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(54) PERFORATED HEAT PIPES

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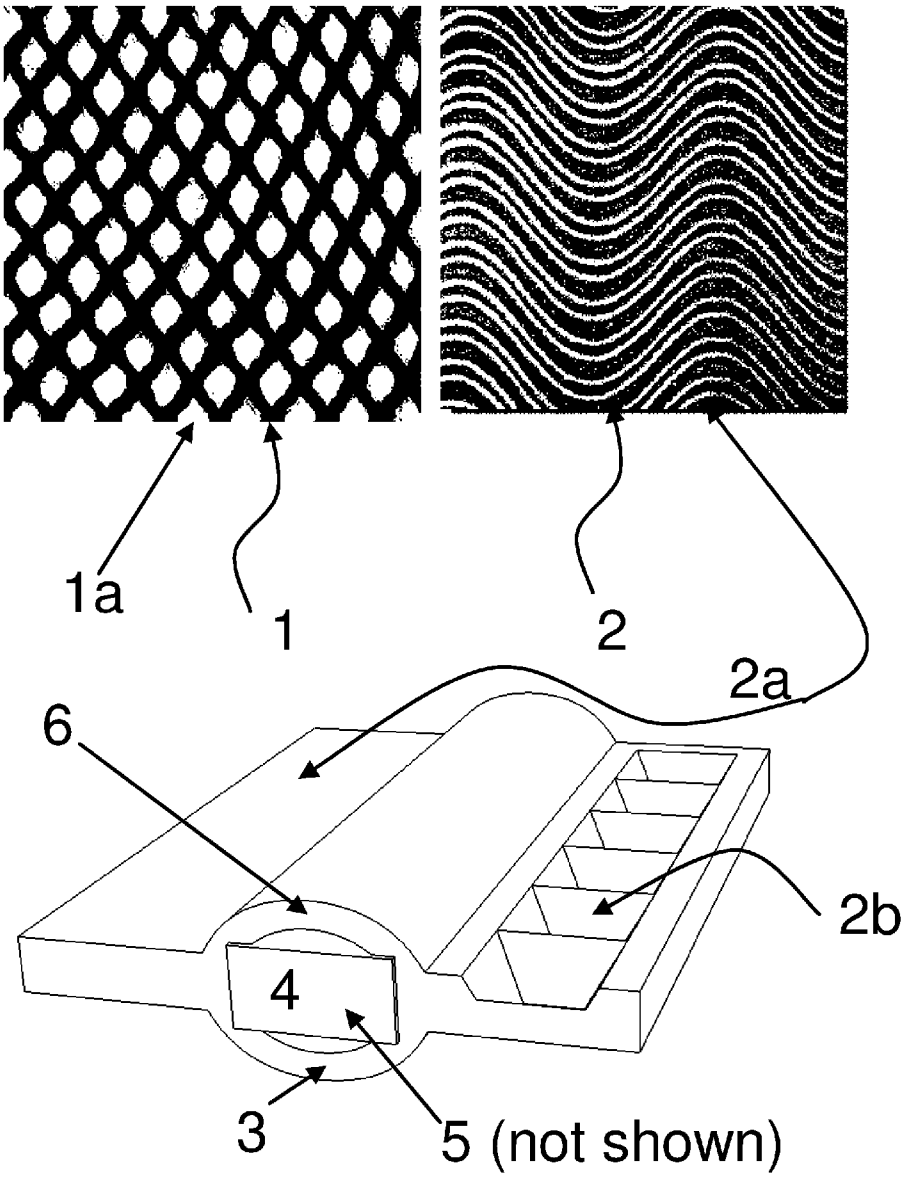
(57) **ABSTRACT**

This invention enables broad commercial use of heat pipe technology in designs ranging from traditional outdoor apparel to high-end sport garments and special tasks garments. Heat pipes of popular mesh or velvet patterns provides integrated heat sink functionality that decreases weight, size and cost of thermal designs. Products of the invention are lightweight, flexible and even elastic that provides maximum comfort to their users.



