

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
12 July 2007 (12.07.2007)

PCT

(10) International Publication Number
WO 2007/079427 A2

(51) International Patent Classification:
F28D 15/00 (2006.01)

(21) International Application Number:
PCT/US2006/062773

(22) International Filing Date:
30 December 2006 (30.12.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

11/306,530	30 December 2005 (30.12.2005)	US
11/306,531	30 December 2005 (30.12.2005)	US
11/307,125	24 January 2006 (24.01.2006)	US
11/307,292	31 January 2006 (31.01.2006)	US
11/307,359	2 February 2006 (02.02.2006)	US
11/308,107	7 March 2006 (07.03.2006)	US
11/308,438	24 March 2006 (24.03.2006)	US
11/308,663	19 April 2006 (19.04.2006)	US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:

US	11/306530 (CIP)
Filed on	30 December 2005 (30.12.2005)

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US (patent), UZ, VC, VN, ZA, ZM, ZW.

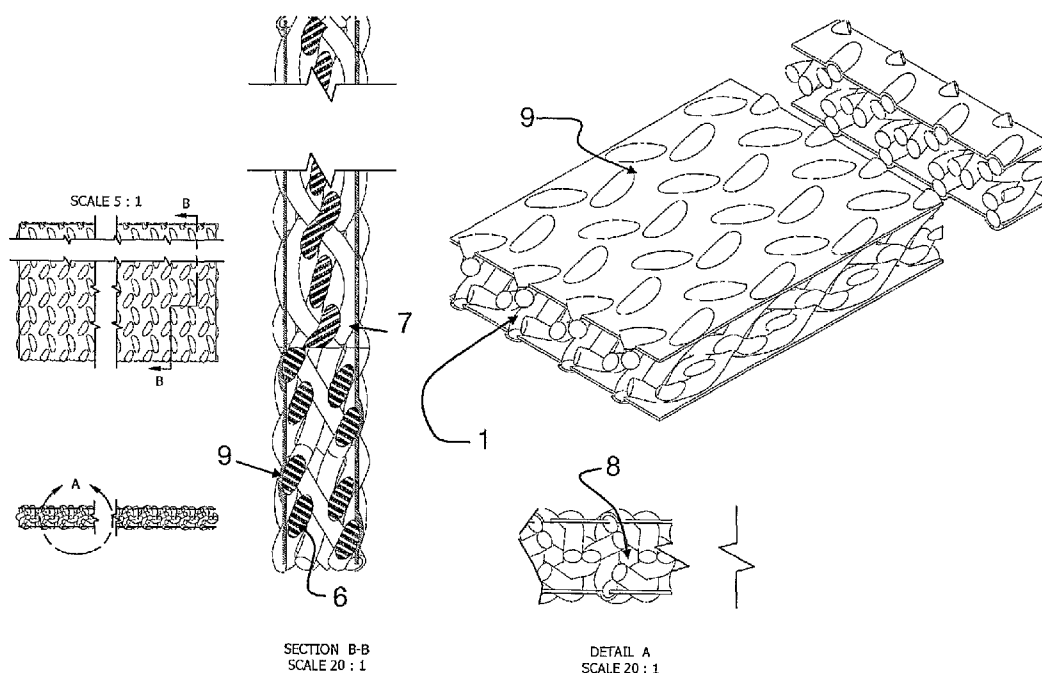
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to the identity of the inventor (Rule 4.17(i))

[Continued on next page]

(54) Title: HEAT TRANSFERRING MATERIAL UTILIZING LOAD BEARING TEXTILE WICKS



(57) Abstract: A heat conducting material that utilizes phase transitions to transport heat. The material can be used to produce heat pipe devices by simple creation of hermetic seams that isolate segments of the material. The material provides superior mechanical flexibility, lower interface resistance, and lower weight, as its textile wick structure is used to offload mechanical stress from peripheral shell of the material.



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- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
 - *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
 - *of inventorship (Rule 4.17(iv))*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

- *without international search report and to be republished upon receipt of that report*

HEAT TRANSFERRING MATERIAL UTILIZING LOAD BEARING TEXTILE WICKS
DESCRIPTION

RELATED APPLICATION DATA

[Para 1] This application is a *continuation-in-part* of each of:

- (1) U.S. patent application Ser. No. 11/306530, filed Dec. 30, 2005, entitled "Heat pipes utilizing load bearing wicks", hereby incorporated by reference
- (2) U.S. patent application Ser. No. 11/306531, filed Dec. 30, 2005, entitled "High flux density thermal interface", hereby incorporated by reference
- (3) U.S. patent application Ser. No. 11/307125, filed Jan. 24, 2006, entitled "Integral fastener heat pipe", hereby incorporated by reference
- (4) U.S. patent application Ser. No. 11/307292, filed Jan. 31, 2006, entitled "High throughput technology for heat pipe production", hereby incorporated by reference
- (5) U.S. patent application Ser. No. 11/307359, filed Feb. 02, 2006, entitled "Stretchable and transformable planar heat pipe for apparel and footwear, and production method thereof", hereby incorporated by reference
- (6) U.S. patent application Ser. No. 11/308107, filed Mar. 07, 2006, entitled "Tunable heat regulating textile", hereby incorporated by reference
- (7) U.S. patent application Ser. No. 11/308438, filed Mar. 24, 2006, entitled "Heat conductive textile and method producing thereof", hereby incorporated by reference

Technical Field

[Para 2] This invention relates to a field of structural design of heat conducting devices that utilize phase transitions of embedded chemicals and often referred as a heat pipes. It provides functional solution that reduces weight-to-performance ratio and improves performance of flexible designs.

