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(72) Inventors; and
(71) Applicants : **KEANE, Craig, Patrick** [US/US]; 283 Cedar Road, Mullica Hill, NJ 08062 (US). **KEANE, Craig, Patrick** [US/US]; 283 Cedar Road, Mullica Hill, NJ 08062 (US).

(74) Agents: **HUBBARD, Brian J.** et al; Condo Roccia Koptiw LLP, 1800 JFK Boulevard, Suite 1700, Philadelphia, PA 19103 (US).

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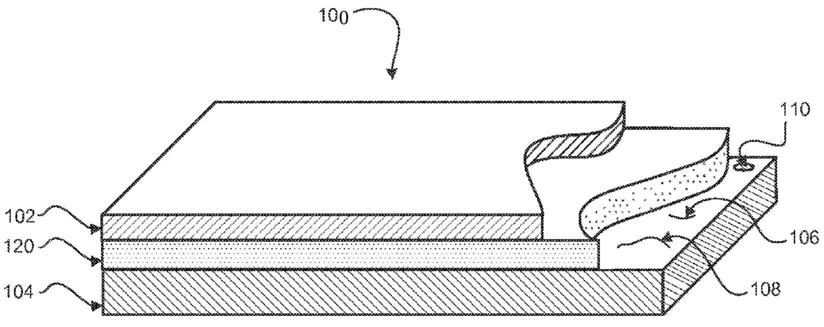
(54) **Title:** SOLID SELF-LEVELING UNDERLAYMENT



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(57) Abstract: Described are flooring systems which include an underlayment material that compresses over projecting irregularities in a subfloor to provide a level surface for a top flooring layer. Such flooring systems may include a top flooring layer, a subfloor, and an underlayment material disposed between the subfloor and the top flooring layer. The underlayment material may comprise a cross-linked polyolefin foam and a compressible foam. Methods for a self-leveling underlayment are disclosed herein, as well as methods of manufacture of the same.

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SOLID SELF-LEVELING UNDERLAYMENT

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Serial No. 61/951,712, filed March 12, 2014, the disclosure of which is incorporated herein in its entirety.

BACKGROUND

[0002] Flooring systems generally comprise an aesthetic *(e.g.,* decorative) top flooring layer installed over a structural substrate (commonly referred to as a subfloor). One major concern in the industry is that the top flooring layer must be installed on a flat, level, substrate for both structural and aesthetic reasons. For example, any bumps or irregularities in the substrate may be visible to the consumer, which is not aesthetically pleasing. Moreover, beyond undesirable light reflection and other cosmetic drawbacks, top flooring layers are generally fragile enough that such irregularities eventually lead to transfer through to the top layer, increased wear, cracking, or other damage. In cases of interlocking top flooring layer components (e.g., laminate flooring, engineered flooring), irregularities in the substrate may prevent proper mechanical interaction, thereby undermining the integrity of the top flooring layer and creating unsightly gaps or even trip hazards.

[0003] In the past, installation instructions for top flooring layers required installers to grind high spots and fill low spots in the substrate before installation. Attempts to address substrate irregularity include using liquid self-leveling compositions. These are wet compositions which flow to low areas and set up. Liquid compositions can be messy, and due to the effects of gravity cannot remediate high spots. Moreover, liquid compositions can be subject to adhesion problems, and may add to labor costs for installation, as well as delay application of the top flooring layer while the liquid composition cures. Therefore, better systems, methods, and self-leveling compositions are needed.

SUMMARY

[0004] A flooring system as disclosed herein may include an underlayment material that compresses over projecting irregularities in a subfloor to provide a level surface for a top flooring layer. Such a flooring system may include a top flooring layer, a subfloor, and an underlayment material disposed between the subfloor and the top flooring layer. The underlayment material may comprise a cross-linked polyolefin foam and a compressible foam. Methods for a self-leveling underlayment are disclosed herein, as well as methods of manufacture.

BRIEF DESCRIPTION OF THE FIGURES

[0005] FIG. 1 depicts a perspective sectional view of a flooring system having a self-leveling underlayment material.

[0006] FIG. 2 depicts a cross-sectional view of a flooring system having a self-leveling underlayment material.

[0007] FIG. 3 depicts a cross-sectional view of a self-leveling underlayment material.

[0008] FIG. 4 depicts a graph of average reflected sound pressure level (SPL) as a function of compressive strength for each of a number of underlayment materials.

[0009] FIGs. 5A-5D provide graphs of average reflected SPL as a function of frequency for various foam underlayment materials.

[0010] FIG. 6 is a diagram of a method for manufacturing a self-leveling underlayment material.

