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(54) Benævnelse: **GIPSPANEL, ANVENDELSE AF ET SÅDANT PANEL OG FREMGANGSMÅDE TIL FREMSTILLING AF ET SÅDANT PANEL**

(56) Fremdragne publikationer:
EP-A2- 2 354 349
WO-A1-2012/095550
WO-A2-2015/184460
JP-A- 2007 310 506
US-A- 5 319 900
US-A1- 2003 019 176
US-A1- 2010 026 457
US-A1- 2014 361 796

DESCRIPTION

FIELD

[0001] The present disclosure relates generally to the field of panels for use in building construction, and more particularly to gypsum panels with environmental sensors, methods of making such gypsum panels, and systems for their use.

BACKGROUND

[0002] Interior wallboard, exterior building sheathing, and roofing panels can be exposed to extreme environmental conditions including moisture, wind, and extreme temperatures during and after construction. Additionally, such systems may be installed improperly, such that seams between panels are not completely sealed. Furthermore, sheathing and roofing panels installed around windows, scuppers, parapet walls, and other openings and areas in the building may be particularly vulnerable to environmental damage.

[0003] When moisture intrusion and/or degradation or destruction of the panels occurs due to these conditions, it often goes unnoticed for a length of time, usually until visually observed. Moreover, leaks and/or degradation that may not be visible via typical inspection methods may never be detected. Thus, such damage conditions, as well as mold and mildew resulting from water infiltration, may intensify to easily avoidable levels because of the lack of early detection systems for these issues.
For example, in environments exposed to freezing temperatures, water leaking into a gypsum roofing or sheathing panel may undergo multiple freeze-thaw cycles and thereby cause separation of the gypsum core and the fiberglass mat facer and associated membrane (e.g., building wrap), if present. Once separation of the mat facer has occurred, wind uplifting causes further separation of the mat facer, sometimes resulting in billowing of the mat facer. A generic panel or method is disclosed in WO A 2012 095550. The method comprises: - determining first temperature information from first temperature data obtained from a first temperature sensor, - determining reference temperature information by using second temperature data obtained from a second temperature sensor, and - comparing the first temperature information with the reference temperature information in order to detect an abnormal condition of the structure, wherein the first sensor is positioned within the structure such that a first distance between the first temperature sensor and an inner surface of the structure is different from a second distance between the second temperature sensor and the inner surface, wherein the first temperature sensor is an RFID transponder arranged to transmit the first temperature data, and wherein the first temperature sensor is arranged to extract operating energy from a radio frequency field.

[0004] Accordingly, it would be desirable to provide gypsum panels having sensors for

detecting environmental conditions in or on the gypsum panel, to monitor and prevent damage to such panels. In particular, it is provided a gypsum panel having the features defined in claim 1. Moreover, it is provided the method of making gypsum panel having the features defined in claim 8. Further preferred embodiments are defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Referring now to the drawings, which are meant to be exemplary and not limiting, and wherein like elements are numbered alike. The detailed description is set forth with reference to the accompanying drawings illustrating examples of the disclosure, in which use of the same reference numerals indicates similar or identical items. Certain embodiments of the present disclosure may include elements, components, and/or configurations other than those illustrated in the drawings, and some of the elements, components, and/or configurations illustrated in the drawings may not be present in certain embodiments.

FIG. 1 is a diagrammatic, fragmentary side elevational view illustrating portions of a manufacturing line for producing gypsum board of a type suitable for use in the manufacture of gypsum board prepared for use in accordance with the present disclosure;

FIG. 2 is an enlarged fragmentary sectional view, taken as indicated toward the left of FIG. 1, of an underlying fiber glass mat used in the manufacture of the gypsum board;

FIG. 3 is a fragmentary plan view taken as indicated by the line 3--3 on FIG. 2;

FIG. 4 is an enlarged sectional view taken as indicated toward the right on FIG. 1 and illustrating both underlying and overlying fiber glass mats, with intervening gypsum composition, used in the manufacture of the board;

FIG. 5 is a fragmentary plan view taken as indicated by line 5--5 on FIG. 4;

FIG. 6 is a fragmentary bottom view taken as indicated by the line 6--6 on FIG. 4 and illustrating the bottom surface of the underlying mat of the board;

FIG. 7 is a transverse sectional view of an edge portion of the completed board, this view being taken as indicated by the line 7--7 on FIG. 4;

FIG. 8 is a further enlarged fragmentary sectional view taken as indicated toward the top of FIG. 4;

FIG. 9 is a further enlarged fragmentary sectional view taken as indicated toward the bottom of FIG. 4;

FIG. 10 is a perspective view partly broken away and in section of an exemplary roof deck system incorporating a panel in accordance with the present disclosure;

FIG. 11 is an enlarged sectional view taken along line 11--11 of FIG. 10;

FIG. 12 is a greatly enlarged sectional view of the circled area of FIG. 11 showing the penetration of the first asphalt layer into the fibrous upper surface of the panel in accordance with the disclosure;

FIG. 13 is a perspective view of another type of roof system incorporating the panel in accordance with the disclosure as the primary support layer;

FIG. 14 is a sectional view taken along line 14--14 of FIG. 13;

FIG. 15 is a perspective view partly broken away and in section of a composite wall structure employing the panel in accordance with the disclosure;

FIG. 16 is a greatly enlarged view of the circled portion of FIG. 15 showing the penetration of the plaster layer into the fibrous surface of the panel;

FIG. 17 is a cross-sectional view of a gypsum panel;

FIG. 18 is a cross-sectional view of a gypsum panel;

FIG. 19 is a perspective view of a building sheathing system having water-resistive and air-barrier properties;

FIG. 20 is a plan view of an environmental sensor assembly;

FIG. 21 is a perspective view of a roof deck assembly; and

FIG. 22 is a partial perspective view of a roof deck assembly.

DETAILED DESCRIPTION

[0006] Disclosed herein are gypsum panels, as well as methods of making such panels and systems for their use. The gypsum panels described herein may be panels for internal or external construction applications, such as for wallboard, external sheathing, or roof board applications. For example, the gypsum panels described herein may be external sheathing panels, such as those described in U.S. Applications No. 15/014,793 (US 2016/022646 A) and 15/014,922 (US 2016/0222656 A), entitled "Gypsum Panels, Systems, and Methods". For example, the gypsum panels described herein may be roof deck panels, such as those described in U.S. Patent No. 5,319, 900..

GYPSUM PANELS

[0007] In the following, there are described some arrangement of gypsum panels and method of making such gypsum panels. However, the scope of protection is defined by the claims. The

inventive gypsum panel has an environmental sensor assembly which is configured as moisture sensor and the environment conditions sensed by the sensor is moisture.
Generally, the gypsum panels may include any suitable construction or configuration known in the industry. For example, the gypsum panels are panels that contain gypsum as a significant component of the panel core (e.g., in amounts of up to 90 percent, by weight, or more) or may be panels that contain gypsum as a component of the panel core in combination with other components (e.g., in amounts of less than 90 percent). Examples of other components that may be present in the panel core include cellulose or other fibers. Furthermore, while the present disclosure is generally directed to building panels that include a gypsum core or layer, other panels may be suitably substituted for the gypsum panel, such as wood-based, foam-based, and other material-based panels that are suitable for the building construction purposes described herein.

[0008] In accordance with the present invention, as shown in FIG. 17, a gypsum panel 1000 includes a gypsum core 101 having a first surface and a second opposed surface, and a first facer material 104 associated with the first surface of the gypsum core 101. For example, the facer material may be any suitable facer material known in the art, including paper and fibrous facer materials. In certain embodiments, as shown in FIG. 17, the facer material 104 is a fibrous material, such as fiberglass. Thus, while certain embodiments herein are described with reference to a fiberglass mat, it should be understood that any suitable paper facer or other fibrous mat material may be substituted and fall within the scope of the disclosure.

[0009] In certain embodiments, the facer material is a nonwoven fibrous mat formed of fiber material that is capable of forming a strong bond with the material of a building panel core through a mechanical-like interlocking between the interstices of the fibrous mat and portions of the core material. Examples of fiber materials for use in the nonwoven mats include mineral-type materials such as glass fibers, synthetic resin fibers, and mixtures or blends thereof. Both chopped strands and continuous strands may be used.

[0010] In certain embodiments, the facer material is a nonwoven fiberglass mat. For example, the glass fibers may have an average diameter of from about 1 to about 17 microns and an average length of from about 1/16 inch (1,59 mm) to about 1 inch (25,4 mm). For example, the glass fibers may have an average diameter of 13 microns (i.e., K fibers) and an average length of ¾ inch (19,05 mm). In certain embodiments, the non-woven fiberglass mats have a basis weight of from about 1.5 pounds to about 4.0 pounds per 100 square feet (0,0732 to 0,1953 Kg/m^2) of the mat. The mats may each have a thickness of from about 10 mils (0,254 mm) to about 50 mils (1,27 mm). The fibers may be bonded together to form a unitary mat structure by a suitable adhesive. For example, the adhesive may be a urea-formaldehyde resin adhesive, optionally modified with a thermoplastic extender or cross-linker, such as an acrylic cross-linker, or an acrylate adhesive resin.

