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(54) **PACKAGING TO IMPROVE SHELFLIFE OF INSULATION PRODUCTS**

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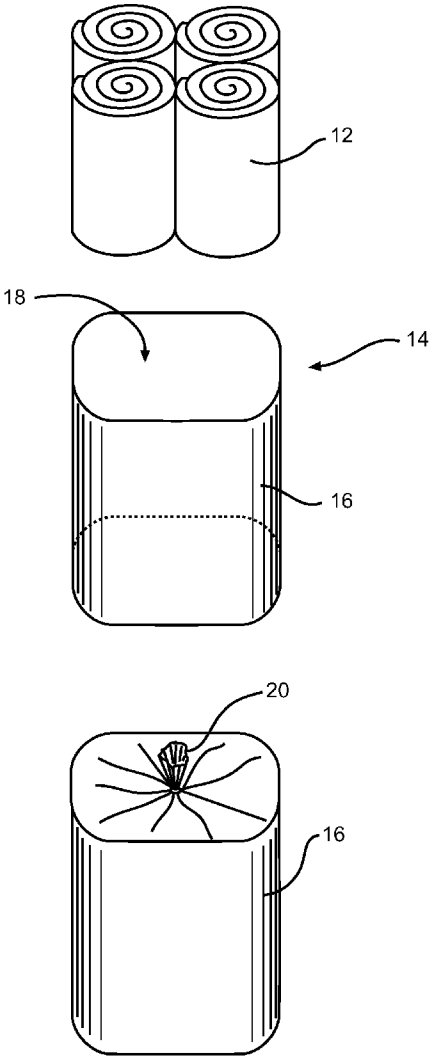
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(57) **ABSTRACT**

Fibrous insulation products have a binder composition that may include a carbohydrate and a crosslinking agent, and potentially other optional ingredients. The shelf life and physical properties of fibrous insulation products, particularly those having bio-based binders, can be improved by packaging that completely envelopes and seals the fibrous product from exposure to atmospheric conditions. Exemplary envelopes disclosed include sealed bags, double stretch wrap and stretch hoods. Properties that can be improved include recovery of loft, restoring force and tensile strength among others.



