US 20030141045 A1

Heat pipe and method of manufacturing the same

Abstract

Disclosed is a heat pipe comprising: an evaporating section, a heat insulating section, a condensing section and a porous sintered powder wick structure, in which the wick structure comprises sub-structures different from one another in at least one selected from group including material, shape and particle size, each of the sub-structures being arranged into each of the evaporating, heat insulating and condensing sections, in which the wick structure has a biporous distribution made through sintering of a powder mixture having various particle sizes to increase porosity and permeability of the wick structure, and in which the heat pipe has an asymmetric cross sectional shape in a radial direction. Powder having a large particle size is readily inserted into the heat pipe to simplify manufacture of the heat pipe while thermal conductivity of the heat pipe is not degraded compared to a conventional structure which is not eccentric.

Images(9)

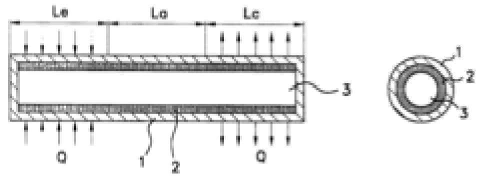

FIG. 1

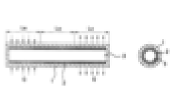

FIG. 3

FIG. 5

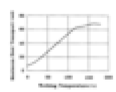

FIG. 7

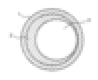

FIG. 2

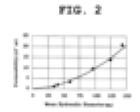

FIG. 4

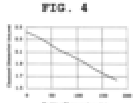

FIG. 6

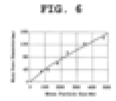

FIG. 8

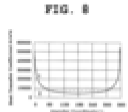

FIG. 9

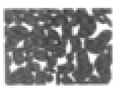

FIG. 11

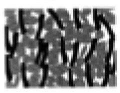

FIG. 13

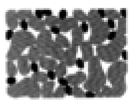

FIG. 15

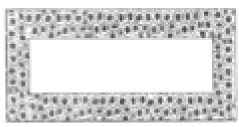

FIG. 10

FIG. 12

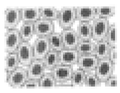

FIG. 14

Claims

What is claimed is:

1. A wick structure composed of a porous sintered powder wick and arranged into a heat pipe which has functional sections including an evaporating section, a heat insulating section and a condensing section, the wick structure comprising:

a method disposing sub-structures different from one another in at least one selected from group including material, shape and particle size, each of the sub-structures being arranged into each of the evaporating, heat insulating and condensing sections, in order to elevate thermal conductivity, amount of heat transport and temperature-controlling performance of the heat pipe.

2. The method in accordance with claim 1, further comprising adding an additive such as $Co(NH_2)_2$ inputted into sintering powder to generate a gas through thermal decomposition of the additive during sintering of a wick to increase porosity and permeability of the wick structure.

3. The method in accordance with claim 1, further comprising an arrangement of a biporous distribution in a radial direction of the heat pipe asymmetrically through sintering of a powder mixture having various particle sizes, to increase porosity and permeability of the wick structure.

4. The method in accordance with claim 1, further comprising manufacturing porous sintered powder wick composed of a powder mixture which contains materials including copper, nickel, graphite, carbon and diamond, each of the materials having shape and thermal conductivity different from one another, to improve a heat transfer ability of the heat pipe in a radial direction.

5. The method in accordance with claim 1, further comprising an absorptive coating applied to the surface of the wick structure or particles constituting the wick structure to increase an ability of the wick structure absorbing a working fluid.

6. The method in accordance with one of claim 1 to **5**, further comprising an absorptive coating for increasing an ability of the wick structure for absorbing a working fluid, the absorptive coating is made of one selected from group including hydrates, hydroxides, carbonates and LiBr.