DETAILED DESCRIPTION

[0011] FIG. 1 illustrates a flooring system 100. The flooring system 100 may be used in a commercial or residential setting. The flooring system 100 may include a top flooring layer 102, which may also be referred to as flooring. The top flooring layer 102 may be mainly for decorative purposes. Examples of top flooring layers 102 include carpet, tile, sheet vinyl, luxury vinyl tile (or planks), solid hardwood, engineered wood, and laminate flooring.

[0012] The flooring system 100 may include a subfloor 104. The term "subfloor" refers to the structural substrate above which a top flooring layer 102 is installed. Examples of subfloors 104 include concrete, plywood, oriented strand board (OSB), composite wood, and in some cases, existing vinyl or hardwood flooring. Often, the subfloor 104 may contain multiple irregularities in its surface. For example, the subfloor 104 may include a depression 106. The depression 106 may be a dimple, a gouge, or a low spot. The subfloor 104 may include projections from its surface such as a bump *(e.g.,* a high spot) 108, or in cases where the subfloor is of plywood, oriented strand board (OSB), or composite wood, a projecting nail head 110. The subfloor may have a multiplicity of irregularities of differing heights and depths. For example, in concrete subfloors, both high spots and low spots are fairly typical.

[0013] The flooring system may include a self-leveling underlayment material 120 interposed between the top flooring layer 102 and subfloor 104. The underlayment material 120 compresses over projecting irregularities in the subfloor 104 to provide a level surface for the top flooring layer 102. The underlayment material 120 may bridge recessed irregularities in the subfloor 104 to provide a level surface for the top flooring layer 102.

[0014] The flooring system 100 may have additional layers (not depicted).

[0015] The top flooring layer 102, underlayment material 120, and subfloor 104, may be assembled by any practicable means. The underlayment material 120 may be laid on the subfloor 104 and the top flooring layer 102 laid upon the underlayment material without affixing them to each other *(e.g.,* a floating installation method). The underlayment material 120 may be glued to the subfloor 104 with adhesive and the top flooring layer 102 glued to the underlayment material with adhesive *(e.g.,* a double glue down installation). One layer of the top flooring layer 102, underlayment material 120, and subfloor 104 may be glued to its adjacent layer with adhesive without affixing the top flooring layer to the subfloor *(e.g.,* a single glue down installation). Similarly, one layer of the top flooring layer 102, underlayment material 120, and subfloor 104 may nailed or tacked to another layer, or both. Examples of nailing and/or tacking installations include carpet installation and hardwood flooring installation over a wood-based subfloor.

[0016] Turning to FIG. 2, a cross section of a flooring system 200 is depicted. The flooring system 200 may be used in a commercial or residential setting. The flooring system 200 may include a top flooring layer 202, which may be carpet, tile, sheet vinyl, luxury vinyl tile (or planks), solid hardwood, engineered wood, and laminate flooring.

[0017] The flooring system 200 may include a subfloor 204 similar to that described in FIG. 1.

[0018] The flooring system 200 may include a self-leveling underlayment material 220 interposed between the top flooring layer 202 and subfloor 204. The underlayment material 220 compresses over projecting irregularities in the subfloor 204 to provide a level surface for the top flooring layer 202. The underlayment material 220 may bridge recessed irregularities in the subfloor 204 to provide a level surface for the top flooring layer 202. The underlayment material 220 may be lightweight and easy to handle.

[0019] The flooring system 200 may include an optional vapor barrier layer 230. As described in detail herein with respect to FIG. 3, the underlayment material 220 itself may have moisture vapor transmission properties that are suitable for certain applications. In some applications, however, additional moisture vapor protection may be desirable. If desired, a vapor barrier layer 230 may be disposed between the top flooring layer 202 and the subfloor 204. The vapor barrier layer 230 may be a film, which may be a polypropylene film, disposed between the underlayment material 220 and the subfloor 204. The vapor barrier layer 230 may be adhered to the underlayment material 220 and/or to the subfloor 204. The flooring system 200 may be assembled by any practicable means, generally depending on the type of subfloor 204 and top flooring layer 202.

[0020] Turning to FIG. 3, a cross section of a self-leveling underlayment material 320 which can be used in the flooring systems of FIG. 1 and/or FIG. 2 is depicted. The underlayment material 320 has at least two layers of distinct composition and/or mechanical properties, and may be a bilaminate (as illustrated). The underlayment material 330 may have additional layers (not depicted).