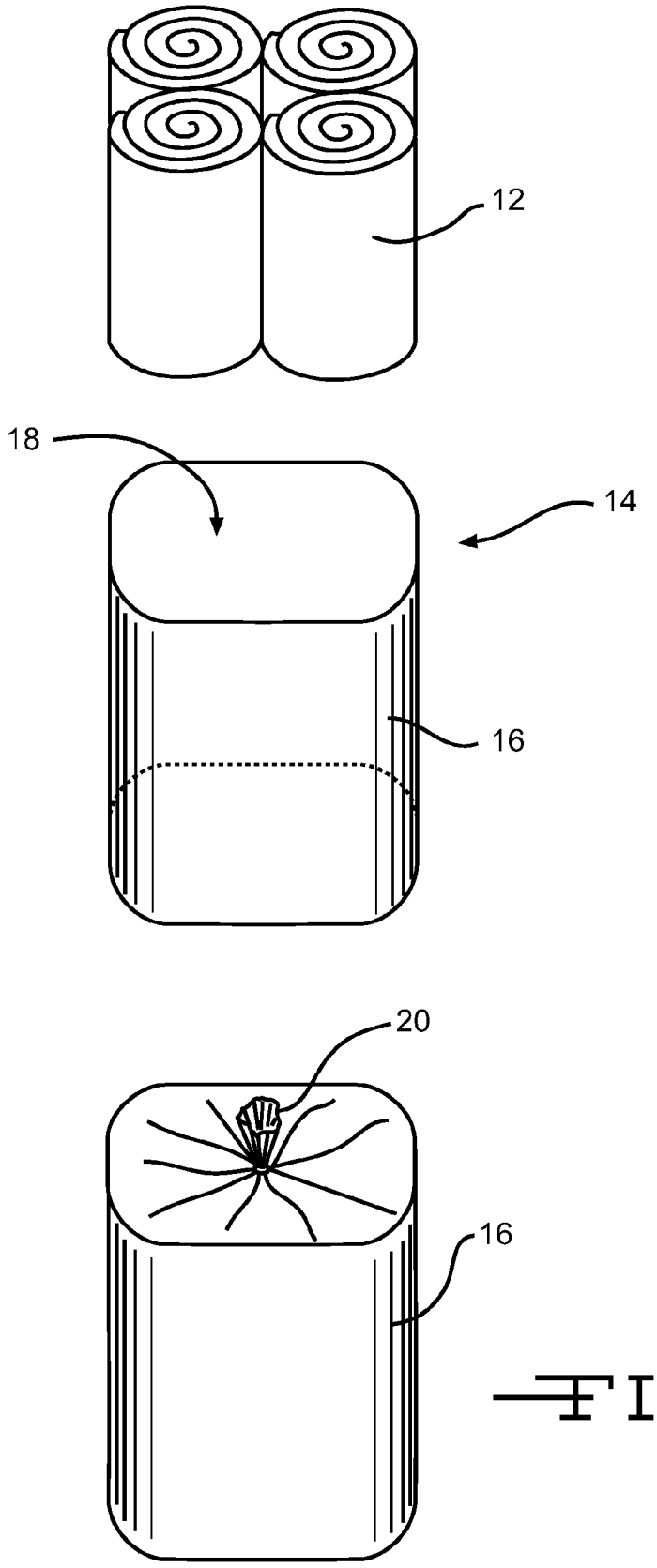


FIG. 1

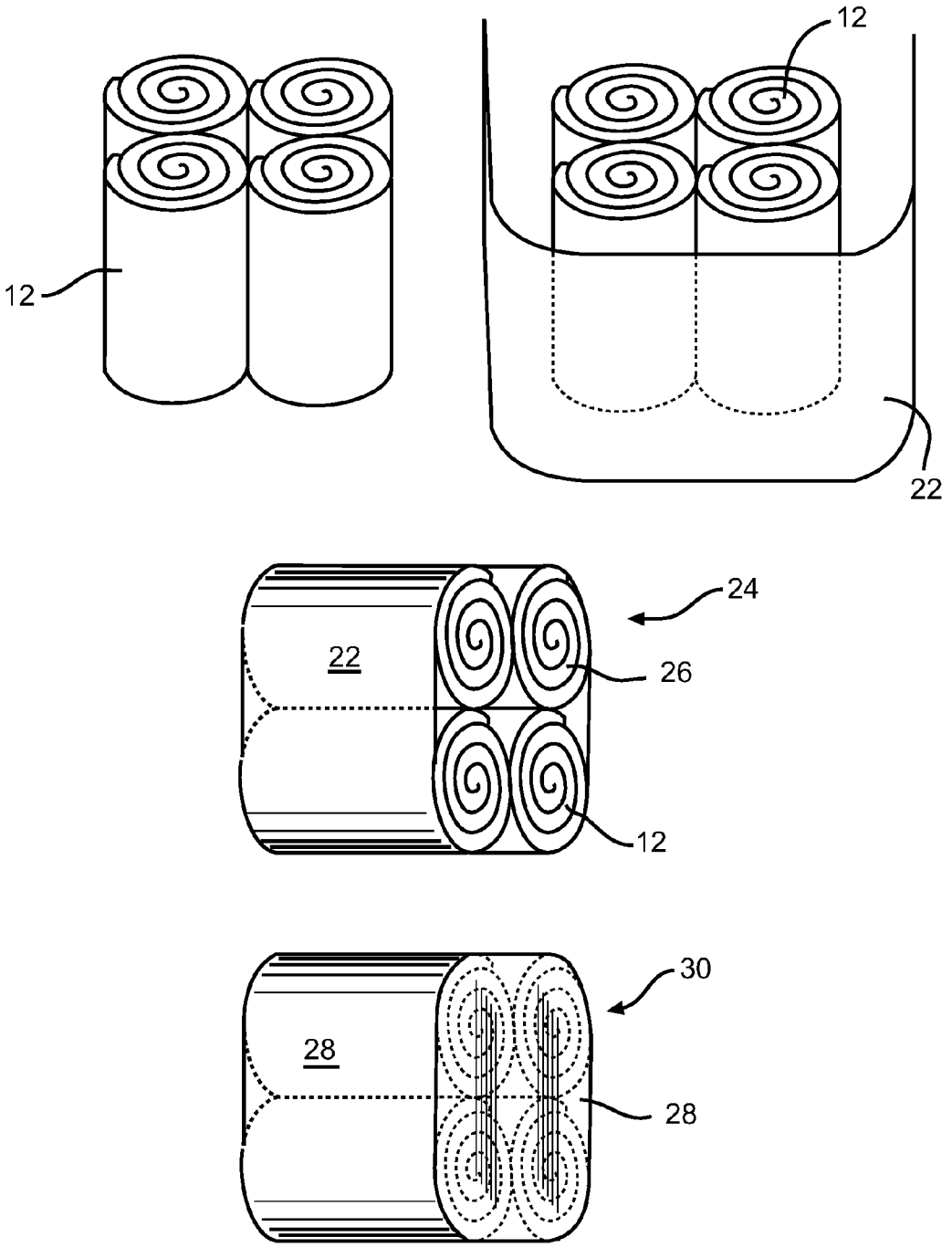


FIG. 2

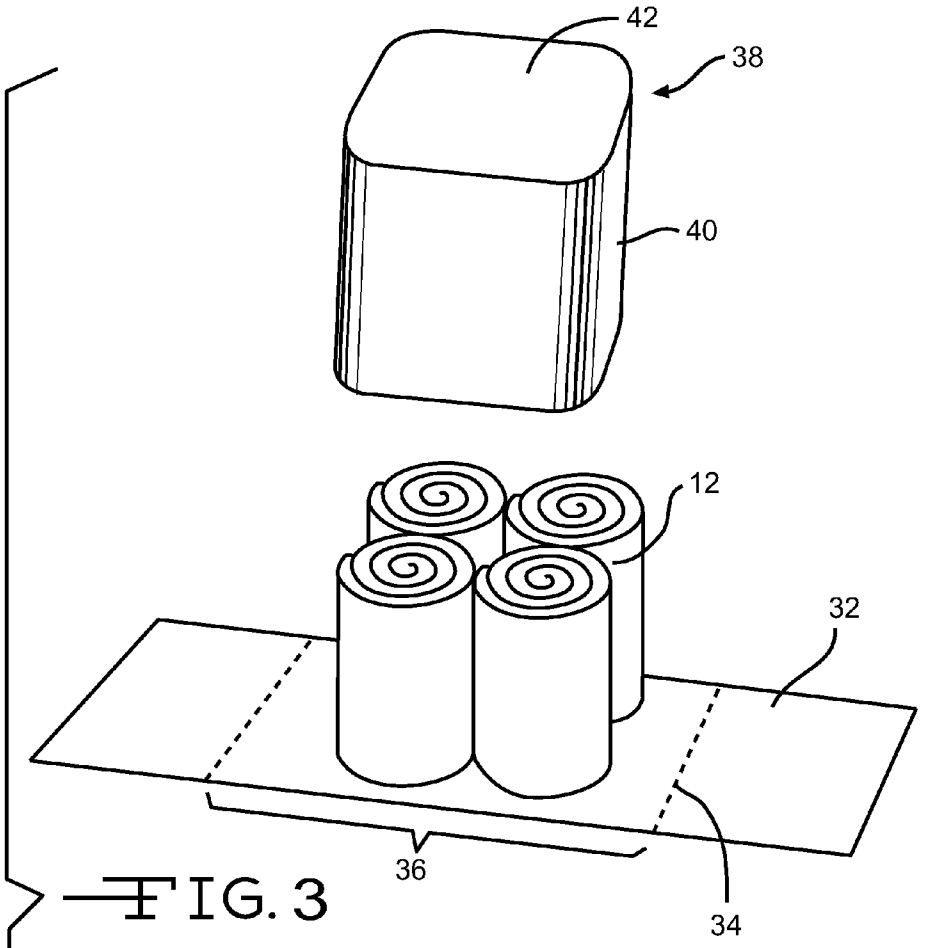


FIG. 3

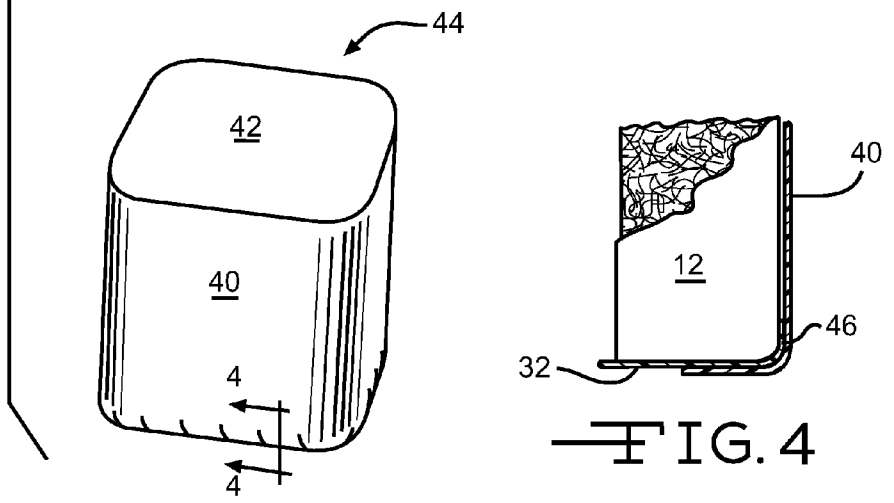


FIG. 4

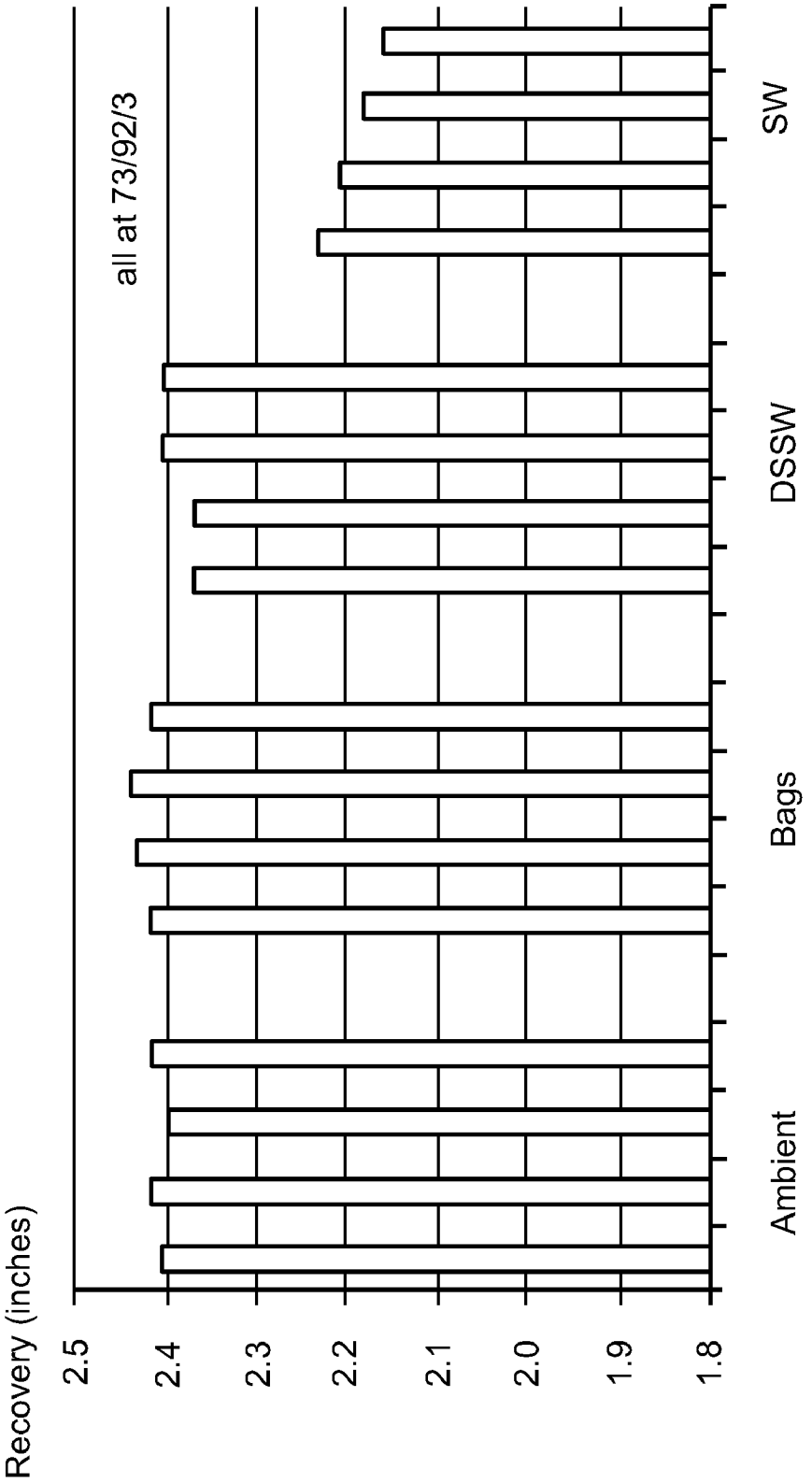

Recovery (inches)
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
all at 73/92/3
Ambient
Bags
DSSW
SW

FIG. 5

PACKAGING TO IMPROVE SHELFLIFE OF INSULATION PRODUCTS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to U.S. patent application Ser. No. 13/037,725 titled "INSULATIVE PRODUCTS HAVING BIO-BASED BINDERS" filed Mar. 1, 2011, and to applications to which it is in turn related, the entire contents of which are expressly incorporated herein by reference.

TECHNICAL FIELD AND INDUSTRIAL APPLICABILITY OF THE INVENTION

[0002] The present invention relates generally to fibrous insulation products and, more particularly, to packaging that improves the physical properties of fibrous insulation products, especially products that contain a bio-based binder.

BACKGROUND OF THE INVENTION

[0003] Conventional fibers are useful in a variety of applications including reinforcements, textiles, and acoustical and thermal insulation materials. Although mineral fibers (e.g., glass fibers) are typically used in insulation products and non-woven mats, depending on the particular application, organic fibers such as polypropylene, polyester, and multi-component fibers may be used alone or in combination with mineral fibers in forming the insulation product or non-woven mat.

[0004] Fibrous insulation is typically manufactured by fiberizing a molten composition of polymer, glass, or other mineral and spinning fine fibers from a fiberizing apparatus, such as a rotating spinner. To form an insulation product, fibers produced by the rotating spinner are drawn downwardly from the spinner towards a conveyor by a blower. As the fibers move downward, a binder material is sprayed onto the fibers and the fibers are collected into a high loft, continuous blanket on the conveyor. The binder material gives the insulation product resiliency for recovery after packaging and provides stiffness and handleability so that the insulation product can be handled and applied as needed in the insulation cavities of buildings. The binder composition also provides protection to the fibers from interfilament abrasion and promotes compatibility between the individual fibers.

[0005] The blanket containing the binder-coated fibers is then passed through a curing oven and the binder is cured to set the blanket to a desired thickness. After the binder has cured, the fiber insulation may be cut into lengths to form individual insulation products, and the insulation products may be packaged for shipping to customer locations.

[0006] It has been found that certain physical properties of fibrous insulation products may deteriorate over aging or storage time. This is particularly true of products stored under conditions of high heat and humidity, and has been found to be a problem for phenolic or formaldehyde based binders as well as bio-based binders. The present invention provides solutions to such problems.

SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to provide packaging for fibrous insulation product that includes a plurality of randomly oriented fibers and a binder composition applied to at least a portion of the fibers and interconnecting the fibers.

[0008] Thus, in a first aspect the invention provides a method of improving the physical properties of a fibrous insulation product subjected to storage in ambient conditions, the method comprising:

[0009] applying a binder to the fibrous product;