7. The method in accordance with one of claim 1 to **5**, wherein the wick structure and a coating applied to the wick structure are planar or cylindrical.
8. The method in accordance with one of claim 1 to **5**, further comprising an absorptive coating applied to the surface of the wick sub-structure of the evaporating section of the heat pipe or particles constituting the wick sub-structure of the evaporating section of the heat pipe.
9. A heat pipe comprising an evaporating section, a heat insulating section, a condensing section and a porous sintered powder wick structure,
wherein the wick structure comprises sub-structures different from one another in at least one selected from group including material, shape and particle size, each of the sub-structures being arranged into each of the evaporating, heat insulating and condensing sections,
wherein the wick structure has a biporous distribution made through sintering of a powder mixture having various particle sizes to increase porosity and permeability of the wick structure, and
wherein the heat pipe has an asymmetric cross sectional shape in a radial direction.
Description

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0055] In order to obtain the foregoing objects, the present invention proposes a heat pipe comprising an evaporating section, a heat insulating section, a condensing section and a porous sintered powder wick structure, in which the wick structure comprises sub-structures different from one another in at least one selected from group including material, shape and particle size, each of the sub-structures being arranged into each of the evaporating, heat insulating and condensing sections, in which the wick structure has a biporous distribution made through sintering of a powder mixture having various particle sizes to increase porosity and permeability of the wick structure, and in which the heat pipe has an asymmetric cross sectional shape in a radial direction.

[0056] Further, the optimum condition for improving performance within the wick will be presented to preferably carry out the invention and a method thereof will be described.

[0057] The application will design and analyze the relation between the capillary head, permeability and pore capacity of a porous medium and the thermal flow of a working fluid in order to improve the performance of the sintered powder wick, and accordingly derive the optimum pore size and the particle size of the metal powder for realizing the optimum pore size. The optimum design policy will be described as follows for the optimum conditions for carrying out wick sintering of each functional component of the heat pipe.

[0058] In other words, although the sintered powder wick advantageously has a capillary pressure larger than that of a grooved wick or mesh screen wick and a thermal conductivity higher than that of the mesh screen wick thereby showing a relatively large heat flux, it is necessary to optimize working parameters of the wick in order to design a heat pipe with excellent performance by utilizing those advantages while compensating disadvantages such as a lower permeability.

[0059] Examples of pore parameters for constructing the optimized porous wick may include the size and shape of particles, the specific volume, pore diameter and porosity of the porous wick, which cooperate with one another to influence the design of the heat pipe.

[0060] The present invention represents that the permeability k in Equation 6, which is an important design parameter of the heat pipe, can be experimentally obtained according to Equation 8:

$k=0.00144 d_0^{179}$ Equation 8,

[0061] wherein d_0 indicates mean hydraulic diameter.

[0062] Other thermal fluid parameters can be obtained through experiments as follows.

[0063] The capillary pressure can be obtained through a test of a porous medium specimen of an equivalent pore diameter.

[0064] The liquid hydraulic head can be obtained through measurement in the wick.

[0065] The permeability can be obtained through the liquid hydraulic head measurement and the Darcy's Law.

[0066] The heat flux can be obtained by evaluating mass flux in an evaporating process through calculation of two-phase pressure loss.

[0067] The wick porosity can be obtained through measurement/evaluation of the thermal conductivity of the wick saturated with liquid.

[0068] The heat flux determining the amount of heat transport of the heat pipe mainly depends on conditions for applying the heat pipe as follows. Examples of the conditions may include the distance between the evaporating section and the condensing section, superheating of a wall of the heat pipe, subcooling of a working fluid, a thermal contact status between a heat source and the wick.

[0069] As described above, working parameters of a specific heat pipe can be designed on the basis of the working parameters of the wick and information about the conditions for applying the heat pipe.

[0070] For example, when a cylindrical MHP has a length l, an outer diameter D_p of 4 mm, an inner diameter or vapor channel diameter D_{ch} of 2 mm and a sintered wick cross section of S, in which the length of an evaporating section is l_e, the length of a heat insulating section is l_t, and the length of a condensing section is l_c, the maximum heat transport Q_{max} can be obtained according to Equation 7.