[0011] In certain embodiments, as shown in FIGS. 2 and 3, facer material mats 6 and 16, contain glass fiber filaments 30 oriented in random pattern and bound together with a resin binder (not shown). One embodiment of glass fiber mat-faced gypsum board 40 is shown in

FIGS. 4 and 7, in which the set gypsum of the core 42 penetrates substantially through the thickness of the mat 6 over substantial area portions thereof and in which the set gypsum of the core 42 penetrates the mat 16 partially, with the surface being thus substantially free of set gypsum. The gypsum-free surface of mat 16, as seen in FIG. 8, is highly textured, and provides an excellent substrate for adhering thereto an overlying component inasmuch as it contains many interstices into which an adhesive composition can flow and bond.

[0012] In certain embodiments, the panels have a thickness from about ¼ inch (6,35 mm) to about 1 inch (25,4 mm). For example, the panels may have a thickness of from about ½ inch (12,7 mm) to about 5/8 inch (15,87 mm).

[0013] In some embodiments, as shown in FIG. 17, gypsum crystals of the gypsum core 101 penetrate a remaining portion of the first fiberglass mat 104 such that voids in the first fiberglass mat 104 are substantially eliminated and the water resistance of the panel 1000 is further enhanced. For example, in one embodiment, the first fiberglass mat 104 has a continuous barrier coating 106 on a surface opposite the gypsum core 101, the continuous barrier coating 106 penetrating a portion of the first fiberglass mat 104, to define the remaining portion of the first fiberglass mat 104. That is, gypsum crystals of the gypsum core 101 penetrate a remaining fibrous portion of the first fiberglass mat 104 such that voids in the first fiberglass mat 104 are substantially eliminated. As used herein the phrase "such that voids in the fiberglass mat are substantially eliminated" and similar phrases refer to the gypsum slurry (e.g., slate coat) filling all or nearly all of the interstitial volume of the fiberglass mat that is not filled by the coating material.

[0014] As used herein, the term "continuous barrier coating" refers to a coating material that is substantially uninterrupted over the surface of the fibrous mat. The continuous barrier coating on the external surface of the facer may be any suitable coating known in the art. For example, the coating may include a binder material and, optionally, a filler. For example, the coating may include a polymer or resin based binder material along with one or more inorganic fillers.

[0015] In certain embodiments, as shown in FIG. 17, the gypsum core 101 includes two or more gypsum layers 102, 108, while in other embodiments the gypsum core includes a single gypsum layer. For example, the gypsum core may include various gypsum layers having different compositions. In some embodiments, the first gypsum layer 102 that is in contact with the fiberglass mat 104 (i.e., the layer that forms an interface with the coating material and at least partially penetrates the remaining fibrous portion of the first fibrous mat) is a slate coat layer. In some embodiments, the first gypsum layer 102 is present in an amount from about 2 percent to about 20 percent, by weight, of the gypsum core 101. The various gypsum layers are shown as separate layers in the figures for ease of illustration; however, it should be understood that overlap of these materials may occur at their interfaces.

[0016] The layers of the gypsum core may be similar to gypsum cores used in other gypsum products, such as gypsum wallboard, drywall, gypsum board, gypsum lath, and gypsum sheathing. For example, the gypsum core may be formed by mixing water with powdered

anhydrous calcium sulfate or calcium sulfate hemihydrate, also known as calcined gypsum, to form an aqueous gypsum slurry, and thereafter allowing the slurry mixture to hydrate or set into calcium sulfate dihydrate, a relatively hard material. In certain embodiments, the gypsum core includes about 80 weight percent or above of set gypsum (i.e., fully hydrated calcium sulfate). For example, the gypsum core may include about 85 weight percent set gypsum. In some embodiments, the gypsum core includes about 95 weight percent set gypsum. The gypsum core may also include a variety of additives, such as accelerators, set retarders, foaming agents, and dispersing agents.

[0017] In certain embodiments, as shown in FIG. 18, a gypsum panel 200 includes two facers 204, 212 that are associated with the gypsum core 201. As with the first facer material, the second facer material may be any suitable facer material, such as paper or fibrous materials. In certain embodiments, both facers 204, 212 are fiberglass mats. The second fiberglass mat 212 is present on a face of the gypsum core 201 opposite the first fiberglass mat 204. In some embodiments, only the first fiberglass mat 204 has a continuous barrier coating 206 on a surface thereof. In other embodiments, both fiberglass mats 204, 212 have a coating 206, 214 on a surface thereof opposite the gypsum core 201. In some embodiments, the gypsum core 201 includes three gypsum layers 202, 208, 210. One or both of the gypsum layers 202, 210 that are in contact with the fiberglass mats 204, 212 may be a slate coat layer.

[0018] As shown in FIG. 17, gypsum panels according to the present disclosure may have a first surface 107 of the panel 1000 formed by the first facer material 104 and/or a continuous barrier coating 106 thereon. The gypsum panel 1000 also has a second surface 109 of the panel opposite the first surface 107.

[0019] In certain embodiments, as shown in FIGS. 10-14 and 21-22, the gypsum panel may be a roof deck panel. For example, installation of a roof deck system in construction of a building, generally involves constructing a frame for support of the roof of a building; affixing to the frame corrugated sheets to provide a surface for support of the other components of the roof deck system; affixing to the corrugated sheets planar support members; and affixing to the planar support members an exterior finishing material having good weathering properties. Roof deck systems which include panels of insulation sandwiched between the aforementioned corrugated sheets and planar support members are used widely also. Such systems are designed to be insulative in character and weather resistant. Such roof deck systems can be used to advantage to conserve energy used for heating and to conserve energy used for air-conditioning. More specifically, such roof deck systems typically include corrugated metal sheets which are mechanically affixed, usually by screws or bolts, to appropriate structural members of the building such as steel beams. The corrugated metal sheets support the weight of the components which overlie it, including the insulating material (when used), the planar support members, and the finishing material. Light weight, low density insulating panels such as expanded polystyrene, polyisocyanurate, and the like, are used widely in such systems, especially in colder climates. The planar support members generally include gypsum boards and are fastened in place by mechanical fasteners such as screws to the underlying corrugated metal sheet. When panels of insulation are used, they are sandwiched between the

underlying corrugated metal sheets and the overlying panels of gypsum board. An exterior finishing material, such as a polymeric or rubber membrane or alternating layers of asphalt and roofing felt, overlies the panels of gypsum board.

[0020] A typical roof deck system incorporating the fibrous mat-faced gypsum board as described above is shown in FIGS. 10 to 12. In this construction, spaced parallel trusses 50 extending between building support members (not shown) support a corrugated metal deck 52 which is welded or otherwise fastened to the trusses. Layers 54 and 56 of insulating sheet material, which may, for example, be of polyisocyanurate, are disposed on the corrugated metal deck. A layer 58 of fibrous mat-faced gypsum board panels of the type described hereabove are secured to the corrugated deck 52 by means of fasteners 60 passing therethrough and through the underlying insulation layers 54 and 56 into the deck 52. The joints of the panel layer 58 are sealed by application of tape 62, as shown in FIG. 10 with respect to one of the panel joints. Overlying the gypsum layer 58 is a waterproof roofing membrane including alternate layers of asphalt 64 and roofing felt 66, three layers of each being shown in the present example. A final coating of asphalt 68 is covered with a crushed gravel topping layer 70.

[0021] In the enlarged view of FIG. 12, the manner in which the first asphalt layer 64 penetrates into the upwardly facing fibrous mat-face of the gypsum board panel layer 58 is illustrated. This penetration assures a secure adhesion of the waterproof membrane to the structural layers of the roof system.

[0022] In some embodiments, as shown in FIG. 21, the roof deck system 150 incorporating the gypsum panels having the environmental sensor assembly includes a gypsum roof board/panel, as an overlayment 158, underlayment 154, or both, as well as insulation 156, and a roof covering or membrane 160, mounted on a steel, wood, or other roof deck 152 (shown as steel). In some embodiments, as shown in FIG. 22, the roof deck system 162 incorporating the gypsum panels having the environmental sensor assembly is a single-ply membrane system. For example, the system may include at least one gypsum roof panel 166, 170, insulation 168, and a single-ply membrane 172 (e.g., EPDM or thermoplastic membrane). Various embodiments of such roofing systems utilizing gypsum roofing panels are known in the art and the present disclosure is meant to encompass any such suitable system configurations or designs incorporating the gypsum panels disclosed herein. For example, the roofing system may incorporate suitable asphalt, EPDM, Turbo Seal, CSPE, Modified Bitumen, PVC, cold liquid membranes, FTPO, TPO, coaltar pitch built up, or other built up roof constructions, among others.

[0023] Referring to FIGS. 13 and 14, a poured-in-place roof deck system is shown including purlins 72 supporting spaced sub-purlins (bulb tees 74 in parallel spaced relation). Fibrous mat-faced gypsum board panels 76 of the type described above are supported on the horizontal flanges 74a of the sub-purlins 74. A reinforcing mesh screen 78 is laid over the sub-purlins and gypsum board panels 76 and a layer of settable gypsum slurry 80 is poured in place over the reinforcing mesh. The slurry 80 is allowed to harden to form a smooth

continuous deck surface 82. Adhesion of the slurry to the gypsum board panel 76 is assured by the penetration of the slurry into the upwardly facing fibrous mat surface of the panels. A roofing membrane including alternate layers of asphalt 84 and roofing felt 86, three layers of each in the illustrated example, is applied to the surface 82. A final layer of asphalt 88 is covered with a coating of crushed rock or gravel 90.

