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(54) **FLEXIBLE INSULATING STRUCTURES AND METHODS OF MAKING AND USING SAME**
FLEXIBLE ISOLIERSTRUKTUREN SOWIE VERFAHREN ZU IHRER HERSTELLUNG UND
VERWENDUNG

STRUCTURES ISOLANTES SOUPLES ET LEURS PROCÉDÉS DE FABRICATION ET
D'UTILISATION

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(56) References cited:

WO-A1-2005/047381 US-A1- 2003 215 640
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Description**BACKGROUND OF THE INVENTION**

5 **[0001]** Many applications benefit from using materials that are both relatively light and good thermal insulators. Aerogels, for example, typically exhibit very low density and very low thermal conductivity and are found in a variety of insulating articles. Aerogel blankets, for example, can be utilized in pipe, aircraft, automotive, building, clothing, footwear, and other types of insulations.

10 **[0002]** U.S. Patent No. 7,399,439, issued to Lee, et al. on July 15, 2008 describes aerogel blankets that are formed using a process for continuously casting solvent filled gel sheet material in which a sol and a gel inducing agent are continuously combined to form a catalyzed sol. A gel sheet is produced by dispensing the catalyzed sol onto a moving element at a predetermined rate effective to allow gelation to occur to the catalyzed sol on the moving element. The solvent is extracted by supercritical fluid drying.

15 **[0003]** U.S. Patent No. 6,989,123 issued to Lee, et al. on January 24, 2006 describes aerogel blankets produced using a process for casting gel sheets, the process including: providing a quantity of fibrous batting material; introducing a quantity of impermeable material to separate the quantity of fibrous batting material into a fiber-roll preform having a plurality of fibrous layers; infusing a quantity of catalyzed sol into the fiber-roll preform; gelling the catalyzed sol in the fiber-roll preform; removing the impermeable material to leave remaining a gel material; introducing a quantity of permeable material to separate the gel material into a plurality of layers. The interstitial solvent phase typically is removed by supercritical fluids extraction.

20 **[0004]** U.S. Patent No. 7,635,411, issued to Rouanet et al., on December 22, 2009, describes blankets produced by preparing an aqueous slurry, which includes hydrophobic aerogel particles, fibers, and at least one wetting agent. Preferably, the hydrophobic aerogel particles form an intimate mixture with the fibers, at least temporarily. The mixture can then be substantially dewatered, compressed, dried to form a web which can be further processed, e.g., by calendaring, to form a blanket.

SUMMARY OF THE INVENTION

30 **[0005]** Considering the vast number of applications requiring thermal insulation, a need continues to exist for flexible insulating articles that have attractive properties and for methods for producing and using them.

[0006] In one embodiment, a flexible insulating structure includes a batting and a mixture of aerogel-containing particles and a binder. The aerogel-containing particles impregnate at least one layer of the batting.

35 **[0007]** In another embodiment, a method for preparing a flexible insulating structure comprises applying a mixture including aerogel-containing particles and a binder to a batting having one or more batting layers; and drying or allowing the binder to dry, thereby forming the flexible insulating structure.

[0008] Articles described herein have low thermal conductivity and present many advantages. For instance, the flexible insulating structure can have improved flame and fire properties and can withstand elevated temperatures. In many implementations, the structure displays good performance under compressive loads and can have acoustic and/or electrical insulation characteristics.

40 **[0009]** Methods for fabricating the flexible insulating structure described herein use widely available materials, are relatively straightforward and amenable to scale-up for industrial manufacturing processes, using, for instance, air-laid and/or roll to roll technology. Use of prefabricated aerogel particles obviates the need for in situ gelling required by many existing methods for preparing aerogel blankets. Batting selection provides opportunities and flexibility to fine tune properties such as thermal conductivity, behavior at elevated temperatures, behavior under compressive load, tensile strength, thickness and others.

45 **[0010]** Other advantages associated with aspects of the invention relate to flexibility of addition of other additives to modify, e.g., improve, fire characteristics, thermal insulation performance at high and/or low, e.g., cryogenic, temperatures, water and water vapor sorption characteristics and so forth.

BRIEF DESCRIPTION OF THE DRAWINGS

50 **[0011]** In the accompanying drawings, reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale; emphasis has instead been placed upon illustrating the principles of the invention. Of the drawings:

55 FIG. 1 is a photograph of an insulating flexible material according to one aspect of the invention.

FIGS. 2A, 2B and 2C illustrate the formation of a sandwich structure including a total of two fabric layers.

FIGS. 3A, 3B and 3C illustrate the formation of a sandwich structure including a total of four fabric layers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] The above and other features of the invention including various details of construction and combinations of parts, and other advantages, will now be more particularly described with reference to the accompanying drawings and pointed out in the claims. It will be understood that the particular method and device embodying the invention are shown by way of illustration and not as a limitation of the invention.

[0013] The invention generally relates to an insulation article (structure) that includes a fiber component, generally in the form of one or more layers, and a nanoporous material, e.g., aerogel-containing particles, to methods for producing and to methods for using the article or structure.

[0014] Generally, the layers are in the form of a lofty fibrous structure (i.e. batting), and in many cases are non-woven. In non-woven materials, fibers are held together by mechanical interlocking in a random web (mesh) or mat; bonding can be achieved using a medium such as, for example, starch, glue, casein, rubber, latex, synthetic resins, cellulose derivatives, by fusing of the fibers and/or by other means, e.g., as known in the art. In some cases, non-woven layers are made of crimped fibers that can range in length from about 0.75 to about 4.5 inches. The diameter of the fibers can be in within the range of about 0.1 to about 10,000 microns. Other fiber dimensions can be selected.

[0015] Woven fiber layers, using leno, plain or other weaving techniques, e.g., as known in the art, also can be employed.

[0016] In some embodiments, the batting has insulating properties. For instance, the batting can have a thermal conductivity no greater than about 80mW/m-K at 23°C, e.g., within the range of from about 20 mW/m-K to about 60mW/m-K, in many cases within the range of from about 25mW/m-K to about 50mW/m-K.

[0017] In other embodiments, the batting is suitable for high temperature applications. For example, the batting employed can withstand temperatures above about 200°C, for instance, above 300°C, and even above 600°C without degradation. In other embodiments, the batting has flame and/or fire resistance, low flame propagation, desirable surface burning characteristics and so forth.

[0018] The batting can be flexible and, in specific examples, it is provided in rolled up fashion.

[0019] The batting can be made from any suitable material such as, for example, metal oxide fibers such as glass fibers, mineral wool fibers, e.g., stone or slag fibers, biosoluble ceramic fibers, carbon fibers, polymer-based fibers, e.g., polyester, aramid, polyolefin, polyethylene terephthalate, polymer blends, co-polymers and so forth, metallic fibers, cellulose fibers, plant-derived fibers, other suitable fibers or combinations of fibers.

[0020] In specific implementations the batting is made in whole or in part of glass fibers, using, for instance: A-glass (a high-alkali glass containing 25% soda and lime, offering good resistance to chemicals, but relatively low electrical properties); C-glass (a special mixture with high chemical resistance); E-glass (electrical grade with low alkali content); S-glass (a high-strength glass with a 33% higher tensile strength than E-glass); D-glass (a low dielectric constant material with superior electrical properties but lesser mechanical properties relative to E-or S-glass); or other types of glass fibers, e.g., as known in the art.