[0010] curing the binder to form a cured fibrous insulation product having defined physical properties; and

[0011] packaging the cured fibrous product in a package that preserves the defined physical properties.

[0012] In this first aspect, the defined physical property of the fibrous product may be any or all of (a) recovery of loft, (b) restoring force, and (c) tensile strength; and the package has a permeance not more than about 0.9 g/hr-ft^2-in Hg; or not more than about 0.5 g/hr-ft^2-in Hg; or between about 0.05 and about 0.5 g/hr-ft^2-in Hg.

[0013] In a second aspect the invention provides a method of minimizing the recovery degradation of a fibrous insulation product having a cured binder, the method comprising storing the cured fibrous product in a package that has a permeance of not more than about 0.9 g/hr-ft^2-in Hg.

[0014] In both aspects, the permeance is preferably less than about 0.5 g/hr-ft^2-in Hg, and may be in the range from about 0.05 to about 0.5 g/hr-ft^2-in Hg. Furthermore, in each aspect, the package has elasticity in the range of about 400% to about 1000%; a tensile strength in the range of about 3500 to about 8400 psi; and a tear strength in the range of 300 to about 900 grams/mil nominal thickness. The package may be made of a composition selected from low-density polyethylene (LDPE) or a copolymer of LDPE with polyvinylchloride, polypropylene or polyamides. The packaging may comprise a bag, a double stretch wrap or a stretch hood, as those terms are defined herein.

[0015] The foregoing and other objects, features, and advantages of the invention will appear more fully hereinafter from a consideration of the detailed description that follows. It is to be expressly understood, however, that the drawings are for illustrative purposes and are not to be construed as defining the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The advantages of this invention will be apparent upon consideration of the following detailed disclosure of the invention, especially when taken in conjunction with the accompanying drawings wherein:

[0017] FIG. **1** is perspective view illustrating a first embodiment of the invention;

[0018] FIG. **2** is perspective view illustrating a second embodiment of the invention;

[0019] FIG. **3** is perspective view illustrating a third embodiment of the invention;

[0020] FIG. **4** is cross sectional view taken along line **4-4** of FIG. **3**, illustrating overlapping portions of the packaging; and

[0021] FIG. **5** is a graph of data from Example 17.

DETAILED DESCRIPTION OF THE INVENTION

[0022] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are described herein. All references

cited herein, including published or corresponding U.S. or foreign patent applications, issued U.S. or foreign patents, and any other references, are each incorporated by reference in their entireties, including all data, tables, figures, and text presented in the cited references.

[0023] In the drawings, the thickness of the lines, layers, and regions may be exaggerated for clarity. It will be understood that when an element such as a layer, region, substrate, or panel is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. Also, when an element is referred to as being "adjacent" to another element, the element may be directly adjacent to the other element or intervening elements may be present. The terms "top", "bottom", "side", and the like are used herein for the purpose of explanation only. Like numbers found throughout the figures denote like elements. It is to be noted that the phrase "binder", "bio-based binder", "binder composition", and "binder formulation" may be used interchangeably herein.