[0024] As regards interior finishing systems for use in a building, installation of such a system generally involves constructing a frame for support of the interior walls of a building; and affixing to the frame planar support members which provide a smooth continuous surface to support an interior finishing material having aesthetic and durability properties. Such systems are designed to be strong and durable and to withstand abuse during the building's occupancy. An example of an interior usage of the present fibrous mat-faced panel is illustrated in FIGS. 15 and 16. In these views, an interior wall system includes spaced vertical studs 92 to which fibrous mat-faced gypsum board panels 94 are attached by spaced fasteners 96 such as screws or nails. A thin layer 98 of plaster is applied to the fibrous mat surface 100 of the panel 94 and is troweled to form a smooth finish surface which may then be decorated by paint, paper or the like in a conventional manner. As shown in the enlarged view of FIG. 16, the plaster 98 penetrates into the fibrous mat surface of the panel 94 to effect a secure mechanical bond of the plaster layer to the panel. Although shown in the context of a wall in FIG. 15, the panel 94 may equally suitably be used as a ceiling panel and can be used with either a wood or metal stud support system. For some applications, it may be found that adjustments need to be made in the water-resistant properties of the core in order to obtain a satisfactory plaster finish.

[0025] In exterior systems, the fibrous mat-faced, water-resistant gypsum board can be affixed to an underlying support member in any suitable way, for example, by the use of nails or screws. In such systems, the underlying support member may include, for example, panels of rigid plastic or metal sheets, for example, in corrugated form, purlins and sub-purlins. Panels of insulating material may be affixed to such support members and underlie panels of said gypsum board which are affixed thereto. The support member is typically affixed to the frame of the building.

[0026] In certain embodiments, as shown in FIGS. 17 and 18, the gypsum panel includes at least one environmental sensor assembly 120, 122, 124 associated with the gypsum panel. Although three environmental sensor assemblies are shown in FIGS. 17 and 18, it should be understood that a sensor assembly may alternatively be provided at one, two, or each of these locations, as well as at other locations in and on the gypsum panel.

[0027] In one embodiment, the environmental sensor assembly 120 is disposed on the first surface of the gypsum panel. In one embodiment, the environmental sensor assembly 122 is disposed on the second surface of the gypsum panel. For example, the first surface of the gypsum panel may be the external-facing surface of the panel upon installation, while the second surface of the gypsum panel may be the internal-facing surface of the panel upon installation. In other embodiments, the environmental sensor assembly is disposed at an

external edge of the gypsum panel. In other embodiments, the environmental sensor assembly 124 is disposed within or at a surface of the gypsum core. For example, the environmental sensor assembly may be positioned on or adjacent the facer material or in another portion of the gypsum of the gypsum core, such as in the slate coat or another of the gypsum layers. In other embodiments, the environmental sensor assembly may be disposed on the surface of the facer material that receives a continuous barrier coating. Thus, the environmental sensor assembly may be disposed at any suitable position on or in the gypsum panel, depending on the desired location and type of environmental condition detection and the particular application of the panel.

[0028] The environmental sensor assembly is configured to detect an environmental condition of the gypsum panel and to communicate data regarding the environmental condition to a reader. For example, the environmental sensor assembly configured to detect one or more environmental conditions such as moisture, temperature, and/or pressure. In accordance with the present invention, the environmental sensor assembly is configured as moisture sensor and the environment conditions sensed by the sensor is moisture.

[0029] The environmental sensor assembly is self-supporting and may include a substrate on which an antenna, a processing module, and a wireless communication module are disposed. As used herein, the term "self-supporting" refers to the sensor assembly being operable to sense the target environmental conditions as a standalone assembly, without the need for a wired connection external to the sensor assembly. As such, the environmental sensor assemblies disclosed herein may advantageously be incorporated into gypsum panels at a variety of positions throughout the panel during manufacturing or at a construction site, without the need for additional labor or materials to wire or programs the sensors. In certain embodiments, the environmental sensor assembly is a passive system. As used herein, the term "passive system" refers to the sensor assembly having no battery and instead using the radio energy transmitted by a reader to power the assembly. Advantageously, passive systems may be used in applications where the panels and/or sensor assemblies are largely inaccessible, making replacement of the assembly or a battery associated therewith impossible without damaging the building or building envelope. Moreover, because passive systems have no power source and often no moving parts, these assemblies may have an extremely long lifespan that is at least equal to the typical lifespan of gypsum panels. In other embodiments, the environmental sensor assembly is an active system that includes an integrated power source, such as a battery, for example a rechargeable battery, such as one powered by solar power.

[0030] In certain embodiments, the environmental sensor assembly is a passive, ultra high frequency single-chip sensor inlay system. In certain embodiments, the antenna is a resistor/inductor/capacitor (RLC) tuned circuit operable to convert the environmental condition into an impedance change, and the processing module is coupled to the antenna and is operable to translate the impedance change into a sensor code by matching antenna impedance to die impedance. Thus, whereas traditional sensors exploit changes in resistance to measure environmental variables, which results in reduced tag read range due to power

dissipated in the resistance, the present sensor assemblies' ability to use inductance or capacitance beneficially avoids issues with read range.

[0031] For example, the antenna may have an antenna impedance operable to vary based on the environmental condition. The processing module may be coupled to the antenna and include a tuning module operable to (i) vary a reactive component impedance in order to change a system impedance including the antenna impedance and the reactive component impedance, and (ii) produce an impedance value representative of the reactive component impedance. The wireless communication module may be coupled to the processing module and operable to communicate the impedance value representative of the reactive component impedance to the reader, which represents the data on the environmental condition. In some embodiments, the environmental sensor assembly also includes a memory module operable to store the impedance value representative of the reactive component impedance.

[0032] For example, the sensor assembly may be a passive radio frequency identification (RFID) sensor, such as the sensor described in PCT Application Publication No. WO2015/184460. As shown in FIG. 20, this passive RFID sensor includes an antenna, a processing module, and a wireless communication module. The antenna has an antenna impedance that may vary with the environment in which the antenna is placed. The processing module couples to the antenna and has a tuning module that may vary a reactive component impedance coupled to the antenna in order to change a system impedance that includes both the antenna impedance and the reactive component impedance. The tuning module then produces an impedance value representative of the reactive component impedance. A memory module may store the impedance value which may then later be communicated to an RFID reader via the wireless communication module. The RFID reader may then exchange the impedance value representative of the reactive components of impedance with the RFID reader such that the RFID reader or another external processing unit may process the impedance value in order to determine environmental conditions at the antenna.

[0033] FIG. 20 is a view of one embodiment of an RFID moisture or humidity sensing tag 3300. Moisture or humidity sensing tag 3300 is a passive RFID tag having a substrate 2101, on which is disposed an integrated circuit (IC) 2100. IC 2100 includes a memory module 2012, a wireless communication engine 2104, and a sensor engine 2106, which includes an antenna. IC 2100 is capable of sensing a change in the environmental perimeters proximate to IC 2100 via impedance changes associated with the antenna. Memory module 2102 is coupled with both the wireless communication engine 2104 and the sensor engine 2106. Memory module 2102 is capable of storing information and data gathered by sensor engine 2106 and communicated via wireless communication engine 2104. Further, wireless communication engine 2104 and sensor engine 2106 may be fully programmable via wireless methods.

[0034] The sensor impedance varies as the coupling of interdigitated capacitor 3304 responds to environmental changes. In one embodiment, interdigitated capacitor 3304 is located proximate to a film 3306 applied above interdigitated capacitor 3304. Film 3306 may be a material having an affinity for water (i.e., moisture or humidity) or other fluids, such as CO,

CO_2, Arsenic, H_2S or other known toxins or gases of interest. When film 3306 absorbs a fluid such as those described previously, the dielectric constant proximate to the interdigitated capacitor 3304 changes causing an impedance change. The impedance of the interdigitated capacitor 3304 sensed by the processing module coupled to the sensor then produces an output, a sensor code, representative of the absorbed material within film 3306. This data may be stored within a memory circuit of IC 2100 or transmitted to an external reader by the wireless communication module of IC 2100.

[0035] In accordance with the present invention, the sensor is configured as a moisture sensor, the sensor assembly measures the presence of water when the surrounding environment becomes wet. The interdigitated capacitor experiences a significant change in capacitance, when it changes from dry to wet; the dipole antenna registers an impedance change depending on the amount of water on the capacitor; and the sensor IC converts this into a code that indicates the amount of water present.

[0036] Advantageously, the sensor assemblies described herein may have a small size, such as approximately 4 inches (101,6 mm) by 1 inch (25,4 mm), and be very thin, so as to provide nominal additional thickness when applied externally to the panel.

METHODS

[0037] Methods of making gypsum panels having water-resistive properties are also provided. In certain embodiments, during manufacturing, a gypsum slurry may be deposited on the uncoated surface of the facer material and set to form a gypsum core of the panel. Where the facer material is a fibrous mat, the gypsum slurry may penetrate some remaining fibrous portion of the thickness of the mat (i.e., some portion of the mat that is not already penetrated by the coating) and provide a mechanical bond for the panel. The gypsum slurry may be provided in one or more layers, having the same or different compositions, including one or more slate coat layers. As used herein, the term "slate coat" refers to a gypsum slurry having a higher wet density than the remainder of the gypsum slurry that forms the gypsum core. These methods may be used to produce gypsum panels having any of the features, or combinations of features, described herein. Enhanced penetration of the gypsum into the fibrous mat may be achieved by chemical modification of the gypsum slurry, by application of a penetration-enhancing coating on the surface of the fibrous mat contacted by the gypsum slurry, and/or by mechanical means.