[0071] Although the amount of heat transport Q of the invention mainly depends on the vapor channel diameter D_{ch} in a vapor channel of the actual heat pipe and the mean hydraulic pore diameter in a liquid channel, the maximum heat transport Q_{max} is varied according to a temperature in the heat insulating section of the heat pipe T_{sat} (or working temperature) due to temperature dependency of thermal-physical characteristics of the working fluid. Further, Q_{max} is varied by a large amount in respect to the inclination angle of the heat pipe installed about the gravitational field.

[0072] In general, on the basis of horizontal installation ($\Phi=0°$), Φ is expressed—when the evaporating section is arranged over the condensing section but+ when the former is arranged under the latter. When Φ is −90°, Q_{max} is restricted by the largest amount from gravitational resistance.

[0073] Based upon the foregoing principles, design/analysis results about main design parameters of a sintered copper powder wick about the MHP can be expressed as in FIGS. **2** to **6**.

[0074] From the relation between the mean hydraulic pore diameter and the permeability in FIG. 2, it can be seen that the permeability increases due to increase in the pore size of the wick. However, since the capillary pressure decreases due to increase in the pore size, the invention employs a wick structure using a metal powder having a biporous distribution or different particle shapes or mixed with fiber in order to prevent degradation of the capillary head. By using the method as above, reduction of the capillary pressure can be minimized while the permeability of the wick is enlarged.

[0075]FIG. 3 is a graph illustrating the optimum size of the wick pores in respect to the working temperatures of the heat pipe for a fixed amount of heat transport thereof. It can be understood that the optimum pore size is 100 to 160 μm from FIG. 3.

[0076]FIG. 4 is a graph illustrating the relation between the vapor channel diameters D_{ch} and the working temperatures, and FIG. 5 is a graph illustrating the relation between the maximum amounts of heat transport Q_{max} and the working temperatures.

[0077]FIG. 6 is a graph illustrating that the wick pores sized as above can be made through sintering of copper powder having particle sizes of 300 to 500 μm. However, copper powder having such a large particle size can be hardly filled between a copper envelope or container having an outer diameter of 4 mm and an iron core having an outer diameter of 2 mm installed in the center of the copper envelope in manufacture of the heat pipe. Therefore, it has been difficult to optimize the pores in the porous sintered powder wick applied to the MHP in the related art.

[0078] Therefore, the invention proposes the first method for realizing the optimum hydraulic diameter of the wick pore, in which the iron core is asymmetrically installed from the radial center of the hollow copper pipe and copper powder filled therebetween undergoes sintering. In particular, the radial cross section is provided asymmetric, as shown in FIG. 7, to optimize the wick pore.

[0079]FIG. 8 is a graph illustrating thermal conductivities radially measured in the outer diameter surface of the heat pipe having the wick structure as above. As shown in FIG. 8, it can be seen that heat transfer heavily takes place at a portion having a relatively smaller wick thickness. When applied to the heat pipe, this selectively applies a contact surface between the heat source and a heat sink in the evaporating section and the condensing section thereby providing an additional function of raising a heat transfer efficiency.

[0080] As the second method of realizing the optimum hydraulic diameter of the wick pore, the invention proposes a wick having biporous structure which is obtained through sintering of mixed copper powders having different particle sizes.

[0081]FIG. 9 illustrates a biporous structure of main pores.

[0082] As the third method for realizing the optimum hydraulic diameter of the wick pore, the invention proposes a method for adding a liquid or solid additive into particulate copper powder and enlarging the pore size among copper powder particles by using a gas which is generated when the additive undergoes thermal reaction or thermal decomposition at a temperature lower than a sintering temperature of copper powder in a sintering process of the wick. The additive for enlarging the permeability of the wick is sufficiently melted and cleared but may reside by a very small amount. Therefore, it is required that the additive does not generate gas through thermal reaction with components of the wick and the working fluid. Examples of the additive satisfying the above characteristic may include $Co(NH_2)_2$. The shape of the wick manufactured according to the above method is shown in FIG. 10.

[0083] As a method for increasing the permeability, the capillary pressure and the heat transfer rate of the heat pipe wick, the invention proposes a wick structure which is manufactured by using a powder mixture made of copper powder and smashed copper (graphite) or cellulose (coconut shells, peach pits and the like) or a powder mixture of copper powder and Polyvinylidene Chloride (PVDC) as a kind of non-cellulose.