[0021] In other specific implementations, the batting consists of, consists essentially of or comprises an insulating synthetic polymeric material such as, for example, Thinsulate™, manufactured by 3M Corporation and advertised as providing 1 to 1.5 times the insulation of duck down; or PrimaLoft® (a registered trademark of the Albany International Corporation), a material based on synthetic microfibers and often a viable alternative to goose down. In many cases, polymeric materials used in battings include polyethylene terephthalate or mixtures of polyethylenene therephthalate and polypropylene. In other cases, the batting polymeric materials include polyethylene terephthalate-polyethylene isophthalate copolymer and/or acrylic. Other polymers, e.g., polyesters, polymer blends, copolymers and so forth can be employed to form the batting.

[0022] The batting material can be characterized by its density. Suitable batting materials can have a density within the range of from about 1 kg/m³ to about 20 kg/m³, e.g., 4 kg/m³. Web or mesh-like batting, such as, for example, those made of fiberglass, can be characterized by mesh numbers, as known in the art, or in other ways suitable for describing the (average) opening size present in the web. Typically, larger mesh numbers indicate smaller openings and smaller mesh numbers indicate larger openings.

[0023] Thickness and weight are other properties typically specified for a particular batting. For instance, the batting layer can have a thickness suitable to a desired application. In specific examples, the batting can be as thin as about 0.5 mm or as thick as about 110 mm. In specific examples, the batting is 4, 8, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 or 102 mm. Thinner battings can be easily rolled, for instance they can be wrapped around smaller radii, while thicker ones can provide added mechanical strength, such as tensile strength and other properties. A suitable batting layer can have a weight of, for example, at least 50 g/m², e.g., 100 g/m², 150 g/m², 200 g/m², 250 g/m² or even higher.

[0024] Provided as an illustrative example, Table 1 shows the properties of several commercial grades of Thinsulate™ Ultra Lite Loft.

Table 1

	Thickness (cm)	Weight (g/m ²)	Density (kg/m ³)
FX100	0.55	105	19.1
LL250	6.4	250	3.9
US100	1.07	128	12.0
US150	1.62	180	11.1
US200	2.14	233	10.9

[0025] The batting can be made of two or more layers, arranged, for example in multi-ply fashion. In many implementations, the multiple layers are all made of essentially the same material and can be the same or different with respect to layer thickness, density, mesh numbers, and/or other batting-related parameters. Layers manufactured from different materials also can be utilized, and such layers can have the same or different layer thickness, density, mesh numbers, and/or other batting-related parameters.

[0026] At least one of the layers present in the structure described herein contains a nanoporous material. As used herein, the term "nanoporous" refers to a material having pores that are smaller than about 1 micron, e.g., less than 0.1 microns. Examples of suitable nanoporous materials include, but are not limited to, oxides of a metal such as, for instance, silicon, aluminum, zirconium, titanium, hafnium, vanadium, yttrium and others, and/or mixtures thereof.

[0027] In an exemplary embodiment the nanoporous material is an aerogel. Aerogels are low density porous solids that have a large intraparticle pore volume and typically are produced by removing pore liquid from a wet gel. However, the drying process can be complicated by capillary forces in the gel pores, which can give rise to gel shrinkage or densification. In one manufacturing approach, collapse of the three dimensional structure is essentially eliminated by using supercritical drying. A wet gel also can be dried using ambient pressure, also referred to as non-supercritical drying process. When applied, for instance, to a silica-based wet gel, surface modification, e.g., end-capping, carried out prior to drying, prevents permanent shrinkage in the dried product. The gel can still shrink during drying but springs back recovering its former porosity.

[0028] Product referred to as "xerogel" also is obtained from wet gels from which the liquid has been removed. The term often designates a dry gel compressed by capillary forces during drying, characterized by permanent changes and collapse of the solid network.

[0029] For convenience, the term "aerogel" is used herein in a general sense, referring to both "aerogels" and "xerogels".

[0030] Aerogels typically have low bulk densities (about 0.15 g/cm³ or less, in many instances about 0.03 to 0.3 g/cm³), very high surface areas (generally from about 300 to about 1,000 square meters per gram (m²/g) and higher, for example from about 600 to about 1000 m²/g), high porosity (about 90% and greater, e.g., greater than about 95%), and a relatively large pore volume (e.g., about 3 milliliter per gram (mL/g), for example, about 3.5 mL/g and higher, for instance, 7 mL/g). Aerogels can have a nanoporous structure with pores smaller than 1 micron (μ m). Often, aerogels have a mean pore diameter of about 20 nanometers (nm). The combination of these properties in an amorphous structure gives the lowest thermal conductivity values (e.g., 9 to 16 mW/m-K, at a mean temperature of 37° C and 1 atmosphere of pressure) for any coherent solid material. Aerogels can be nearly transparent or translucent, scattering blue light, or can be opaque.

[0031] A common type of aerogel is silica-based. Aerogels based on oxides of metals other than silicon, e.g., aluminum, zirconium, titanium, hafnium, vanadium, yttrium and others, or mixtures thereof can be utilized as well.

[0032] Also known are organic aerogels, e.g., resorcinol or melamine combined with formaldehyde, dendretic polymers, and so forth, and the invention also could be practiced using these materials.

[0033] Suitable aerogel materials and processes for their preparation are described, for example, in U.S. Patent Application No. 2001/0034375 A1 to Schwertfeger et al., published on October 25, 2001.

[0034] In many implementations, the aerogel employed is hydrophobic. As used herein, the terms "hydrophobic" and "hydrophobized" refer to partially as well as to completely hydrophobized aerogel. The hydrophobicity of a partially hydrophobized aerogel can be further increased. In completely hydrophobized aerogels, a maximum degree of coverage is reached and essentially all chemically attainable groups are modified.

[0035] Hydrophobicity can be determined by methods known in the art, such as, for example, contact angle measurements or by methanol (MeOH) wettability. A discussion of hydrophobicity in relation to aerogels is found, for example, in U.S. Patent No. 6,709,600 B2 issued to Hrubesh et al. on March 23, 2004.

[0036] Hydrophobic aerogels can be produced by using hydrophobizing agents, e.g., silylating agents, halogen- and in particular fluorine-containing compounds such as fluorine-containing alkoxysilanes or alkoxysiloxanes, e.g., trifluor-

opropyltrimethoxysilane (TFPTMOS), and other hydrophobizing compounds known in the art.

[0037] Silylating compounds such as, for instance, silanes, halosilanes, haloalkylsilanes, alkoxyalkylsilanes, alkoxyhalosilanes, disiloxanes, disilazanes and others are often utilized. Examples of suitable silylating agents include, but are not limited to diethyldichlorosilane, allylmethyldichlorosilane, ethylphenyldichlorosilane, phenylethyldiethoxysilane, trimethylalkoxysilanes, e.g., trimethylbutoxysilane, 3,3,3-trifluoropropylmethyldichlorosilane, symdiphenyltetramethyldisiloxane, trivinyltrimethylcyclotrisiloxane, hexaethyldisiloxane, pentylmethyldichlorosilane, divinylpropoxysilane, vinyldimethylchlorosilane, vinylmethyldichlorosilane, vinyldimethylmethoxysilane, trimethylchlorosilane, hexamethyldisiloxane, hexenylmethyldichlorosilane, hexenyldimethylchlorosilane, dimethylchlorosilane, dimethyldichlorosilane, mercaptopropylmethyldimethoxysilane, bis{3-(triethoxysilyl)propyl}tetrasulfide, hexamethyldisilazane and combinations thereof.

[0038] Hydrophobizing agents can be used during the formation of aerogels and/or in subsequent processing steps, e.g., surface treatment.

[0039] In some examples, the aerogel has a hydrophilic surface or shell obtained, for example, by treating hydrophobic aerogel with a surface active agent, also referred to herein as surfactant, dispersant or wetting agent.