[0021] The underlayment material 320 may comprise a cross-linked layer 322. The cross-linked layer 322 may contribute sufficient structural integrity to the underlayment material 320, such that the underlayment material may bridge recessed irregularities in a subfloor to provide a level surface for a top flooring layer. The cross-linked layer 322 may comprise a cross-linked polypropylene copolymer (EPC) and a linear low density/polyethylene (LLDPE) blend foam with an EPC content of about 20% to 90% by weight. Preferably, the EPC content is between 50% and 90%. More preferably, the EPC content is between 70% and 90%. Other olefin materials that are suitable for use include, for example, homopolymers and copolymers of polyethylene, including high-density polyethylene (HDPE), low-density polyethylene (LDPE), very-low-density polyethylene (VLDPE), ultra-low-density polyethylene (ULDPE), and polymers or copolymers of polypropylenes, including cross-linked ethylene propylene copolymer. The cross-linked layer 322 may comprise a foam underlayment material such as, the FLOORMUFFLER™ underlayment available from Diversified Foam Products, Inc. (www.floormuffler.com).

[0022] The cross-linked layer 322 may have a 25% compressive strength of at least about 0.85 kg/cm2, as measured by JIS K6767. Preferably, the cross-linked layer 322 has a 25% compressive strength of at least about 1.0 kg/cm2. More preferably, the cross-linked layer 322 has a 25% compressive strength of at least about 1.2 kg/cm2.

[0023] The cross-linked layer 322 may contribute reduced moisture vapor transmission rates (MVTR) to the underlayment material 320 without the need for the additional barrier layers. The cross-linked layer 322 may have a MVTR of <3.0 lb/1000ft2/24hr. Flooring industry standards for MVTR of less than 3.0 lb/1000ft2/24hr are typically achieved by adding additional vapor barrier layers that add to both product cost and weight.

[0024] The cross-linked layer 322 may contribute a desirable reflected sound pressure level (SPL) to the underlayment material 320. FIG. 4 provides a graph of reflected sound pressure level (SPL), averaged over the range of 300-1000 Hz, as a function of compressive strength for a number of underlayment materials, including those used in prior art flooring systems, with compressive strengths of less than about 0.85 kg/cm2, that tend to produce average reflected sound pressure levels of more than about 13.5dB. As shown in FIG. 4, foams with 25% compressive strengths of at least about 0.85 kg/cm2 tend to produce average reflected sound pressure levels of less than about 13.5 dB. Compressive strength is a property of the foam structure obtained primarily by the selection of resin, foam density, and the manufacturing processes used to convert resin into foam. It should be understood that higher polypropylene content may produce higher compressive strength and, accordingly, lower average reflected SPL. Density may also be a factor. For example, to increase compressive strength from approximately 3 kg/cm2 to approximately 6 kg/cm2, the foam density may be increased from about 100 kg/m3 to about 121 kg/m3.

[0025] SPL varies with foam composition, extent of cross-linking, density, and thickness. FIG. 5A provides graphs of average reflected SPL as a function of frequency for various polypropylene content embodiments of a cross-linked layer 322 (FIG. 3). Average reflected SPL graphs are provided for embodiments having polypropylene content of about: (1) 25 to 30%, (2) 50% to 60%, and (3) 70% to 90%. FIG. 5B provides graphs of average reflected SPL as a function of frequency for various gel-fraction embodiments of the cross-linked layer 322 (FIG. 3). Average reflected SPL graphs are provided for embodiments having gel fractions of about: (1) 40%, (2) 45%, (3) 50%, and (4) 55%. The gel fraction (a.k.a., cross-link percentage or cross-link level) may range from about 15% to about 80%. Higher cross-link levels are possible; however, if cross-linking is too high, the foam will be difficult to roll onto a core, and will be difficult to lay flat. The cross-linked layer 322 (FIG. 3) may have a range of cross-linking from about 40% to about 60%. The cross-linked layer 322 (FIG. 3) may have a range of cross-linking from about 50% to about 60%. The type of resins selected, the amount of chemical cross-linking agent used, and the amount of exposure to a radiation source, such as an electron beam irradiation device, dictate the degree of cross-linking. Also, in general, higher cross-link percentage provides slightly higher compressive strength. It is expected, therefore, that higher cross-link percentage should lead to slightly lower reflected SPL for the cross-linked layer 322 (FIG. 3). It is also expected that higher cross-link percentage should also lead to lower MVTR.

[0026] The density of the cross-linked layer 322 (FIG. 3), as determined by method ASTM D3575, may be about 20 to about 200 kg/m3. The cross-linked layer 322 (FIG. 3) may have a range of density from about 40 to about 100 kg/m3. The cross-linked layer 322 (FIG. 3) may have a range of density from about 50 to about 60 kg/m3. Higher density tends to increase the compressive strength of the foam and thereby reduce the reflected SPL. Increasing foam density, however, tends to add to product cost due to increased raw material consumption to manufacture. For example, the 25% compressive strength results (and associated reflected sound properties) described above may result from formulating a cross-linked polyethylene, polyethylene blend, or other polymeric foam at higher densities (such as 100 to 200 kg/m3), though it is expected that such formulation may be cost prohibitive. Density may be controlled by a number of factors, the types of resins used, the degree of cross-linking, process conditions, and the type and amount of foaming agent used. FIG. 5C provides graphs of average reflected SPL as a function of frequency for various density embodiments of the cross-linked layer 322 (FIG. 3). Average reflected SPL graphs are provided for embodiments having a density of about: (1) 56 kg/m3, (2) 40 kg/m3, (3) 45 kg/m3, and (4) 50 kg/m3.

