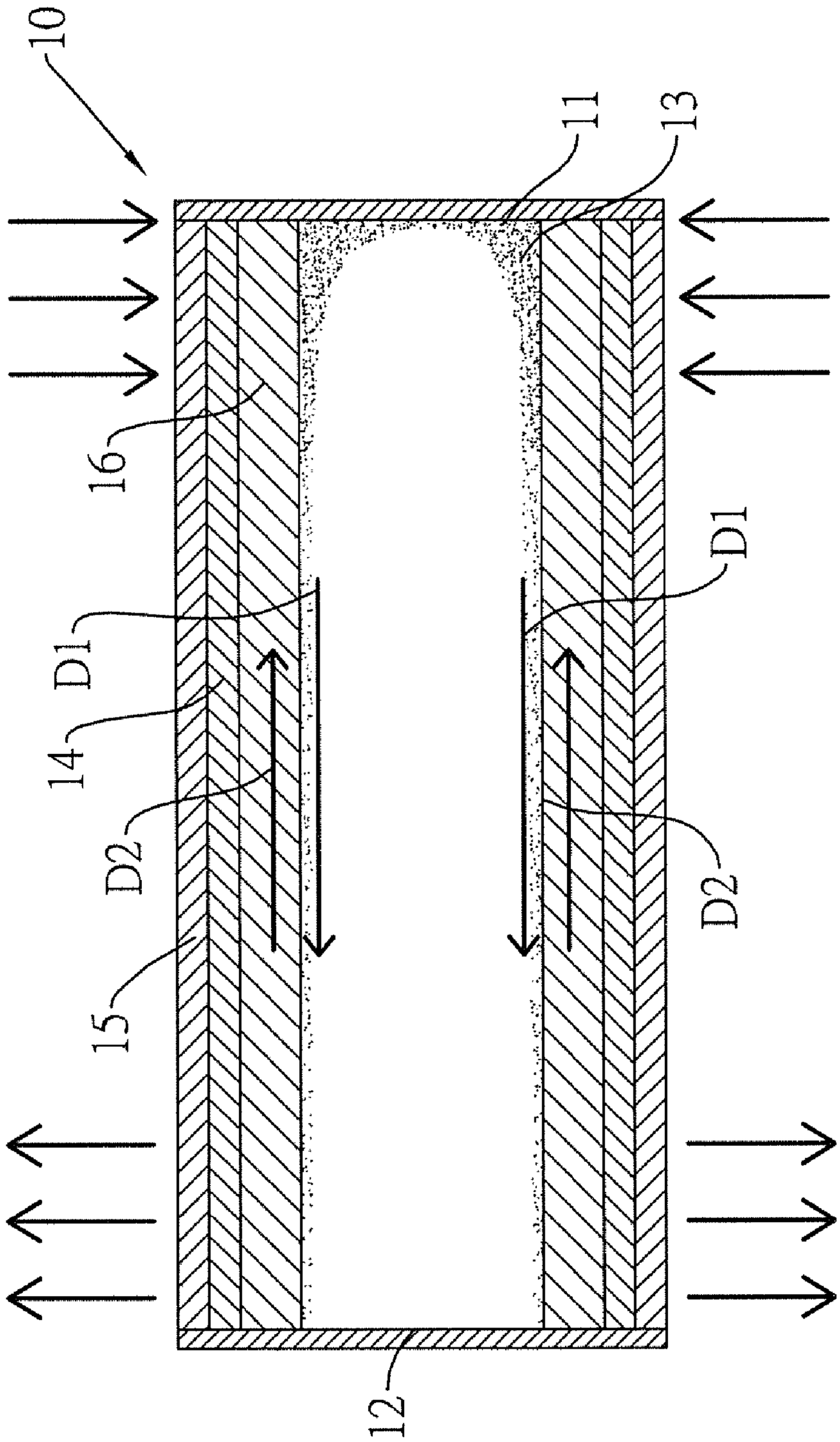



FIG. 1

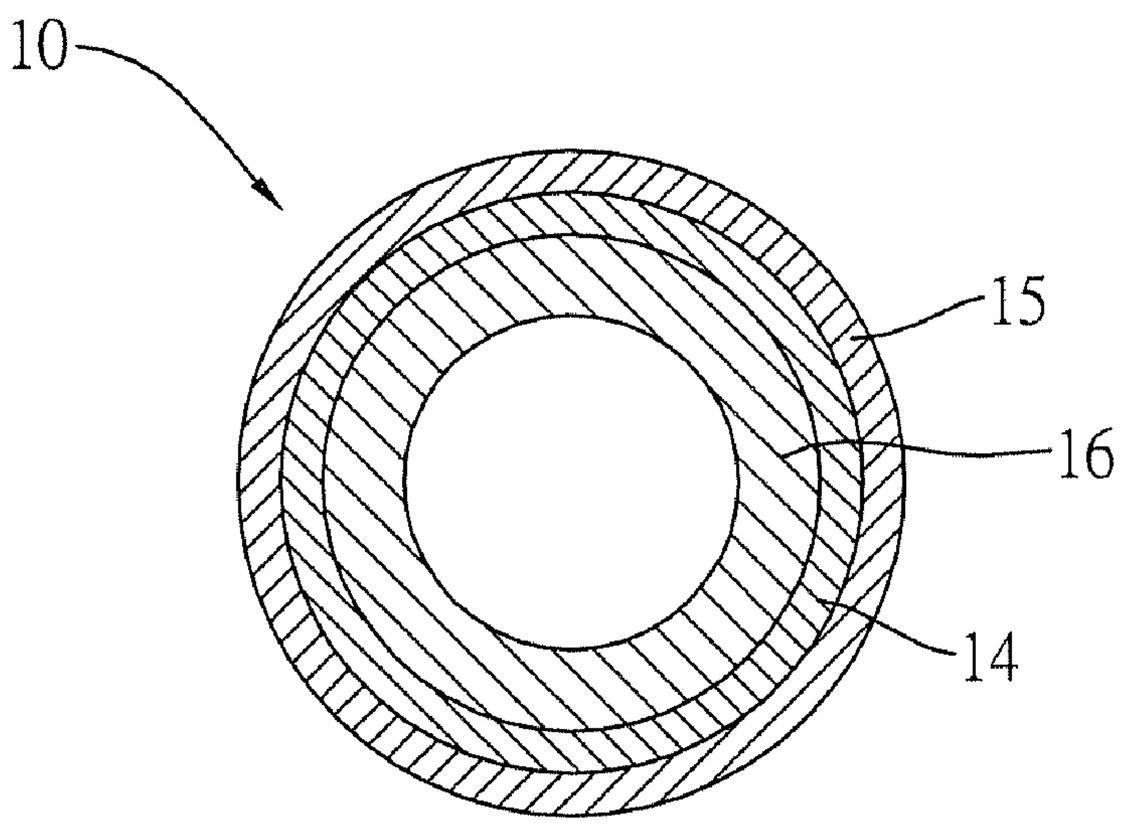



FIG. 2

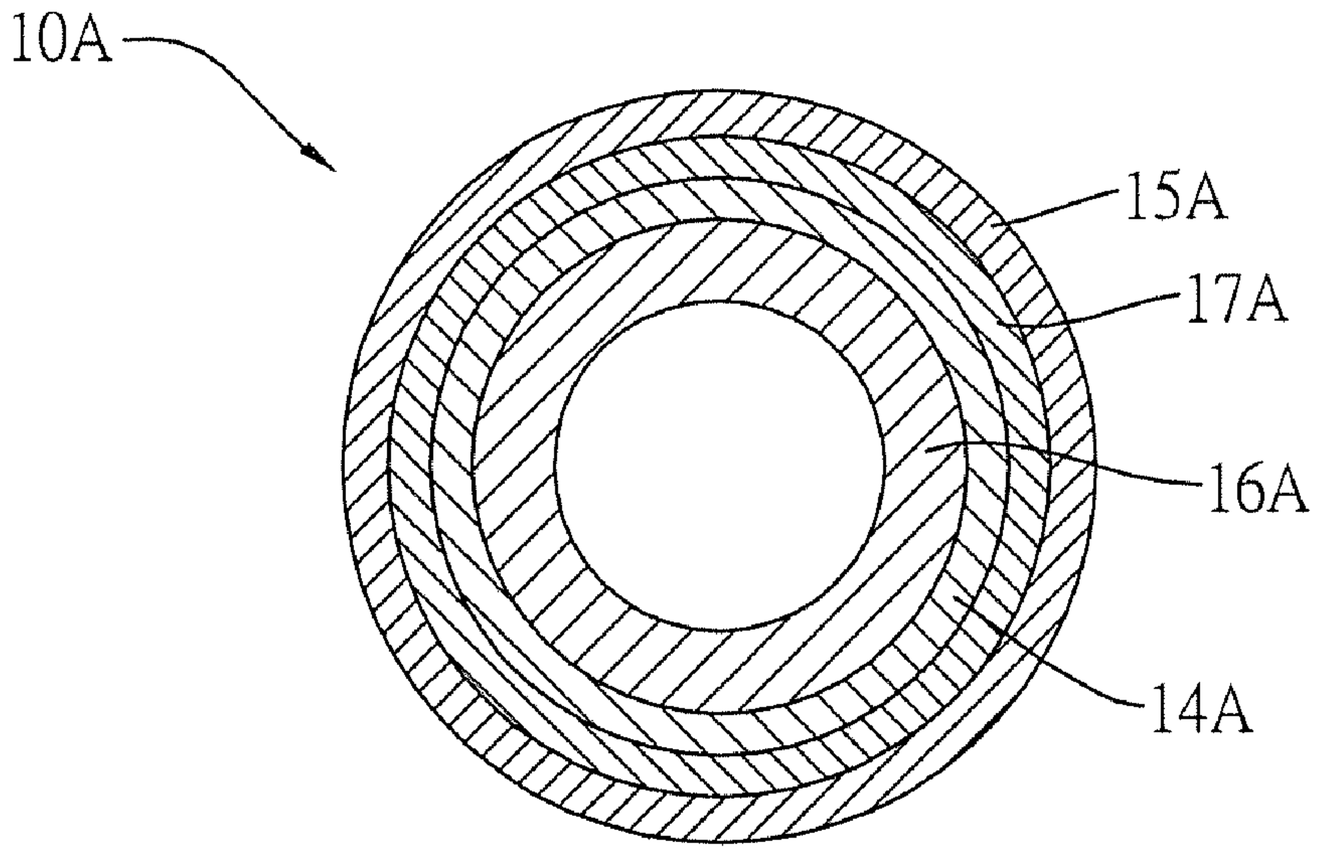



FIG. 3