[0038] In certain embodiments, the external surface of the fibrous mat is coated with a continuous barrier coating that penetrates a portion of the first fiberglass mat, to define the remaining portion of the first fiberglass mat that gypsum crystals of the gypsum core penetrate, such that voids in the first fiberglass mat are substantially eliminated.

[0039] In certain embodiments, the gypsum core includes multiple layers that are sequentially applied to the fiberglass mat, and allowed to set either sequentially or simultaneously. In other

embodiments, the gypsum core includes a single layer. In some embodiments, a second fiberglass mat may be deposited onto a surface of the final gypsum slurry layer (or the sole gypsum slurry layer), to form a dual mat-faced gypsum panel. For example, the first and/or second fiberglass mat may include a barrier coating on its surface that penetrates a portion of the mat. The gypsum slurry or multiple layers thereof may be deposited on the fiberglass mat by any suitable means, such as roll coating.

[0040] In some embodiments, the gypsum core includes at least three gypsum layers, with the outermost gypsum layers of the gypsum core (i.e., the layers that form an interface with the fiberglass mats). In certain embodiments, both outermost layers are chemically altered for enhanced penetration.

[0041] In certain embodiments, the first and/or second fibrous mats are already coated upon contacting the gypsum (or other panel core) slurry. In some embodiments, the methods include applying the continuous coating to the first and/or second fibrous mat, either before or after contacting the mats with the panel core slurry. In certain embodiments, applying the barrier coating includes spray coating, ribbon coating, curtain coating, knife coating, or direct roll coating. In some embodiments, the barrier coating is applied to each of the first and/or second fibrous mats in an amount from about 1 pound to about 9 pounds, per 100 ft^2 (0,0488 to 0,4394 Kg/m^2). For example, the barrier coating may be applied to the first and/or second fibrous mat in an amount from about 2 pounds to about 8 pounds, per 100 ft^2 (0,0976 to 0,3906 Kg/m^2). In other embodiments, coated fibrous mats may be obtained in a pre-fabricated form.

[0042] In some embodiments, the method also includes mechanically vibrating at least the first fiberglass mat having the first gypsum slurry deposited thereon to effect penetration of the gypsum slurry into the remaining fibrous portion of the first fiberglass mat.

[0043] In certain embodiments, the panel core slurry (or layers thereof) may be deposited on the non-coated side of a horizontally oriented moving web of pre-coated fibrous mat. A second coated or uncoated fibrous mat may be deposited onto the surface of the panel core slurry opposite the first coated fibrous mat, e.g., a non-coated surface of the second coated fibrous mat contacts the panel core slurry. In some embodiments, a moving web of a pre-coated or uncoated nonwoven fibrous mat may be placed on the upper free surface of the aqueous panel core slurry. Thus, the panel core material may be sandwiched between two fibrous mats, one or both having a barrier coating. In certain embodiments, allowing the panel core material and/or continuous barrier coating to set includes curing, drying, such as in an oven or by another suitable drying mechanism, or allowing the material(s) to set at room temperature (i.e., to self-harden).

[0044] In certain embodiments, as shown in FIGS. 1 to 9, dry ingredients (not shown) from which the gypsum core is formed are pre-mixed and then fed to a mixer of the type commonly referred to as a pin mixer 2. Water and other liquid constituents (not shown) used in making

the core are metered into the pin mixer 2 where they are combined with the dry ingredients to form an aqueous gypsum slurry. The slurry 4 is dispersed through one or more outlets at the bottom of the mixer 2 onto a moving sheet of fibrous mat 6. The sheet of fibrous mat 6 is indefinite in length and is fed from a roll (not shown) of the mat. In certain embodiments, the two opposite edge portions of the fibrous mat 6 are progressively flexed upwardly from the mean plane of the mat 6 and then turned inwardly at the margins so as to provide coverings for the edges of the resulting board 40. In FIG. 1, this progressive flexing and shaping of the edges of the mat 6 are shown for only one side edge of the mat and the conventional guiding devices which are ordinarily employed for this purpose are omitted from the figure for the sake of clarity. FIG. 7 shows an edge of the set gypsum core 42 covered by the overlapped edge portion 6A of the mat 6. FIG. 7 shows also score marks 10 and 10A of the mat 6, the score marks permitting the formation of good edges and flat surfaces. The score marks 10 and 10A are made by a conventional scoring wheel 12. An advantage of using the glass fiber mat is that it is capable of being scored and edged like conventional paper facing.

[0045] Another sheet of fibrous mat 16 is fed from a roll (not shown) onto the top of slurry 4, thereby sandwiching the slurry between the two moving fibrous mats which form the slurry. The mats 6 and 16 with the slurry 4 sandwiched therebetween enter the nip between the upper and lower forming or shaping rolls 18 and 20, and are thereafter received on a conveyer belt 22. Conventional edge guiding devices, such as indicated at 24, shape and maintain the edges of the composite until the gypsum has set sufficiently to retain its shape. In due course, sequential lengths of the board are cut and further processed by exposure to heat which accelerates the drying of the board by increasing the rate of evaporation of excess water in the gypsum slurry.

[0046] With reference to FIG. 7, it has been observed that the set gypsum of the core 42 is effective in forming satisfactory bonds with the mats and between the edge portions of the overlying mat 16 and the overlapped edge portion 6A of the underlying mat 6, thus making it unnecessary to use a bond improver in the slurry or an edge paste to form the aforementioned bonds.

[0047] The method of making the gypsum panel includes associating a self-supporting environmental sensor assembly with the gypsum panel. For example, the environmental sensor assembly may be any suitable assembly described herein, such as those including an antenna, a processing module, and a wireless communication module, and configured to detect an environmental condition of the gypsum panel and wirelessly communicate data on the environmental condition to a reader.

[0048] For example, the environmental sensor assembly may be associated with the panel prior to or after setting of the gypsum core. In certain embodiments, the environmental sensor assembly is positioned in the gypsum slurry, for example at, near, or distal from the facer material, prior to setting. In other embodiments, the environmental sensor assembly is attached or affixed to an external surface or edge of the gypsum panel. In other embodiments, the environmental sensor assembly is attached or affixed to a surface of the facer material

opposite the gypsum core and covered by, embedded in, or surrounded by a coating material. In other embodiments, the environmental sensor assembly is attached or affixed between the facer material and the gypsum core.

[0049] Alternatively, as discussed above with reference to FIGS. 13 and 14, a poured-in-place gypsum panel system may be used for roofing applications, wherein the environmental sensor assembly is applied during the pour-in-place process.

[0050] In some embodiments, the environmental sensor assembly is applied in-line with the gypsum panel manufacturing process. In other embodiments, the environmental sensor assembly is applied post-panel manufacturing, such as at a construction site or intermediate storage or other manufacturing/processing facility.

APPLICATIONS

[0051] Systems and methods for detecting an environmental condition at a gypsum panel are also provided herein. In certain embodiments, a system includes at least one gypsum panel containing an environmental sensor assembly, such as are described herein, and at least one reader for receiving the data wirelessly communicated from the environmental sensor assembly. In certain embodiments, a method of monitoring an environmental condition of a gypsum panel includes providing at least one gypsum panel having an environmental sensor assembly associated therewith, detecting an environmental condition of the gypsum panel, via the environmental sensor assembly, and wirelessly communicating data on the environmental condition from the environmental sensor assembly to a reader.

[0052] The reader may be any suitable wireless sensor reader known in the art. For example, the reader may be a handheld manual reader. In other embodiments, the reader is a stationary powered reader mounted at a building containing the at least one gypsum panel. For example, at a building containing one or more gypsum panels having environmental sensor assemblies installed as roof deck or interior/exterior sheathing, a powered reader may be mounted at one or more sites on and/or around the building to continuously or intermittently monitor the status of the environmental sensor assemblies. In certain embodiments, a building control system is provided to receive information from the reader(s). In some embodiments, a reader may be mounted on a drone that is configured to approach the at least one gypsum panel to receive the data wirelessly communicated from the environmental sensor assembly. In certain embodiments, the sensing data is digitized and wirelessly communicated to off-the-shelf readers using a standard UHF Gen 2 protocol READ command for further processing.

[0053] In certain embodiments, the system also includes a processing unit and the reader is configured to communicate the data on the environmental condition to the processing unit, and the processing unit is operable to determine at least one condition status at the environmental sensor assembly from the data. For example, the reader may be configured to communicate the impedance value representative of the reactive component impedance to the processing

unit, such that the processing unit is operable to determine at least one condition status at the environmental sensor assembly from the impedance value representative of the reactive component impedance.

[0054] In certain embodiments, the system includes an integration service that allows for programming of the sensors without requiring complex IT infrastructure and middleware. For example, the integration service may provide for a repository of all sensor tag-related data, e.g. sensor range and calibration data, that can be accessed securely by authorized web services and apps, a repository of measurement data related to the sensor-tagged panels, and a decision flow engine, e.g. so that if an sensor-tagged panel exceeds a preset level (e.g., a preset moisture level), a notification is sent by SMS/email to a service technician.