[0027] FIG. 5D provides graphs of average reflected SPL as a function of frequency for various thickness embodiments of the cross-linked layer 322 (FIG. 3). Average reflected SPL graphs are provided for embodiments having thicknesses of about: (1) 4.5 mm; (2) 2.0 mm; and (3) 3.0 mm. The thickness of the cross-linked layer 322 (FIG. 3) may be in a range from about 0.5 mm to about 6.0 mm. The thickness of the cross-linked layer 322 (FIG. 3) may be in a range from about 1.5 mm to about 2.5 mm. Thickness is dictated by the resin selection, type and amount of chemical foaming agent used, extruded sheet thickness, tension during the foaming operation, and the amount of heat applied during the conversion of sheet into foam.

[0028] A 100ft2 roll of cross-linked layer 322 (FIG. 3) may weigh less than about 5 lbs, while providing low reflected sound pressure levels in the 300 Hz to 1000 Hz range and MVTR performance that meets flooring industry standards.

[0029] Returning to FIG. 3, the underlayment material 320 may comprise a compressible layer 324. The compressible layer 324 provides the ability for the underlayment material 320 to compresses over projecting irregularities in a subfloor to provide a level surface for a top flooring layer. The compressible layer 324 may comprise a fiber (such as a non-woven), a film (such as a thermoplastic polyolefin film, a PVC film, an EVA film, a vinyl film, or other membrane), a foil (such as a metallic foil), or a foam (such as a memory foam, polyurethane foam, EVA foam, PVC foam, latex foam, or a polyolefin foam).

[0030] The compressible layer 324 may comprise polyethylene. The compressible layer 324 may consist essentially of polyethylene. The compressible layer 324 may consist essentially of a polyethylene foam.

[0031] The compressible layer 324 may comprise a cross-linked foam. A cross-linked foam for compressible layer 324 may have different properties than the cross-linked layer 322. For example, the cross-linked layer 322 and the compressible layer 324 may have different densities, different gel fractions, or different physical properties *(e.g.,* compressive strength, tensile strength, or thermal stability).

[0032] The compressible layer 324 may comprise a non-cross-linked foam.

[0033] The compressible layer 324 may comprise a memory foam.

[0034] The compressible layer 324 may comprise non-cross-linked polyethylene. The compressible layer 324 may consist essentially of non-cross-linked polyethylene. The compressible layer 324 may consist essentially of a non-cross-linked polyethylene foam.

[0035] The compressible layer 324 (for example, a non-cross-linked polyethylene foam) may have a density less than about 25 kg/m3. The compressible layer 324 may have a density less than about 20 kg/m3. The compressible layer 324 may have a density selected to compress under loading.

[0036] The compressible layer 324 (for example, a non-cross-linked polyethylene foam) may have a thickness in a range from about 0.5 mm to about 6.0 mm. The thickness of the compressible layer 324 may be in a range from about 1.5 mm to about 2.5 mm.

[0037] The compressible layer 324 (for example, a non-cross-linked polyethylene foam) may have a 25% compressive strength of less than about 1 kg/cm2 as measured by JIS K6767. The compressible layer 324 may have a 25% compressive strength of less than about 0.8 kg/cm2 as measured by JIS K6767.

[0038] The compressible layer 324 (for example, a non-cross-linked polyethylene foam) may contribute to the SLP and MVTR of the underlayment material 320.

[0039] The compressible layer 324 (for example, a non-cross-linked polyethylene foam) may be embossed or de-bossed for lamination, traction, or alignment purposes. The compressible layer 324 may receive printed materials, such as instructions, trademarks, or other communications.

[0040] The compressible layer 324 (for example, a non-cross-linked polyethylene foam) may be laminated to the cross-linked layer 322 at the interface 326 of their surfaces. Alternatively, the compressible layer 324 may be connected to the cross-linked layer 322 by any known means *(e.g.,* mechanical) provided that the underlayment material 320 has at least two layers of distinct composition and/or mechanical properties.

[0041] The compressible layer 324 (for example, a non-cross-linked polyethylene foam) may have a relatively more open cell structure than the cross-linked layer 322. The compressible layer 324 may comprise a network of pores 328.