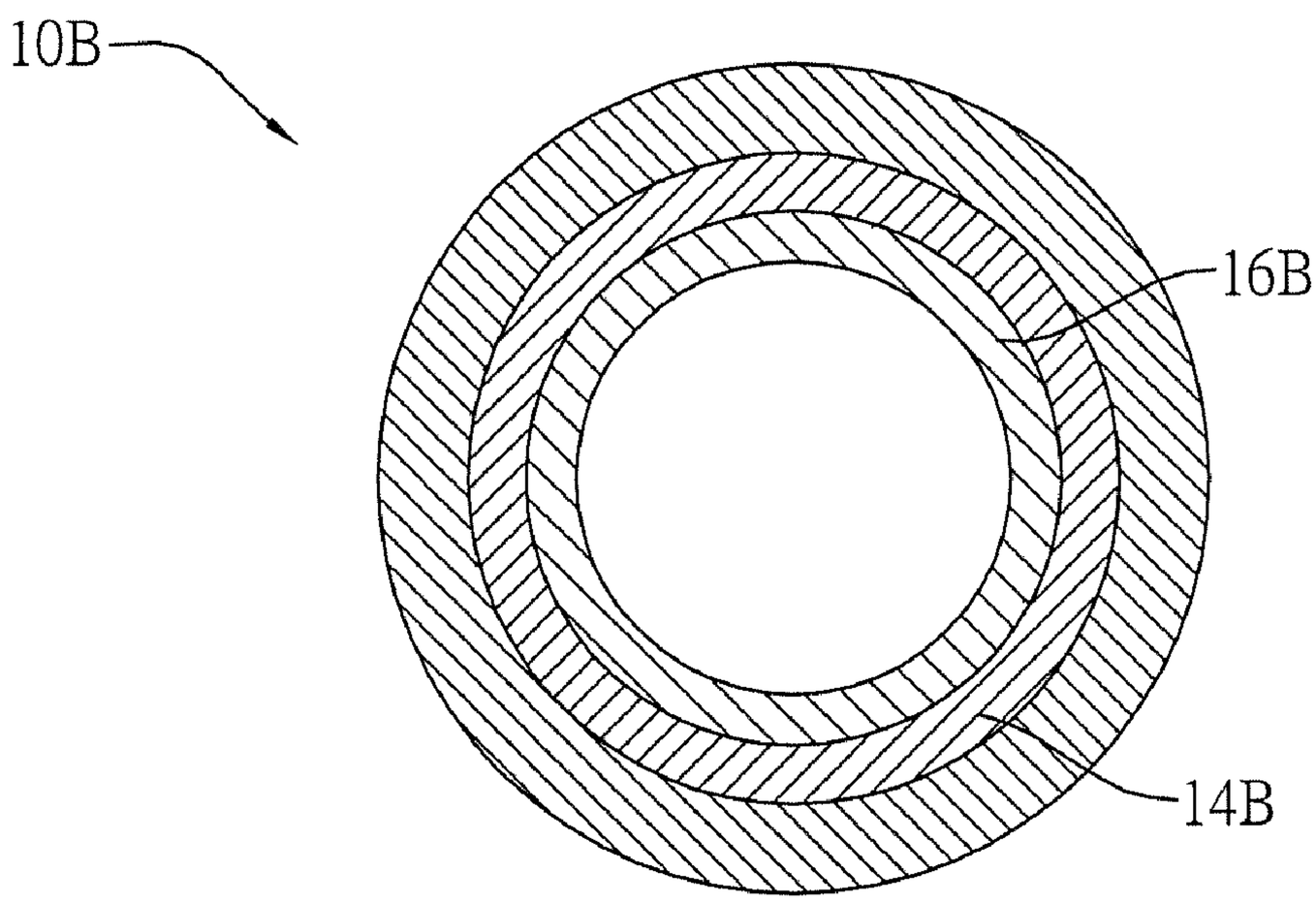



FIG. 4

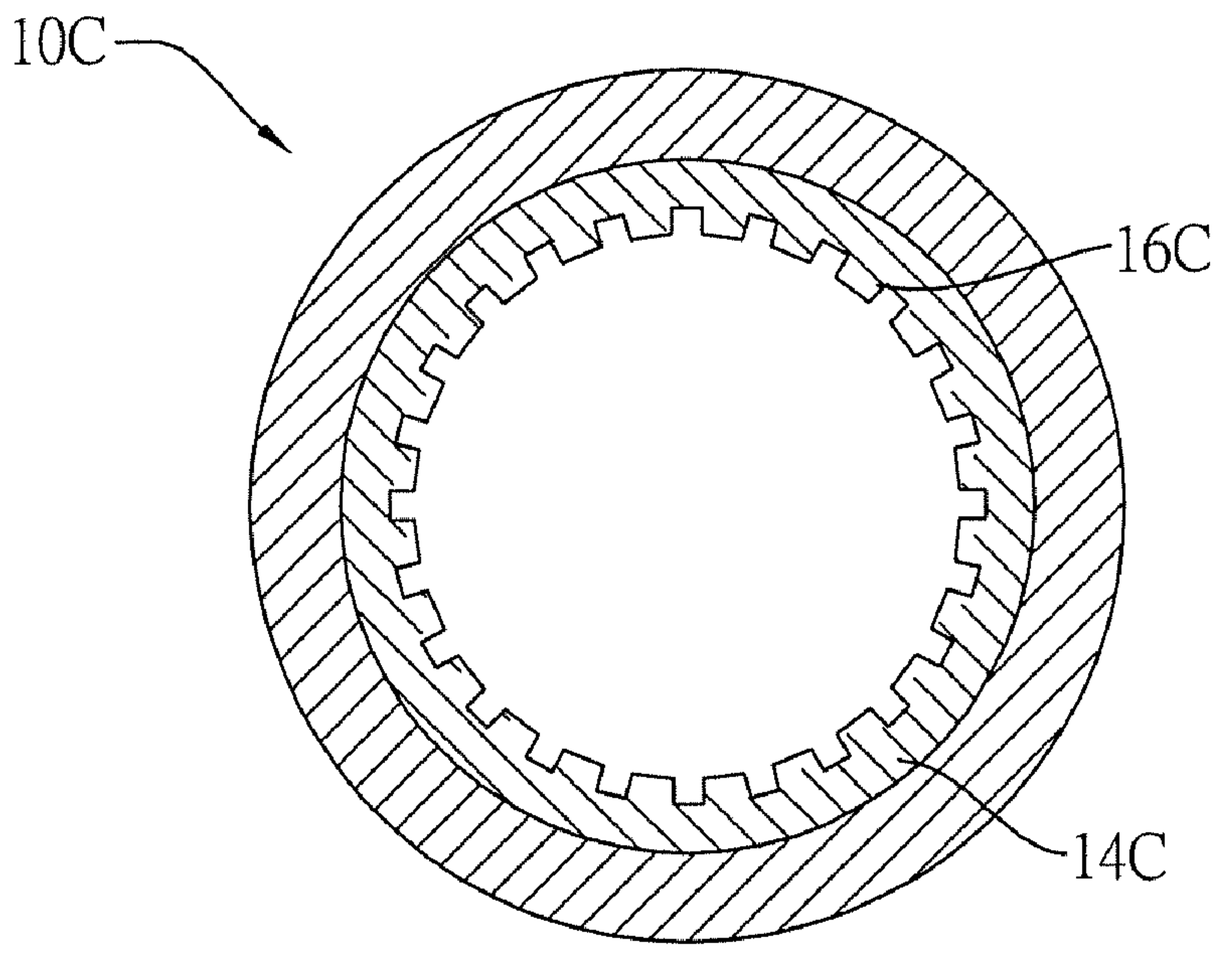



FIG. 5

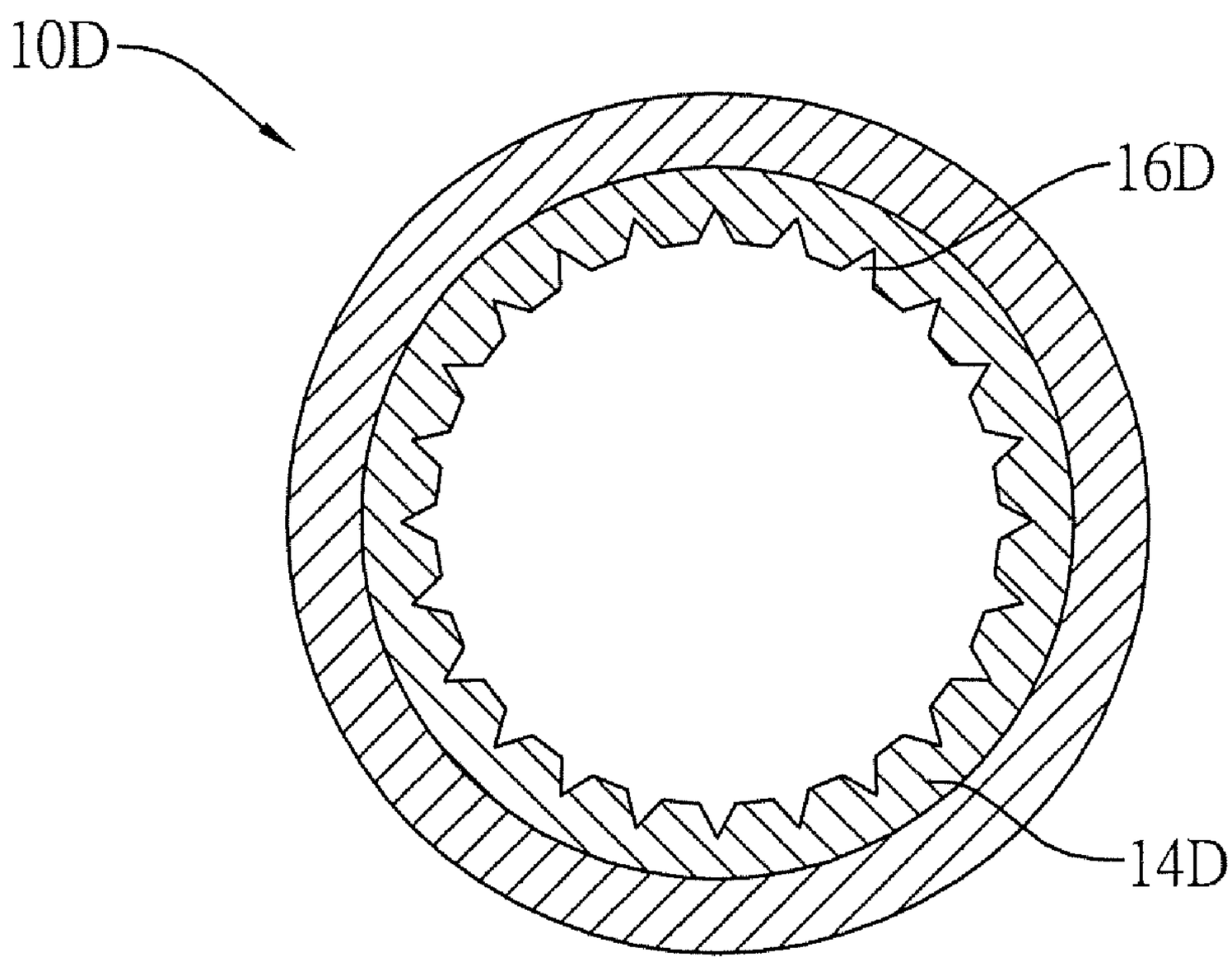



FIG. 6