[0024] "Mineral fibers" refers to any mineral material that can be melted to form molten mineral that can be drawn or attenuated into fibers. Glass is the most commonly used mineral fiber for fibrous insulation purposes and the ensuing description will refer primarily to glass fibers, but other useful mineral fibers include rock, slag and basalt.

[0025] "Product properties" refers to a battery of testable physical properties that insulation batts possess. These may include at least the following common properties:

[0026] "Recovery"—which is the ability of the batt or blanket to resume it's original or designed thickness following release from compression during packaging or storage. It may be tested by measuring the post-compression height of a product of known or intended nominal thickness, or by other suitable means.

[0027] "Stiffness" or "sag"—which refers to the ability of a batt or blanket to remain rigid and hold its linear shape. It is measured by draping a fixed length section over a fulcrum and measuring the angular extent of bending deflection, or sag. Lower values indicate a stiffer and more desirable product property. Other means may be used.

[0028] "Tensile Strength"—which refers to the force that is required to tear the fibrous product in two. It is typically measured in both the machine direction (MD) and in the cross machine direction ("CD" or "XMD").

[0029] "Lateral weight distribution" (LWD or "cross weight")—which is the relative uniformity or homogeneity of the product throughout its width. It may also be thought of as the uniformity of density of the product, and may be measured by sectioning the product longitudinally into bands of equal width (and size) and weighing the band, by a nuclear density gauge, or by other suitable means.

[0030] "Vertical weight distribution" (VWD)—which is the relative uniformity or homogeneity of the product throughout its thickness. It may also be thought of as the uniformity of density of the product, and may be measured by sectioning the product horizontally into layers of equal thickness (and size) and weighing the layers, by a nuclear density gauge, or by other suitable means.

Of course, other product properties may also be used in the evaluation of final product, but the above product properties are ones found important to consumers of insulation products.

Binder Compositions

[0031] The present invention encompasses both traditional phenolic-formaldehyde binders, as well as the more recent formaldehyde-free binders, including polyacrylic binders and carbohydrate, starch or bio-based binders. Carbohydrate bio-based binders are described herein as an exemplary embodiment.

[0032] In one exemplary embodiment, a bio-based component is a carbohydrate and the binder includes a carbohydrate and a crosslinking agent. Typically the carbohydrate has reactive hydroxyl groups and the crosslinking agent has reactive carboxyl groups. In some exemplary embodiments, the carbohydrate-based binder composition also includes a coupling agent, a process aid agent, an extender, a pH adjuster, a catalyst, a crosslinking density enhancer, a deodorant, an antioxidant, a dust suppressing agent, a biocide, a moisture resistant agent, or combinations thereof. The binder may be used in the formation of insulation materials and non-woven chopped strand mats. In addition, the binder is free of added formaldehyde. Further, the binder composition has a reduction in particulate emission compared to conventional phenol/urea/formaldehyde binder compositions. The inventive binder may also be useful in forming particleboard, plywood, and/or hardboards.

[0033] In one or more exemplary embodiment, the binder includes at least one carbohydrate that is natural in origin and derived from renewable resources. For instance, the carbohydrate may be derived from plant sources such as legumes, maize, corn, waxy corn, sugar cane, milo, white milo, potatoes, sweet potatoes, tapioca, rice, waxy rice, peas, sago, wheat, oat, barley, rye, amaranth, and/or cassava, as well as other plants that have a high starch content. The carbohydrate polymer may also be derived from crude starch-containing products derived from plants that contain residues of proteins, polypeptides, lipids, and low molecular weight carbohydrates. The carbohydrate may be selected from monosaccharides (e.g., xylose, glucose, and fructose), disaccharides (e.g., sucrose, maltose, and lactose), oligosaccharides (e.g., glucose syrup and fructose syrup), and polysaccharides and water-soluble polysaccharides (e.g., pectin, dextrin, maltodextrin, starch, modified starch, and starch derivatives).

[0034] The carbohydrate polymer may have a number average molecular weight from about 1,000 to about 8,000. Additionally, the carbohydrate polymer may have a dextrose equivalent (DE) number from 2 to 20, from 7 to 11, or from 9 to 14. The carbohydrates beneficially have a low viscosity and cure at moderate temperatures (e.g., 80-250° C.) alone or with additives. The low viscosity enables the carbohydrate to be utilized in a binder composition. In exemplary embodiments, the viscosity of the carbohydrate may be lower than 500 cps at 50% concentration and between 20 and 30° C. The use of a carbohydrate in the inventive binder composition is advantageous in that carbohydrates are readily available or easily obtainable and are low in cost.

[0035] In at least one exemplary embodiment, the carbohydrate is a water-soluble polysaccharide such as dextrin or maltodextrin. The carbohydrate polymer may be present in the binder composition in an amount from about 40% to about 95% by weight of the total solids in the binder composition, from about 50% to about 95% by weight of the total solids in the binder composition, from about 60% to about 90%, or from about 70% to about 85%. As used herein, % by weight indicates % by weight of the total solids in the binder composition.

[0036] In addition, the binder composition contains a crosslinking agent. The crosslinking agent may be any compound suitable for crosslinking the carbohydrate. In exemplary embodiments, the crosslinking agent has a number average molecular weight greater than 90, from about 90 to about 10,000, or from about 190 to about 4,000. In some exemplary embodiments, the crosslinking agent has a number average molecular weight less than about 1000. Non-limiting examples of suitable crosslinking agents include polycarboxylic acids (and salts thereof), anhydrides, monomeric and polymeric polycarboxylic acid with anhydride (i.e., mixed anhydrides), citric acid (and salts thereof, such as ammonium citrate), 1,2,3,4-butane tetracarboxylic acid, adipic acid (and salts thereof), polyacrylic acid (and salts thereof), and polyacrylic acid based resins such as QXRP 1734 and Acumer 9932, both commercially available from The Dow Chemical Company. In exemplary embodiments, the crosslinking agent may be any monomeric or polymeric polycarboxylic acid, citric acid, and their corresponding salts. The crosslinking agent may be present in the binder composition in an amount up to about 50% by weight of the binder composition. In exemplary embodiments, the crosslinking agent may be present in the binder composition in an amount from about 5.0% to about 40% by weight of the total solids in the binder composition or from about 10% to about 30% by weight.

[0037] Optionally, the binder composition may include a catalyst to assist in the crosslinking. The catalyst may include inorganic salts, Lewis acids (i.e., aluminum chloride or boron trifluoride), Bronsted acids (i.e., sulfuric acid, p-toluenesulfonic acid and boric acid) organometallic complexes (i.e., lithium carboxylates, sodium carboxylates), and/or Lewis bases (i.e., polyethyleneimine, diethylamine, or triethylamine). Additionally, the catalyst may include an alkali metal salt of a phosphorous-containing organic acid; in particular, alkali metal salts of phosphorus acid, hypophosphorus acid, or polyphosphoric acids. Examples of such phosphorus catalysts include, but are not limited to, sodium hypophosphite, sodium phosphate, potassium phosphate, disodium pyrophosphate, tetrasodium pyrophosphate, sodium tripolyphosphate, sodium hexamethaphosphate, potassium phosphate, potassium tripolyphosphate, sodium trimetaphosphate, sodium tetramethaphosphate, and mixtures thereof. In addition, the catalyst or cure accelerator may be a fluoroborate compound such as fluoroboric acid, sodium tetrafluoroborate, potassium tetrafluoroborate, calcium tetrafluoroborate, magnesium tetrafluoroborate, zinc tetrafluoroborate, ammonium tetrafluoroborate, and mixtures thereof. Further, the catalyst may be a mixture of phosphorus and fluoroborate compounds. Other sodium salts such as, sodium sulfate, sodium nitrate, sodium carbonate may also or alternatively be used as the catalyst/accelerator. The catalyst or cure accelerator may be present in the binder composition in an amount from about 0% to about 10% by weight of the total solids in the binder composition, or from about 1.0% to about 5.0% by weight, or from about 3.0% to about 5.0% by weight.