[0042] The underlayment material 320 may comprise additional layers. For example, a vapor barrier polypropylene film may be adhered to the cross-linked layer 322 or compressible layer 324 before the underlayment material 320 is rolled (as described below). Thus, the underlayment material 320 may be delivered to the point of installation with the optional vapor barrier already adhered thereto, thus simplifying installation of the underlayment material and vapor barrier. The underlayment material 320 may include non-skid elements affixed adhered to the cross-linked layer 322, compressible layer 324, or both. The underlayment material 320 may include a foil layer to reflect heat.

[0043] The underlayment material 320 may include means to adhere adjoining sections of underlayment. The underlayment material 320 may include a tape strip (not depicted) to facilitate installation. The underlayment material 320 may comprise a first roll (not depicted) having a tape strip on a first planar surface of the underlayment, and a pull-out lip (not depicted) on the first planar surface, axial to the tape strip, such that when the first roll is unrolled and laid out next to a second roll that has also been unrolled and laid out, the tape strip of the first roll will engage the lip of the second roll, thereby connecting the first and second rolls. This may include creating a moisture resistant engagement between the tape strip and the lip *(e.g.,* sealing what otherwise may be a vapor gap between two adjacent underlayment sections). The lip may extend axially from the roll in a range from about 0.5 in to about 8 in. The lip may be formed from a layer affixed to the underlayment 320 that extends axially fully across the roll, or may be a strip.

[0044] The underlayment material 320 may include at least one of an anti-microbial additive, a flame retardant additive, and an adhesion promoter.

[0045] The underlayment material 320 may have an Impact Insulation Class (IIC) value greater than about 40, greater than about 50, and/or greater than about 55, but less than about 80.

[0046] The thickness of the underlayment material 320 may be in a range from about 1 mm to about 15 mm. The thickness of the underlayment material 320 may be in a range from about 3 mm to about 10 mm. Relatively thick layers of around 6.0 millimeters or more may interfere with wall molding or door clearances. The thickness of the underlayment material 320 may be in a range from about 4 mm to about 6 mm.

[0047] FIG. 6 provides a flowchart of an example method 600 for manufacturing a polyolefin foam underlayment material comprising at least two layers of distinct composition and/or mechanical properties. At 602, for the first layer, one or more polyolefin resins may be mixed with a foaming agent, one or more cross-linking agents, and/or one or more additives, into a homogenous mixture. Examples of polyolefin resins include polyethylene and/or polypropylene. Examples of cross-linking agents include peroxides (e.g., di cumyl peroxide, etc.) for polyethylenes, and di vinyl benzene for polypropylenes. Examples of additives include flame retardants, adhesion promoters, colorants, and anti-microbial agents. A homogenous mixture may be achieved by spinning the mixture in a mechanical mixer designed for compounding plastic resins. Examples of such mixers are well-known. To ensure complete and proper mixing, agitation rate, temperature, and processing duration may be selectively controlled during this step by well-known industrial process control means.

[0048] At 604, the mixture may charged, for example, into a conventional plastics extruder, into which the ingredients are conveyed in a barrel by a screw, to produce a solid, thin, plastic web. The ingredients may be initially compressed and mixed as the materials move along the screw. Heater elements, along with the shearing action of materials against each other and the screw and barrel, cause the resins to melt into a viscous liquid state. Additives and/or colorants may be added to the product at this stage of the process as well. The screw pushes the melted extrudate through a die opening to produce the thin, solid web. The web may typically be between about 0.2 and about 3.0 millimeters in thickness, although not limited, as thicker or thinner webs can be produced as desired. As it is extruded, the web may cool from a molten state to a solid state. The web may then be trimmed, and wound into a roll.

[0049] At 606, the polymer resins may be cross-linked, for example by irradiation by electron beam. Other methods, such as chemical cross-linking, for example, may be employed. The degree of cross-linking may be controlled to result in a typical cross-link density of about 15% to about 80%. A higher percentage level of cross-linking is possible if desired. A desired degree of cross-linking may be achieved by the type of resins selected, the amount of chemical cross-linking agent used, and/or the exposure to a radiation source such as an electron beam irradiation device.

[0050] At 608, the continuous polymer web may be converted into a relatively low-density foam. For example, the foam may be heated by radiant heaters, molten salt, hot air, or other heating devices. The heat causes a reaction of the chemical foaming agent that causes the foaming agent to releases gases, thus forming a cellular structure in the web. The combination of resins selected, cross-linking, and the process used may be selected to create a fine-celled structure, with typical cells ranging from about 0.1 to about 1.0 millimeter. It should be understood that larger and smaller cell sizes are possible.