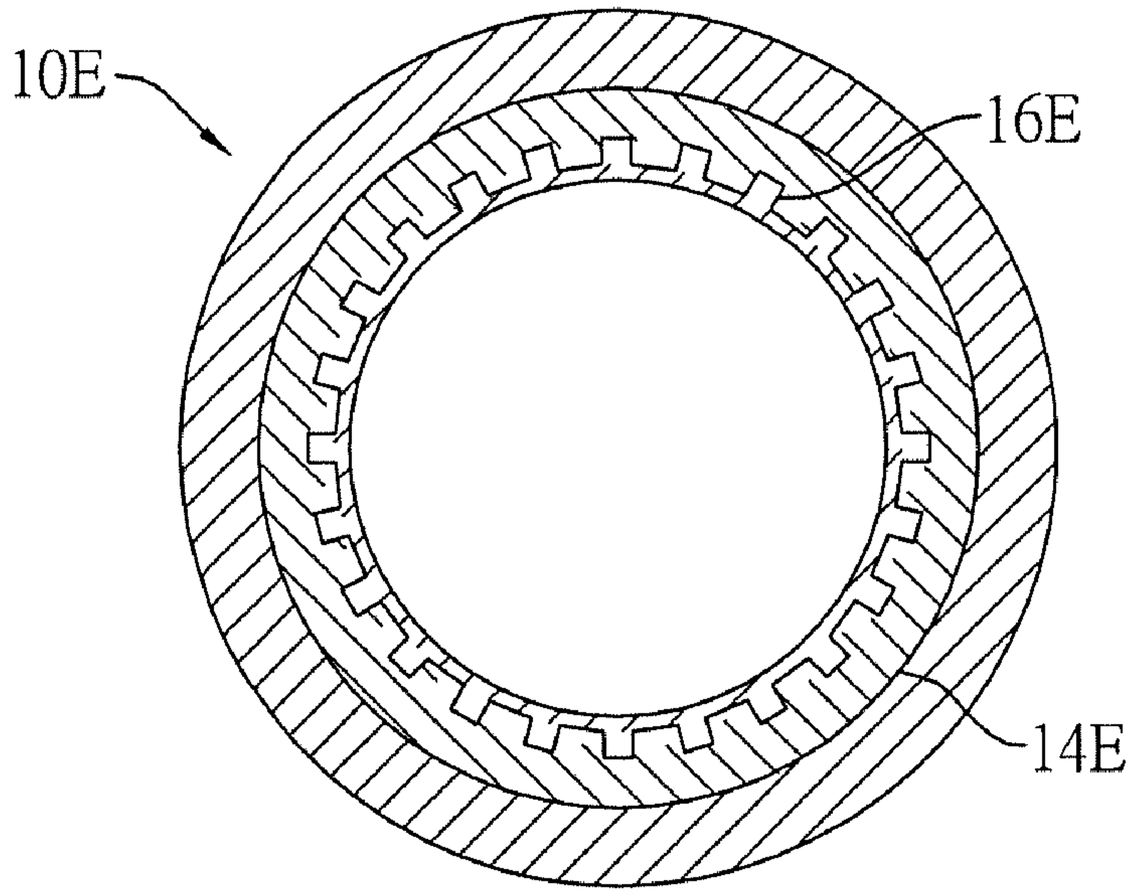



FIG. 7

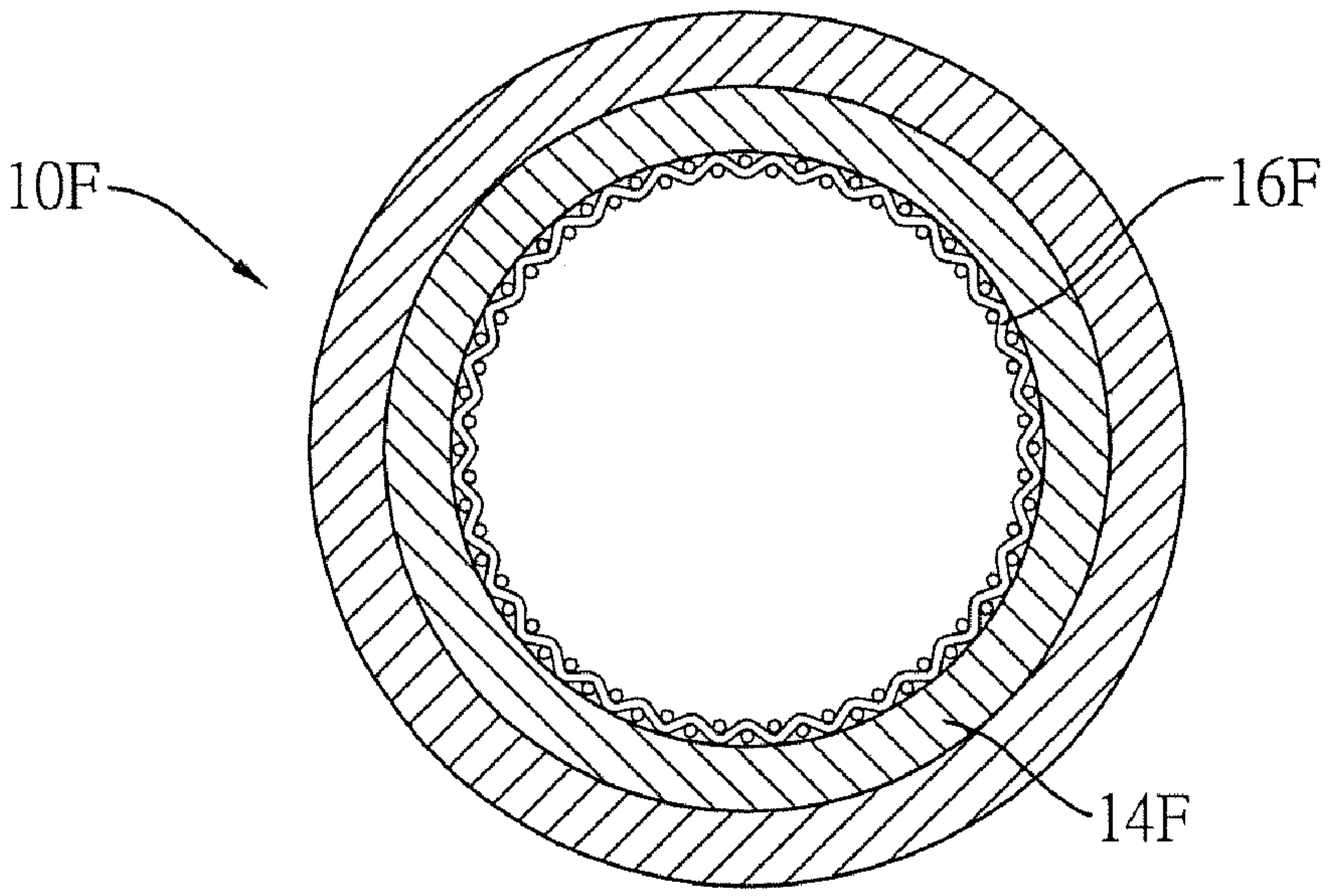



FIG. 8

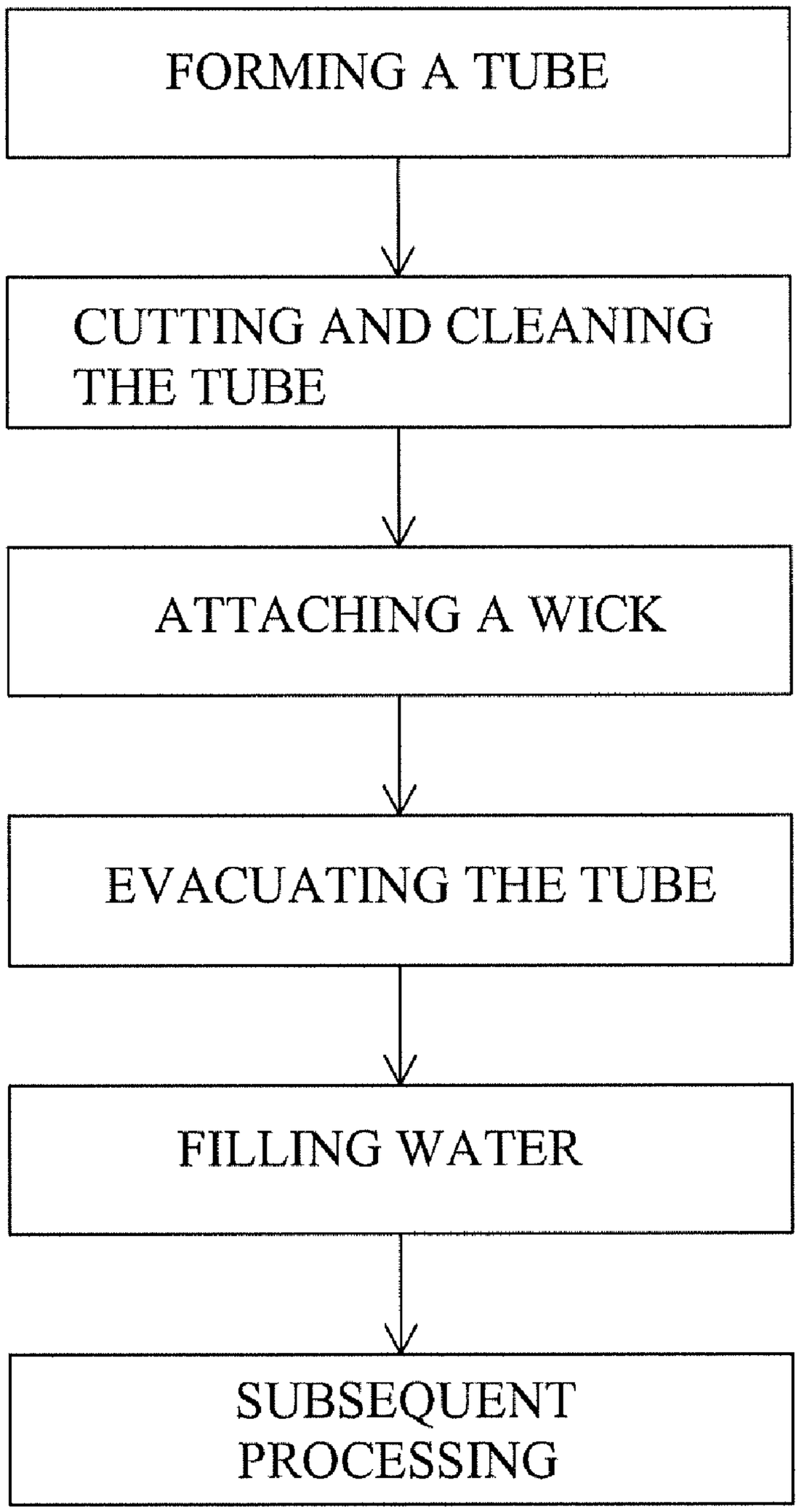

FORMING A TUBE
CUTTING AND CLEANING THE TUBE
