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DESCRIPTION

FIELD OF THE INVENTION

[0001] The present disclosure and related inventions are in the general field of engineered foams for use as a layer in foam mattress constructions.

BACKGROUND OF THE INVENTION

[0002] Solid foams, included closed cell and open cell (reticulated) structures, provide lightweight cellular engineering materials for weight bearing and distribution (pressure distribution) and energy absorption. In general, open-cell-structured foams have pores that are interconnected in a network. The interstitial spaces of open-cell foams can be filled with gas, liquid or solid material. The density of foam is determined in part by both the amount of structural material which forms the cells, such as polyurethane, polyethylene or latex, and the volume or size of the cells.

[0003] Closed-cell foams generally do not have interconnected pores, generally have relatively higher compressive strength due to the closed cell bubble structures, and are relatively more dense. The closed-cell structure foams have higher dimensional stability, low moisture absorption coefficients, and higher strength compared to open-cell-structured foams. The closed cells can be filled with gases to provide improved insulation, or with other materials to alter the physical properties of the foam. All types of foam have been widely used as core material in sandwich structure composite materials.

[0004] A special class of closed-cell foams is known as syntactic foam, which contains hollow particles embedded in a matrix material. The spheres can be made from several materials, including glass, ceramic, and polymers. The advantage of syntactic foams is that they have a very high strength-to-weight ratio, making them ideal materials for many applications, including deep-sea and space applications. One particular syntactic foam uses shape memory polymer which enables the foam to take on the characteristics of shape memory resins and composite materials with hysteresis properties which enable it to be reshaped repeatedly when heated above a certain temperature and cooled.

[0005] Shape memory foams have been increasingly used in bedding products such as mattresses and pillows. A significant performance issue and problem with visco-elastic and latex foam mattresses is the concentration of heat which accumulates during use as a result of the high density and low thermal conductivity of the foam material.

[0006] Many different variations of solid foams, open and closed cell, have been made in with different types of fillers have been made. Foams have been which contain gel material, for example as described in U.S. Patent No. 4,232,129, and polyurethane gel foams are disclosed in international application WO 88/01878 (low viscosity liquid) as an additive. International application WO 2009/070801 discloses gel infused foam formed by surface application of a gel precursor to a piece of foam.

[0007] Gels are defined as a substantially dilute cross-linked systems which exhibit little or no flow when in a steady-state. By weight, gels are mostly liquid, yet they behave like solids due to a three-dimensional cross-linked network within the liquid. Crosslinks within the fluid create the gelatin structure. Gels are a dispersion of molecules of a liquid within a solid in which the solid is the continuous phase and the liquid is the discontinuous phase. Gels consist of a solid three-dimensional network that spans the volume of a liquid medium and increases surface tension. The network structure may result from physical bonds (physical gels) or chemical bonds (chemical gels), as well as crystallites or other junctions that remain intact within the fluid. Different mediums can be used as an extender including water (hydrogels), oil, and air (aerogel). Gels are mostly fluid in composition by weight and volume and exhibit densities similar to those of their constituent liquids.

[0008] Gels, including polyurethane gels provide even pressure distribution and reduced pressure concentration by deformation in multiple dimensions in response to loads. Gels have measurable hardness and elastic properties, which can be engineered and selected for particular applications and uses. Test method ISO 3386-1 provides for calculation of a compression stress/strain value for gel and a resultant hardness value. A gel sample (5cm x 5cm x 2.5cm) is compressed to 70%, with hardness measure as the stress applied (kPa) at 40% compression. Polyurethane gels are known to be resistant to hardening over time, have limited expandability and are resistant to degradation.

[0009] In addition to gel as an additive to foam for enhanced mechanical (e.g. shock absorption) properties, phase change material (PCM) has been combined with foam to enhance or improve thermal transfer and temperature regulation properties.

PCMs are materials with a high heat of fusion which melt and solidify at particular temperature or temperature range depending upon the type and purity of the material, and are capable of storing and releasing large amounts of energy in the phase transition. Heat is absorbed or released when the material changes from solid to liquid and vice versa. Latent heat storage can be achieved through solid-solid, solid-liquid, solid-gas and liquid-gas phase change. However, the only phase change used for PCMs is the solid-liquid change. Initially, the solid-liquid PCMs behave like sensible heat storage (SHS) materials; i.e. temperature increases as heat is absorbed. Unlike conventional SHS, however, when PCMs reach the temperature at which the phase change occurs, heat is absorbed at an almost constant temperature. Heat absorption continues without a significant rise in temperature until all the material is transformed to the liquid phase. When the ambient temperature around a liquid material falls, the PCM solidifies, releasing its stored latent heat. A large number of PCMs are available in any required temperature range from -5 up to 190 °C. Within the human comfort range of 20° to 30°C, some PCMs are very effective, and can store 5 to 14 times more heat per unit volume than conventional storage materials such as water, masonry or rock.