Background Art

[Para 3] Applications of heat pipes often become impractical due to complexity associated with fitting of these components into tightly packed spaces or because of mobility restrictions they could cause. Another implication is that systems can be utilized at temperatures below freezing point of selected chemicals. The crystallization might severely damage the shell of a heat pipe device. It also disables its functions until the liquid melts.

[Para 4] Prior art disclosed by Eastman in US Patent 4,194,559 exploits compromise solutions that prevent freeze damage of the device in expense of added free volume that increases total volume and weight of a solution. Prior arts described in US Patents 4,279,294, 5,647,429, and 6,595,270 shows attempts to utilize polymer materials such as an aromatic polyamide fiber of extremely high tensile strength (Kevlar fiber), polytetrafluoroethylene, nylon, or polyimides as a construction material for outer shell of a flexible heat pipe. All of them nevertheless require rigid geometry of thick round walls and/or Imbedded spacers to prevent collapse of referenced devices. Invention of Fitzpatrick, et al. presented in US Patent 4,279,294 uses low boiling point liquid and utilizes

underground installation to prevent explosion of the pipe. Pressure and geometrical constraints imposed by surrounding soil allows transfer of mechanical load from the shell of the device to ambient matter such as packed rocks and sand.

[Para 5] Invention of Oktay, et al. described in UP patent 5,647,429 uses polymer flexible heat pipes that rely on thickness of peripheral walls to stabilize geometry of the device. This approach requires excessive wall thickness that contributes to lower performance-to-weight ration. In US patent 6,595,270 Machiroutu, et al. suggests use of polymer shell in design of micro heat pipes with diameter less than 1 mm and notable length. This invention lacks to account for high gas permeability of polymers that explains impractically short service life of the inventions because of extremely high surface-to-volume ratio.

[Para 6] One prior art invention of Rosenfeld, et al. described in US Patent 6,446,706 provides highest performance among all competitors. It has form factor of a tape with high unidimensional flexibility. Nevertheless design is subject to freeze damage and its specific heat transfer performance is reduced by presence of one or two layers of vapor transmitting spacer material. Rosenfeld's invention accounts for at least five distinct material layers: two layers form outer shell, two layers of wick, and one layer of spacer with holes. While the spacer prevents collapse of the heat pipe under positive outer pressure it also attributes to decrease in flexibility, resists vapor transport, increases overall weight and size of the heat pipe assembly. The shell of the design and the separator are two load bearing elements of Rosenfeld's invention that take load of differential pressure that exists between ambient and inner volumes.

Disclosure of Invention

[Para 7] This invention overcomes cited technical challenges of prior art by utilizing a lightest shell that transfers mechanical load to novel load bearing wick structure 1. Instant

invention discloses a design of heat transferring material that can be transformed into a heat pipe-like device. Unlike competitive technologies the material of instant invention provides convenient topological solution for compact designs, confined spaces, and moving elements. All listed benefits are coming from distinct feature embedded in all embodiments of present invention. This feature is structure of wick 1. In prior art wick utilizes highly porous materials, commonly felt, that have poor mechanical strength and must be protected by choice of spacers and strong external shell. Distinctively, instant invention realizes advantages of modern fibers. Disclosed herein wick structure 1 combines high tensile strength, efficient capillary pumping action, and effective vapor transport.

[Para 8] Figure 1 helps to understand the concept of the invention. It shows schematic structure of wick 1. Braided fibers 2 form complex topological arrangement of a cable. At first, they form yarns, and then the yarns are braided to form plaits, that in turn braided to final structure. This creates segregated plurality of channels with width ranging from sub-micron to hundreds, and thousands of microns. Chemical structure of fibers 2 is selectable from broad range of materials. Phase changing chemical(s) 3 in their liquid state 4 have high affinity to at least one type of fibers 2. Considering presence of very narrow channels 6 and high affinity, assembly 1 is capable of efficient adsorption of liquid 4, yet existence of channels with large width 8, and potential of arranging fibers with low affinity to liquid 4 inside of those channels, keeps channels 8 free from liquid 4 and allows gas 5 of chemical(s) 3 to occupy that space.