[0084]FIG. 11 illustrates a wick structure made of metal powder and carbon fiber. As shown in FIG. 11, various sizes of pores are distributed in the wick thereby improving the capillary pressure and the permeability of the wick while the carbon fiber enhancing the thermal conductivity.

[0085] As a method for reducing a recovery time of the heat pipe from a partial dry out status of the wick due to increase of input heat into the evaporating section of the heat pipe, the invention proposes a method for adding an absorptive or absorbent material into the working fluid for absorbing the same. When the working fluid is water, examples of the material having the above capability may include hydrate such as $MnCl_2$, $NiCl_2$, $CaCl_2$, $BaCl_2$ and LiBr. Such hydrate exists in the form of a water solution of the working fluid such as water at a room temperature until the wick in the evaporating section is heated. When the wick in the evaporating section is heated, the hydrate is separated from the water solution and coated on the particle surface of the evaporating section wick as shown in FIG. 12. Then, the hydrate absorbs water again to assist return or supply of the working fluid into the evaporating section wick. As described above, almost of the hydrate ingredient added into the working fluid is coated on the surface of the evaporating wick thereby to accelerate reflow of the working fluid toward the evaporating section from the condensing section.

[0086]FIG. 12 illustrates a hydrate which is coated on surface particles of the evaporating section wick of the heat pipe having a rectangular cross section. Such an additive accelerates a recovery time of the evaporating section from a dried status due to overheating, thereby to enhance temperature controlling features and working limits of the heat pipe.

[0087] The wick can undergo sintering by using a powder mixture of different metals in order to raise the thermal conductivity of the wick.

[0088]FIG. 13 illustrates a sintered wick structure made of a powder mixture in which copper powder is mixed with crystal powder of nickel, graphite or diamond. In such a wick, the evaporating and condensing sections have thermal conductivities elevated in the radial direction thereby improving the heat exchange performance of the heat pipe.

[0089] Further, in order to maximize the heat transport ability of the heat pipe while maximizing the heat transfer performance thereof with the outside, the invention optimizes the characteristics of the heat pipe by applying a wick having different sub-structures, each of which is adequate to a function of each functional component of the heat pipe. Therefore, the invention applies the first sub-structure for elevating the capillary pressure and the thermal conductivity to the evaporating section, the second sub-structure having a high permeability to the heat insulating section and the third sub-structure for elevating the permeability and thermal conductivity to the condensing section as shown in FIG. 14.

[0090] The above structures can apply the metal powder mixtures having different particle sizes or different kinds such as copper and nickel or carbon fiber to the each functional component of the heat pipe through sintering while utilizing the above characteristics.

[0091] Further, the above wick structures and coats can employ any of planar and cylindrical structures.

[0092]FIG. 15 illustrates a planar wick structure which has a rectangular cross section.

[0093] As described above, the inventive heat pipe has the biporous structure which is optimized to the sintered powder wick so that the maximum heat transport is improved by a large amount. For example, when the inventive structure is applied to a heat pipe having an outer diameter of 4 mm, the heat transport ability is improved for 1.3 times over a conventional sintered powder wick and two times over a conventional grooved wick.

[0094] Further, the maximum heat transport ability and the ability of resisting against gravity are enhanced to increase the difference from conventional products.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040]FIG. 1 illustrates the structure of a heat pipe in the related art;

[0041]FIG. 2 is a graph illustrating the mean hydraulic pore diameter and permeability;

[0042]FIG. 3 is a graph illustrating the optimum size of wick pores in respect to the working temperatures of a heat pipe for a fixed amount of heat transport thereof;

[0043]FIG. 4 is a graph illustrating the relation between vapor channel diameters D_{ch} and working temperatures;

[0044]FIG. 5 is a graph illustrating the relation between the maximum amounts of heat transport Q_{max} and working temperatures;