[0010] PCMs have been applied to fabrics and to thin foam layers as a surface coating for temperature control, particularly for heat retention and storage properties, as disclosed for example in U.S. Patent Nos. 5,290,904 and 5,955,188. The PCM is provided in microsphere encapsulation and mixed with a polymer binder for adhesion to a substrate. U.S. Patent No. 5,677,048 discloses coating of skived foam with PCM in a polymer binder dispersion for penetration of fabric-backed foam. U.S. Patent No. 6,699,266, discloses use of PCMs with melting temperatures in a range of 18 to 32 degrees Centigrade, held in a liquid suspension in a support pad to absorb body heat with no appreciable increase in temperature of the pad. Heat conducted into the support pad from a body is absorbed by the phase change material, i.e. absorbed as latent heat in the solid-to-liquid transition of the phase change material. U.S. Patent No. 5,366,801 discloses a coating of PCM capsules as a textile finish. U.S. Patent No. 5,637,389 discloses foam with embedded PCM microcapsules. And U.S. patent application US2004/0234726 discloses polyurethane gel combined with emulsified or finely dispersed phase change material in the gel.

[0011] Prior art document US 2009/0142551 A1 discloses an engineered foam for use as a layer in a foam mattress construction according to the preamble of independent claim 1.

[0012] It is an object underlying the present invention to provide an engineered foam for use as a layer in a foam mattress construction having improved thermal management capabilities.

SUMMARY OF THE INVENTION

[0013] The object underlying the present invention is achieved by an engineered foam for the use as a layer in a foam mattress construction according to independent claim 1. Preferred embodiments are defined in the dependent claims.

[0014] The present invention is of foam mattress constructions made and engineered foams which contain additives for improved mechanical and thermal properties. In accordance with one aspect of the disclosure and inventions, there is provided engineered foam for use as a layer in a foam mattress construction having multiple layers including a top layer of foam and at least one additional layer of foam, and a coating of phase change material applied to a top surface of the top layer of foam. Surface application of phase change material to a top surface of a top layer of foam of a foam mattress provides more efficient transfer of heat away from a body on the mattress and reduced heat accumulation at the body-mattress interface. The surface applied phase change material is micro-encapsulated phase change material in combination with a binder, and applied to a substantial area of a top surface of a top layer of foam of a mattress. The surface application of phase change material can be used on any of the foam types used in mattress construction and aftermarket foam pads, and with foam additives such as gel or other material in the foam structure. The engineered foams can also be used in innerspring and pocketed spring mattresses, and as separate foam cushions or layers outside of mattress upholstery.

In preferred embodiments of the foam mattress constructions, the upper or uppermost layers of a one-sided mattress are typically made of various types of visco-elastic or "memory" foam. In each of the preferred embodiments of the foam mattress constructions, at least one of the upper layers and preferably a top foam layer includes a temperature control additive. In addition, at least one of the upper layers has a gel material in the foam, i.e. integrated into the cellular structure of the foam. As further described, the temperature control additive is preferably in the form of a phase change material, for example as packaged or contained in micro-capsules or microspheres and applied to or otherwise integrated with the foam material, but is preferably located substantially at a surface of the foam and not within the foam structure. In a preferred foam mattress construction, in addition to the coated top layer, there is at least one intermediate layer and preferably two intermediate layers and even more preferably two or more intermediate layers which underlie the top layer. The intermediate layers may be of the same type of foam or a different type of foam as top layer, and with or without any gel additive. The intermediate layer or layers may be of the same or greater thickness than top layer, and when there are two or more intermediate layers the respective thicknesses may be the

same of different.

[0015] These and other aspects of the disclosure and inventions are further described herein with reference to the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a perspective view of an embodiment of a foam mattress of the present disclosure;

FIG. 2 is a partial cross-sectional view of an alternate embodiment of a foam mattress of the present disclosure;

FIG. 3 is a partial cross-sectional view of an alternate embodiment of a foam mattress of the present disclosure;

FIG. 4 is a partial cross-sectional view of an alternate embodiment of a foam mattress of the present disclosure;

FIG. 5 is a partial cross-sectional view of an alternate embodiment of a foam mattress of the present disclosure;

FIG. 6 is a partial cross-sectional view of an alternate embodiment of a foam mattress of the present disclosure;

FIG. 7 is a partial cross-sectional view of an alternate embodiment of a foam mattress of the present disclosure;

FIG. 8 is a partial cross-sectional view of an alternate embodiment of a foam mattress of the present disclosure;

FIG. 9 is a partial cross-sectional view of an alternate embodiment of a foam mattress of the present disclosure;

FIG. 10 is a perspective view of an alternate embodiment of a foam mattress construction of the present disclosure;

FIG. 11 is a perspective view of an alternate embodiment of an innerspring mattress construction of the present disclosure,

FIG. 12 is an exploded view of an alternate embodiment of a foam mattress construction of the present disclosure.