[0051] A desired thickness may be achieved by the resin selection, type and amount of chemical foaming agent used, extruded sheet thickness, tension during the foaming operation, amount of heat applied during the conversion of sheet into foam. For example, an extruded sheet having a thickness of about 1 millimeter may produce a relatively high density polyolefin foam having a thickness of about 1.5 millimeter if little foaming agent is used. A relatively low density foam having a thickness of about 2.5 millimeter may be produced if a greater quantity of foaming agent is used. A desired density may be achieved by the selection of resins used, the degree of cross-linking, process conditions, and the type and amount of foaming agent used.

[0052] At 610, for the second *(e.g.,* non-cross-linked) layer, one or more polyolefin resins may be mixed with a foaming agent and/or one or more additives, into a homogenous mixture. Examples of polyolefin resins include polyethylene and/or polypropylene. Examples of additives include flame retardants, adhesion promoters, colorants, and anti-microbial agents. A homogenous mixture may be achieved by spinning the mixture in a mechanical mixer designed for compounding plastic resins. To ensure complete and proper mixing, agitation rate, temperature, and processing duration may be selectively controlled during this step by well-known industrial process control means.

[0053] At 612, the mixture may charged, for example, into a conventional plastics extruder, into which the ingredients are conveyed in a barrel by a screw, to produce a solid, thin, plastic web. The ingredients may be initially compressed and mixed as the materials move along the screw. Heater elements, along with the shearing action of materials against each other and the screw and barrel, cause the resins to melt into a viscous liquid state. Additives and/or colorants may be added to the product at this stage of the process as well. The screw pushes the melted extrudate through a die opening to produce the thin, solid web. The web may typically be between about 0.2 and about 3.0 millimeters in thickness, although not limited, as thicker or thinner webs can be produced as desired. As it is extruded, the web may cool from a molten state to a solid state. The web may then be trimmed, and wound into a roll.

[0054] At 614, the continuous polymer web may be converted into a relatively low-density foam. For example, the foam may be heated by radiant heaters, molten salt, hot air, or other heating devices. The heat causes a reaction of the chemical foaming agent that causes the foaming agent to releases gases, thus forming a cellular structure in the web. The combination of resins selected and the process used may be selected to create a coarse-celled structure, with typical cells ranging from about 0.5 mm to about 5 mm, preferably about 1 mm to about 2 mm. It should be understood that larger and smaller cell sizes are possible.

[0055] A desired thickness may be achieved by the resin selection, type and amount of chemical foaming agent used, extruded sheet thickness, tension during the foaming operation, amount of heat applied during the conversion of sheet into foam. For example, an extruded sheet having a thickness of about 1 millimeter may produce a relatively high density polyolefin foam having a thickness of about 1.5 millimeter if little foaming agent is used. A relatively low density foam having a thickness of about 2.5 millimeter may be produced if a greater quantity of foaming agent is used. A desired density may be achieved by the selection of resins used, process conditions, and the type and amount of foaming agent used.

[0056] At 616, the two layers are laminated together. Any conventional means may be used.

[0057] At 618, the finished foam web may be rolled onto a core, such as a cardboard or paper tube, for example.

[0058] At 620, the finished foam web may undergo further processing, for example, the foam web may be coated with an adhesive layer or release layer, laminated with films (including, for example, lips and tape strips as described above), foils, fabrics, nonwovens, or other foams, or molded for any of a variety of uses.

EXAMPLES

Reflected Sound Test

[0059] Reflected sound pressure levels are measured using a test method loosely based on Association of European Producers of Laminate Flooring test method EPLF NORM02 1029-1. The test method employed is a simplified version of EPLF NORM02 1029-1 to compare relative differences in reflected sound between different underlayment materials. The sound source for the test is the tapping machine specified by ASTM E492 placed on the center of the test specimen. The test specimen consists of a 6' x 6' square sample of the particular underlayment and laminate flooring centered on a 12' x 16' x 6" concrete slab, which is specified for ASTM E492 testing. Three measuring microphones are placed in the same room as the tapping machine to measure the sound produced by the tapping machine impacting the floor sample. The microphones are placed 120 degrees apart, 1.5 meters from the center of the floor sample. Third octave frequency band measurements from 100 Hz to 10,000 Hz are taken for 15 seconds for each of the three microphones. The average sound pressure levels are then calculated for the 300 Hz to 1000 Hz range.

Percent Of Polymer Cross-Linking

[0060] Apparatus used to determine the percent of polymer cross-linking includes: 100 mesh, 0.004" wire diameter, type 304, stainless steel baggies; numbered wires & clips; a Miyamoto thermostatic oil bath apparatus; an analytical balance; a fume hood; a gas burner; a high temperature oven; an anti-static gun; and three 3.5 liter wide mouth stainless steel containers with lids. Reagents and materials used include: a solvent, such as tetralin high molecular weight solvent, used to determine the gel fraction; acetone; and silicone oil.