[0040] Increasing the amount of surfactant tends to increase the depth to which the aqueous phase can penetrate and thus the thickness of the hydrophilic coating surrounding the hydrophobic aerogel core.

[0041] The insulating structure described herein can include additives such as fibers, opacifiers, color pigments, dyes or mixtures and, in some cases, these additives are present in the aerogel component. For instance, a silica aerogel can be prepared to contain fibers and/or one or more metals or compounds thereof. Specific examples include aluminum, tin, titanium, zirconium or other non-siliceous metals, and oxides thereof. Non-limiting examples of opacifiers include carbon black, titanium dioxide, silicon carbide, zirconium silicate, and mixtures thereof. Additives can be provided in any suitable amounts, e.g., depending on desired properties and/or specific application.

[0042] Generally, the nanoporous material employed, e.g. a silica aerogel such as described herein, is prefabricated, as opposed to being formed in situ, during the manufacture of the insulation structure. Specific embodiments, for example, utilize aerogel-containing particles, e.g., granules, pellets, beads, powders or other types of aerogel-containing particulate material. Suitable particulate materials can consist, consist essentially of or comprise aerogel, e.g., a silica-based aerogel.

[0043] The particles can have any particle size suitable for an intended application. For instance, the aerogel particles can be within the range of from about 0.01 microns (μm) to about 10.0 millimeters (mm) and can have, for example, a mean particle size in the range of 0.3 to 5.0 mm. In many examples, the average particle size is within the range of from about 1 micron to 100 μm , for instance within the range of 8-10 μm . Other suitable particle sizes are within the range of from about 0.3 to about 1 μm ; from about 1 to about 3, 5 or 8 μm ; from about 10 to about 15 or about 20 μm ; from about 20 to about 35 μm ; or from about 35 to about 50 μm . Combinations of particle sizes also can be used. In specific examples, the particle size is selected considering factors such as desired degree of penetration through the batting, the type of batting utilized, size of mesh openings in the batting layer(s), batting or batting layer thickness, and so forth.

[0044] Examples of commercially available aerogel materials in particulate form are those supplied under the trade-name of Nanogel® by Cabot Corporation, Billerica, Massachusetts. Nanogel® aerogel granules have high surface area, are greater than about 90% porous and are available in a wide range of particle sizes such as, for example, the ranges described above. Specific grades of translucent Nanogel® aerogel include, for instance, those designated as TLD302, TLD301, TLD201 or TLD100; specific grades of IR-opacified Nanogel® aerogel include, e.g., those under the designation of RGD303 or CBTL103; specific grades of opaque Nanogel® aerogel include, for instance, those designated as OGD303.

[0045] The aerogel-containing material, preferably in particulate form, can also be derived from a monolithic aerogel or aerogel-based composites, sheets, blankets and so forth. For example, pieces of such aerogel materials can be obtained by breaking down, chopping, comminuting or by other suitable techniques through which aerogel particles can be obtained from aerogel monoliths, composites, blankets, sheets and other such precursors.

[0046] Examples of materials that can be processed to produce particles or pieces of aerogel-containing material include aerogel-based composite materials, such as those containing aerogel and fibers (e.g., fiber-reinforced aerogels) and, optionally, at least one binder. The fibers can have any suitable structure. For example, the fibers can be oriented in a parallel direction, an orthogonal direction, in a common direction or a random direction. There can be one or more types of fibers. The fibers can be different in terms of their composition, size or structure. In the composite, the one type of fibers can be in different dimensions (length and diameter) and their orientation can be different. For example long fibers are in plane aligned whereas smaller fibres are randomly distributed. Specific examples are described, for instance, in U.S. Patent No. 6,887,563, issued on May 3, 2005 to Frank et al.. Other examples include at least one aerogel and at least one syntactic foam. The aerogel can be coated to prevent intrusion of the polymer into the pores of the aerogel, as described, for instance in International Publication No. WO 2007047970, with the title Aerogel Based Composites. In yet other examples, the aerogel can derive from a blanket, e.g., arrangements in which blanket sheets are laminated together to form a multilayer structures. Described in U.S. Patent No. 5,789,075, issued on August 4, 1998 to Frank et al, are cracked monoliths and these also can serve as suitable precursor in producing the self supporting rigid composite

disclosed herein. In further examples the aerogel employed includes a composite of an aerogel material, a binder and at least one fiber material as described, for instance, in U.S. Patent No. 6,887,563, issued on May 3, 2005 to Frank et al.. Other suitable examples of aerogel material that can be used are fiber-web/aerogel composites that include bicomponent fibers as disclosed in U.S. Patent No. 5,786,059 issued on July 28, 1998 to Frank et al.. The aerogel particles also can be derived from sheets or blankets produced from wet gel structures, as described, for instance, in U.S. Patent Application Publication Nos. 2005/0046086 A1, published March 3, 2005, and 2005/0167891 A1, published on August 4, 2005, both to Lee et al.. Commercially, aerogel-type blankets or sheets are available from Cabot Corporation, Billerica, Mass. or from Aspen Aerogels, Inc., Northborough, Mass.

[0047] Combinations of aerogel-containing materials also can be employed. For instance, different types of aerogel-containing materials e.g., combinations or mixtures of granular aerogels having different particle sizes, acoustic and/or light transmitting properties. Blends of aerogel with other materials, such as, for instance, non aerogel nanoporous metal oxides, e.g., silica, including but not limited to fumed silica, colloidal silica or precipitated silica, carbon black, titanium dioxide, perlite, microspheres such as glass, ceramic or polymeric microspheres, silicates, copolymers, tensides, mineral powders, fibers, and so forth also can be used.

[0048] The nanoporous material, e.g., in the form of pre-fabricated aerogel particles, typically is provided in combination with other components. In many embodiments, the nanoporous material, e.g., pre-prepared aerogel-containing particles, is provided in combination with a binder. In many examples, the binder is a material that, under certain conditions, sets, hardens or becomes cured. For convenience, these and similar such processes are referred to herein as "drying". Preferably, these "drying" processes are irreversible.

[0049] In many implementations, the binder comprises, consists essentially of or consists of gypsum, a material based on calcium sulfate hemihydrate ($\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$). Typically, the calcined gypsum (calcium sulfate) is used in an aqueous slurry form; drying induced crystallization causes the formation of crystals of calcium sulfate which interlock to provide mechanical properties to the binder. In case of lime plaster (based on calcium oxide), the aqueous slurry forms calcium hydroxide which under the influence of carbon dioxide in the atmosphere forms calcium carbonate.

[0050] Other suitable binders comprise, consist essentially of or consist of one or more materials such as, for instance, cement, lime, mixed magnesium salts, silicates, e.g., sodium silicate, plaster and/or other inorganic or inorganic-containing compositions. Cements, for example, often include limestone, clay and other ingredients, e.g., hydrous silicates of alumina. Hydraulic cements, for instance, are materials that set and harden after being combined with water, as a result of chemical reactions with the mixing water, and that, after hardening, retain strength and stability even under water. The key requirement for this strength and stability is that the hydrates formed on immediate reaction with water be essentially insoluble in water. Setting and hardening of hydraulic cements is caused by the formation of water-containing compounds, which are produced as a result of reactions between cement components and water. The reaction and the reaction products are referred to as hydration and hydrates or hydrate phases, respectively. As a result of the immediate start of the reactions, stiffening can be observed which is initially slight but which increases with time. The point at which the stiffening reaches a certain level is referred to as the start of setting. Further consolidation is called setting, after which the hardening phase begins. The compressive strength of the material then grows steadily, over a period that ranges from a few days in the case of "ultra-rapid-hardening" cements to several years in the case of ordinary cements.