DETAILED DESCRIPTION OF PREFERRED AND ALTERNATE EMBODIMENTS

[0017] Novel engineered foams and foam mattress constructions are disclosed which include engineered foams as layers in foam mattresses. As used herein, the term "engineered foam" refers to and means the various different types and configurations of described foams and attendant properties, and the various described additives and treatments and related methods of manufacturing and processing. Each of the various alternate embodiments of the foam mattresses are constructed of multiple layers of foam of differing types, configurations, dimensions, properties and additives or modifiers.

[0018] In preferred embodiments of the foam mattress constructions, the upper or uppermost layers of a one-sided mattress (wherein top to bottom orientation of the layers remains the same, with the uppermost layers being the first layers in contact with, proximate to or initially compressed by a load such as a human body) are typically made of various types of visco-elastic or "memory" foam with densities in an approximate range of 2.0-8.0 lbs/cu.ft., and an initial force deflection (IFD, 25% indentation) in an approximate range of 10 to 20 lbs. As used herein, the terms "upper layer", "upper layers", "comfort layers" and "top layer" and "topper" all refer to and mean the one or more layers of a foam mattress construction which are located in an upper or uppermost region of the mattress, proximate to or forming the support surface of the mattress, and supported by one or more intermediate layers and a one or more base layers or core layers, which generally has an aggregate thickness dimension greater than a thickness dimension of the upper layers.

[0019] In each of the preferred embodiments of the foam mattress constructions, at least one of the upper layers and preferably a top foam layer includes a temperature control additive. In addition, at least one of the upper layers has a gel material in the foam, i.e. integrated into the cellular structure of the foam. As further described, the temperature control additive is preferably in the form of a phase change material, for example as packaged or contained in micro-capsules or microspheres and applied to or otherwise integrated with the foam material, but is preferably located substantially at a surface of the foam and not within the foam structure. The phase change material (PCM) may be of the paraffinic hydrocarbon type as listed in Table I, and preferably

contained or encapsulated within microspheres (also referred to as "micro-capsules"), which may range in diameter from 1 to 100 microns. Polymeric microspheres containing paraffinic wax or n-octadecane or n-eicosane are commercially available and are suitable for combination with foam, either as an additive in any area or region of a particular piece or layer of foam, or as a surface coating, for example when contained in a water based acrylic-latex coating which can be applied to a foam surface by spraying or roll coating to any desired thickness or density, such as for example in the range of 50-100 g/m². The paraffinic wax can be selected or blended to have a desired melt temperature or range. The polymer for the microspheres is selected for compatibility with the foam material. For the described mattress applications and constructions, a preferred PCM has a phase transition temperature range is 28-32 degrees C, such as are commercially available from Outlast Technologies, Inc.

[0020] In a representative embodiment of a foam mattress constructed with engineered foams including phase change material, a foam mattress **10** as shown in **FIG. 1** has an uppermost or top layer or top layer **100** (also referred to herein as "PCM coated layer" and "top layer of foam") which is made of a visco-elastic foam with a density in an approximate range of 4.0 to 8.0 lbs./cu.ft. and an IFD (25% indentation) in an approximate range of 10 to 20 lbs. In the preferred embodiments at least one side of the top layer **100** has a convoluted surface, i.e. non-planar which is oriented downward to face the underlying layers of the mattress **10**. However, the disclosure also includes top layers, and other layers which are planar on both sides. On a top surface of the top layer **100**, an area **101** is a prescribed area in which a PCM is applied by sprayed, rolled or other mode of application as a relatively thin layer or coating, referred to generally herein as "PCM coating". The area **101** is illustrated as somewhat less than the total surface area of the top layer **100**, but can alternatively be equal to the total surface area of top layer **100**. The PCM is in the described microcapsule encapsulation form, and in combination with an adhesive or binding agent (or "binder") which adheres the PCM microcapsules to the surface of top layer **100**. The PCM microspheres are mixed with an acrylic binder that makes up 55% of the solids, for example in a mixed liquid formulation which is sprayed onto the foam surface. The foam with the applied PCM can then be passed under heaters to evaporate the liquid carrier from the surface.

[0021] A preferred thickness of the applied PCM layer is on the order of approximately 50-100 mils or greater, and may be varied in accordance with the concentration of PCM microcapsules, the type of PCM in the microcapsules, and the amount of heat absorption desired. It is preferred that the PCM coating layer reside primarily and substantially at the surface of top layer **100**, although some penetration of the PCM into the top layer **100** is acceptable. This configuration maximizes the thermal transfer and heat sink efficiency of the PCM with a body in contact with top layer **100**. In a further alternate embodiment, the top layer **100** is substantially impregnated with PCM, either by application to one or both surfaces of the layer **100**, or integrated into the foam structure in the manufacturing process. These alternate embodiments are more suitable for the foam mattress constructions in which the top layer **100** has a relatively small thickness dimension, for example 2 inches or less, whereby the PCM in the top layer **100** is present in sufficient quantity and held in close proximity to a body in contact with the top layer **100** for efficient thermal transfer.