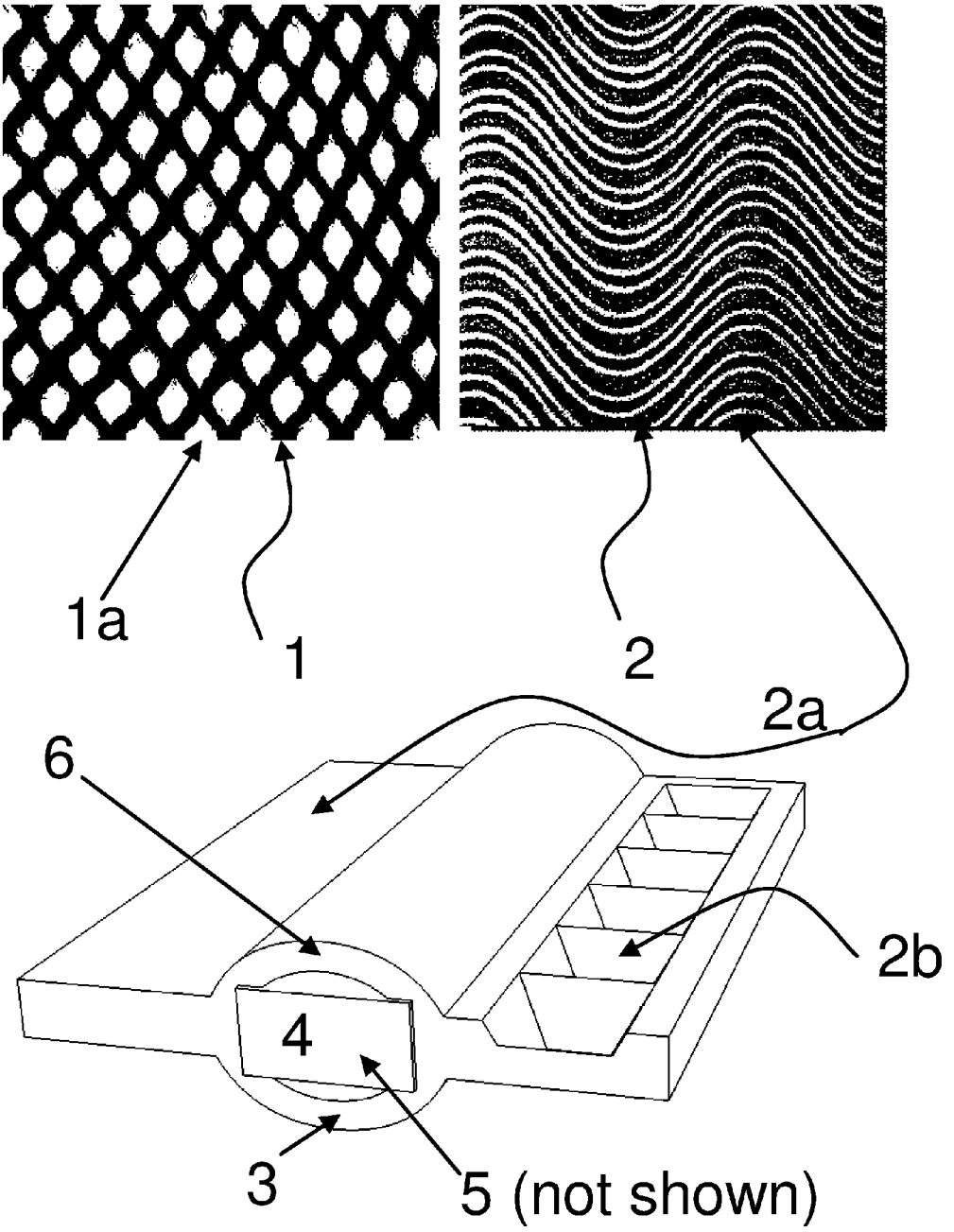


Fig. 1

PERFORATED HEAT PIPES

PRIOR ART

[0001] Idea of use of heat pipes in conjunction with human wearable apparel was exploited for sake of thermal stress management. Inventors suggested uses of various heat reservoirs to absorb the heat (U.S. Pat. No. 6,763,671). All these ideas provide short term benefits with expense of reduced mobility and added weight.

Prior art inventors (U.S. Pat. No. 5,269,369) suggest redistribution of heat between distinct pieces of apparel that creates discomfort in dressing as well as causes faults in practical use of such apparel systems.

DETAILED DESCRIPTION

[0002] The essence of this invention is to provide completely passive lightweight solution that will be able to reduce thermal stress of wearier and have unlimited operating time. Benefit of this invention is effective combination of natural ability of a body to redistribute/manage heat and efficient heat exchange properties of the apparel system combined with its primary functions.

[0003] Each apparel article according to this invention is uniquely designed for a specific use scenario. This makes them comfortable, practical, lightweight, and reliable unlike prior art designs. Heat pipes are employed to increase heat exchange between the body surface and a heat source/recipient (in most scenarios ambient air).

[0004] Heat pipe uses a thin shell impermeable or partially impermeable to gases. Material of choice for the shell is:

[0005] laminated single or multilayer metal foil (aluminum or other)

[0006] inorganic film (silicate based or other)

[0007] polymer or rubber (natural or synthetic with or without nano-composites or other additives)

[0008] composites, fabrics, etc.

[0009] Heat pipes are permanently imbedded into or form by itself the apparel structure. This improves apparel durability and reduces its weight. Preferred liquid of the heat pipes of the invention is medium pressure commercial refrigerants, while low or high pressure refrigerants and other liquids are not excluded. Use of medium pressure refrigerants allows to overcome problem associated with high gas permeability of polymer materials. Preferred shape of the invention is a planar mesh or a planar ribbon with flaps. Spatial mesh structures are also the subject of this invention.

[0010] FIG. **1** illustrates the concept of invention. The mesh shape **1** allows for significant airflow through the pipe that voids the need for dedicated heat sinks, and allows for effective integration of the pipe into apparel and other systems by sewing, gluing, or fastening etc through the voids **1** a of the mesh, while preserving breathable properties of the product.