[0045]FIG. 6 is a graph illustrating the relation between the mean pore size and the wick pore diameter;

[0046]FIG. 7 is a graph illustrating a wick structure having an asymmetric radial cross section;

[0047]FIG. 8 is a graph illustrating thermal conductivities radially measured in the outer diameter surface of the heat pipe having the wick structure of the asymmetric cross section shown in FIG. 7;

[0048]FIG. 9 illustrates a biporous structure of main pores;

[0049]FIG. 10 illustrates a wick structure in which a liquid or solid compound is added into copper powder having fine particle size;

[0050]FIG. 11 illustrates a wick structure made of metal powder and carbon fiber;

[0051]FIG. 12 illustrates a hydrate which is coated on surface particles of an evaporating section wick of a heat pipe having a rectangular cross section;

[0052]FIG. 13 illustrates a sintered wick structure made of a powder mixture in which copper powder is mixed with crystal powder of nickel, graphite or diamond;

[0053]FIG. 14 is a sectional view illustrating a heat pipe having sections with their own wick structures different from one another in length; and

[0054]FIG. 15 illustrates a planar wick structure.

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a heat pipe in use for heat transfer, cooling and heat radiation, and more particularly, to an internal structure of a Miniature Heat Pipe (MHP) and a method of manufacturing the same.

[0003] 2. Description of the Related Art

[0004] Well known to those skilled in the art, a heat pipe functioning to efficiently transfer heat from one place to another is used as a critical part of a heat transporting apparatus. In particular, an MHP can be effectively used for heat transport and thermal diffusion for cooling a high density electronic circuit or an electronic chip.

[0005]FIG. 1 is a sectional view illustrating an internal structure of a heat pipe. As shown in FIG. 1, the heat pipe is constituted of a wall in the outer side thereof, a channel for flowing a working fluid for performing heat transport and a porous wick structure provided between the wall and the channel for regulating the working fluid to continuously perform heat transport.

[0006] Further, the heat pipe is divided into an evaporating section, a heat insulating section and a condensing section in length as shown in FIG. 1.

[0007] The operational principle of the heat pipe is as follows: When the working fluid saturated in the wick in the evaporating section evaporates due to heat from an external heat source, vapor moves toward the condensing section due to the difference of vapor pressure to perform heat transport, and then cools and condenses in the condensing section again to perform heat radiation. In this case, condensed the working fluid is absorbed into the condensing wick and then returns to the condensing section due to the difference of capillary pressure between the condensing and evaporating sections. Such motion and returning processes are so repeated that heat continuously transfers from the evaporating section into the condensing section.

[0008] In general, movement of the working fluid mainly depends on the amount of heat transfer, the capillary pressure of the wick and permeability as resistance against flow of the working fluid in the wick.

[0009] The capillary pressure P_c is determined according to Equation 1:

$$P_c = \frac{4\sigma\cos\theta}{d_0}.$$

[0010] wherein d_0 is mean hydraulic diameter, σ is surface tension coefficient and θ is wetting angle of the wick.

[0011] The capillary pressure has the following relation as in Equation 2:

$P_c = P_v + P_l + P_g$ Equation 2,

[0012] wherein, P_l, P_v and P_g mean pressure loss of liquid channel, pressure loss of vapor channel and gravity resistance, respectively.

[0013] The pressure loss of liquid channel and the pressure loss of vapor channel are expressed, respectively, as in Equations 3 and 4 according to the Darcy's Law and the Equation of Poiselle:

$$P_l = \frac{Q\mu_l l_{ef}}{\rho_l L S \xi d_0^v}.$$

and

$$P_v = \frac{128 Q\mu_v l_{ef}}{\pi D_{ch}^4 \rho_v L}.$$

[0014] Further, the pressure loss due to gravity resistance is expressed as in Equation 5:

$P_g = \rho_l gl$ Equation 5, $\sin \varphi$

[0015] wherein g means gravitational constant.

[0016] Further, permeability k determining the migration resistance of the working fluid in the wick has the following relation with the porosity of the wick as in Equation 6:

$$k = \frac{f(\Pi)}{\beta} D^2.$$

[0017] wherein D means particle diameter.