[0022] A further advantage of the topical layer, coating or surface application of PCM to the top layer **100** of a foam mattress is that the PCM is present in an effective amount or concentration without altering the support characteristics or feel of the foam. The top layer **100** retains all of its compression, resilience and support properties which are effectively unaltered by the relatively thin layer or PCM. Furthermore there is no degradation of the foam structure, and no surface tension is created which alters the firmness or feel of the top layer **100**. The area **101** of the PCM coating or layer is sufficient to be in thermal contact with one or more bodies on the mattress **10** and to effectively absorb heat from the body or bodies, i.e. to undergo the phase transition without an appreciable increase in the temperature at the surface of top layer **100**. The size, shape and thickness of area **101** of the foam top layer **100** can be varied for any desired thermal performance on any size or type of foam mattress, or with any type of mattress (foam or innerspring or other non-foam core or components). Multiple areas or zones of surface applied PCM may be formed on top layer **100**. Applying PCM as a coating to an area or areas within the boundaries of top layer **100** results in concentration of PCM enhances the thermal transfer efficiency. Application by template or controlled spray provides precise control and tolerances and is adaptable to any size mattress. Preferably the PCM does not penetrate into the foam structure no more than 1 to 2 mm.

[0023] A particular advantage of the surface application or coating of PCM on the top layer of a foam mattress construction is the absorption of heat from one or more bodies on the mattress and reduction in the increase of the surface temperature of the mattress. With the PCM in the closest possible proximity to the body heat source, the transfer of heat into the foam of the mattress is retarded. The foam of the mattress thus receives and stores a lesser amount of heat. As the mattress cools, the stored heat is released from the PCM more efficiently than heat from a non-PCM coated foam mattress. The PCM surface coating **101** can be applied to any layer of a foam mattress of any configuration. For example, in a foam mattress with a top layer with relatively thin thickness of for example one inch, PCM may be applied to an underside of such layer and provide the described thermal functions. Alternatively, both sides of one or more foam layers of a mattress may be coated with PCM in the same or different patterns. Also, differing types of PCM materials may be surface applied to the same or opposing sides of one or more

foam layers. Blends of different PCM materials may be surface applied, either in a single application or as applied layers. A further advantage of surface application of PCM over infusion, impregnation or knife-over-roller application is, in addition to achieving the desired thermal effects, the application is faster than these other methods and the distribution of PCM on the foam is more precise and uniform, and the even distribution is not dependent upon or affected by the internal cellular structure of the foam. PCM surface coating can be applied to any type of foam which is suitable for use in a foam mattress, or to any foam layers of any type of mattress such as innerspring or pocketed coil spring mattresses.

[0024] One or more layers of the foam mattress constructions of the present disclosure may be comprised of foam material, such as visco-elastic foam including for example natural or synthetic latex, polyurethane or polyethylene foams, and gel such as polyurethane gels, preferably in particular form. In a preferred embodiment, the gel containing foam layer of layers of a foam mattress construction is comprised of any of the disclosed foam materials with discrete particles of gel interspersed and generally evenly distributed throughout the foam structure or cellular network. The gel particles may range in size from less than 1mm to greater than 5mm in diameter. Substantially even distribution of gel particles throughout the foam structure produces a hybrid material in which the physical properties of the foam and gel, including hardness, density, energy absorption and thermal conductance are combined. To the extent that the mechanical properties of the foam and gel differ, the combination of the two materials produces a hybrid material with hybrid properties. For example, a visco-elastic foam with particular density and hardness properties will correspondingly deform at a particular rate under a load. The presence of a dispersed gel additive (the density of which is generally greater than that of foam, e.g. in a range of 600 to 1100 kg/m³), for example in particle form, in the same foam can alter the rate and degree of deformation as well as the recovery rate (memory) when unloaded.

[0025] The thermal properties of gel are also employed when present as an additive in particulate or other form in the foam, and in combination with PCM applied to a surface of the foam. In general, gel has greater thermal conductivity than foam, and the thermal conductivity can be altered by use of certain fillers. In the engineered foams and foam mattress constructions of the present disclosure, the thermal conductivity of the PCM coating applied to the top layer 100 can be selected, matched or balanced with reference to the thermal conductivity of the foam and/or the thermal conductivity of the gel in top layer 100 for the desired thermal management properties. In this aspect of the disclosure, the thermal conductivity of the PCM corresponds to the thermal conductivity of the foam of the foam layer to which the PCM is applied, and/or to the gel in the foam layer to which the PCM is applied.