[0038] The binder may contain many additional optional or additive ingredients such as coupling agents, processing aids, surfactants, corrosion inhibitors, biocidal agents, pH adjusters or buffers, moisture resistance agents, dust suppressors, fillers or extenders, flame retardants, dyes, pigments, fillers, colorants, UV stabilizers, thermal stabilizers, anti-foaming agents, anti-oxidants, emulsifiers, preservatives (e.g., sodium benzoate), and the like. Such optional ingredients are described more fully in the literature, including U.S. patent application Ser. No. 13/037,725 titled "INSULATIVE PRODUCTS HAVING BIO-BASED BINDERS" filed Mar. 1, 2011 and U.S. patent application Ser. No. 12/900,540, filed Oct. 8, 2010, which claims priority benefits from U.S. Provisional Patent Application Ser. No. 61/250,187entitled "Bio-Based Binders For Insulation And Non-Woven Mats" filed Oct. 9, 2009, the entire contents of each of which are expressly incorporated herein by reference.

[0039] The binder further includes water to dissolve or disperse the active solids for application onto the fibers. Water may be added in an amount sufficient to dilute the aqueous binder composition to a viscosity that is suitable for its application to the fibers and to achieve a desired solids content on the fibers. In particular, the binder composition may contain water in an amount from about 50% to about 98.0% by weight of the total solids in the binder composition.

[0040] The binder composition may be made by dissolving or dispersing the crosslinking agent in water to form a mixture. Next, the carbohydrate may be mixed with the crosslinking agent in the mixture to form the binder composition. If desired, a cure accelerator (i.e., catalyst) may be added to the binder composition. The binder composition may be further diluted with water to obtain a desired amount of solids. If necessary, the pH of the mixture may be adjusted to the desired pH level with organic and inorganic acids and bases.

[0041] In the broadest aspect of the invention, the carbohydrate-based binder composition is formed of a carbohydrate (e.g., maltodextrin) and a crosslinking agent (e.g., polyacrylic acid or citric acid)—as seen in Sample A of Table 1. Samples B and C add other optional ingredients like a processing aid or polyol, or a catalyst or cure accelerator in suitable range amounts. The range of components used in the inventive binder composition according to embodiments of the invention set forth in Table 1 is given in weight percent of total solids (i.e. dry weight 5%).

TABLE 1

Component	Sample A	Sample B	Sample C
Carbohydrate	60.0-95.0	5.0-90.0	5.0-90.0
Crosslinking Agent	5.0-40.0	5.0-40.0	5.0-40.0
Process Aid Agent	0	1.0-40.0	1.0-40.0
Catalyst/Cure Accelerator	0	0	1.0-5.0

Fibrous Products with Bio-Based Binders

[0042] In one exemplary embodiment, the binder composition is used to form a fibrous product, typically an insulation product. Fibrous products are generally formed of matted inorganic fibers bonded together by a cured thermoset polymeric material. Examples of suitable inorganic fibers include glass fibers, wool glass fibers, and ceramic fibers. Optionally, other reinforcing fibers such as natural fibers and/or synthetic fibers such as polyester, polyethylene, polyethylene terephthalate, polypropylene, polyamide, aramid, and/or polyaramid fibers may be present in the insulation product in addition to the glass fibers. The term "natural fiber" as used in conjunction with the present invention refers to plant fibers extracted from any part of a plant, including, but not limited to, the stem, seeds, leaves, roots, or phloem. Examples of natural fibers suitable for use as the reinforcing fiber material include basalt, cotton, jute, bamboo, ramie, bagasse, hemp, coir, linen, kenaf, sisal, flax, henequen, and combinations thereof. Insulation products may be formed entirely of one

type of fiber, or they may be formed of a combination of types of fibers. For example, the insulation product may be formed of combinations of various types of glass fibers or various combinations of different inorganic fibers and/or natural fibers depending on the desired application for the insulation. The embodiments described herein are with reference to insulation products formed primarily of glass fibers.

[0043] The term "fibrous products" is general and encompasses a variety of compositions, articles of manufacture, and manufacturing processes. "Fibrous products" may be characterized and categorized by many different properties; density for example, which may range broadly from about about 0.2 pounds/cubic foot ("pcf") to as high as about 10 pcf, depending on the product. Low density flexible insulation batts and blankets typically have densities between about 0.2 pcf and about 5 pcf, more commonly from about 0.3 to about 4 pcf. Fibrous products also include higher density products having densities from about 1 to about 10 pcf, more typically from about 2 or 3 pcf to about 8 pcf, such as boards and panels or formed products. Higher density insulation products may be used in industrial and/or commercial applications, including but not limited to metal building insulation, pipe or tank insulation, insulative ceiling and wall panels, duct boards and HVAC insulation, appliance and automotive insulation, etc.

[0044] Another property useful for categorization is the rigidity of the product. Residential insulation batts are typically quite flexible and they can be compressed into rolls or batts while recovering their "loft" upon decompression. In contrast, other fibrous products, such as ceiling tiles, wall panels, foundation boards and certain pipe insulation to mention a few, are quite rigid and inflexible by design. These products will flex very little and are unlikely to be adapted or conformed to a particular space.

[0045] Shape is another important property. Some fibrous products are flexible, as noted and can be forced to assume conforming shapes, while other are formed and shaped for a specific purpose. In some embodiments, the shape is substantially planar, as in duct boards, ceiling tiles and some wall insulation. In other embodiments, the fibrous insulation product is manufactured with a particular shape (e.g. cylindrical) suitable for a particular size conduit, pipe or tank. In other cases, specific shapes and cutouts, often die-cut, are included in certain appliance insulation products, automotive insulation products and the like. Finally, other shapes may be created with nonwoven textile insulation products.

[0046] Other classifications of fibrous insulation products can include the method of manufacture. The manufacture of glass fiber insulation may be carried out in a continuous process by rotary fiberization of molten glass, immediately forming a fibrous glass pack on a moving conveyor, and curing the binder on the fibrous glass insulation batt to form an insulation blanket. Rotary fiberization and other manufacturing processes are described in the literatures and the details need not be repeated here.

[0047] The binder may be present in an amount from about 1% to 30% by weight of the total fibrous product, more usually from about 2% to about 20% or from about 3% to about 14%. Binder content of the fibrous products is typically measured by loss on ignition or "LOI" of the cured product.

[0048] While in a curing oven, the insulation pack may be compressed by upper and lower foraminous oven conveyors to form a fibrous insulation blanket. It is to be appreciated that the insulation blanket also has an upper surface and a lower surface. In particular, the insulation blanket has two major surfaces, typically a top and bottom surface, and two minor or side surfaces, and is oriented so that the major surfaces have a substantially horizontal orientation. The upper and lower oven conveyors may be used to compress the insulation pack to give the insulation blanket a predetermined thickness.

[0049] The curing oven may be operated at a temperature from about 100° C. to about 325° C., or from about 250° C. to about 300° C. The insulation pack may remain within the oven for a period of time sufficient to crosslink (cure) the binder and form the insulation blanket. The inventive binder composition cures at a temperature that is lower than the curing temperature of conventional formaldehyde binders. This lower curing temperature requires less energy to heat the insulation pack, and non-woven chopped strand mat described in detail below, which results in lower manufacturing costs.