[Para 9] During operations of the material of the invention variations in shape and temperature alter the ratio of gas 5 and liquid 4. Because of presence of broad variety of channels an increase in volume of liquid 4 occupies more medium width channels 7 thus increasing throughput of liquid 4. A decrease in volume of liquid 5 frees intermediate channels 7 for transport of gas 5.

[Para 10] Wick 1 not only provides desirable transport characteristics for both liquid 4 and gas 5, but also creates highly durable inner skeleton with high flexibility, extreme tensile strength and good resistance against kinks and compressions. While these benefits are brilliant already, there is one more that makes the design of this invention to perform way better than any known competitor. Braided exterior surface of wick 1 is highly corrugated and has features from nanometer to millimeter scale. This surface is ideal template for durable junction and support of exterior shell 9 of the material.

[Para 11] Shell 9 follows topography of exterior surface of wick 1 which makes it highly corrugated and highly flexible even when shell 9 is made of metal. Wick 1 provides continuous support to ultra-thin film of the shell 9. Said film is bonded to wick's 1 exterior fibers 2 chemically and/or topologically. Chemical binding is achievable through use of glues, activators, cross – polymerization and other well known bonding techniques. Topological bonding is established when material of shell 9 embeds or partially surrounds segments of fibers 2. In resulting aggregate the film of shell 9 has support by fibers 2 at very close intervals that commonly less than 100 microns apart.

[Para 12] The high density of the bond points makes shell 9 very capable to sustain extreme pressure difference between inner volume 10 of wick 1 and outer environment. In model experiments two microns thick copper film was sustaining pressure difference in excess of 4 MPa at temperature of 100 C. Ultra thin shell 9 provides notable benefits such as reduced thermal resistance, reduced weight, increased flexibility, as well as reduced production cost due to lower material consumption. The only drawback is reduced durability with respect to pinhole damage and abrasion. Yet this drawback is easy to overcome by protecting exterior surface with additional full or partial layer of abrasion resistant polymer (e.g. Butyl, Nitrile, Vinyl etc.). Regions essential for interface to external heat receivers/sources 11 can be left

unprotected. This way ultra – thin shell 9 easily deforms adapting surface topography of the source and providing efficient thermal junction 11.

[Para 13] It is well known in art of textile and cable manufacturing that there is no limit on types and complexity of braiding patterns. Modern braiding, knitting, weaving and 3D weaving equipment can combine hundreds different types of fibers producing any desirable unidimensional, two-dimensional and three-dimensional textiles.

[Para 14] Description of present invention is equally expandable without a change on case of planar textile, and three-dimensional textile structure. Embodiment utilizing planar topology of the material of instant invention can provide isotropic two-dimensional heat transport or, depending of layout of fibers 2 of wick 1, can provide complex anisotropic heat distribution pattern. In some embodiments it is possible to fit an artistic design into layout of fibers 2 that will be reflected in heat distribution pattern of the material.

[Para 15] Embodiments utilizing three-dimensional topology of the material of instant invention provide not only complex heat distribution pattern but also allow combination of custom mechanical properties. While most trivial isotropic heat transfer resistance is one of the cases covered by these embodiments, other patterns might provide higher additional benefits to targeted technical solutions. In one example, three-dimensional structure of wick 1 that formed by 3D textile is filled with high strength composite making it suitable for use as harness, bulk structural part, armor or any other special application. Peripheral volume of wick 1 in this example has structure previously described for the material of instant invention. Shell 9 seals wick 1. Resulting product has high heat transfer characteristics defined by thin peripheral layer that functions as a heat pipe connecting all exterior points of the product. Yet the product has desirable mechanical and other special characteristics defined by composition of the inner volume. It is obvious that any other

combination of properties is easily achievable and does not deviate from the concept presented by this invention.

[Para 16] Textile composition of wick 1 makes this invention uniquely suitable for implementation on highly efficient dedicated thermal interface regions. In one embodiment illustrated on Figure 4 standard sewing equipment is utilized to stitch a thin heat conductive filament 12 (e.g. copper, silver, or aluminum wire) through volume of wick 1. Stitching pattern covers an area 11 of interface region for intended heat source. Shell 9 covers and seals this interface region 11. Resulting assembly is capable of delivering increased heat flux from a heat source to liquid 4. This is achieved because heat flux bypasses a material of wick 1 and creates boiling regions on large surface area of filaments 12 immersed in liquid 4.

Brief Description of Drawings

[Para 17] Figure 1 shows cross-section of schematic structure of wick 1 (top), and its appearance from outside (below).

[Para 18] Figure 2 shows construction of braided composite yarn with intrinsic cavity 8 (left), yarn appearance is similar to thread but have braiding (right).

[Para 19] Figure 3 shows planar material of the invention wherein textile wick 1 is constrained between walls of shell 9. Top view (top left), front view (bottom left), side view (center). Details (right) shows corrugated pattern of shell surface (top) and persistence of intrinsic cavities (bottom).