[0026] According to the invention, the thermal conductivity of the gel in the top layer of foam is matched with the thermal conductivity of the foam of the top layer of foam and the thermal conductivity of the phase change material.

[0027] In the various embodiments of the foam mattress constructions 10 shown in FIGS. 2-9, additional foam layers are provided in combination with the top layer 100 with the PCM coating layer 101. Any of the various layers may be planar on one or both sides, or convoluted or otherwise contoured on one or both sides. The layers of the foam mattresses are referenced in groups as core layers C1-Cn, intermediate layers I1-In, top layer 100. Gel is depicted in particulate form at G in FIGS. 2-9. In a preferred foam mattress construction, in addition to the PCM coated top layer 100, there is at least on intermediate layer I and preferably two intermediate layers and even more preferably two or more intermediate layers which underlie the top layer 100. The intermediate layers may be of the same type of foam or a different type of foam as top layer 100, and with or without any gel additive. The intermediate layer or layers I may be of the same or greater thickness than top layer 100, and when there are two or more intermediate layers the respective thicknesses may be the same or different, as illustrated.

[0028] A preferred core construction of layers C1-C3 includes relatively thick layers C1 and C3, each having a planar side and a non-planar side such as convoluted, with the non-planar sides in an opposing arrangement, and a medial core layer C2 which is planar and of substantially less thickness. The relative thicknesses of layers C1 and C3 may be the same or different as illustrated. Representative total thickness dimensions for layers C1 and C3 range from approximately 2 to 6 inches with a density of approximately between 2 to 2.25 lb/ft³, preferably 2.05 lb/ft³. Representative thickness dimension for the medial core layer C2 is in the approximate range of 0.5 to 2 inches. The core layers C1 and C3 can also be configured with full thickness dual planar edge regions, indicated at 105 (shown in FIG. 1), which provide increased foam density and rigidity along the longitudinal edges of the mattress. Alternatively, as shown in FIG. 12, a planar insert 1051 can be provided at the edges, such as the longitudinal edges of layer C3 to provide greater hardness or rigidity in that region, and a flush planar wall construction of layers C3 and I1, alternatively, optionally, or additionally along the longitudinal edge of layer C1, as shown in FIGS. 1 and 11.

[0029] FIG. 11 illustrates an alternate embodiment of a mattress of the disclosure wherein layers 100 and I1 are combined with an innerspring 200. The innerspring 200 or spring core may be any type of innerspring which has a plurality of springs, such as coil springs or the like, which are arranged in a matrix and interconnected either by wire or other material such as fabric, such as pocketed or encased coils.

[0030] Covering or upholstery for the different types of mattresses are illustrated in **FIGS. 1, 10 and 11**, indicated at **U**, enclosing the described foam constructions and other internal components such as innerspring or pocketed coils. As shown in **FIG. 10**, a PCM coated top layer **110** can be used external to the upholstery **U** of a mattress, which supplied for example as an accessory or an aftermarket product for use with a mattress. This provides the improved thermal properties and additional support of top layer **110** in combination with any mattress.

REFERENCES CITED IN THE DESCRIPTION

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- [US5637389A \[0010\]](#)
- [US20040234726A \[0010\]](#)
- [US20090142551A1 \[0011\]](#)

Patentkrav

1. Behandlet skum (10) til brug som et lag i en skummadraskonstruktion, som har flere lag (100, 101, C1-C3, I1-I3), og som omfatter et øvre lag (100) af skum
5 og mindst et yderligere lag (C1-C3, I1-I3) af skum og en belægning af faseovergangsmateriale (101), som er påført oversiden af det øvre skumlag (100), og som i det øvre skumlag (100) yderligere omfatter en gel (G),
kendetegnet ved, at varmeledningsevnen af gelen (G) i det øvre skumlag (100) stemmer overens med varmeledningsevnen for skummet i det øvre
10 skumlag (100) og varmeledningsevnen for faseovergangsmaterialet (101).
2. Behandlet skum (10) ifølge krav 1, hvor det øvre skumlag (100), som på sin øvre flade er påført faseovergangsmaterialet (101), er i berøring med mindst et yderligere lag (C1-C3, I1-I3) af skum i en skummadraskonstruktion.
15
3. Behandlet skum (10) ifølge krav 1, hvor faseovergangsmaterialet (101) er indeholdt i mikrokapsler.
4. Behandlet skum (10) ifølge krav 1, hvor det mindst ene yderligere lag skum
20 (C1-C3, I1-I3) af skum har en tykkelsesdimension, som er lig med eller større end en tykkelsesdimension gældende for det øvre skumlag (100).