[0050] In some exemplary embodiments, the insulation blanket that emerges from the oven is rolled onto a take-up roll or cut into sections having a desired length. It may or may not be faced with a barrier material. Optionally, the insulation blanket may be slit into layers and by a slitting device and then cut to a desired length.

[0051] A significant portion of the insulation placed in the insulation cavities of buildings is in the form of insulation blankets rolled from insulation products such as is described above. Faced insulation products are installed with the facing placed flat on the edge of the insulation cavity, typically on the interior side of the insulation cavity. Insulation products where the facing is a vapor retarder are commonly used to insulate wall, floor, or ceiling cavities that separate a warm interior space from a cold exterior space. The vapor retarder is placed on one side of the insulation product to retard or prohibit the movement of water vapor through the insulation product.

[0052] Formed or shaped products may include a further step, optionally during cure, that molds or shapes the product to its specific final shape. Rigid boards are a type of shaped product, the shape being planar. Other shaped products may be formed by dies or molds or other forming apparatus. Rigidity may be imparted by the use of higher density of fibers and/or by higher levels of binder application. As an alternative to rotary fiberizing, some fibrous insulation products, particularly higher density, non-woven insulation products, may be manufactured by an air-laid or wet-laid process using premade fibers of glass, other minerals or polymers that are scattered into a random orientation and contacted with binder to form the product.

[0053] In other embodiments, the binder composition may be applied to the web by a suitable binder applicator, such as a spray applicator or a curtain coater. Once the binder has been applied to the web, the binder coated web is passed through at least one drying oven to remove any remaining water and cure the binder composition. The formed fibrous product that emerges from the oven is an assembly or mat of randomly oriented, dispersed, individual fibers, and may be rolled onto a take-up roll for storage for later use as illustrated.

[0054] In some cases, it is even possible to use scraps of continuous fibers, such as E-glass, and cut them to lengths suitable for fluid-dispersed manufacturing processes. In one embodiment of textile pipe insulation, lengths of scrap E-glass are cut ranging from about 0.5 to about 6 inches, nominally about 2 inches in length. These are dispersed by a fluid (water or air), the fluid is removed, and the fibers are sprayed with a bio-based binder which is cured as before.

[0055] Some exemplary fibrous products that can be manufactured using the bio-based binders according to the invention include those illustrated in Table A below.

TABLE A

Bio-based binder formulations for representative products*

	Flexible Duct Media	Metal Building Insulation	Warm & Dry boards	Ceiling Tile boards A	Ceiling Tile boards B	Ceiling Tile boards C
Maltodextrin	65-70	65-70	65-70	65-70	45-50	55-60
Citric Acid	25-30	25-30	25-30	25-30	30-35	25-30
Sodium hypophosphite	2-5	2-5	2-5	2-5	2-5	2-5
Glycerol					10-15	
Polyglycol						7-10
Surfactant (e.g. SURFYNOL 465)			0.1-0.3%	0.1-0.3%	0.1-0.3%	0.1-0.3%
Organopolysiloxane moisture resistance additive (e.g. Polon MR)	Up to 0.5%	Up to 0.5%	0.4-0.5%	Up to 0.5%	Up to 0.5%	Up to 0.5%

*In Table A above, each ingredient of the binder composition is given as a range of typical values of percentage of dry weight of the binder composition.

[0056] Whereas examples 4, 5, 7, and 12 relate to flexible, light density residential insulation, examples 8, 9 and 10 further illustrate commercial fibrous products other than the typical flexible residential insulation. A more complete listing of non-residential insulation fibrous products that can be manufactured using a bio-based binder composition according to the invention is set forth in Table B, below.

TABLE B

Selected Commercial and Industrial Fibrous Products which may use a Bio-Based Binder

	Rigid Boards	Flexible, Light Density Insulation	Rigid Pipe Insulation and pipe rolls	Textile E-glass Nonwoven
Density	Wide range of densities-from 1.5 to 10 pcf	Light density - Ranging from 0.3 to 4.0 pcf	Ranging from 3-6 pcf	Ranging from 0.8 to 4 pcf
Binder content	about 2 to about 20% LOI	about 2 to about 13% LOI	about 3 to about 15% LOI	about 5 to about 20% LOI
Manufacturing method	Rotary fiber forming process	Rotary fiber forming process	Rotary fiber forming process plus on or offline molding/pipe formation process	Air-laid nonwoven process
Exemplary Owens Corning Products	QUIET R Duct Board QUIET R Duct Liner Board 700 Series Insulation Insul-Quick Insulation SCR Insulation Board Curtainwall QuietZone Shaftwall Warm -N -Dri Energy Board TremDrain Exterior Foundation Barrier Board Ceiling Board Blanks	Certified R Metal Building Insulation ELAMINATOR ® Pre-Engineered Metal Roof Insulation MBI Plus Metal Bldg Utility Blanket Unfaced Metal Building Insulation for Canada Flexible Duct Media Insulation QUIET R Rotary Duct Liner SOFTR Duct Wrap FRK TIW Types I and II FLEX-Wrap for pipes and tanks H2V Series RA Series Select Sound Thermorange FlameSpread 25 Sonobatts Thermal Batts	EVOLUTION Paper-Free ASJ VAPORWICK Insulation FIBERGLAS ™ Pipe and Tank Insulation rolls	QUIET R Textile Duct Liner DURAFLEX Transportation

[0057] There are numerous advantages provided by the inventive binder formulations. For example, unlike conventional urea-formaldehyde binders, inventive binders have a light color after curing (in low density products). In addition, the carbohydrate is natural in origin and derived from renewable resources. By lowering or eliminating formaldehyde emission, the overall volatile organic compounds (VOCs) emitted in the workplace are reduced. Additionally, because carbohydrates are relatively inexpensive, the insulation product or chopped fiber mat can be manufactured at a lower cost. Further, the binder has low to no odor, making it more desirable to work with.

Packaging for Fibrous Products with Bio-Based Binders

[0058] The packaging will generally comprise a complete envelope surrounding the fibrous product. Various illustrative embodiments for packaging are described herein. Referring to a first embodiment, shown in FIG. **1** and referred to as a "sealed bag", four rolls **12** of a fibrous insulation product are shown initially in an unwrapped state. A sealable bag **14** having side walls **16** and a bottom defining an open interior **18** is employed to form the complete envelope. The rolls **12** are inserted into the interior **18** of the bag **14** via the open top and the bag is drawn tightly closed at the neck **20**. The bag is made of materials having the properties described herein.

[0059] In the alternative embodiment shown in FIG. **2** the rolls **12** are wrapped by a first web **22** of packaging material to form a "stretch wrap" (SW) bundle **24** with the ends **26** of the rolls **12** exposed to the atmosphere. A wrapping apparatus (not shown) is configured to install the web **22** around the rolls **12**. The rolls **12** in the SW bundle **24** are then reoriented relative to the wrapping apparatus, e.g. by rotating the SW bundle **24** by about 90 degrees while the wrapping apparatus remains in its same orientation or, alternatively, by rotating the wrapping apparatus while the SW bundle **24** remains in its original orientation. After the reorientation of the SW bundle **24**, a second web **28** of packaging material is wrapped around the SW bundle **24** in a direction transverse to the direction of the first web **22**, forming a sealed "double stretch wrapped," (DSW) bundle **30** in which no areas of fibrous product are exposed to the atmosphere. In the DSW sealed bundle **30** the exposed ends **26** of the stretch wrap bundle **24** have been encased or encapsulated by the second web **28**, sealing the envelope about the fibrous product. The second web **28** may be the same material as the first web **22**, or it may be different. At least one, and optionally both, of the webs **22**, **28** have the properties described herein.