[Para 20] Figure 4 shows integral interface region created by stitching of solid heat conducting filament 12. Section view (in the middle) shows filament 12 stitched through portion of volume occupied by wick 1. Detail view B on left shows interface region 11

formed by shell 9 that seals both wick 1 and filament 12. Isometric view (bottom) shows appearance of described feature 11.

Modes for Carrying Out the Invention

[Para 21] Material of the invention can exist in linear, planar and volumetric form. Following embodiments show sample modes to carry out these forms of the material.

Mode A

[Para 22] Example of previously described unidimensional topology can be realized by using cable structure to form wick 1 along preferred direction of the pipe as shown on Figure 1. The braiding uses nylon fibers to cover tows around central channel 8. In best mode Teflon fibers are used instead of the nylon. Peripheral tows use polyester or cotton fibers. In best mode each tow uses micro fiber polyester in core and spun polyester on cover for peripheral tows, while Teflon filaments as a cover fiber for central tows. Wick 1 is wrapped by thin film (e.g. Mylar) having one micrometer thick aluminum layer and low density polyethylene on each side. The wrap is heat sealed when ambient pressure is in excess of 100 KPa over inside pressure of channels in wick 1. This step creates hermetic corrugated shell 9 that embeds segments of polyester fibers 2 from exterior surface of wick 1.

[Para 23] Inner channels of wick 1 are purged with airless water steam at pressure slightly above ambient. This step removes gases from volume of wick's 1 channels as material gets heated to 100 C and continuous jet of airless water in gas state expels all adsorbed gases from wick 1. In next step output end of material assembly is sealed and continuous line of the material of instant invention is segmented by periodic seals creating segments along its preferred direction. This creates a line of isolated domains with preset length. There is no restriction on maximal length of produced linear material.

[Para 24] In one embodiment braiding equipment is used inline as a starting step of described process. This allows continuous production of the material of instant embodiment by putting all described steps inline. The product is spool of segmented cable that functions as a heat pipe yet has much higher flexibility and lesser weight.

Mode B

[Para 25] In alternative embodiment instead of water used as chemical 3 in the above embodiment chemical 3 is chosen as medium pressure refrigerant R134a. The tow content in best mode is spun polyester with exception for peripheral tows where content is 70 aramid/30 percent tinned copper. Wrap film is replaced with 5 micrometer thick tinned copper foil that is wrapped around wick 1 with slight overlap. The wrap is heat sealed at 230 C with external pressure of 100 KPa. This step creates hermetical corrugated shell 9 that is soldered to supporting wick fibers 2. In next step channels of wick 1 are purged with R134a chilled to -30 C and leading end of the assembly is sealed. Continuous production squeezes leading segment to expel excess of refrigerant and seals leading segment from supplying end. This makes subsequent segment to become the leading segment that again gets squeezed and sealed at supplying end. This sequence performs continuous production of line of segmented material of the invention. Segment length is selected as desired.

[Para 26] Produced material of instant embodiment is spool of segmented cable that functions as a heat pipe yet has much higher flexibility and lesser weight, and lesser thermal resistance of walls. The material of present embodiment is also heat sealable. Application of heat and pressure across short segment causes melting and thermal degradation of embedded polymer materials and allows tinned copper film to create permanent hermetic joint that segments the product on shorter domains. This benefit

additionally differentiates the material of invention from prior art. In fact, known prior art offers devices that can not be cut without damage. The material of instant invention can be cut on smaller pieces by means of described heat-seal step.

Mode C

[Para 27] In yet another embodiment cable design described in previous two embodiments is reduced to a single braided yarn. Figure 2 shows one of many possible yarn constructions that are disclosed in co-pending patent applications. This yarn is created by braiding six fibers one of which has low affinity to selected liquid 4. This braiding allows for intrinsic channel 8 along the axis. The whole yarn works as a capillary size tube with porous walls. The size of the pores 6 is smaller than the size of channel 8. When used in conjunction with a liquid 4 that has high affinity to the material of the fibers, the yarn quickly absorbs the liquid through the walls. When wetted, the walls behave as a continuous surface. The surface angle of the liquid on this surface is zero degree. This make internal channel an ideal capillary for quick transport of the liquid 4 and gas 5 along the yarn. The fiber with low affinity to liquid 4 ensures that channel 8 does not get blocked by liquid 4.

[Para 28] In current example filaments composing fibers are graphite. Shell 9 is created by electroplating of copper. Electroplated film embeds closely packed filaments on peripheral surface of yarn 1. Chemical 3 is R134a. The yarn 1 is segmented by periodic seals that create plurality of consequent isolated domains. Each of the domains has functions of micro heat pipe. Yet its differentiated from prior art designs of micro heat pipes by very low thermal resistance of ultra thin walls of shell 9, high mechanical strength that defined by fiber strength, flexibility that defined by corrugated at micron scale surface of shell 9. In addition segmented structure of produced yarn makes it insensitive to damages, because all

damages are localized to particular domains. The yarn of present embodiment can be produced in spools of continuous segmented micro heat pipe material. It is obvious that other fiber 2 and shell 9 materials as well as chemicals 3 can be used as well.