DRAWINGS

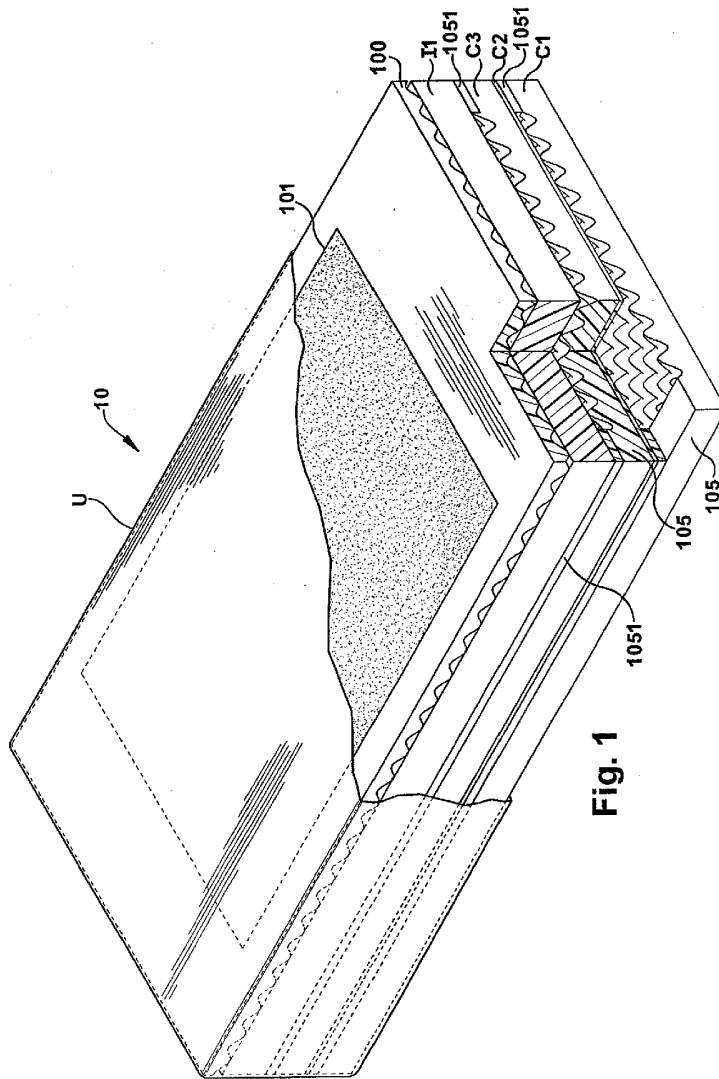


Fig. 1

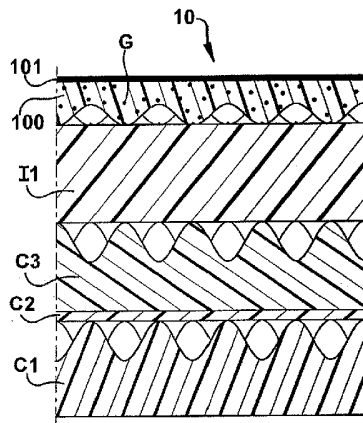


Fig. 2

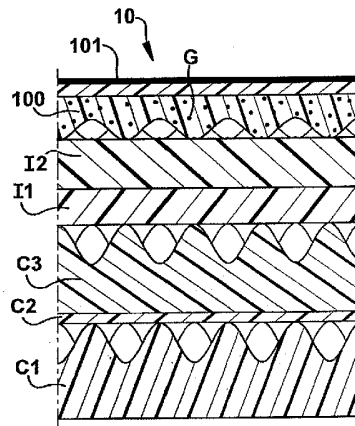


Fig. 3

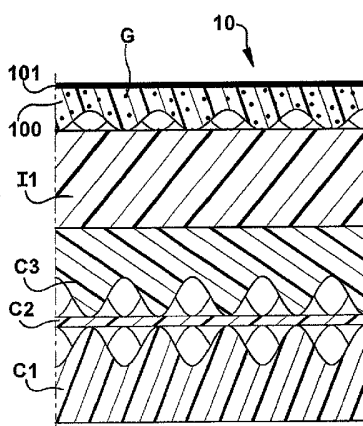


Fig. 4

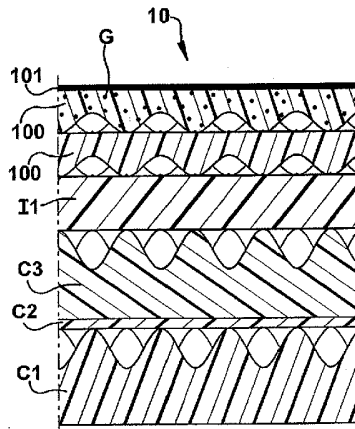


Fig. 5