[0055] In certain embodiments, raw data is collected from these sensors via the reader for processing to be performed by a data processing unit where computation occurs to determine a humidity or temperature measurement. Further, with reference to FIG. 20, wireless communication engine 2104 and sensor engine 2106 may be fully programmable via wireless methods. Passive RFID sensors of FIG. 20 may be deployed as an array of smart sensors (e.g., multiple sensor assemblies on one or multiple panels installed at a single site) to collect data that may be sent back to a central processing unit. Another embodiment provides an environmental sensing method for use in an RF system including the steps of: calibrating an RF sensor by developing a first calibration value indicative of an absence of a detectable quantity of a substance and a second calibration value indicative of a presence of the detectable quantity of the substance, installing the sensor in a structure, exposing the structure to the substance, interrogating the sensor to retrieve a sensed value, and detecting the presence of the substance in the structure as a function of the sensed value relative to the first and second calibration values.

[0056] As shown in FIG. 19, a building may include a sheathing system including at least two gypsum panels 300 and a seaming component 320 configured to provide a seam at an interface between at least two of the gypsum panels 300. Environmental sensor assemblies 350, 352 may be provided on or in one or more internal wallboard, external sheathing, or roof panels, as described herein. In particular, such gypsum panels having environmental sensor assemblies may be useful in sheathing or roofing systems in which improved water resistance is desired, so that water infiltration may be detected quickly and efficiently.

[0057] In certain embodiments, the seaming component in such systems includes tape or a bonding material. For example, the seaming component may be a tape including solvent acrylic adhesives, a tape having a polyethylene top layer with butyl rubber adhesive, a tape having an aluminum foil top layer with butyl rubber adhesive, a tape having an EPDM top layer with butyl rubber adhesive, a tape having a polyethylene top layer with rubberized asphalt adhesive, or a tape having an aluminum foil top layer with rubberized asphalt adhesive. For example, the seaming component may be a bonding material such as synthetic stucco plasters, cement plasters, synthetic acrylics, sand filled acrylics, solvent based acrylics, solvent based butyls, polysulfides, polyurethanes, silicones, silyl modified polymers, water-based

latexes, EVA latexes, or acrylic latexes. Thus, the above-described panels may be installed with either a tape, liquid polymer, or other suitable material, to effectively treat areas of potential water and air intrusion, such as seams, door/window openings, penetrations, roof/wall interfaces, and wall/foundation interfaces. As such, the building sheathing panels, when used in combination with a suitable seaming component, may create an effective water-resistive and/or air-barrier envelope.

[0058] Thus, in certain embodiments, the gypsum panels described herein are configured to detect moisture, temperature, or pressure on roofs, on other exterior building components, on exterior building components covered with a membrane of other covering, within roofs or walls, and within the building envelope. The system is configured to detect environmental conditions that could lead to the deterioration of roof systems or other building components. In particular in accordance with the present invention the gypsum panel is configured to detect moisture. Thus, the systems described herein may advantageously provide early detection of moisture intrusion prior to damaging the roof or building system.

[0059] Instead of the traditional manual inspections of roofing and/or other gypsum panels, the use of the readers described herein will reduce or eliminate the labor associated with inspections. The readers could be handheld or could be attached to a drone which would transport a reader from tag to tag (i.e., sensor assembly to sensor assembly). Alternately, the reader would be a powered reader, such as those used in highway and DOT applications, mounted on a roof or other location that reads the tags and relays the information over the internet or similar system to a smart building control system. In addition to external sheathing and roofing applications, the panels and sensors could also be used in the interior of the building, to identify moisture intrusion anywhere in the building, including mold and mildew resistant basement applications, behind shower and tile board, and/or on or behind exterior sheathing.

[0060] Moreover, the present panels eliminate the need for wired sensors and sensors containing a microcontroller, in which the labor involved in programming and installation is very high. In these wired embodiments, a technician having microcontroller/PLC programming knowledge would have to program the system to operate. The present system will be virtually plug-and-play, and any programming may be done before panel installation in the form of a GUI (graphical user interface) that will integrate with existing facility management software. In systems having a stationary reader(s), such as commercial buildings, the reader advantageously may by connected to the building network and maintained by a building engineer along with other facility systems (e.g., HVAC, fire suppression, lighting, occupancy control).

[0061] While the disclosure has been described with reference to a number of embodiments, it will be understood by those skilled in the art that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions, or equivalent arrangements not described herein, but which are commensurate with the claims. Additionally, while various embodiments of the invention have

been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

REFERENCES CITED IN THE DESCRIPTION

Cited references

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Patent documents cited in the description

- WO2012095550A [0003]
- US014793 [0006]
- US2016022646A [0006]
- US15014922B [0006]
- US20160222656A [0006]
- US5319900A [0006]
- WO2015184460A [0032]

Patentkrav

1. Panel (200, 1000) omfattende en panelkerne (101, 201) med en første overflade (107) og en modsat anden overflade (109);
et første forsidemateriale (104, 204) forbundet med den første overflade (107) af kernen (101, 201); og
en miljøsensoranordning (120, 122, 124, 3300) forbundet med panelet (200, 1000) og konfigureret til at detektere en miljøtilstand af panelet (200, 1000) og trådløst at kommunikere data vedrørende miljøtilstanden til et læseapparat,
hvor miljøsensoranordning (120, 122, 124, 3300) er selvbærende og omfatter en antenne, et bearbejdningsmodul og et trådløst kommunikationsmodul (2104), og
hvor miljøsensoranordningen (120, 122, 124, 3300) er anbragt mellem kernen (101, 201) og det første forsidemateriale (104, 204) eller indeni kernen (101, 201), **kendetegnet ved, at**
panelkernen (101, 201) er en gipskerne, og
miljøsensoranordningen (120, 122, 124, 3300) er konfigureret som en fugtsensor, og hvor miljøtilstanden er fugt.

2. Panelet (200, 1000) ifølge krav 1, hvor miljøsensoranordningen (120, 122, 124, 3300) omfatter en passiv radiofrekvensidentifikationssensor.

3. Panelet (200, 1000) ifølge krav 1, hvor:

antennen omfatter en modstands-induktor-kondensator afstemt kreds, der kan anvendes til at omdanne miljøtilstanden til en impedansændring, og

bearbejdningsmodulet er koblet til antennen og kan anvendes til at oversætte impedansændringen til en sensorkode ved at matche antenneimpedans med matriceimpedans.

4. Panelet (200, 1000) ifølge krav 1, hvor:

antennen har en antenneimpedans, der kan variere baseret på miljøtilstanden,

bearbejdningsmodulet er koblet til antennen og omfatter et afstemningsmodul, der kan anvendes til at (i) variere en reaktiv

komponentimpedans for at ændre en systemimpedans omfattende antenneimpedansen og den reaktive komponentimpedans, og (ii) producere en impedansværdi, der er repræsentativ for den reaktive komponentimpedans,

det trådløse kommunikationsmodul (2104) er koblet til bearbejdningsmodulet og kan anvendes til at kommunikere impedansværdien, der er repræsentativ for den reaktive komponentimpedans til læseapparatet, og

dataet vedrørende miljøtilstanden omfatter impedansværdien, der er repræsentativ for den reaktive komponentimpedans.

5. Panelet (200, 1000) ifølge krav 4, hvor miljøsensoranordningen (120, 122, 124, 3300) yderligere omfatter et hukommelsesmodul (2102), der kan anvendes til at lagre impedansværdien, der er repræsentativ for den reaktive komponentimpedans.

6. Panelet (200, 1000) ifølge krav 1, hvor:

forsidematerialet (104, 204) er en fibermåtte eller papir, eller

forsidematerialet (104, 204) er en belagt eller ikke-belagt glasfibermåtte, idet panelet yderligere omfatter et andet forsidemateriale (212) forbundet med den anden overflade (109) af gipskernen (101, 201), og/eller

gipskernen (101, 201) omfatter en flerhed af gipslag.

7. Anvendelse af panelet (200, 1000) ifølge et hvilket som helst af kravene 1 til 6 som et udvendigt beklædningspanel, indvendigt vægpladepanel eller tagdækningspanel.

8. Fremgangsmåde til at fremstille et panel (200, 1000), omfattende:

at aflejre en panelkerneopslæmning på en overflade af et første forsidemateriale (104, 204);

at lade panelkerneopslæmningen størkne for at danne en panelkerne (101, 201) af et panel; og

at forbinde en selvbærende miljøsensoranordning (120, 122, 124, 3300) med panelet (200, 1000),

hvor miljøsensoranordningen (102, 122, 124, 3300) omfatter en antenne, et bearbejdningsmodul og et trådløst kommunikationsmodul, og er konfigureret til at detektere en miljøtilstand af panelet (200, 1000) og trådløst at kommunikere data vedrørende miljøtilstanden til et læseapparat,

hvor miljøsensoranordningen (120, 122, 124, 3300) er anbragt mellem kernen (101, 201) og det første forsidemateriale (104, 204) eller indeni panelkernen (101 201),

fremgangsmåden er **kendetegnet ved, at**

panelkerneopslæmningen er en gipsopslæmning, og panelkernen (101, 201) er en gipskerne, og

miljøsensoranordningen (120, 122, 124, 3300) er konfigureret som en fugtsensor, og hvor miljøtilstanden er fugt.