[0011] The shape of ribbon with flaps **2** allows convenient integration of the pipe into apparel and other systems by sewing through the flaps **2***a* or gluing or laminating. The flaps may also contain perforations **2***b* of various patterns including the mesh patterns.

[0012] Preferred shell material of the invention is polyester backed thermoplastic elastomer film (such as TPSiV produced by Dow Corning Company, or other TPE). Preferred wick is made of mesh fabric (felt, braided, or other). Its lattice may be is interlaced with water soluble PVA mesh fabric. The purpose of soluble PVA mesh is to form vapor transport channels in the heat pipe structure that can be removed from partial assembly.

[0013] Preferred design can be manufactured using variety of processes. Herein there is an example of such: A layer of TPSiV film **3** is covered with a layer of felt **4** of the same composition, all elements are maintained below +30° C., liquid 1,2-dichloro-1,1,2,2-tetrafluoroethane (R-114) **5** is dispensed to saturate the felt, second layer of TPSiV film **6** is placed on top of the assembly, hot stamp with mesh pattern is pressed against the assembly at pressure in excess of 44 atm at 295° C., after setting time the stamp is cooled.

[0014] Described process creates sealed flat heat pipe with mesh pattern **1** of blanks that can be also cut through holes. Upon temperature increases above +4° C. internal pressure caused by R-114 evaporation reshapes flexible shell material and creates vapor transfer channels. The size of the pattern is defined by two factors in addition to artistic perception:

[0015] vapor pressure of selected liquid at desirable operating temperature of the pipe

[0016] the material properties and the wall thickness for selected outer films

[0017] Use of smaller separations allows for use of thinner material film and higher internal pressure.

[0018] Invented heat pipe can be custom cut to desired shape without need for special equipment using standard hot knife and a wise or a clamp. The pipe sheets or decals can be sewed together or to any fabric using standard sewing equipment. This makes the product suitable for general apparel manufacturing.

[0019] Plurality of alternative manufacturing techniques can be utilized to create the device of invention. As an example, tree dimensional mesh can be created as following. Material of the wick in form of yarns is braided to form three-dimensional sparse structure. It is then spray-coated with liquid rubber. Because of high viscosity sprayed polymer doe not penetrate into the wick volume but creates flexible cast around strings composing the layout. Additional coats of various materials can be deposited on top of initial cast, including electrodeposited metals, polymers, composites ceramics, etc.

[0020] The essence of the invention survives modifications of materials composing peripheral shell, wick, liquid, as it is well known how to make these alteration. For example both metal felt and plaited carbon can be used as a wick structure. The alterations will affect the method of production and the liquid of choice. Described patterns can provide additional functions such as artistic look, energy harvesting, weight distribution management (e.g. in turbine engine designs), mechanical support (e.g. PV panels of satellites).

[0021] Invention provides benefits to apparel, electronics (e.g. as a heat sink material), automotive industry (e.g. alternative to engine or fuel cell cooling systems), appliances, construction materials, etc. Examples of articles benefiting from this heat pipe technology are hockey jersey, baseball hat, wall insulation, engine cylinder block, etc. Sheets of these heat pipes of planar of foam like 3D meshes can be utilized as a thermal barrier for fire protection, building thermal insulation, energy harvesting by heat pumps, and other traditional thermal applications.

[0022] The mesh structure of the invention contributes to high transport efficiency of capillary wicks. The small area

of segments created by the mesh is compensated by two or three dimensional flow pattern of the mesh. This allows for large geometrical dimensions of the heat pipes with minimal degradation of their efficiency.

What is claimed is:

1. A heat pipe device having a shape of one or two or three dimensional mesh, wherein each cell of said mesh contains an element with structure of linear heat pipe and a junction, wherein said junction is formed by material or materials of the pipe's walls, and wherein said junction may contain holes, and the term mesh comprises ordered, unordered, periodic, or non-periodic composition.

2. A device of claim **1**, wherein said cells form parallel rows evenly or not evenly distributed.

3. A device of claim **1**, wherein said cells form a two dimensional lattice pattern.

4. A device of claim **1**, wherein said cells form a three-dimensional pattern.

5. A device of claim **3**, wherein said pattern has through holes.

6. A device of claim **1**, wherein said cells form a two dimensional ornament or picture or other artistic element.

7. A device of claim **1**, wherein said heat pipe uses a polymer based composite in construction of gas partly permeable walls.

8. A device of claim **1**, wherein said heat pipe uses a metal foil in construction of gas impermeable walls.

9. A device of claim **1**, wherein said heat pipe uses an inorganic film in construction of gas impermeable walls.

10. A device of claim **1**, wherein said heat pipe uses nano-particles, nano-composites, nano-clay or other functional additives in construction of gas impermeable walls.

11. Use of device of claim **1** in production of human wearable apparel items.

12. Use of device of claim **1** in construction of heat sinks for electronic components.

13. Use of device of claim **1** for thermal protection or insulation.

14. Use of device of claim **1** for energy harvesting.

15. Use of device of claim **1** in production of pet's wearable items.

16. Use of device of claim **1** in production of human wearable gear or equipment.

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