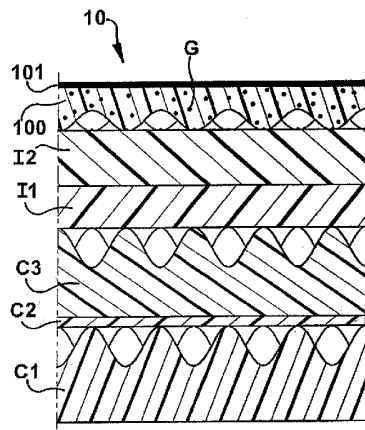


Fig. 6

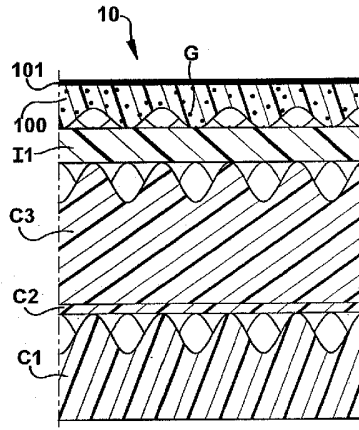


Fig. 7

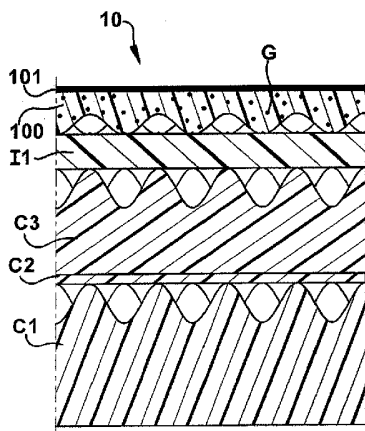


Fig. 8

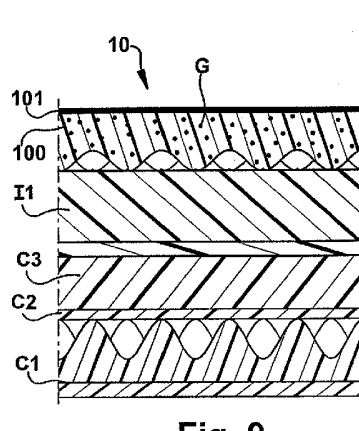
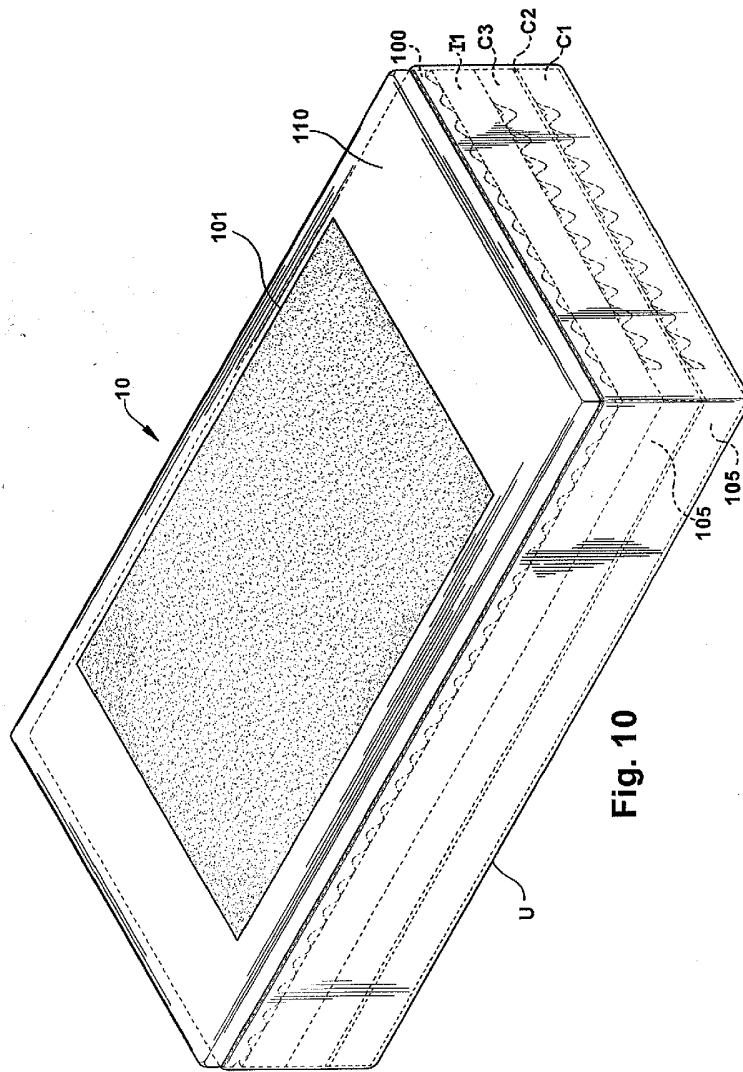
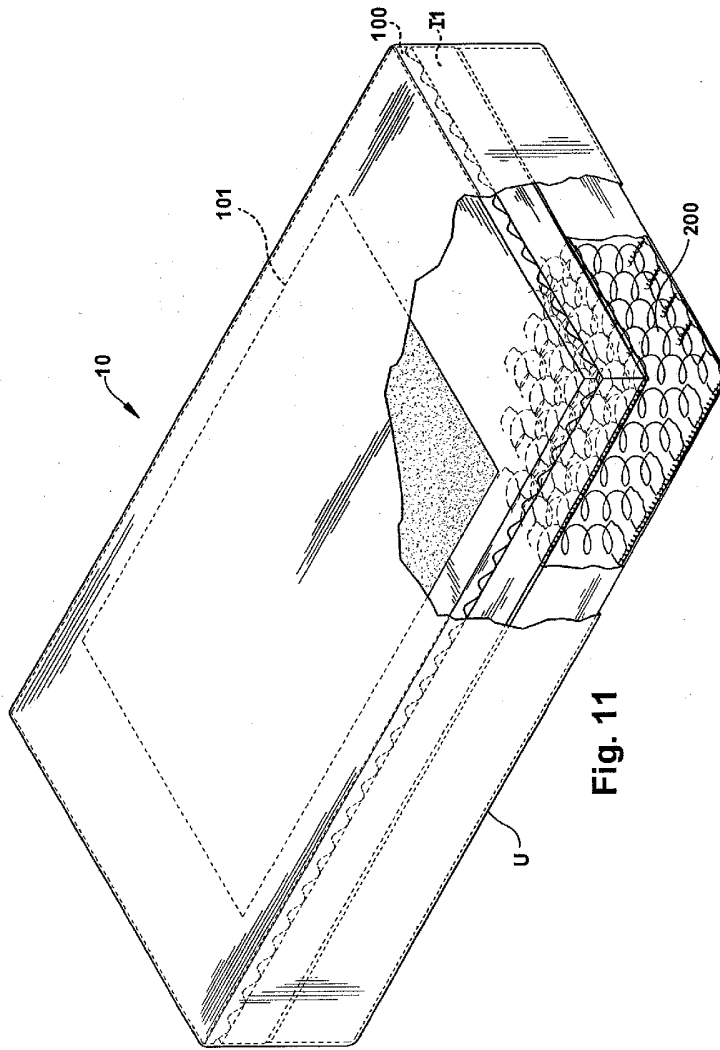