9. Fremgangsmåden ifølge krav 8, hvor miljøsensoranordningen (120, 122, 124, 3300) omfatter en passiv radiofrekvensidentifikationssensor.

10. Fremgangsmåden ifølge krav 8, hvor:

antennen omfatter en modstands-induktor-kondensator afstemt kreds, der kan anvendes til at omdanne miljøtilstanden til en impedansændring, og

bearbejdningsmodulet er koblet til antennen og kan anvendes til at oversætte impedansændringen til en sensorkode ved at matche antenneimpedans med matriceimpedans.

11. Fremgangsmåden ifølge krav 8, hvor:

antennen har en antenneimpedans, der kan variere baseret på miljøtilstanden,

bearbejdningsmodulet er koblet til antennen og omfatter et afstemningsmodul, der kan anvendes til at (i) variere en reaktiv komponentimpedans for at ændre en systemimpedans omfattende antenneimpedansen og den reaktive komponentimpedans, og (ii) producere en impedansværdi, der er repræsentativ for den reaktive komponentimpedans,

det trådløse kommunikationsmodul (2104) er koblet bearbejdningsmodulet og kan anvendes til at kommunikere impedansværdien, der er repræsentativ for den reaktive komponentimpedans, til læseapparatet, og

dataet vedrørende miljøtilstanden omfatter impedansværdien, der er repræsentativ for den reaktive komponentimpedans.

12. Fremgangsmådenifølge krav 8, hvor miljøsensoranordningen (120, 122, 124, 3300) yderligere omfatter et hukommelsesmodul, der kan anvendes til at lagre impedansværdien, der er repræsentativ for den reaktive komponentimpedans.

13. Fremgangsmådenifølge krav 8, hvor forsidematerialet (104, 204) er en fibermåtte eller papir, eller forsidematerialet er en belagt eller ikke-belagt glasfibermåtte.

14. Fremgangsmåden ifølge krav 8, hvor miljøsensoranordning (120, 122, 124, 3300) placeres i gipsopslæmningen forud for størkning.

15. Fremgangsmåden ifølge krav 8, hvor gipspanelet (200, 100) er et udvendigt beklædningspanel, indvendig vægpladepanel eller tagdækningspanel.