ATTACHING A WICK
EVACUATING THE TUBE
FILLING WATER
SUBSEQUENT PROCESSING

FIG. 9

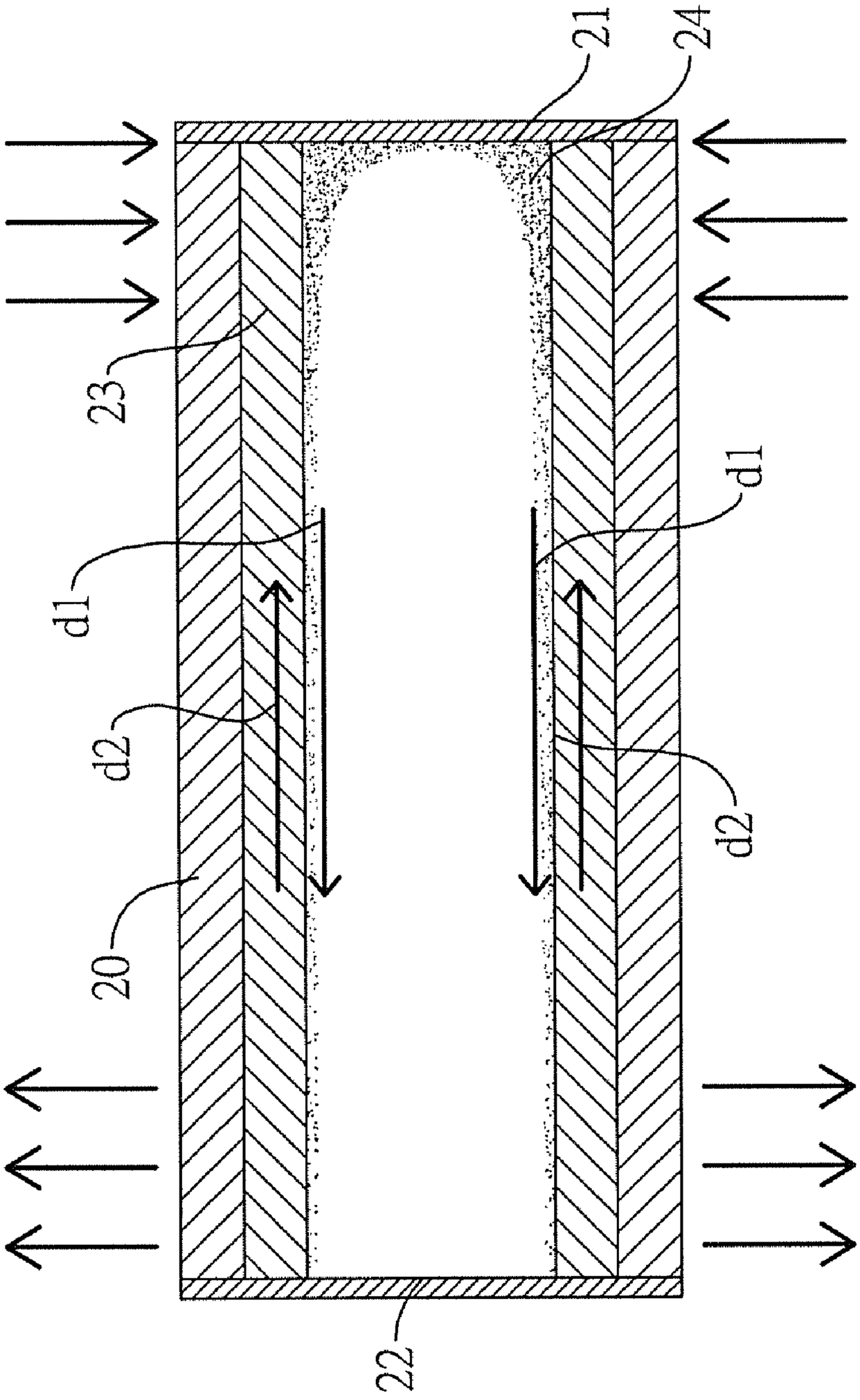



FIG. 10
PRIOR ART

# HEAT PIPE MADE OF COMPOSITE MATERIAL AND METHOD OF MANUFACTURING THE SAME

## BACKGROUND OF THE INVENTION

**[0001]** 1. Field of the Invention

**[0002]** The present invention relates to a heat pipe, and more particularly to a heat pipe made of copper and aluminum for high performance and less weight and manufacturing cost.