Methods to produce the material of instant invention in planar topology

[Para 29] Methods to produce the material of instant invention in planar topology account for plurality of realizations. Depending on target application and raw material selection the best mode will vary. That is why only few best mode methods producing the material are disclosed.

Mode D

[Para 30] Process of velvet manufacturing is well known to one experienced in textile science. Intermediate product of velvet production is two layers (A and B hereinafter) of weaved material joint by center pile. Instant embodiment utilizes this intermediate product without it being cut in between. In this embodiment chemical 3 is water and both weaved layers have warp and weft fibers (X and Y filaments hereinafter) of polyester filaments. The pile is formed by Z directional fibers of Teflon. Weaved layers of X and Y filaments are slightly different between layers A and B. In best mode they both have twill patterns but oriented 90 degrees with respect to each other. The pile of Z fibers joins both layers completing wick 1.

[Para 31] Wick 1 of present embodiment is sealed between two layers of film (e.g. Mylar type, metal foil, Inorganic film, polymer composite, etc.) that forms shell 9 that comprises at least a layer of gas impermeable material. In one realization shell 9 is formed by one micron thick tinned copper foil on outer side coated with 1 mil soft vinyl film. Production process

accounts following inline steps: (i) wick 1 is sandwiched between walls of shell 9; (ii) aggregate is sealed on tail edge and leading edge by hot roller or press creating a leading segment; (iii) aggregate is purged with airless water steam at temperature above 100 C passing through volume of wick 1; (iv) aggregate is sealed on both side edges using hot roller or press; (v) sealed leading segment is chilled to room and rolled into spool; (vi) subsequent segment becomes the leading segment and undergoes all listed steps.

[Para 32] While twill weave pattern creates channels 6 and 7 that might have different preferred orientation on opposite sides of wick 1, the pile of Z fibers forms one volume of channel 8 that expels liquid 4 and remains filled with gas 5 at all time. This is achieved because Teflon Z fibers are highly hydrophobic. At room temperature pressure inside the material is below ambient, yet Z oriented fibers prevent channel 8 from collapse, even when additional mechanical pressure is applied. Twill pattern creates template on both external sides of the material. This template creates notable corrugations on shell 9 that contribute to its flexibility. Added layer of vinyl not only creates abrasion resistant coat but is also easily removable by solvents. This creates convenient way to make low thermal resistance interface regions. The material can be custom cut by localized application of heat and pressure using slightly modified commercial heat-seal equipment.

[Para 33] Processing steps of instant embodiment can be altered in many ways. To keep present patent brief these alterations are omitted, as it is obvious how to produce described material, and many other approaches can be derived from one disclosed herein. All these alterations are still considered as a part of instant invention.

[Para 34] Twill pattern of present embodiment can be substituted on many other weaving patterns (e.g. plain weave, jacquard, etc.). Pile of Z fibers may use several different types of filaments at the same time. In one example a percentage of Teflon filaments can be substituted with polyester filaments thus creating hydrophilic links between opposite sides

of wick 1 of the material. In another example yarns of polyester can be used as a part of Z fibers to produce rows of hydrophilic junctions between opposite sides of wick 1.

Mode E

[Para 35] Another mode is used to produce planar material of the invention that instead of water uses low or medium or high pressure commercial refrigerant as chemical(s) 3. Wick 1 of present embodiment is analogous to the one described above and also uses velvet process. In one mode it is made of polyester fibers only. Amount of Z fibers is reduced to 1–10 percent from that used in traditional velvet production. This makes lighter less dense pile. Walls of shell 9 are formed by layers of 0.5 mil unsaturated or thermoplastic polyester film. The film uses ambient surface of wick 1 as a template and acquires high degree of corrugation conformal to topography of exterior surface of wick 1. Shell 9 is cross linked with exterior filaments of wick 1 to create permanent bond. The step of polyester crosslinking is well known in the field of related art.

[Para 36] In alternative example warp fibers of weaved layers are substituted on fine copper wire (e.g. 50–100 micrometers in diameter). Shell 9 is thin copper foil that is friction-welded or otherwise bonded to said warp wires.

[Para 37] Refrigerant 3 is purged through volume of wick 1. Purge step is performed when assembly of the material is partially compressed by external counter pressure (volumetric or mechanical). Compression step allows to control amount of refrigerant 3 deposited in volume of wick 1.

[Para 38] Steps of sealing and segmenting of the material are similar to previously described. They are used to complete production of the material of present embodiment. Unlike material of previous embodiment the material of present embodiment has positive

internal differential pressure that contributes to its ability to adsorb and dump external mechanical forces. Reduced pile density increases volume of channel 8 thus increasing transport efficiency of gas 5. Internal pressure expands channel 8 and contributes to corrugation of shell 9.

[Para 39] In one example mode the material of instant embodiment was created by stitching together two layers of twill weave textile to form wick 1 element of instant embodiment.