[0061] An empty wire mesh bag is weighed and the weight recorded. For each sample, about 2 grams to about 10 grams +/- about 5 milligrams of sample is weighed out and transferred to the wire mesh bag. The weight of the wire mesh bag and the foam cutting is recorded.

[0062] Each bag is attached to the corresponding number wire & clips. When the solvent temperature reaches a target temperature, the bundle (bag and sample) is immersed in the solvent. The samples are shaken up and down about 5 or 6 times to loosen any air bubbles and fully wet the samples. The samples are attached to an agitator and agitated so that the solvent can dissolve the foam. Oil bath apparatus is shut off. The samples are then cooled in a fume hood.

[0063] The samples are washed by shaking up and down about 7 or 8 times in a container of primary acetone. The samples are washed a second time in a second acetone wash. The washed samples are washed once more in a third container of fresh acetone as above. The samples are hung in a fume hood to evaporate the acetone, about 1 to about 5 minutes.

[0064] The samples are dried in a drying oven for about 1 hour. The samples are cooled for a minimum of about 15 minutes. The wire mesh bag is weighed on an analytical balance and the weight was recorded. Gel fraction can be calculated as Gel Fraction = 100* (C - A)/ (B - A), where A = empty wire mesh bag weight; B = wire bag wt + foam sample before immersion in solvent; and C = wire bag wt + dissolved sample after immersion in solvent.

CLAIMS

1. A flooring system, comprising:

a top flooring layer;

a subfloor; and

an underlayment material disposed between the subfloor and the top flooring layer, wherein the underlayment material comprises:

a cross-linked polyolefin foam; and

a foam selected to compresses over projecting irregularities in the subfloor to provide a level surface for the top flooring layer.

2. The flooring system of claim 1, wherein the underlayment material bridges voids in the subfloor to provide a level surface for the top flooring layer.

3. The flooring system of claim 1, wherein the cross-linked polyolefin foam is produced from a resin composition comprising a blend of polyethylene and polypropylene.

4. The flooring system of claim 1, wherein the foam selected to compresses over projecting irregularities in the subfloor to provide a level surface for the top flooring layer is a non-cross-linked foam.

5. The flooring system of claim 4, wherein the non-cross-linked foam is a polyolefin foam.

6. The flooring system of claim 4, wherein the non-cross-linked foam consists essentially of polyethylene.

7. The flooring system of claim 1, wherein the cross-linked polyolefin foam has a fine cell structure with cells having diameters between about 0.1 millimeter and about 0.5 millimeter.

8. The flooring system of claim 5, wherein the non-cross-linked polyolefin foam has an open cell structure with cells having diameters between about 0.5 millimeter and about 4 millimeter.

9. A flooring system, comprising:

a top flooring layer;

a subfloor; and

an underlayment material disposed between the subfloor and the top flooring layer, wherein the underlayment material comprises:

a cross-linked polyolefin foam; and

a non-cross-linked polyolefin foam;

wherein the underlayment material compresses over projecting irregularities in the subfloor to provide a level surface for the top flooring layer.

10. The flooring system of claim 9, wherein the underlayment material bridges voids in the subfloor to provide a level surface for the top flooring layer.

11. The flooring system of claim 9, wherein the cross-linked polyolefin foam comprises a blend of polyethylene and polypropylene.

12. The flooring system of claim 9, wherein the non-cross-linked polyolefin foam consists essentially of polyethylene.

13. The flooring system of claim 9, wherein the underlayment material includes at least one of an anti-microbial additive, a flame retardant additive, and an adhesion promoter.

14. The flooring system of claim 9, further comprising a vapor barrier layer disposed between the top flooring layer and the subfloor.

15. The flooring system of claim 9, wherein the cross-linked polyolefin foam is laminated to the non-cross-linked polyolefin foam.

16. The flooring system of claim 15, wherein the underlayment material is laminated to a layer comprising at least one of a non-woven, a film, a foil, or another foam.

17. The flooring system of claim 9, wherein the cross-linked polyolefin foam has a fine cell structure with cells having diameters between about 0.1 millimeter and about 0.5 millimeter.

18. The flooring system of claim 9, wherein the non-cross-linked polyolefin foam has an open cell structure with cells having diameters between about 0.5 millimeter and about 4 millimeter.

19. A method, comprising:

placing an underlayment material between a subfloor and a top flooring layer, wherein the underlayment material comprises:

a cross-linked polyolefin foam; and

a non-cross-linked polyolefin foam;

wherein the underlayment material compresses over projecting irregularities in the subfloor to provide a level surface for the top flooring layer.