DRAWINGS

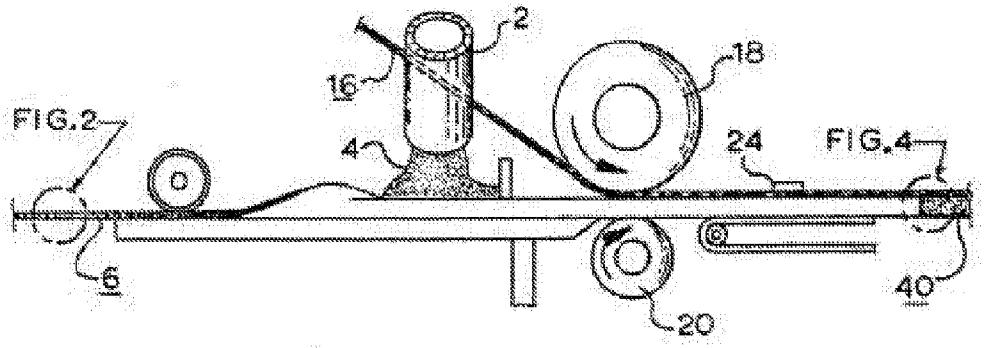


FIG.1

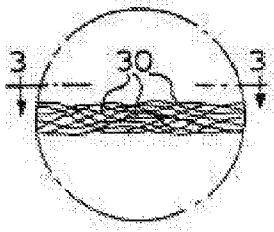


FIG.2

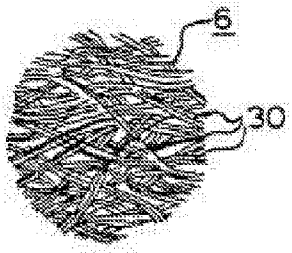


FIG.3

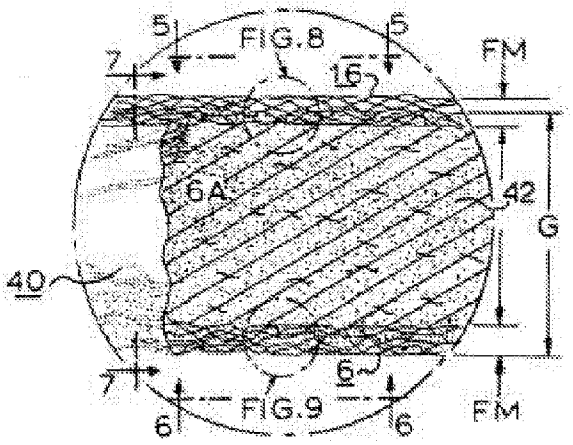


FIG.4

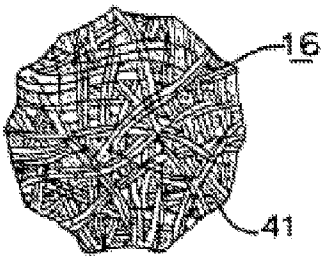


FIG.5

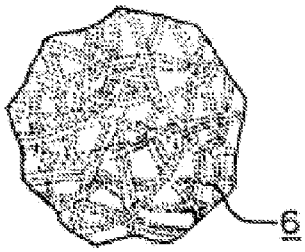


FIG.6

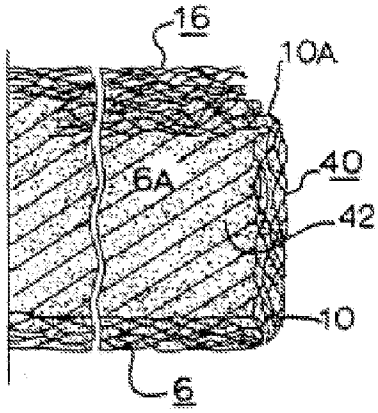


FIG.7

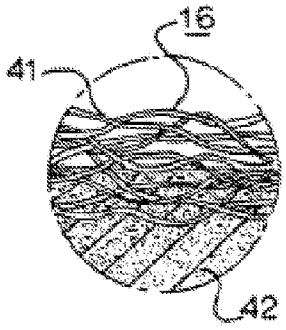


FIG.8

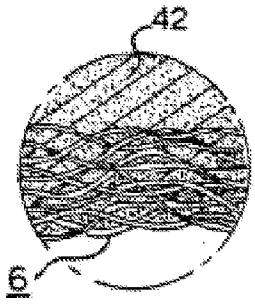


FIG.9

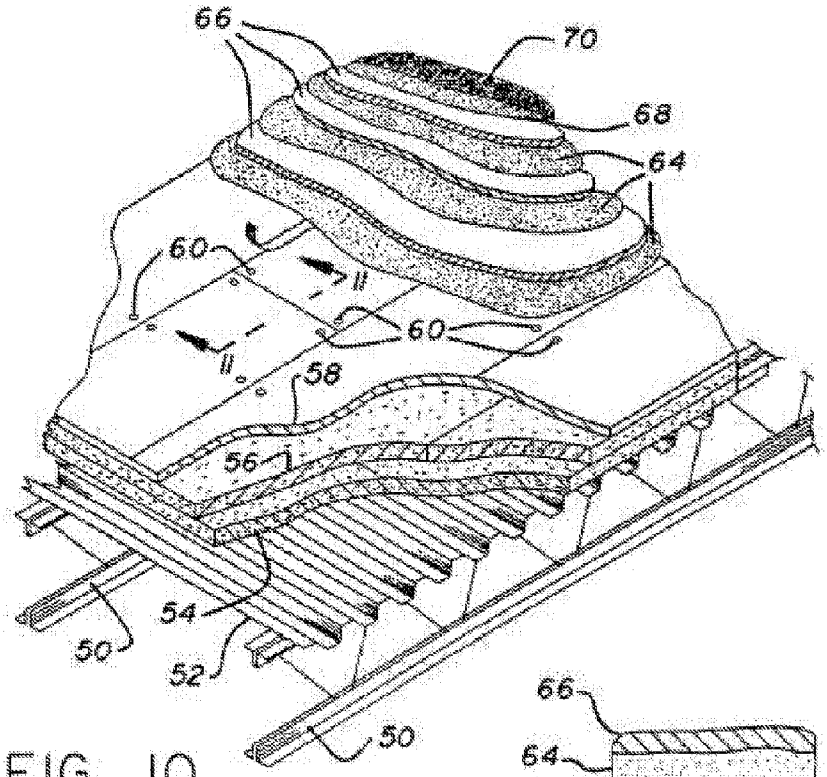


FIG. 10

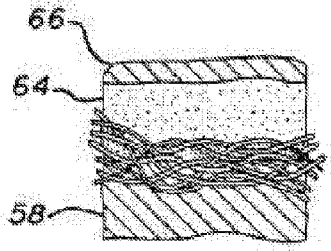


FIG. 12

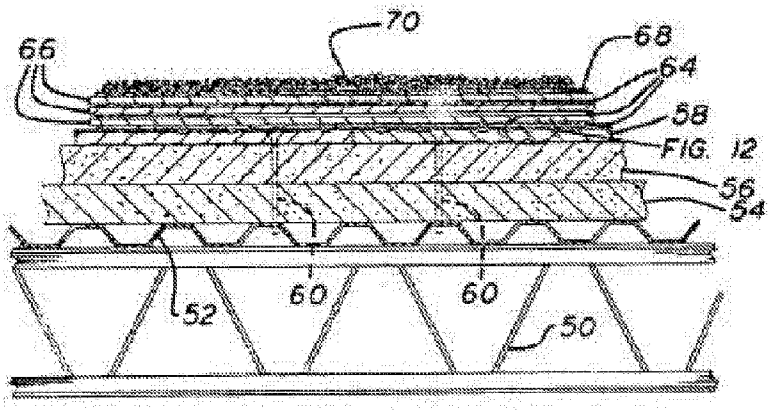


FIG. 11