[0018] Further, the quantity of thermal transport Q_{max} due to flow of thermal fluid is obtained on the following assumption.

[0019] Characteristic parameters of the wick in the heat pipe are uniform, the sintered powder wick is saturated with the working fluid, the evaporating and condensing sections have uniform heat flux, saturated vapor having a temperature T_s moves through a vapor channel, liquid and gas have non-compressive fluid flow expressed with the Navier-Stocks equation, vapor has no heat source or cooling source, liquid flow within the porous wick follows the Darcy's Law, frictional force at the vapor-liquid interface is very small compared to liquid pneumatic resistance within the wick so as to be disregarded, and the working fluid evaporates at the surface of the evaporating section.

[0020] On the basis of the foregoing assumption, the amount of heat transport Q is calculated as in Equation 7:

$$Q = \frac{\pi L}{4 l_{ef}} \frac{\frac{4\sigma\cos\theta}{d_0} - \rho g l \sin\phi}{\frac{\mu_l}{\rho_l (D_p^2 - D_{ch}^2)\xi d_0^v} + \frac{32\mu_v}{D^4 \rho_v}}.$$

[0021] In the meantime, the heat pipe is restricted in the performance thereof by viscous limit, capillary limit, entrain or flooding limit, sonic limit and boiling limit.

[0022] Therefore, design parameters are determined considering the foregoing working limits in designing the heat pipe. The viscous limit and the boiling limit are considered, in particular, in a low temperature heat pipe used at or under 200° C. When the evaporating section of the heat pipe undergoes dry out due to overheating in order to improve working ability at thermal limit conditions of the heat pipe, ability and time of the heat pipe for recovering from the dry out are also considered.

[0023] The foregoing “dry out” means that the amount of heat inputted into the heat pipe exceeds the maximum heat transport Q_{max} so that the amount of the working fluid evaporating at the evaporating section exceeds the amount of the working fluid returning to the evaporating section from the condensing section, thereby leaving the evaporating section completely dry for a certain time. The temperature of the evaporating section rises rapidly and drops again as the working fluid returns to the wick so that the heat pipe recovers the ability thereof. However, if a function for recovering this ability is slow, the temperature controlling ability of the heat pipe is disabled. Then, the corresponding heat pipe cannot be used at or over the amount of heat which is being inputted.

[0024] As shown in FIG. 1, the heat pipe has a longitudinal section divided into a evaporating section, a heat insulating section and a condensing section. In this case, it is preferred that the heat pipe has the first partial wick structure which may elevate capillary pressure and thermal conductivity, the heat insulating section has the second partial wick structure having high permeability, and the condensing section has the third partial wick structure which may elevate the permeability and the thermal conductivity.

[0025] In order to satisfy the foregoing requirements, a typical heat pipe has a wick structure constituted into the following four configurations, or combined configurations or variations thereof. The configurations have the following characteristics together with advantages and disadvantages.

[0026] Metal sintered powder wicks have an excellent fluid transport ability against gravitational resistance due to a large value of capillary head, excellent thermal conductivity due to a fin effect of porous metal sintered powder. Further, rapid temperature elevation rarely takes place since the viscous limit gradually takes place. However, the metal sintered powder wicks have a large amount of pressure loss occurring in movement of the working fluid due to a small value of permeability.

[0027] Grooved wicks have a small pressure loss in movement of the working fluid due to a large permeability. In particular, it is advantageous in price since a simple grooved wick can be integrally manufactured in manufacture of a heat pipe envelope or container. However, the simple groove wick has drawbacks that capillary pressure is small due to a large capillary diameter, working ability is inferior in a partially superheated-dry state, and viscous limit occurs abruptly thereby resulting in rapid temperature growth.

[0028] Fine fiber bundle wicks have characteristics that capillary pressure is large, but permeability is small and thus pressure loss is large in movement of the working fluid, and working ability is inferior in a partially superheated-dry state.

[0029] In mesh screen wicks, capillary pressure is about in the middle and permeability is small so that pressure loss is large in movement of the working fluid as well as thermal resistance is large.