[0051] The binder can also consist of, consist essentially of or comprise one or more organic materials such as, for example, acrylates, other latex compositions, epoxy polymers, polyurethane, polyethylene polypropylene and polytetrafluoroethylene polymers, e.g., those available under the designation of Teflon™. Many organic binders can become set or hardened through polymerization or curing processes, e.g., as known in the art.

[0052] The binder can be combined with the aerogel component in any suitable ratio. Examples include but are not limited to aerogel to binder weight ratios within the range of 100 to 5 to 100 to 30. Other ratios of aerogel to binder can be selected. In specific examples, the aerogel to binder weight ratios are 100:10; 100:15; 100:20 or 100:25.

[0053] Some aspects of the invention employ one or more surfactants. Suitable surfactant that can be used in conjunction with the aerogel (e.g., aerogel particles) and binder can be ionic (anionic and cationic) surfactants, amphoteric surfactants, nonionic surfactants, high molecular surfactants, high molecular compounds and so forth. Combinations of different types of surfactants also can be utilized.

[0054] Anionic surfactants can include, for example, alkyl sulfates and higher alkyl ether sulfates, more specifically, ammonium lauryl sulfate, and sodium polyoxyethylene lauryl ether sulfate. Cationic surfactants include, for instance, aliphatic ammonium salts and amine salts, more specifically, alkyl trimethylammonium, and polyoxyethylene alkyl amine, for example. Amphoteric surfactants may be of betain type, such as alkyl dimethyl betain, or of oxido type, such as alkyl dimethyl amine oxido, for example. Nonionic surfactants include glycerol fatty acid ester, propylene glycol fatty acid ester, sorbitan fatty acid ester, polyoxyethylene sorbitan fatty acid ester, tetraoleic acid polyoxyethylene sorbitol, polyoxyethylene alkyl ether, polyoxyethylene alkyl phenyl ether, polyoxyethylene polyoxypropylene glycol, polyoxyethylene polyoxypropylene alkyl ether, polyethylene glycol fatty acid ester, higher fatty acid alcohol ester, polyhydric alcohol fatty acid ester, and others

[0055] Specific examples of surfactants that can be utilized include but are not limited to Pluronic P84, PE6100, PE6800, L121, Emulan EL, Lutensol FSA10, Lutensol XP89 all from BASF, MP5490 from Michelmann, AEROSOL OT (sodium di-2-ethylhexylsulfosuccinate), BARLOX 12i (a branched alkyl dimethylamine oxide), LAS (linear alkylbenzene sulfonates) and TRITON 100 (octylphenoxypolyethoxy(9-10)ethanol), TWEEN surfactants like TWEEN 100 surfactant, and BASF pluronic surfactants and others. A general class is glycols, alkoxylates polyoxyalkylene fatty ethers, such as polyoxyethylene fatty ethers, sorbitan esters, mono and diglycerides, polyoxyethylene sorbitol esters, polymeric surfactants like Hypermen polymer surfactants, sodium coco-PG-dimonium chloride phosphate and coamidopropyl PG-dimonium chloride phosphate, phosphate esters, polyoxyethylene (POE) fatty acid esters, Renex nonionic surfactants (nonionic esters formed by reaction of ethylene oxide and unsaturated fatty acids and heterocyclic resin acids.), alcohol ethoxylates, alcohol alkoxylates, ethylene oxide/propylene oxide block copolymers, polyoxyethylene derivatives of sorbitan esters or combinations thereof.

[0056] The specific amount of surfactant can be chosen by considering factors such as particle size, surfactant type and/or other suitable criteria. In many cases, the weight ratio of the surfactant to the amount of aerogel-containing particles and binder is at least about 1:100, e.g., from about 10:100 to about 30:100. Exemplary ratios that can be utilized include 5:100; 15:100; 20:100 or 25:100; 35:100.

[0057] Other ingredients can be present. As used herein, the terms "another" ingredient", "other ingredients" or "additional ingredient(s)" refer to compounds or materials that are external to the pre-prepared nanoporous material (e.g., aerogel-containing particles) employed. For example, if Nanogel® aerogel particles are utilized, the term "other ingredient" refers to ingredients that can be combined with the Nanogel® aerogel particles being used, rather than to ingredients already present in or at the surface of the Nanogel® aerogel particles. These other ingredients can be used to provide reinforcement to a final product, to wet the outer surface of aerogel particles, to increase adhesion to a batting substrate, rendering the composition more likely to stick to a particular batting material, to provide or enhance other characteristics desired in the composition or the finished insulating article, or for other reasons.

[0058] Examples of other ingredients that can be employed include but are not limited to opacifiers, viscosity regulators, curing agents, agents that enhance or slow down the rate at which the binder hardens, agents or materials that promote mechanical strength, viscosity regulators, pH modifiers, plasticizers, lubricants, reinforcements, fire retardants (such as, for example, halogen containing compounds, bromates, borates, aluminum tri-hydroxide, magnesium hydroxide, other oxides and/or other compounds known in the field of fibers, plastics, and composites), and others. Combinations of other ingredients also can be utilized.

[0059] In specific examples, the other ingredients are selected from fibers, fumed silica, colloidal silica or precipitated silica, opacifiers, including but not limited to carbon black and titanium dioxide, perlite, microspheres such as glass or polymeric microspheres, silicates, e.g., calcium silicate, copolymers, tensides, mineral powder, film building components, surfactants, and any combination thereof.

[0060] Fibers, for example, typically have elongated, e.g. cylindrical, shapes with length to diameter aspect ratios that are greater than 1, preferably greater than 5, more preferably greater than 8. In many examples suitable fibers have a length to diameter ratio of at least 20. The fibers can be woven, non-woven, chopped, or continuous. Fibers can be mono-component, bi-component, e.g., including a core made of one material and a sheath made of another material, or multi-component. Fibers may be hollow or solid and may have a cross-section that is flat, rectangular, cylindrical or irregular. The fibers may be loose, chopped, bundled, or connected together in a web or scrim.

[0061] Examples of fibers that can be added include mineral wool fibers, e.g., glass, stone or slag fibers; bio-soluble ceramic fibers; or a woven, non-woven or chopped form of continuously made glass or stone fiber. Carbon fibers, polymer-based fibers, metallic, e.g., steel, fibers, cellulose fibers, plant-derived, e.g., cotton, wood or hemp fibers. Combinations of fibers also can be used.

[0062] Amounts of other ingredients added may depend on specific applications and other factors. Thus other ingredients can be present, in amounts greater than 0 weight % of the total weight of the mixture, e.g., greater than 2 weight %, for example greater than 5 weight %, greater than 10 weight %, greater than 15 weight %, greater than 20 weight % or greater than 25 weight %. They can be present in the composition in amounts that are less than about 90 % by weight, e.g., less than about 75 weight % or less than 50% by weight.

[0063] Dry blending or wet mixing techniques can be utilized to combine the nanoporous material (such as pre-prepared aerogel-containing particles), binder, and, if used, surfactant and/or other ingredients. Two, more or all components can be added simultaneously. Ingredients also can be combined sequentially, using any suitable order.

[0064] In many embodiments, one or more of the starting materials contain a liquid and mixing produces a slurry. In other embodiments, dry starting materials can be combined with a liquid, in any suitable order, and mixing can be used to generate a slurry.

[0065] Mixing can be carried out manually (e.g., by manual stirring or shaking). In specific implementations, the slurry is formed with the aid of a blender or mixer, such as, for example, a cement mixer, a hand-held or an industrial impeller. Ribbon blender, double ribbon blades, planetary mixers and other suitable mixing devices, e.g., as known in the art, also can be utilized. In some cases, blade design and/or properties, e.g., increased blade sharpness, can reduce the

amount of time necessary to complete the mixing process and, in some cases, the properties of the final product. In specific examples, light particles, e.g., aerogel particles, are forced into a liquid phase. In other examples, liquid droplets are lifted to the lighter particles.