**[0003]** 2. Description of the Prior Arts

**[0004]** Heat pipes provide very high conductivity for transmitting heat and are used in thermal management applications in a variety of systems and products. With reference to FIG. **10**, a conventional heat pipe is a sealed hollow tube **20**, is filled with water **24**, is evacuated to lower an evaporation temperature of the water **24** and has an inner surface, an evaporator end **21**, a condenser end **22** and a wick **23**. The wick **23** is attached to the inner surface of the tube **20**.

**[0005]** The heat pipe works on a principle of evaporative cooling of the water **24**. The evaporator end **21** absorbs heat from a heat source and transfers the heat to the water **24**. The water **24** absorbs the heat and evaporates to form vapor. The vapor flows to the condenser end **22** in a direction of arrows d**1**, dissipates the heat to cooling components (e.g. fins) and then condenses to form droplets. The condensed water **24** flows back to the evaporator end **21** in a direction of arrows d**2** due to capillary force exerted by the wick **23**. Thereby, the water **24** is circulated in the tube **20** and transfers heat from the evaporator end **21** to the condenser end **22**.

**[0006]** One kind of the conventional heat pipe is made of a high thermal conductivity material such as copper. However, copper has a density of 8.92 grams per cubic centimeter and that results in a relatively heavy weight of the heat pipe. Besides, copper is an expensive metal and thus results in a high cost of the heat pipe. Another kind of the conventional heat pipe is made of a lighter and less costly material such as aluminum. However, aluminum gets corroded when it comes in contact with water over time. Further, aluminum and water react to generate hydrogen gas which gets accumulated inside the heat pipe as a non-condensable gas. This results in a significant loss in performance of the heat pipe. Accordingly, heat pipes with both less weight and manufacturing cost and high performance are needed.

**[0007]** To overcome the shortcomings, the present invention provides a heat pipe made of composite material to mitigate or obviate the aforementioned problems.

## SUMMARY OF THE INVENTION

**[0008]** The main object of the present invention is to provide a heat pipe made of copper and aluminum for high performance and less weight and manufacturing cost.

**[0009]** To achieve the foregoing objective, the heat pipe made of composite material in accordance with the present invention is a sealed hollow tube being a multilayer structure made of a composite material including copper and aluminum, is filled with water and has an inner surface, an evaporator end, a condenser end and a wick. The wick is attached to the inner surface of the tube. The invention provides a cost effective and lightweight heat pipe as it uses aluminum, which is cheap and light in weight. Also, the invention provides a high performance heat pipe system as it uses copper, which is highly thermally conductive. Therefore, the heat pipe is desirable for thermal management applications in a variety of products.

**[0010]** Other objectives, advantages and novel features of the invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** FIG. **1** is a side view in partial section of a first embodiment of a heat pipe made of composite material in accordance with the present invention;

**[0012]** FIG. **2** is a cross sectional front view of the heat pipe made of composite material in FIG. **1**;

**[0013]** FIG. **3** is a cross sectional front view of a second embodiment of a heat pipe made of composite material in accordance with the present invention;

**[0014]** FIG. **4** is a cross sectional front view of a third embodiment of a heat pipe made of composite material in accordance with the present invention;

**[0015]** FIG. **5** is a cross sectional front view of a fourth embodiment of a heat pipe made of composite material in accordance with the present invention;

**[0016]** FIG. **6** is a cross sectional front view of a fifth embodiment of a heat pipe made of composite material in accordance with the present invention;

**[0017]** FIG. **7** is a cross sectional front view of a sixth embodiment of a heat pipe made of composite material in accordance with the present invention;

**[0018]** FIG. **8** is a cross sectional front view of a seventh embodiment of a heat pipe made of composite material in accordance with the present invention;

**[0019]** FIG. **9** is a flow diagram of a method of manufacturing a heat pipe made of composite material in accordance with the present invention; and

**[0020]** FIG. **10** is a side view in partial section of a conventional heat pipe in accordance with the prior art.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0021]** With reference to FIGS. **1** and **2**, a heat pipe made of composite material in accordance with the present invention is a sealed hollow tube **10** being a multilayer structure made of a composite material, is filled with water **13**, is evacuated to lower an evaporation temperature of the water **13** and has an inner surface, an evaporator end **11**, a condenser end **12** and a wick **16**. The composite material includes a high thermal conductivity material such as copper and a lighter and less costly material such as aluminum. The wick **16** is attached to the inner surface of the tube **10**.

**[0022]** In a first embodiment, the tube **10** comprises an inner layer **14** and an outer layer **15**. The inner layer **14** is made of copper. The outer layer **15** is made of aluminum and is clad around the inner layer **14** using a method such as diffusion bonding or press fitting. The wick **16** is attached to an inner surface of the inner layer **14**.

**[0023]** With reference to FIG. **3**, in a second embodiment, the tube **10**A comprises an inner layer **14**A, a mid layer **17**A and an outer layer **15**A. The inner layer **14** is made of copper. The mid layer **17**A is made of aluminum and is clad around the inner layer **14**A using a method such as diffusion bonding or press fitting. The outer layer **15**A is made of copper and is clad around the mid layer **17**A using a method such as diffu-

sion bonding or press fitting. The wick **16**A is attached to an inner surface of the inner layer **14**A.