[Para 40] In all embodiments disclosed above the segments can be created on completed material later on. Processes that allow creation said segments use creation of hermetic seams. The seams can be used to create new isolated segments and to change shape of the material by removing some isolated segments. There are many various processes that can be applied to create said seams. Examples are heat-sealing process that uses simultaneous application of heat and pressure; friction welding; laser welding.

Mode F

[Para 41] Advent of three dimensional textiles allows simple transfer of modes of all previous embodiments on case of wick 1 that is formed by three-dimensional weaving. It is obvious how to transfer all steps of previously disclosed modes to instant embodiment, except the steps of sealing and segmenting. Because of significant height and width dimensions of wick 1, different approach is used to segment and seal the material of present embodiment. Instead of producing continuous line or film of material described in previous modes, wick 1 is precut on segments of specific length. Then each segment is independently processed.

[Para 42] Shell 9 is bonded to wick 1 to completely seal its volume. Depending on selection of chemical 3 it may be disposed into volume of wick 1 before or after the bonding step. To

perform such disposition after bonding of shell 9 is complete, small opening in shell 9 is preserved or created. After the disposition said opening is sealed.

Industrial Applicability

[Para 43] Inner skeleton structure utilized by the material of present invention makes it highly flexible and lightweight opposed to prior art heat transferring devices. This creates broad range of industrial applications. That is why only some of them will be mentioned here. Polyester based realization mode disclosed above makes an excellent material that is suitable for human wearable applications. Examples include medical devices, apparel and footwear.

[Para 44] Lightweight and flexible planar material of the invention directly benefits to design of heat dissipating and heat shielding elements of electronic and mechanical equipment (e.g. computer cases, heat sinks, etc.)

[Para 45] Three-dimensional material based on three-dimensional textiles benefits to designs of heat dissipating/transmitting harnesses and fasteners as described in co-pending patent application.

What is claimed is:

[Claim 1] A composite material characterized by:

- (i) a textile structure comprising a plurality of intrinsic channels and worming a wick (1)
 - (ii) a shell (9) surrounding said textile structure and sealing it from ambient space thus creating isolated volumes inside said wick (1)
 - (iii) a chemical(s) (3) capable to undergo phase transition from liquid to gas state in desired temperature interval and creating differential pressure between ambient space and said volumes, wherein said chemical is sealed inside said volumes of wick (1),
- wherein said textile structure offloads mechanical stress from said shell while preserving said intrinsic channels, wherein said stress is created by combination of said differential pressure and other factors, and mechanical strength of said shell along is insufficient to sustain said differential pressure within said thermal range while preserving original geometrical structure of the material.

[Claim 2] A material of claim 1 wherein said volumes are sequentially arranged in one or two dimensions, and are isolated from each other by at least one hermetic seam.

[Claim 3] A material of claim 1 wherein said textile is braided structure.

[Claim 4] A material of claim 1 wherein said textile is weaved structure.

[Claim 5] A material of claim 1 wherein said textile is knitted structure.

[Claim 6] A material of claim 3 forming a composite yarn, wherein said textile contains filaments with high affinity and filaments with low affinity to said chemical (3) in its liquid state.

[Claim 7] A material of claim 1 wherein said textile is composite of several textile elements connected into permanent assembly by processes analogous to stitching, welding, thermosetting, or chemical crosslinking.

[Claim 8] A material of claim 1 wherein said textile utilizes X, Y and Z directional filaments composing three-dimensional textile part.

[Claim 9] A material of claim 1 wherein said textile utilizes filaments with different affinity to chemical (3) present in its liquid state.

[Claim 10] A material of claim 1 wherein said volumes can be hermetically separated from each other by means of hermetic seams and said seams are created by heat-seal method, wherein said method comprises at least simultaneous application of pressure and heat.

[Claim 11] A material of claim 1 wherein said shell (9) composed of polymer film.

[Claim 12] A material of claim 1 wherein said shell (9) comprises metal foil.

[Claim 13] A material of claim 1 wherein said shell (9) comprises inorganic film.

[Claim 14] A material of claim 1 wherein said shell (9) is corrugated.

[Claim 15] A material of claim 1 comprising one or more thermal interface regions (11), wherein said region (11) is characterized by solid heat conductive filaments stitched through at least a portion of volume of said wick (1) in direction that is normal to its outer surface.