[0066] Parameters such as mixing speed, temperature, degree of shear, order and/or addition rate of the liquid and/or solid materials, and others can be adjusted and may depend on the scale of the operation, the physical and/or chemical nature of the compounds, and so forth.

[0067] Mixing techniques can be selected to change (typically reduce) the absolute size of the aerogel particles. In specific examples, the mixing technique selected provides enough shear to reduce the size of at least some of the aerogel particles, e.g., to improve penetration of the aerogel material into and/or through the batting being utilized. In other examples, e.g., in cases in which the starting aerogel particles have a particle size suitable for a particular batting, a more gentle mixing technique can be utilized. In yet other examples, the mixing technique is selected to modify the size distribution of the aerogel particles. In turn, a change in the particle size distribution can be utilized to provide improved particle packing efficiency.

[0068] Mixing can be conducted at room temperature or at other suitable temperatures. Typically, the components are combined in ambient air but special gas atmospheres and/or pressures can be provided.

[0069] In many cases, the slurry is aqueous, i.e., its liquid phase contains more than 50% volume percent water. Non-aqueous slurries also can be used. Such non-aqueous slurries can contain one or more organic compounds, such as, for example organic solvents, surfactants, thinners, and so forth. Non-aqueous slurries can contain water in an amount of from about 0 to about 50 volume percent, for example, 5, 10, 15, 20, 25, 30, 35, 40, 45 or 49 volume %.

[0070] The slurry viscosity is selected considering factors such as, for example, the type of batting material utilized, batting thickness, number of batting layers being treated with the slurry, techniques employed to treat the batting with the slurry and so forth. Denser and/or thicker webs, for instance, may benefit from use of low viscosity slurries, whereas more viscous slurries can be used in conjunction with thin and/or open webs. In many cases, the slurry has a viscosity within the range of from about 2,000 centipoise (cp) to about 100,000 cp, for example, 10,000 cp; 20,000cp; 30,000 cp; 40,000 cp; 50,000cp; 60,000 cp; 70,000 co; 80,000 cp; or 90,000 cp.

[0071] The batting can be treated with the slurry by various processes. In many embodiments, the batting layer or layers are impregnated with the slurry. In some implementations, the process selected provides penetration of at least one of the batting layers utilized. In other implementations, the process provides penetration through two or more batting layers. In one example, the slurry is applied to a first batting layer, which is then covered by a second batting layer. Slurry is then applied to the second batting layer and the process is continued for the desired number of layers. In further implementation, the method selected is suitable for scale-up or industrial processes such as, for example, air-laid and/or roll to roll manufacturing.

[0072] Specific techniques contemplated for applying the slurry to the batting include but are not limited to: dipping or immersing the batting in the slurry, e.g., with or without bath agitation, pouring of the slurry over the batting, infusion, spraying or painting of the batting with the slurry, and/or other processes, e.g., as known in the art. It was discovered that soaking the batting in the slurry was particularly useful in impregnating multi (two or more) layered battings. In specific implementations, the soaking was conducted in the presence of shaking, stirring, or another suitable form of agitation for the entire soaking period or for a lesser time interval. Intermittent agitation of the immersion bath also can be employed.

[0073] Applying the slurry to the batting can be conducted at ambient conditions, e.g., room temperature and/or atmospheric pressure or at other suitable conditions. For instance, the batting can be treated at temperatures higher than room temperature. Pressure differentials can be used, for instance, to promote penetration of the slurry through web openings in the batting.

[0074] In many implementations, the aerogel-containing particles are distributed throughout the thickness of the single or multi-layered batting. Insulating structures that contain aerogel (or other nanoporous material) distributed throughout the thickness of all the batting layer(s) employed can be referred to as "impregnated" structures or articles. In "partially" impregnated structures, aerogel (or other nanoporous material) is distributed through some but not all the batting layers employed. In "painted" insulating structures, aerogel (or other nanoporous material) is present at one face of the structure but does not penetrate to the opposite face of the painted layer, e.g., to the inner face of an outer batting layer in a multi-layer arrangement.

[0075] The treated batting can be dried, e.g., at room temperature or at a higher than room temperature, using air or special atmospheres, e.g., inert gas. Drying can be carried out by simply allowing the slurry to dry or by using an oven, drying chamber, gas flow directed to the slurry-containing batting, drawing a vacuum through the treated batting, or any other suitable drying apparatus, e.g., as known in the art. In specific examples, the drying step is conducted using equipment and/or techniques suitable for a scale-up or industrial manufacturing process.

[0076] The structure can include additional elements. For example, one or both external (outer) faces of the structure described herein can be covered with a film, foil, coating or another type of outer layer for protection, to provide a reflective coating, water barrier or water vapor barrier, to form a multi-ply arrangement.

[0077] To produce such structures, one or more cover layers, made, for example of a film, foil, coating, or another suitable material can be affixed to one or both outer faces of the structure at any suitable time during or after the fabrication process. For instance, a cover can be provided at an outer face of an outer batting layer, before applying the mixture (slurry). In other cases, the cover can be attached to an outer face of the finished structure. When both (outer) faces of the structure are covered, the cover layers can be the same or different. For example, both coatings can be made of the same water or water vapor barrier material. In other cases, one cover layer can be designed to provide protection during unrolling, while the other can be a reflective film.

[0078] The cover can be attached by any suitable means. For instance, it can be laminated, glued, painted, sprayed, secured by mechanical means such as staples, fasteners, and so forth, or otherwise bonded to an outer face of the batting or the finished structure.

[0079] Additional elements also can be provided in the form of one or more internal layers made from a material other than a batting material. In one approach for fabricating such a structure, one or more non-batting layer is interspersed with batting layers and the process can be adapted to ensure that one or more of the batting layers become impregnated with the slurry. Immersion techniques, a sequential application of slurry to each batting layer or other suitable methods can be utilized.

[0080] The structure can contain at least one internal non-batting layer and at least one cover layer.

[0081] The resulting structure (article) can be in the form of a blanket, mat, sheet, flexible board and the like. The structure has at least some flexibility, and in many cases is sufficiently flexible to make possible wrapping the structure around an object, rolling and/or unrolling it, bending, folding and other operations desired in aerogel-containing blankets or flexible composites. A photograph of an insulating flexible material according embodiments described herein is shown in FIG. 1.

[0082] In many cases, the flexible insulating structure described herein has a thermal conductivity (at 23° C and 1 atmosphere) that is no greater than about 50 milliwatts divided by meter times degree Kelvin (mW/(m·K), e.g., no greater than about 30, for instance no greater than about 25 and in many cases no greater than about 23 mW/(m·K).

[0083] The structure can have other properties such as specific light transmission characteristics, e.g., transmit at least some visible light, acoustic insulation properties, e.g., sound absorbing and/or sound reflecting characteristics. The insulating flexible structure described herein also can have electrical insulating properties.

[0084] Properties associated with fire safety requirements such as, for instance, total calorific content, flames spread index, surface burning characteristics, combustibility, also can be provided.

[0085] In many implementations, the structure is capable of withstanding temperatures of at least 150°C, often at least 300°C, e.g., within the range of from about 100°C to about 800°C, such as, for example, within the range of from about 200°C to about 600°C, without significant deterioration.

[0086] In many cases the structure has hydrophobic properties.

[0087] The structure can perform well under compressive load, having, for instance, load bearing properties.