[0060] In a third embodiment, shown in FIG. **3** and referred as a "stretch hood", the rolls **12** are placed on a first web or slip sheet **32**. The slip sheet **32** may include perforations **34** for separating the web into sections such as the section **36**. A bag-like envelope or "hood" **38** having side walls **40**, a top **42** and an open bottom is lowered over the rolls **12**. The slip sheet **32** is folded up the sides of the rolls **12** and is tucked under the descending hood **38** so that the slip sheet **32** and hood side wall **40** overlap (as shown at corner **46** in FIG. **4**) to form a sealed bundle or envelope **44**. The hood **38** and the slip sheet **32** are made of materials having the properties described herein. In addition, the hood **38** may be an elastic material that can either be stretched to fit over the rolls and relaxed to tightly seal the rolls **12**, or it may be a material that can be shrunk, such as by means of the application of heat.

[0061] Certain properties of the packaging have been found to be useful for accomplishing the advantageous features. These properties and suitable ranges are described in the paragraphs that follow. For example, it appears important to keep ambient humidity and moisture from the reaching the fibrous product. Therefore, the permeance of the packaging material is an important factor. Permeance—and its thickness-normalized counterpart, permeability—are measures of the rate at which a membrane or film will pass or transmit water vapor. ASTM E96 is one of several standard procedures for assessing moisture vapor transmission rates (MVTR). It introduces a membrane or film to two differing moisture environments and monitors the flow of water vapor (grains/hour) across the known area (ft^2) of the film as the two environments equilibrate. Because the rate of transmission of moisture is dependent, in part, on the driving force of the vapor pressure (inches Hg), this is also factored into the calculation. Thus, the English units for permeance of a material of given thickness (inches) are grains/hr*ft^2*inches Hg or abbreviated to g/hr-ft^2-in Hg. This is equivalent to another permeance unit known as "perms" although the literature often confuses permeance and permeability when using "perms." Strictly, permeance is dependent on material thickness and is given along with the material thickness. Permeability, on the other hand, is normalized to a standard thickness of 1 inch.

[0062] The permeance of suitable packaging will generally be less than 0.9 grains/hr*ft^2*inches Hg, and will typically be less than 0.5. Although less permeable materials will work, there is little need to require permeance less than about 0.05. Consequently, a useful range of permeance is from about 0.05 to about 0.5 grains/hr*ft^2*inches Hg, or ideally from about 0.05 to about 0.25 grains/hr*ft^2*inches Hg. It will be appreciated that these levels of permeance refer to the total package and may be achieved by one or more layers of packaging materials. These levels of permeance may also be achieved by using thinner or fewer layers of materials having low permeability, as well as by using thicker or more layers of materials having high permeability. Some examples are provided below.

[0063] In one particular variation, the packaging may have variable permeance, depending on the relative humidity. For example, at higher humidity levels, e.g. above about 60% relative humidity, the packaging is more permeable than at lower relative humidity, e.g. below about 30%. To illustrate, the following potential permeance ranges are provided for the respective relative humidities (RH):

Relative humidity (%)	Permeance (grains/hr*ft^2*inches Hg)
<20% RH	0.05-0.25
21-40% RH	0.09-0.5
41-60% RH	0.12-0.7
61-80% RH	0.3-0.8
>81% RH	0.5-0.9

[0064] Materials having a variable permeance feature are described for use as a house vapor barrier in U.S. Pat. No. 7,829,197 to Chen, et al. (DuPont). This material is claimed to have a wet cup permeance of 10 to 75 times the dry cup permeance, wet and dry being defined as 75% and 25% rela-

tive humidity respectively. This feature allows for internal moisture to escape if packaged under high humidity conditions.

[0065] Another property that becomes important for packaging—especially for the SW and DSW embodiments—is the elasticity of the wrapping or packaging material. Elasticity is usefully measured according to ASTM D882 as the percentage a material can be stretch beyond its original length without breaking; this is useful in providing compression of the fibrous products and reducing storage space requirements. Packaging materials may or may not be pre-stretched during manufacturing, for example about 85% to 150% more than original length. After this pre-stretching step, further stretching is generally desirable: elasticities of about 300% up to about 1000% are useful, and in particular elasticity may be in the range of about 400 to about 800%.

[0066] A third property important for packaging material is the strength of the film. This can be measured two ways: (1) as a tensile strength—(ASTM D 822) the force necessary to create a break when an elongation force is applied at the ends of the film (i.e. pulled from two ends linearly with the film); and (2) as a tear strength—(ASTM D1922) the force necessary to create a break when applied in a direction normal (approximately perpendicular) to the film (e.g. an edge is pulled or torqued in opposing directions). Tear strength may be measured in a machine direction (MD) and a cross-machine or transverse direction (TD) but this directionality is not critical to the invention.

[0067] Tensile strengths of suitable packaging materials generally range from about 3500 to about 8400 pounds/square inch (psi). In some embodiments, the tensile strength may be from about 3500 to about 6000 psi; while in other embodiments, the tensile strength may be from about 6000 to about 8400 psi. The tear strength is generally in the range of from about 100 to 900 g/mil nominal thickness. In some embodiments (e.g. bags), the tear strength can be lower and may be from about 100 to about 600 g/mil nominal thickness; while in other embodiments (e.g. stretch wraps), the tensile strength should be higher, e.g. from about 600 to about 900 g/mil nominal thickness.

[0068] A fourth factor relevant to packaging properties is the ability of the material to cling to itself, also known as a coefficient of friction (COF), as measured by ASTM 1894. This is less important for bags than for stretch wrap. Bags may have a COF in the range of from about 0.1 to about 0.6, or from about 0.25 to about 0.45. Stretch wrap, on the other hand, should be "stickier" and have a COF of at least 0.6 and preferably at least 1.0.

[0069] Another property of packaging materials is the degree to which the material is clear or opaque. Generally, clear or nearly clear materials are preferred for visibility to the fibrous products inside. ASTM D1003 describes the degree of transparency in terms of percent, ranging from 0 (clear) to100% (opaque). Generally a haze of 20% or less is desirable.

[0070] Thickness is another property of packaging materials and it impacts other properties mentioned above, such as permeance, strength, elasticity, etc. Thicknesses are generally in the range from about 0.25 to about 5 mils (one mil=0.001 inch); or from about 0.5 to about 3.5 mils

[0071] The packaging materials useful with the invention may be made of any material that meets the physical properties described above. Applicants have found that certain polymeric plastic materials are suitable. Some examples of suitable polymeric plastics include, polyethylene (PE), both high-density (HDPE) and low-density (LDPE) versions; polypropylene (PP); biaxially-oriented polypropylene (BOPP); polyvinylidene chloride (PVDC); copolymers of PE and PVC; copolymers of PE and PP; copolymers of PE and polyamides. In copolymer combinations, LDPE may be used as the PE component.

[0072] Having generally described this invention, a further understanding can be obtained by reference to certain specific examples illustrated below which are provided for purposes of illustration only and are not intended to be all inclusive or limiting unless otherwise specified.

EXAMPLES

Examples 1-14

[0073] Examples 1 to 14 herein are incorporated from Examples 1-14, including tables 4-33 that appear in U.S. patent application Ser. No. 13/037,725 titled "INSULATIVE PRODUCTS HAVING BIO-BASED BINDERS" filed Mar. 1, 2011, already incorporated herein.

Example 15

[0074] Various packaging materials are obtained having the physical properties listed in Table 34.