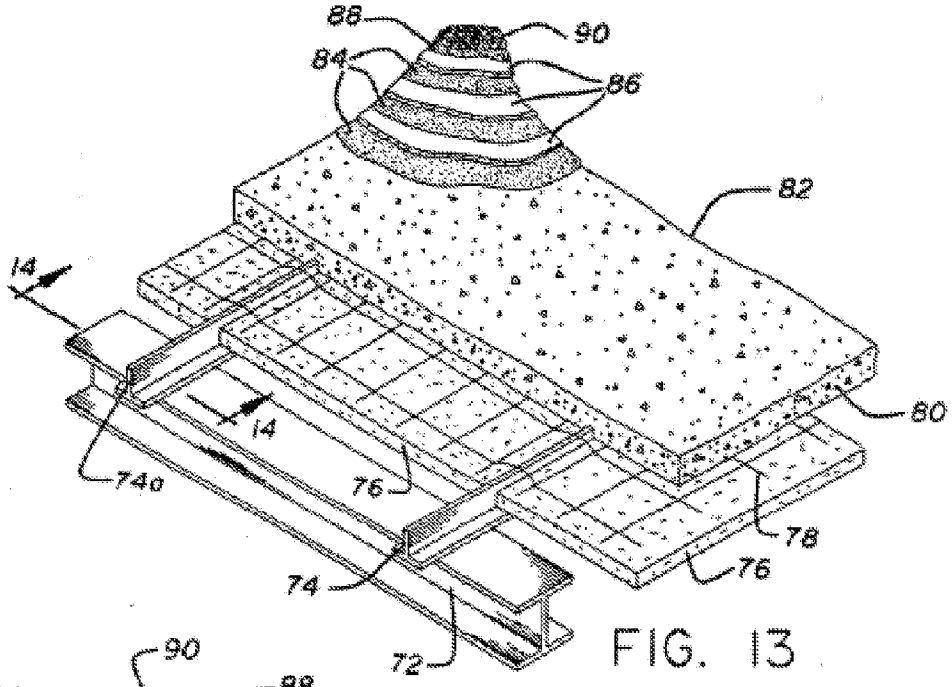


FIG. 13

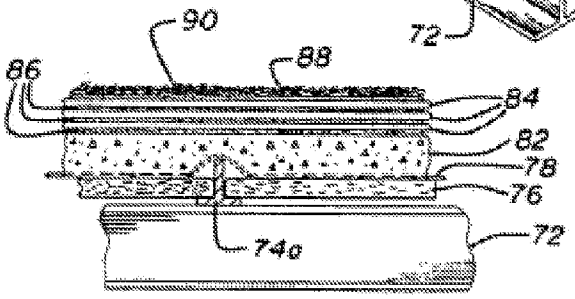


FIG. 14

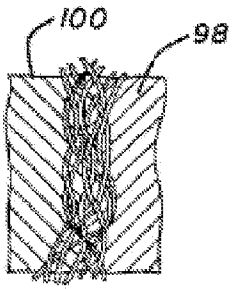


FIG. 16

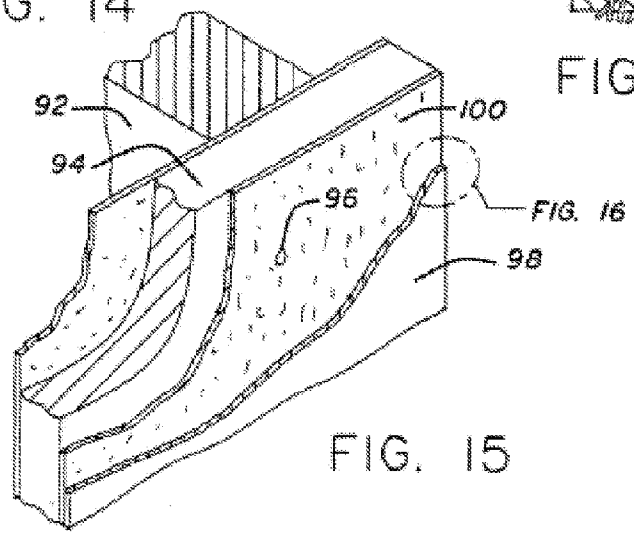


FIG. 15

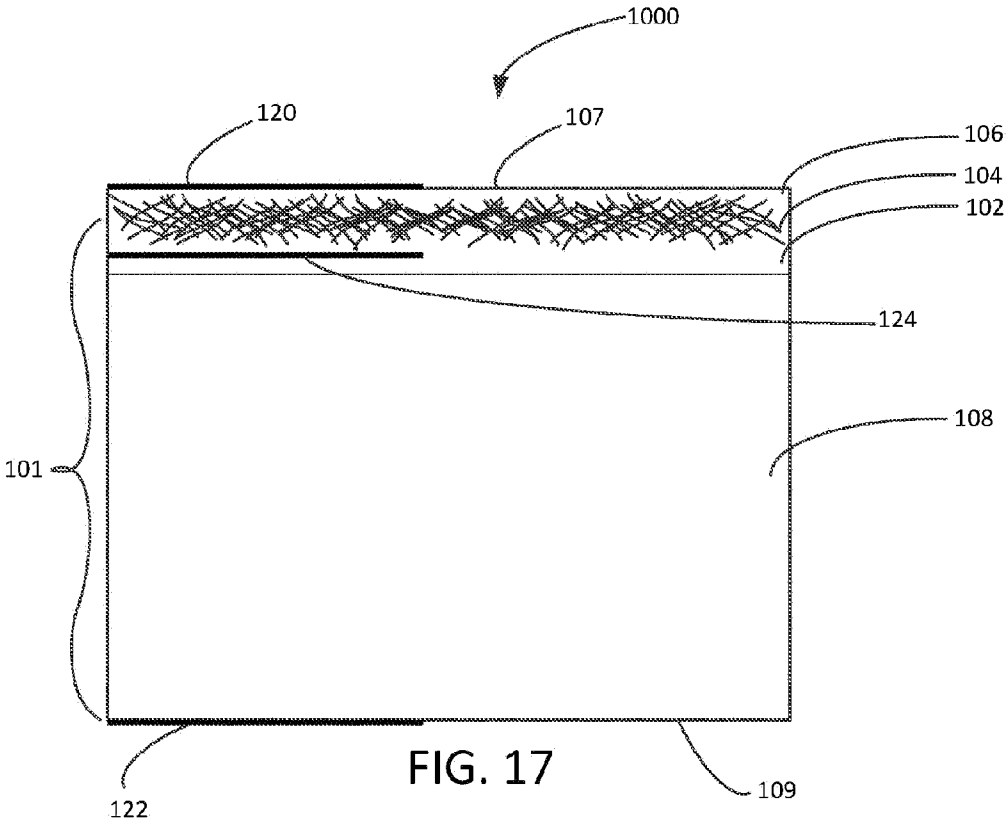


FIG. 17

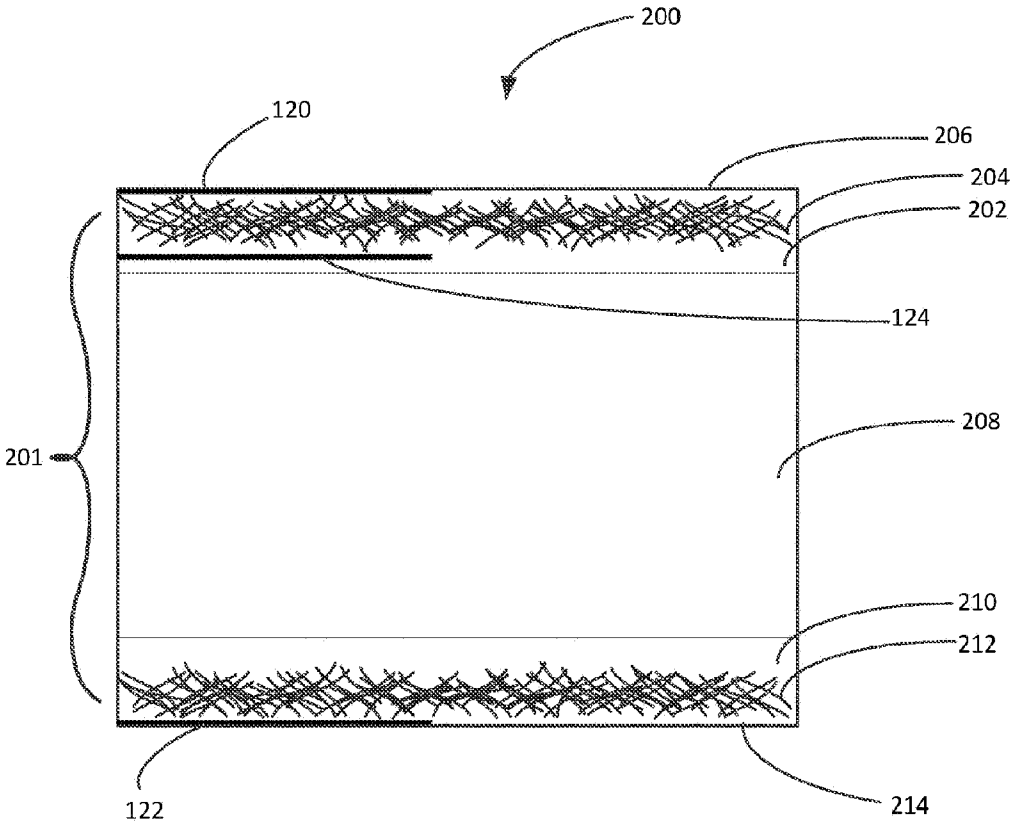


FIG. 18

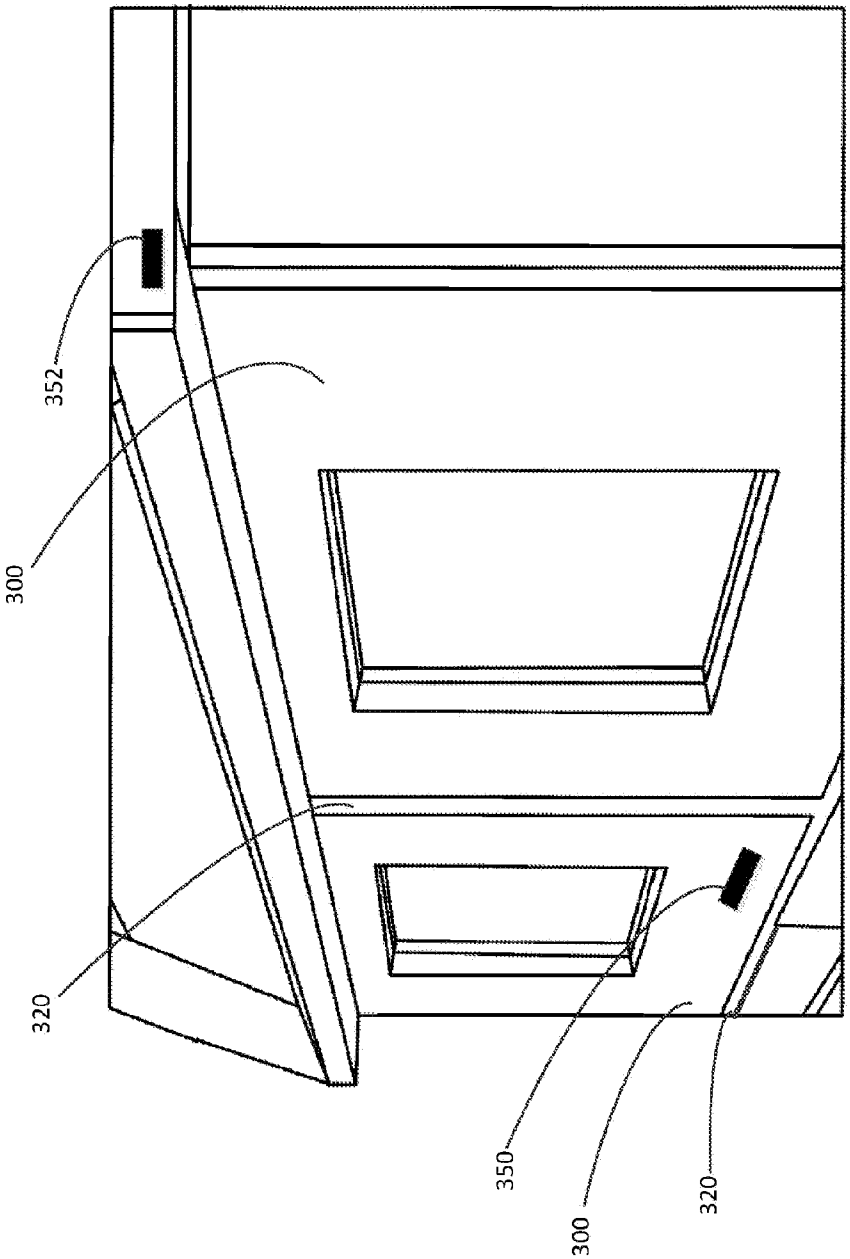


FIG. 19

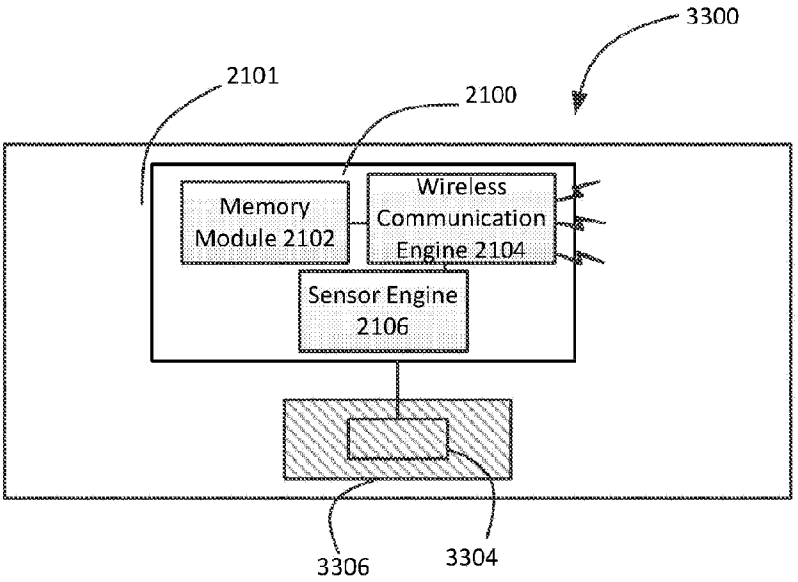

3300
2101
2100
Memory Module 2102
Wireless Communication Engine 2104
Sensor Engine 2106
3306
3304

FIG. 20

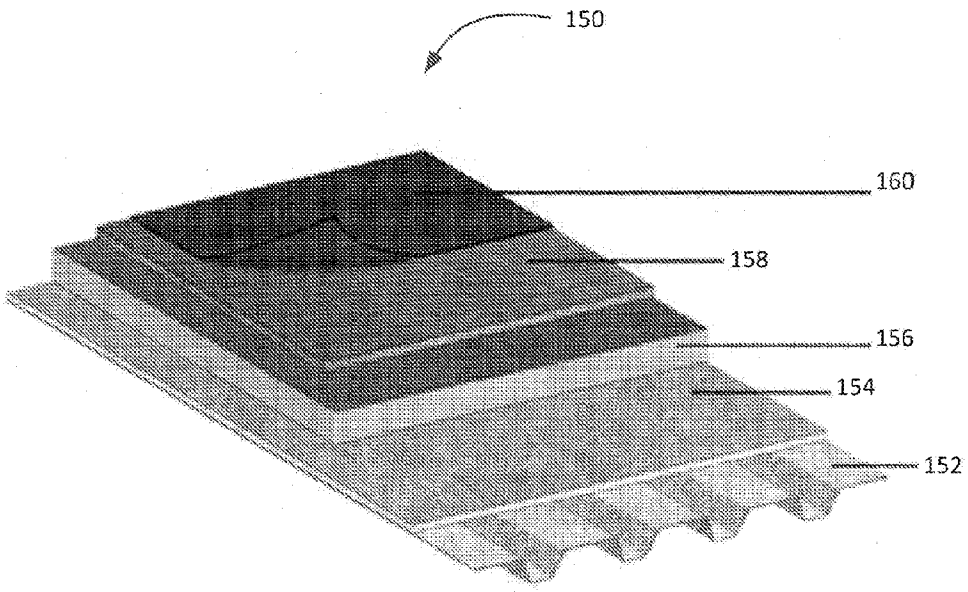


FIG. 21

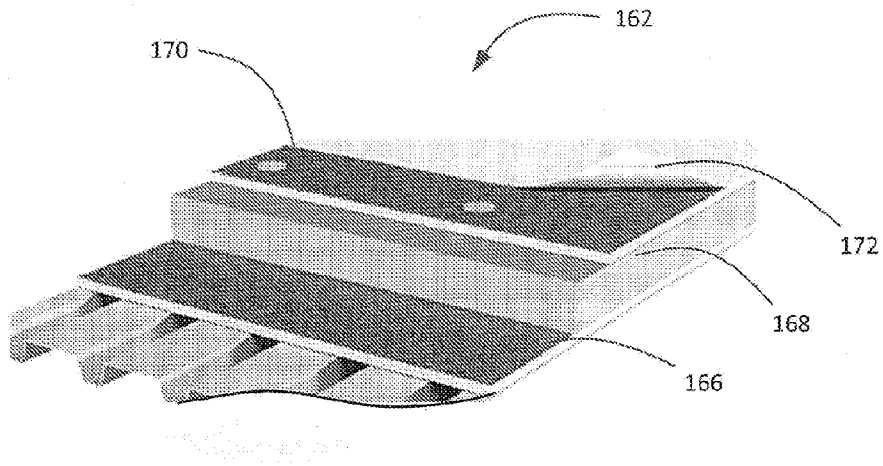


FIG. 22