[0088] The insulating, flexible structure can be used to insulate pipes, e.g., in pipe-in-pipe arrangements, vessels or other industrial equipment, in buildings, automotive, ship, aircraft and other applications, in clothing, footwear, sporting equipment, and so forth. In many implementations, the structure is used in high temperature applications, e.g., within the range of from about 150°C to about 800°C. In one example, a method for insulating an object includes incorporating the flexible insulating structure of Claim 1 in an article containing the object; and exposing the article to a temperature of at least 150°C.

EXEMPLIFICATION

Example 1

[0089] 300 g deionized water, 0.33 g of a 50% solution of Pluronic P84 (BASF), 16.7 g of calcium sulfate hemi-hydrate (Sigma Aldrich) and 33 g TLD302 grade Nanogel® aerogel were blended for 3 minutes using a Waring Commercial 7010G Blender mixer from Waring Products, CT, on Low setting to form a mixture (or slurry).

[0090] The mixture was poured over two kinds of synthetic microfiber thermal insulators, namely: Thinsulate™ 100 (from 3M) and PrimaLoft® 1.8 oz (with the backing removed). After 45 minutes, examination of the samples revealed that only water had permeated through the PrimaLoft® insulation and nothing had permeated through the Thinsulate™ material. It is believed that the batting in the Thinsulate™ insulation interfered with the penetration of aerogel particles.

Example 2

[0091] 500 g deionized water, 0.33 g of a 50% solution of Pluronic P84 (BASF), 16.7 g of calcium sulfate hemi-hydrate (Sigma Aldrich) and 33 g TLD302 grade Nanogel® aerogel were blended using a Waring Commercial 7010G Blender on the "Low" setting for 3 minutes.

[0092] The mixture was poured over samples of PrimaLoft® with the backing removed. The PrimaLoft® material was made up of 4 layers of fabric. Several groups of samples were studied, each layer in the samples corresponding to 1/4th of a PrimaLoft® fabric. Group #1 samples had one layer; Group #2 samples were in the form of one layer sandwich; Group #3 samples had two layers; and Group #4 samples had a two layer sandwich arrangement.

[0093] In the "sandwich" arrangements, one or two layers were placed down, the mixture was poured over the upper surface of the bottom layer(s) and one or two layers were placed on top.

[0094] To illustrate, shown in FIG. 2A, for instance, is bottom fabric layer 12. The mixture 14, containing aerogel and binder, is added to the upper surface of layer 12, as shown in FIG. 2B. Fabric layer 16 is then placed on top of mixture 14, resulting in a sandwich structure containing two layers (12 and 16), as shown in FIG. 2C.

[0095] A sandwich structure with more than two layers can be prepared as illustrated in FIGS. 3A through 3C. Shown in FIG. 3A are two stacked bottom fabric layers, specifically fabric layers 22 and 24. Mixture 14 (containing aerogel and binder) is added (poured) at the upper surface of fabric layer 24, as shown in FIG. 3B. The structure is completed by covering the top of mixture 14 with layers 26 and 28, resulting in a sandwich structure containing more than 2 layers (in this case a total of four layers), as shown in FIG. 3C.

[0096] After 24 hours, for each one of the one layer samples (Group #1), the mixture had permeated through the layer to the bottom. When pulled apart, the sandwiched one layer samples (Group #2) had an even amount of dried mixture on either side. For the two layer samples (Group #3) the mixture did not permeate through to the bottom. When pulled apart, the two layer sandwich type samples (Group #4) presented a clean top layer with no dried mixture.

Example 3

[0097] 500 g deionized water, 0.33 g of a 50% solution of Pluronic P84 (BASF), 16.7 g of calcium sulfate hemi-hydrate (Sigma Aldrich) and 33 g TLD302 grade Nanogel® aerogel (particle size in the 1.2 to 3.2mm range) were blended on Lo setting, using a Waring Commercial 7010G Blender mixer from Waring Products, CT, for 3 minutes.

[0098] Portions of the mixture were placed in plastic screw top containers as follows. Container #1 included mixture along with 2 one-layer pieces of PrimaLoft®; container #2 included mixture along with 45 2 cm x 2 cm pieces of 1 layer thick PrimaLoft®. Both containers were shaken for 1 hour. The samples were removed and laid flat in a mold and allowed to dry overnight. Both approaches resulted in samples of PrimaLoft® that were well impregnated with the Nanogel® aerogel mixture.

Example 4

[0099] The mixture included the same ingredients and amounts used in Example 3, above, except for using grade TLD201 (particle size in the 1 to 30microns, d50 of 8-10 microns) Nanogel® type aerogel (rather than the TLD302 grade of Example 3). Blending was carried out by hand and the mixture was shaken with one-layer large pieces and one-layer 2 cm x 2 cm pieces and dried overnight. The samples were found to be well impregnated with the aerogel containing mixture.

[0100] The TLD201 grade Nanogel® aerogel had a particle size of 8-10 microns, which was believed to be approximately the same as the sheared down particle size obtained using TLD302 grade Nanogel® type aerogel and mechanical blending. The results indicated that both approaches led to well impregnated samples.

Example 5

[0101] 500 g deionized water, 0.33 g of a 50% solution of Pluronic P84 (BASF), 16.7 g of calcium sulfate hemi-hydrate (Sigma Aldrich) and 33 g TLD302 grade Nanogel® aerogel were blended on Lo setting, using a Waring Commercial 7010G Blender mixer from Waring Products, CT, for 3 minutes.

[0102] The mixture was placed in a gallon plastic container. Fully layered (all 4 PrimaLoft® layers) material (with the backing removed) was cut to 6" x 6" (Sample A). Another piece of fully layered PrimaLoft® material was cut into samples or 4 cm x 2 cm (Sample B). All these samples were soaked in the mixture for 5 minutes, after which they were placed on a wire mesh funnel. Excess liquid was removed by applying a vacuum. Another sample (Sample C) was made from two fully layered pieces of 6" x 6" PrimaLoft® that were soaked then placed on top of one another (for a total of 8 layers) and allowed to dry. All samples continued drying in an 80° C oven for 16 hours.

[0103] Thermal conductivity measurements were conducted according to the ASTM C518 method on a Lasercomp Model Fox 200, from Lasercomp, MA.

[0104] Sample A had a thermal conductivity of 25.57 mW/m·K and Sample C had a thermal conductivity of 23.46 mW/m·K. The sample made of multiple smaller pieces (Sample B) was not flat enough to allow thermal conductivity measurements.

[0105] Both Samples A and C were bendable and cuttable. Sample B was more rigid.

Other Observations

[0106] Drawing a vacuum was found to assist in the drying process but seemed ineffective in drawing the slurry through an insulating material such as PrimaLoft®.

[0107] Both stirring and shaking appeared beneficial in impregnating PrimaLoft® material, and was particularly useful when handling fully-layered PrimaLoft®.

Claims

1. A flexible insulating structure comprising:

(a) a flexible, lofty and fibrous batting;

(b) a mixture of aerogel-containing particles and a binder, the aerogel-containing particles impregnating at least one layer of the batting.

2. The flexible insulating structure of claim 1, wherein the thermal conductivity of the structure is no greater than about 23 mW/m·K at 23° C and 1 atmosphere.

3. The flexible insulating structure of claim 1, wherein the entire batting is impregnated with the aerogel-containing particles.

4. The flexible insulating structure of claim 1, wherein the binder is an inorganic binder.

5. The flexible insulating structure of claim 1, wherein the mixture further includes a surfactant.

6. The flexible insulating structure of claim 1, wherein the batting is woven or non-woven and is selected from the group consisting of polymeric fiber batting, glass fiber batting, mineral wool fiber batting, carbon fiber and any combination thereof.