[0030] The foregoing basic wick structures cannot be compared on the basis of a single criterion since they have their own advantages and disadvantages and can be modified into structures which can complement the disadvantages. However, the sintered powder wicks are preferred to other wicks with regard to heat transport ability and ability against gravitational resistance which are the basic performances of the heat pipes. The sintered powder wicks have a very dense inter-particle structure causing the capillary pressure thereof to be larger than that of the grooved wicks or the mesh screen wicks and the thermal conductivity to be higher than that of the mesh screen wicks thereby to show a relatively large heat flux.

[0031] The sintered powder wicks have a more excellent working ability against gravitational resistance compared to other wick structures such as the grooved or mesh screen wicks. However, the sintered powder wicks are not superior in the maximum heat transfer due to a large amount of liquid pneumatic resistance.

[0032] Further, those structures applied to the conventional sintered powder wicks generally have a single porous structure. Therefore, the MHP requires metal powder having a relatively large particle size in order to increase the permeability of the wick. However, the pore size of the wick is not optimized due to problems of the internal structure and a manufacturing process of the wick so that the basic relative superiority of the sintered powder wick is not sufficiently utilized.

[0033] Therefore, for the purpose of obtaining the optimized shape of the wick as above, the U.S. Pat. No. 6,056,044 proposes a wick structure which uses microscopic multi-capillary tubes via the MEMS to have different particle sizes so as to improve the capillary pressure and the permeability.

[0034] However, in the foregoing structure, the manufacturing process is sophisticated and accordingly the manufacturing cost is elevated. In other words, after a bonding agent is coated on underlying mesh screens, another mesh screens are scrolled into the multiple pipes thereby making the manufacture of the multiple pipes difficult.

[0035] In order to overcome the foregoing problems, it is proposed that wick structures belonging to functional components have difficulties from one another with pore size, pore shape, thermal conductivity and absorbing ability of the working fluid. However, a powder mixture having different particle sizes is hardly constructed into a biporous wick in practice.

[0036] The above problem is caused due to the fact that powder having a large particle size can be hardly inserted into the MHP considering that the inside diameter of the outer wall of the conventional MHP is limited with size.

SUMMARY OF THE INVENTION

[0037] Accordingly the present invention is proposed to solve the foregoing problems in regard to a conventional MHP having a single wick or a multi-capillary tube structure, and it is an object of the invention to provide a porous sintered powder wick structure having sub-structures, which are different in material, shape or particle size from one another adequate to requirements of evaporating, heat insulating and condensing sections, so as to increase porosity and permeability of the wick structure. Therefore, in order to arrange the wick sub-structures different in material, shape or particle size from one another, a mixture of such powder undergoes sintering to have a biporous structure thereby providing a heat pipe of an eccentric structure having a radially asymmetric sectional shape.

[0038] Further, the invention proposes a method for improving ability and time for recovering from dry out due to overheating in an evaporating section of the heat pipe in order to improve working ability in occurrence of thermal limit conditions.

[0039] Moreover, the invention proposes a method for minimizing the pore size of the sintered powder wick by rapidly recovering the heat pipe function from such an superheated dry state and forming an absorptive coating on the surface of the wick in the evaporating section by adding a hydrate into the working fluid.

Referenced by

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US7137441 *	Mar 15, 2004	Nov 21, 2006	Hul-Chun Hsu	End surface capillary structure of heat pipe
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US7301602 *	Mar 31, 2005	Nov 27, 2007	Canon Kabushiki Kaisha	Stage apparatus and exposure apparatus
US7520315 *	Jul 19, 2006	Apr 21, 2009	Foxconn Technology Co., Ltd.	Heat pipe with capillary wick
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US7874347 *	May 31,	Jan 25, 2011	Hon Hai Precision Industry Co., Ltd.	Heat pipe with hydrophilic layer and/or protective layer

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US20100181048 *	Jun 11, 2009	Jul 22, 2010	Foxconn Technology Co., Ltd.	Heat pipe
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