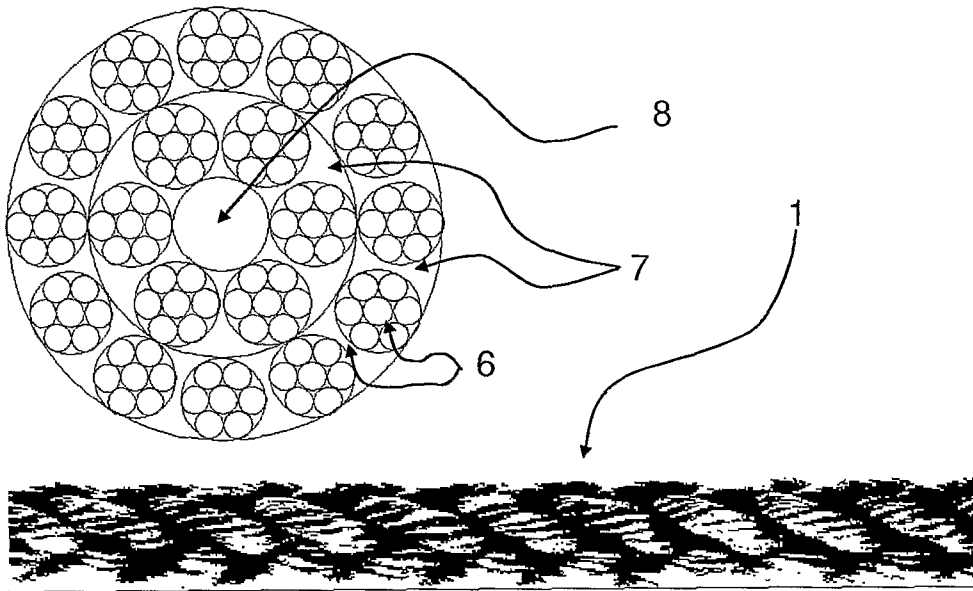


Figure 1

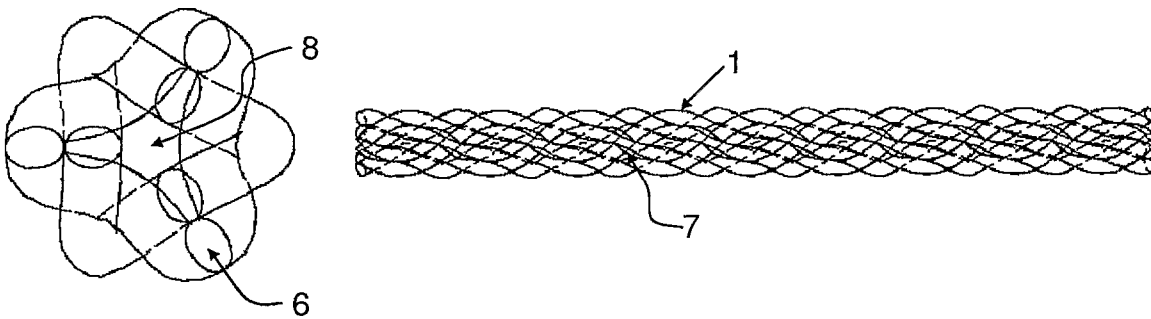


Figure 2