7. The flexible insulating structure of claim 1, wherein the batting is a polyester fiber batting.

8. The flexible insulating structure of claim 1, further comprising at least one cover layer providing protection, a reflective coating, a water barrier or a water vapor barrier.

9. The flexible insulating structure of claim 1, further comprising one or more non-batting internal layers.

10. A method for preparing a flexible insulating structure, the method comprising:

applying a mixture including aerogel-containing particles and a binder to a flexible, lofty and fibrous batting having one or more batting layers, wherein at least one layer of the batting is impregnated with the aerogel-containing particles; and
drying or allowing the binder to dry, thereby forming the flexible insulating structure.

11. The method of claim 10, wherein the mixture further contains a surfactant.

12. The method of claim 10, wherein the mixture is a slurry.

13. The method of claim 12, wherein the batting is immersed or soaked in the slurry.

14. The method of claim 13, wherein the immersion or soaking is conducted in the presence of agitation.

15. The method of claim 10, wherein the entire flexible insulating structure is impregnated with aerogel-containing particles.

16. The method of claim 10, wherein the flexible insulating structure is partially impregnated or painted with aerogel-containing particles.

17. The method of claim 10, further comprising applying a cover layer to an outer face of the batting.
18. The method of claim 10, further comprising applying a cover layer to an outer face of the flexible insulating structure.
- 5 19. The method of claim 10, wherein the flexible insulating structure further includes at least one internal non-batting layer.

Patentansprüche

- 10 1. Flexible Isolierstruktur umfassend:

- (a) eine flexible, voluminöse und faserige Watte;
(b) eine Mischung aus aerogelhaltigen Teilchen und einem Bindemittel, wobei die aerogelhaltigen Teilchen wenigstens eine Schicht der Watte imprägnieren.

- 15 2. Flexible Isolierstruktur nach Anspruch 1, wobei die Wärmeleitfähigkeit der Struktur nicht größer als ungefähr 23 mW/m·K bei 23 °C und 1 Atmosphäre ist.

3. Flexible Isolierstruktur nach Anspruch 1, wobei die gesamte Watte mit den aerogelhaltigen Teilchen imprägniert ist.

4. Flexible Isolierstruktur nach Anspruch 1, wobei das Bindemittel an anorganisches Bindemittel ist.

5. Flexible Isolierstruktur nach Anspruch 1, wobei die Mischung außerdem einen oberflächenaktiven Stoff einschließt.

- 25 6. Flexible Isolierstruktur nach Anspruch 1, wobei die Watte gewebt oder nichtgewebt ist und ausgewählt ist aus der Gruppe bestehend aus Polymerfaserwatte, Glasfaserwatte, Mineralwollefaserwatte, Kohlenstofffaser und einer beliebigen Kombination davon.

7. Flexible Isolierstruktur nach Anspruch 1, wobei die Watte eine Polyesterfaserwatte ist.

8. Flexible Isolierstruktur nach Anspruch 1, außerdem umfassend wenigstens eine Deckschicht, die Schutz bereitstellt, einen reflektierenden Überzug, eine Wassersperre oder eine Wasserdampfsperre.

9. Flexible Isolierstruktur nach Anspruch 1, außerdem umfassend eine oder mehrere Nicht-Watte-Innenschichten.

- 35 10. Verfahren zum Herstellen einer flexiblen Isolierstruktur, wobei das Verfahren umfasst:

Aufbringen einer Mischung, die aerogelhaltige Teilchen und ein Bindemittel einschließt, auf eine flexible, voluminöse und faserige Watte mit einer oder mehreren Watteschichten, wobei wenigstens eine Schicht der Watte mit den aerogelhaltigen Teilchen imprägniert wird; und Trocknen oder Trocknenlassen des Bindemittels, wodurch die flexible Isolierstruktur gebildet wird.

11. Verfahren nach Anspruch 10, wobei die Mischung außerdem einen oberflächenaktiven Stoff enthält.

- 45 12. Verfahren nach Anspruch 10, wobei die Mischung eine Aufschlämmung ist.

13. Verfahren nach Anspruch 12, wobei die Watte in der Aufschlämmung eingetaucht oder eingeweicht wird.

14. Verfahren nach Anspruch 13, wobei das Eintauchen oder Einweichen in Gegenwart von Rühren durchgeführt wird.

- 50 15. Verfahren nach Anspruch 10, wobei die gesamte flexible Isolierstruktur mit aerogelhaltigen Teilchen imprägniert wird.

16. Verfahren nach Anspruch 10, wobei die flexible Isolierstruktur teilweise mit aerogelhaltigen Teilchen imprägniert oder angestrichen wird.

- 55 17. Verfahren nach Anspruch 10, außerdem umfassend das Aufbringen einer Deckschicht auf eine Außenseite der Watte.

18. Verfahren nach Anspruch 10, außerdem umfassend das Aufbringen einer Deckschicht auf eine Außenseite der flexiblen Isolierstruktur.
19. Verfahren nach Anspruch 10, wobei die flexible Isolierstruktur außerdem wenigstens eine innere Nicht-Watte-Schicht einschließt.

Revendications

1. Structure isolante souple comprenant :

(a) une nappe souple, élastique et fibreuse ;
 (b) un mélange de particules contenant un aérogel et d'un liant, les particules contenant un aérogel imprégnant au moins une couche de la nappe.

2. Structure isolante souple selon la revendication 1, dans laquelle la conductivité thermique de la structure n'est pas supérieure à environ 23 mW/m.K à 23°C et 1 atmosphère.

3. Structure isolante souple selon la revendication 1, dans laquelle toute la nappe est imprégnée de particules contenant un aérogel.

4. Structure isolante souple selon la revendication 1, dans laquelle le liant est un liant inorganique.

5. Structure isolante souple selon la revendication 1, dans laquelle le mélange comprend en outre un tensioactif.

6. Structure isolante souple selon la revendication 1, dans laquelle la nappe est tissée ou non tissée et est sélectionnée parmi le groupe composé d'une nappe de fibres polymères, d'une nappe de fibres de verre, d'une nappe de fibres de laine minérale, de fibre de carbone et d'une quelconque combinaison de celles-ci.

7. Structure isolante souple selon la revendication 1, dans laquelle la nappe est une nappe de fibres de polyester.

8. Structure isolante souple selon la revendication 1, comprenant en outre au moins une couche de couverture fournissant une protection, un revêtement réfléchissant, une barrière contre l'eau ou une barrière contre la vapeur d'eau.

9. Structure isolante souple selon la revendication 1, comprenant en outre une ou plusieurs couches internes différentes de la nappe.

10. Procédé de préparation d'une structure isolante souple, le procédé comprenant :

l'application d'un mélange comprenant des particules contenant un aérogel et un liant sur une nappe souple, élastique et fibreuse comprenant une ou plusieurs couches de nappe, dans lequel l'au moins une couche de la nappe est imprégnée des particules contenant un aérogel ; et
 l'étape consistant à sécher ou laisser sécher le liant, formant ainsi la structure isolante souple.

11. Procédé selon la revendication 10, dans lequel le mélange contient en outre un tensioactif.

12. Procédé selon la revendication 10, dans lequel le mélange est une pâte.

13. Procédé selon la revendication 12, dans lequel la nappe est immergée ou trempée dans la pâte.

14. Procédé selon la revendication 13, dans lequel l'immersion ou le trempage est réalisé(e) en présence d'agitation.

15. Procédé selon la revendication 10, dans lequel toute la structure isolante souple est imprégnée de particules contenant un aérogel.

16. Procédé selon la revendication 10, dans lequel la structure isolante souple est partiellement imprégnée de/peinte avec des particules contenant un aérogel.