TABLE 34

Representative Packaging Material Properties

	Sample 1 (Bag)	Sample 2 (Bag)	Sample 3 (DSW film)	Sample 4 (DSW film)
nominal thickness (mils)	2.0	2.0	1.5	1.5
No. of layers	1	1	3	2
composition	LDPE	LDPE/PP copolymer	LDPE	PE
permeance g*in/hr*ft^2*in Hg	0.25	0.3	0.15	0.3
elasticity (%)	700%	800%	600%	550%
tensile/elongation (psi)	4500	5000	7000	7500
tear (g/mil)	875	900	600	575
Coeff. of Friction	0.35	0.4	1.5	2.0
haze (%)	14%	16%	6%	7%

Example 16

[0075] Flexible duct media (FDM) is a type of fibrous insulation that is often used around flexible conduit or tubing. It is generally available in rolls designated with R values 4.2, 6 or 8 and having nominal thickness of 1.25, 2, and 2.25 inches, respectively. FDM was produced with a bio-based binder according to the invention in R6 thicknesses (nominally 2 inches) and placed in various types of packaging for testing. The comparison points were the recoveries achieved after storage at ambient conditions for 7 days ("ambient x7d"). The experimental conditions tested include accelerated temperature and humidity tests as well as variations in time (x21 days vs. x7 days). For example, the condition labeled "73/92" indicates a temperature of 73F and relative humidity (RH) of

92%; and the condition labeled "73/92-92/50" indicates a cycled temperature and humidity profile simulating day and night in a humid area of the country; i.e. 73F with 92% RH by night and 92F with 50% RH by day. Products were sampled and tested at 7 days ("x7d") and at 21 days ("x21d"). The controlled variables were stretch wrap bundle packaging (SW) and double wrapped sealed bundle packaging (DSW) as described above. The data presented in Table 35 are the averages of 18 measurements at three longitudinal positions times two vertical locations on four different rolls (18×3×2×4=432 total values) for each condition. Percent recovery degradation is calculated as the difference in recovery height (vs. ambient x7d) divided by the initial recovery height at ambient x7d.

TABLE 35

Recovery Data Summary

Binder and Condition	Average Recovery Thickness	Std. Dev.	95% CI	Avg % degradation vs ambient x7
Bio-based-SW-ambient x7d	2.41	0.07	0.12	
Bo-based-SW-ambient x21d	2.38	0.06	0.09	1.2
Bo-based-SW-73/92 x7d	2.10	0.01	0.02	13.0
Bo-based-SW-73/92 x21d	1.93	0.02	0.04	20.0
Bo-based-SW-73/92-92/50 x7d	2.13	0.01	0.02	11.7
Bo-based-SW-73/92-92/50 x21d	2.00	0.01	0.02	17.1
Bo-based-DSW-ambient x7d	2.59	0.03	0.05	
Bo-based-DSW-ambient x21d	2.50	0.04	0.06	3.3
Bo-based-DSW-73/92 x7d	2.54	0.04	0.06	1.8
Bo-based-DSW-73/92 x21d	2.21	0.04	0.06	14.6
Bo-based-DSW-73/92-92/50 x7d	2.33	0.02	0.02	10.0
Bo-based-DSW-73/92-92/50 x21d	2.27	0.03	0.06	12.3

[0076] The data show that, for all control variables, a small amount (e.g. about 1 to 3%) of recovery degradation occurred over the time lapse of an additional 14 days from 7 to 21 days. However, the DSW packaging performed better than the SW packaging in protecting against recovery degradation for bio-based binder products exposed to high temperature and humidity conditions.

Example 17

[0077] FDM was produced with a bio-based binder according to the invention in R6 thicknesses (nominally 2 inches) and placed in various types of packaging for testing. The experimental condition "73/92/3" includes exposure to accelerated temperature and humidity e.g. 73F and 92% relative humidity (RH) for 3 days when recovery was again tested. The controlled packaging variables were sealed bags, stretch wrap bundle packaging (SW) and double wrapped sealed bundle packaging (DSW) as described above relative to ambient conditions. The data are presented in FIG. **5**.

[0078] FIG. **5** shows that both the DSW packaging and the enclosed bags performed better than the SW packaging and about as well as the ambient product.

Example 18

[0079] FDM was produced with a phenolic binder in R6 thicknesses (nominally 2 inches) and was tested initially at ambient conditions. These products were then exposed to varying environmental conditions for testing. Recovery was tested again at the end of the specified period. The data are presented in Table 36, and show that products having phenolic binder undergo a similar loss of physical properties upon exposure to hot and humid conditions, and thus may be improved with the packaging of the invention.

TABLE 36

Recovery Data Summary- phenolic binder

Condition	Average Recovery Thickness (inches)	Std. Dev.
ambient	2.16	0.05
92/50/3	2.12	0.05
73/93-92/50-3	2.01	0.10
73/93-92/50-7	1.92	0.16
55/90/3	2.03	0.12
55/90/7	1.92	0.05
73/92/3	1.98	0.13
73/92/7	1.96	0.02
90/90/3	1.90	0.03
90/90/7	2.00	0.12

[0080] The invention of this application has been described above both generically and with regard to specific embodiments. Although the invention has been set forth in what is believed to be the preferred embodiments, a wide variety of alternatives known to those of skill in the art can be selected within the generic disclosure. The invention is not otherwise limited, except for the recitation of the claims set forth below.

What is claimed is:

1. A method of improving the physical properties of a fibrous insulation product, the method comprising:

applying a binder to the fibrous product;

curing the binder to form a cured fibrous insulation product having defined physical properties; and

packaging the cured fibrous product in a package that preserves the defined physical properties.

2. The method of claim **1** wherein the package for the packaging step is selected from a sealable bag, a double wrapped package and a stretch hood.

3. The method of claim **2**, wherein the binder is a bio-based binder.

4. The method of claim **1** wherein the defined physical property is at least one property selected from recovery of loft, restoring force, and tensile strength.

5. The method of claim **1** wherein the package is made of a polymer selected from low-density polyethylene (LDPE) or a copolymer of LDPE with polyvinylchloride, polypropylene or polyamides.

6. The method of claim **1** wherein the package has a permeance not more than about 0.9 g/hr-ft^2-in Hg.

7. The method of claim **6** wherein the package has a permeance not more than about 0.5 g/hr-ft^2-in Hg.

8. The method of claim **7** wherein the package has a permeance between about 0.05 and about 0.5 g/hr-ft^2-in Hg.

9. The method of claim **6** wherein the package has a permeance that varies with the relative humidity, permeance being greater at higher humidity.

10. The method of claim **1** wherein the package is made of a material having elasticity in the range of about 400% to about 1000%.

11. A method of minimizing the recovery degradation of a fibrous insulation product having a cured binder, the method comprising:

storing the cured fibrous product in a package that has a permeance not more than about 0.9 g/hr-ft^2-in Hg.

12. The method of claim **10** wherein the package has a permeance not more than about 0.5 g/hr-ft^2-in Hg.

13. The method of claim **12** wherein the package has a permeance between about 0.05 and about 0.5 g/hr-ft^2-in Hg.

14. The method of claim **11** wherein the package has elasticity in the range of about 400% to about 1000%.

15. The method of claim **11** wherein the package has tensile strength in the range of about 3500 to about 8400 psi.

16. The method of claim **11** wherein the package has tear strength in the range of 300 to about 900 grams/mil nominal thickness.

17. The method of claim **11** wherein the package is selected from a sealable bag, a double wrapped package and a stretch hood.

19. The method of claim **11** wherein the package is a stretch hood.

20. The method of claim **11** wherein the package is made of a polymer selected from low-density polyethylene (LDPE) or a copolymer of LDPE with polyvinylchloride, polypropylene or polyamides.

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