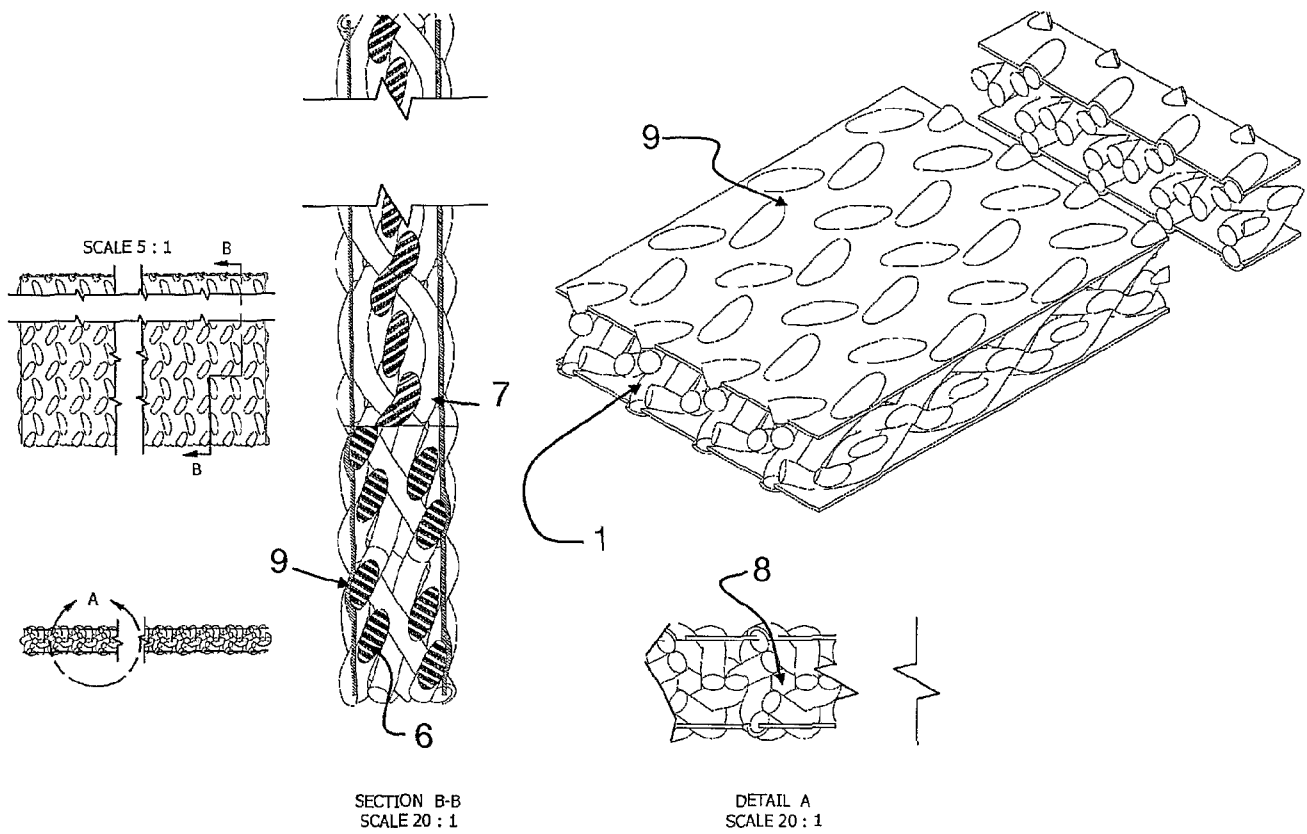


Figure 3

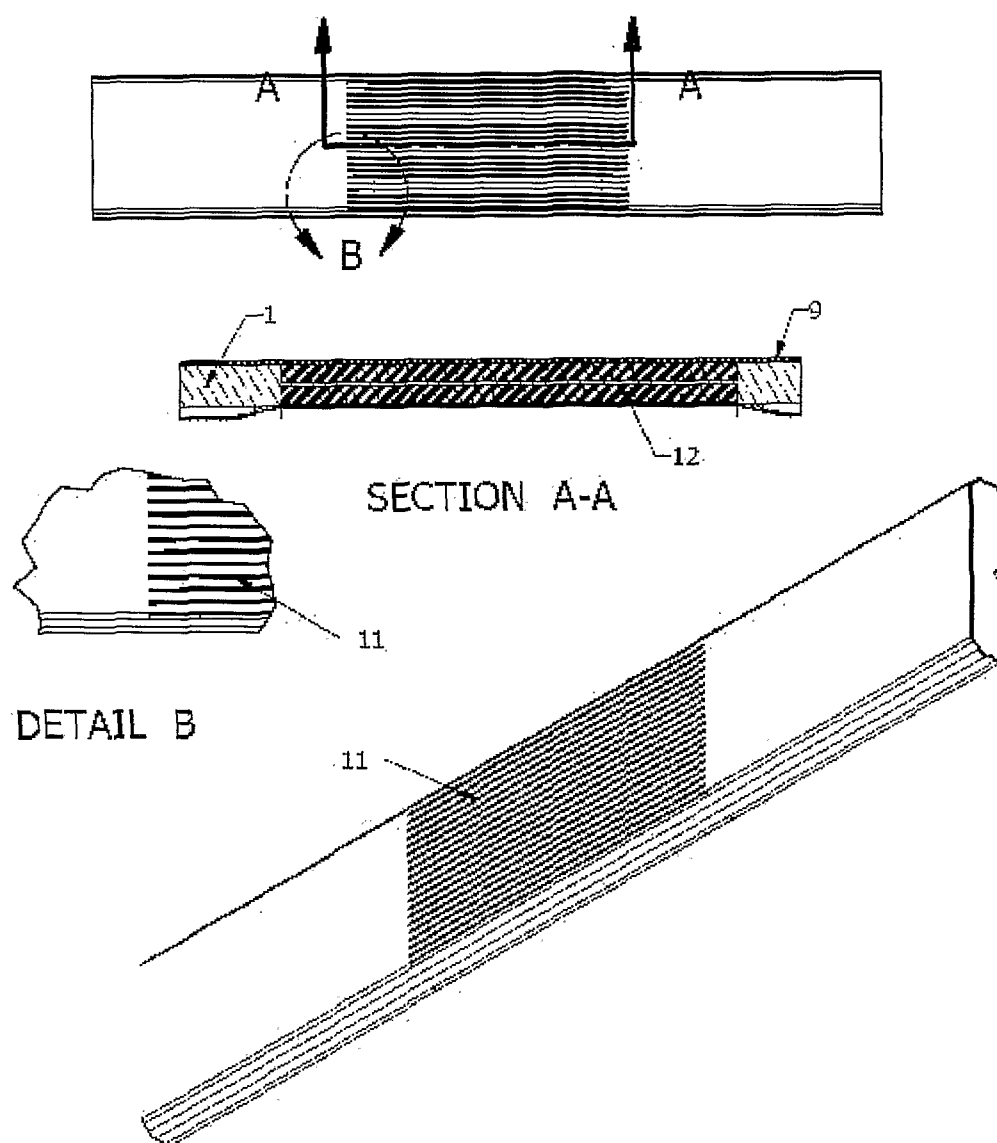


Figure 4