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17. Procédé selon la revendication 10, comprenant en outre l'application d'une couche de couverture sur une face externe de la nappe.
- 5 18. Procédé selon la revendication 10, comprenant en outre l'application d'une couche de couverture sur une face externe de la structure isolante souple.
19. Procédé selon la revendication 10, dans lequel la structure isolante souple comprend en outre au moins une couche interne différente de la nappe.

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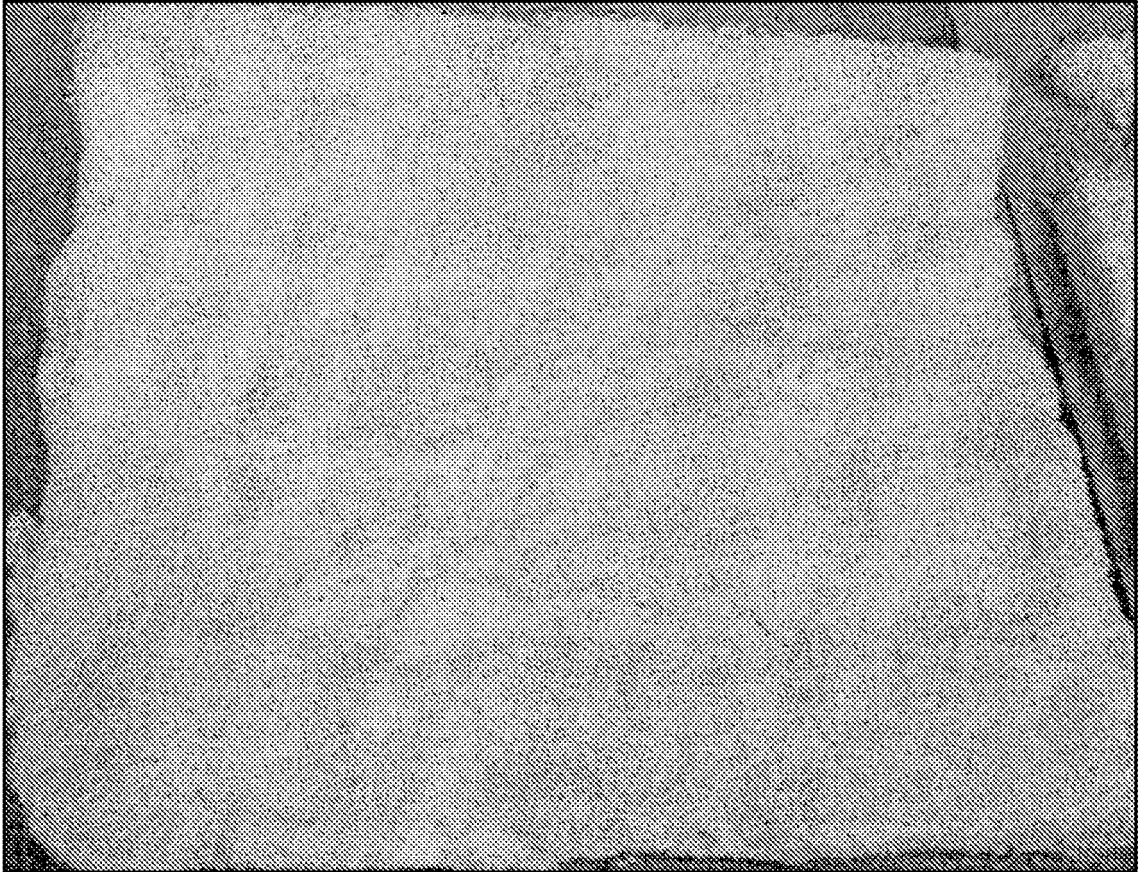
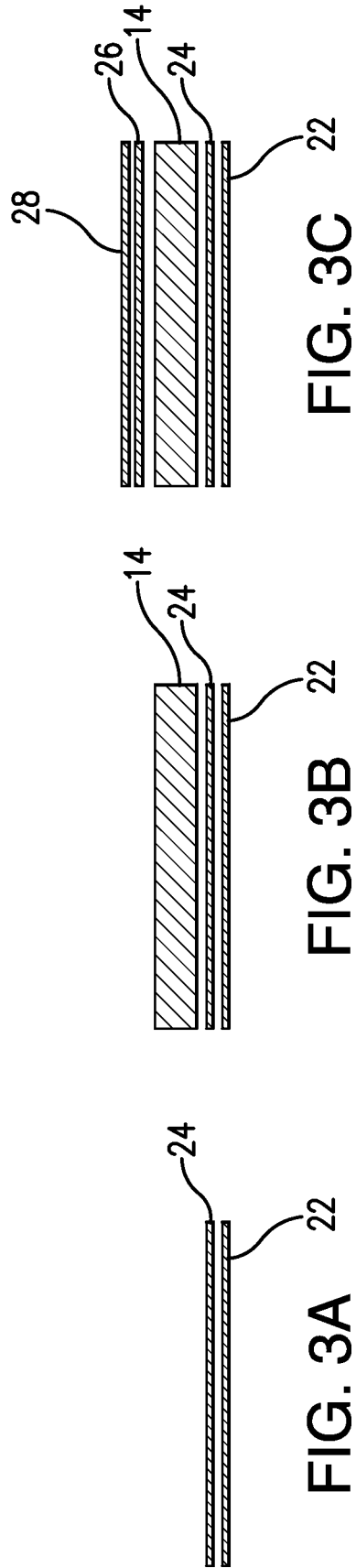
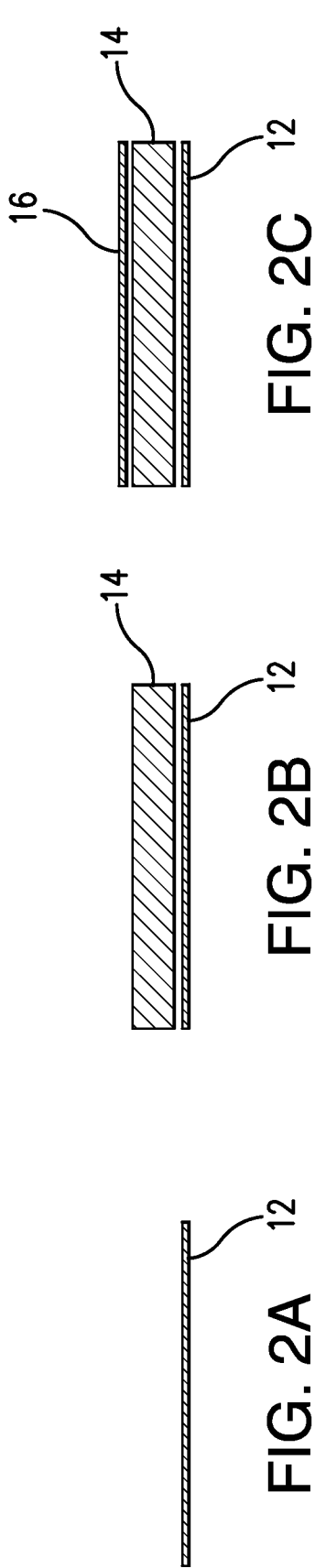


FIG. 1



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 7399439 B, Lee [0002]
- US 6989123 B, Lee [0003]
- US 7635411 B, Rouanet [0004]
- US 20010034375 A1, Schwertfeger [0033]
- US 6709600 B2, Hrubesh [0035]
- US 6887563 B, Frank [0046]
- WO 2007047970 A [0046]
- US 5789075 A, Frank [0046]
- US 5786059 A, Frank [0046]
- US 20050046086 A1 [0046]
- US 20050167891 A1, Lee [0046]