Fig. 9





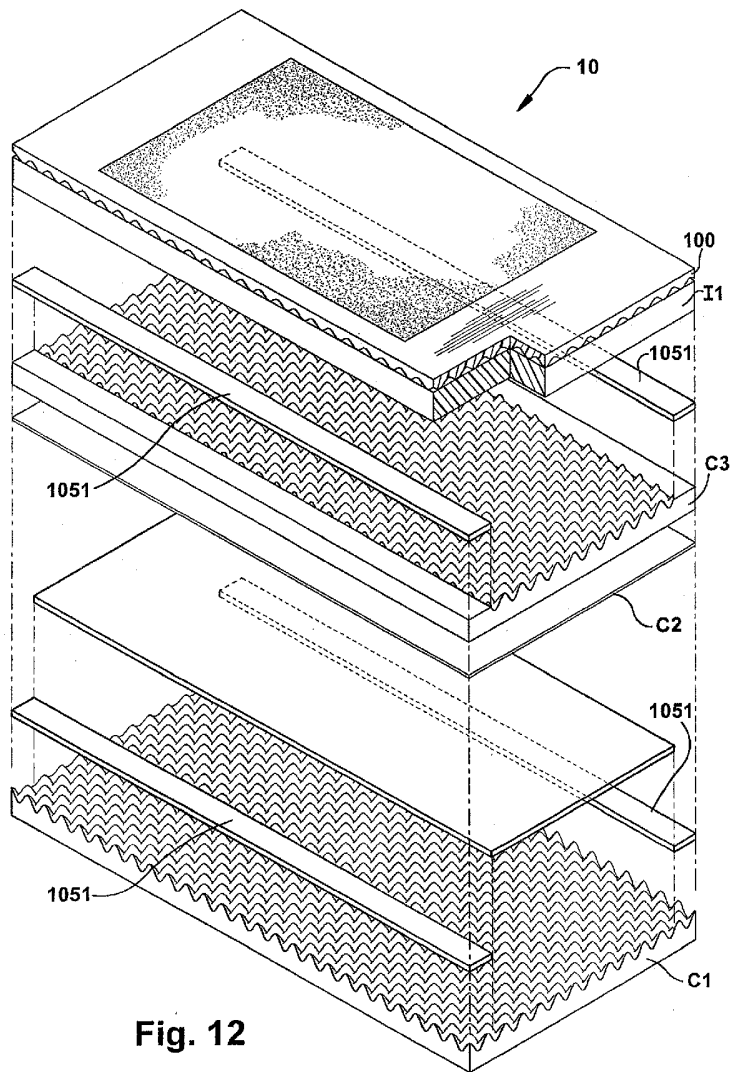


Fig. 12