**[0024]** The wick **16** may be a screen mesh wick, a groove wick or a fiber wick. FIGS. **4** to **8** show various embodiments of the wick **16**. With reference to FIG. **4**, the wick **16**B is a screen mesh wick and has a mesh structure mounted around the inner surface of the inner layer **14**B. With reference to FIG. **5**, the wick **16**C is a groove wick and has multiple axial grooves. The grooves of the wick **16**C are formed around the inner surface of the inner layer **14**C and are rectangular in cross section. With reference to FIG. **6**, the wick **16**D is a groove wick and has multiple axial grooves. The grooves of the wick **16**D are formed around the inner surface of the inner layer **14**D and are triangular in cross section. With reference to FIG. **7**, the wick **16**E is both a screen mesh wick and a groove wick and has multiple axial grooves and a mesh structure. With reference to FIG. **8**, the wick **16**F is a fiber wick and has a fiber wick structure mounted around the inner surface of the inner layer **14**F.

**[0025]** With reference to FIG. **1**, when the heat pipe is in operation, the evaporator end **11** contacts a heat source and the condenser end **12** contacts cooling components. The water **13** absorbs heat at the evaporator end **11** and gets evaporated to form vapor. The vapor flows to the condenser end **12** in a direction of arrows D**1**, dissipates the heat to the cooling components and then condenses to form droplets. The condensed water **13** flows back to the evaporator end **11** in a direction of arrows D**2** due to capillary force exerted by the wick **16**. In this manner, the heat transfer effect is achieved.

**[0026]** The present invention provides a high performance, cost effective and lightweight heat pipe as it uses both copper and aluminum. Therefore, the heat pipe is desirable for thermal management applications in a variety of electronics products such as notebook computers, desktop computers, servers, LEDs, etc.

**[0027]** With reference to FIG. **9**, a method of manufacturing a heat pipe made of composite material in accordance with the present invention comprising:

**[0028]** Step 1. Forming a tube: an outer layer is clad around an inner layer using a method such as diffusion bonding or press fitting to form a tube with a multilayer structure.

**[0029]** Step 2. Cutting and cleaning the tube: the tube is cut to a desirable length and is cleaned.

**[0030]** Step 3. Attaching a wick: a wick is attached to an inner surface of the inner layer to provide capillary force and one end of the tube is sealed thereafter.

**[0031]** Step 4. Evacuating the tube: the tube is evacuated.

**[0032]** Step 5. Filling water: water is filled into the tube and the other end of the tube is sealed thereafter.

**[0033]** Step 6. Subsequent processing: the tube is flattened to have a rectangular cross-section or the tube is bended to form a desirable shape corresponding to a product that needs to be cooled.

**[0034]** Even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and features of the invention, the disclosure is illustrative only. Changes may be made in the details, especially in matters of shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

What is claimed is:

**1**. A heat pipe made of composite material being a sealed hollow tube being a multilayer structure made of a composite material including copper and aluminum, evacuated, filled with water and having an inner surface, an evaporator end, a condenser end, and a wick attached to the inner surface of the tube.

**2**. The heat pipe made of composite material as claimed in claim **1**, wherein the tube has

an inner layer made of copper; and

an outer layer made of aluminum and clad around the inner layer.

**3**. The heat pipe made of composite material as claimed in claim **2**, wherein the outer layer is diffusion bonded to the inner layer.

**4**. The heat pipe made of composite material as claimed in claim **2**, wherein the outer layer is press-fitted to the inner layer.

**5**. The heat pipe made of composite material as claimed in claim **1**, wherein the tube has

an inner layer made of copper;

a mid layer made of aluminum and clad around the inner layer; and

an outer layer made of copper and clad around the mid layer.

**6**. The heat pipe made of composite material as claimed in claim **5**, wherein the mid layer is diffusion bonded to the inner layer and the outer layer is diffusion bonded to the mid layer.

**7**. The heat pipe made of composite material as claimed in claim **5**, wherein the mid layer is press-fitted to the inner layer and the outer layer is press-fitted to the mid layer.

**8**. The heat pipe made of composite material as claimed in claim **1**, wherein the wick is a screen mesh wick and has a mesh structure mounted around the inner surface of the tube.

**9**. The heat pipe made of composite material as claimed in claim **1**, wherein the wick is a groove wick and has multiple axial grooves formed around the inner surface of the tube.

**10**. The heat pipe made of composite material as claimed in claim **9**, wherein the grooves of the wick are rectangular in cross section.

**11**. The heat pipe made of composite material as claimed in claim **9**, wherein the grooves of the wick are triangular in cross section.

**12**. The heat pipe made of composite material as claimed in claim **1**, wherein the wick is both a screen mesh wick and a groove wick and has multiple axial grooves and a mesh structure.

**13**. The heat pipe made of composite material as claimed in claim **1**, wherein the wick is a fiber wick and has a fiber wick structure mounted around the inner surface of the tube.

**14**. A method of manufacturing a heat pipe made of composite material comprising:

a tube forming step, wherein an outer layer is clad around an inner layer to form a tube with a multilayer structure;

a wick attaching step, wherein a wick is attached to an inner surface of the inner layer and one end of the tube is sealed thereafter; and

water filling step, wherein water is filled into the tube and the other end of the tube is sealed thereafter.

**15**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14**, wherein the outer layer is clad around the inner layer by diffusion bonding.

**16**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14**, wherein the outer layer is clad around the inner layer by press fitting.

**17**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14** further comprising a step of cutting the tube to a desirable length after the tube forming step.

**18**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14** further comprising a step of cleaning the tube after the tube forming step.

**19**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14** further comprising a step of evacuating the tube after the wick attaching step.

**20**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14** further comprising a subsequent processing of flattening the tube after the water filling step.

**21**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14** further comprising a subsequent processing of bending the tube after the water filling step.

**22**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14**, wherein the wick is a screen mesh wick and has a mesh structure mounted around the inner surface of the tube.

**23**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14**, wherein the wick is a groove wick and has multiple axial grooves formed around the inner surface of the tube.

**24**. The method of manufacturing a heat pipe made of composite material as claimed in claim **23**, wherein the grooves of the wick are rectangular in cross section.

**25**. The method of manufacturing a heat pipe made of composite material as claimed in claim **23**, wherein the grooves of the wick are triangular in cross section.

**26**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14**, wherein the wick is both a screen mesh wick and a groove wick and has multiple axial grooves and a mesh structure.

**27**. The method of manufacturing a heat pipe made of composite material as claimed in claim **14**, wherein the wick is a fiber wick and has a fiber wick structure mounted around the inner surface of the tube.

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