20. An underlayment material for placing between a subfloor and a top flooring layer, wherein the underlayment material comprises:

a cross-linked polyolefin foam to bridge voids in the subfloor; and

a non-cross-linked polyolefin foam to compress over projecting irregularities in the subfloor;

thereby providing a level surface for the top flooring layer.

21. An underlayment material for placing between a subfloor and a top flooring layer, wherein the underlayment material comprises:

a cross-linked polyolefin foam to bridge voids in the subfloor; and

another cross-linked polyolefin foam to compress over projecting irregularities in the subfloor, provided that the polyolefin foams do not have identical properties;

thereby providing a level surface for the top flooring layer.

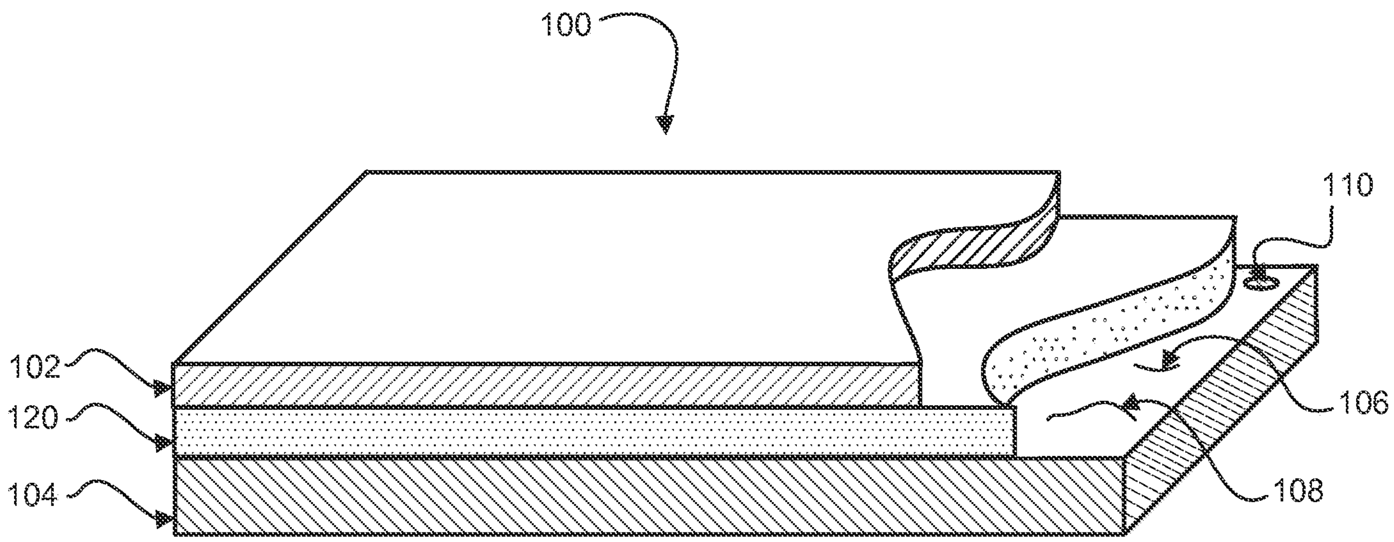


FIG. 1

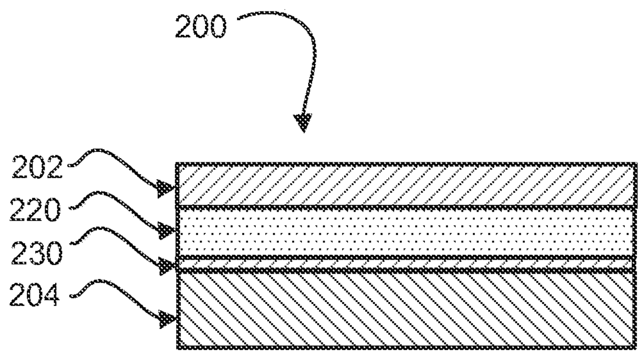


FIG. 2

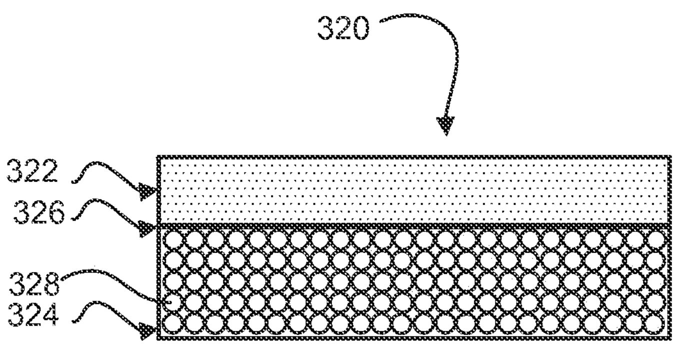


FIG. 3

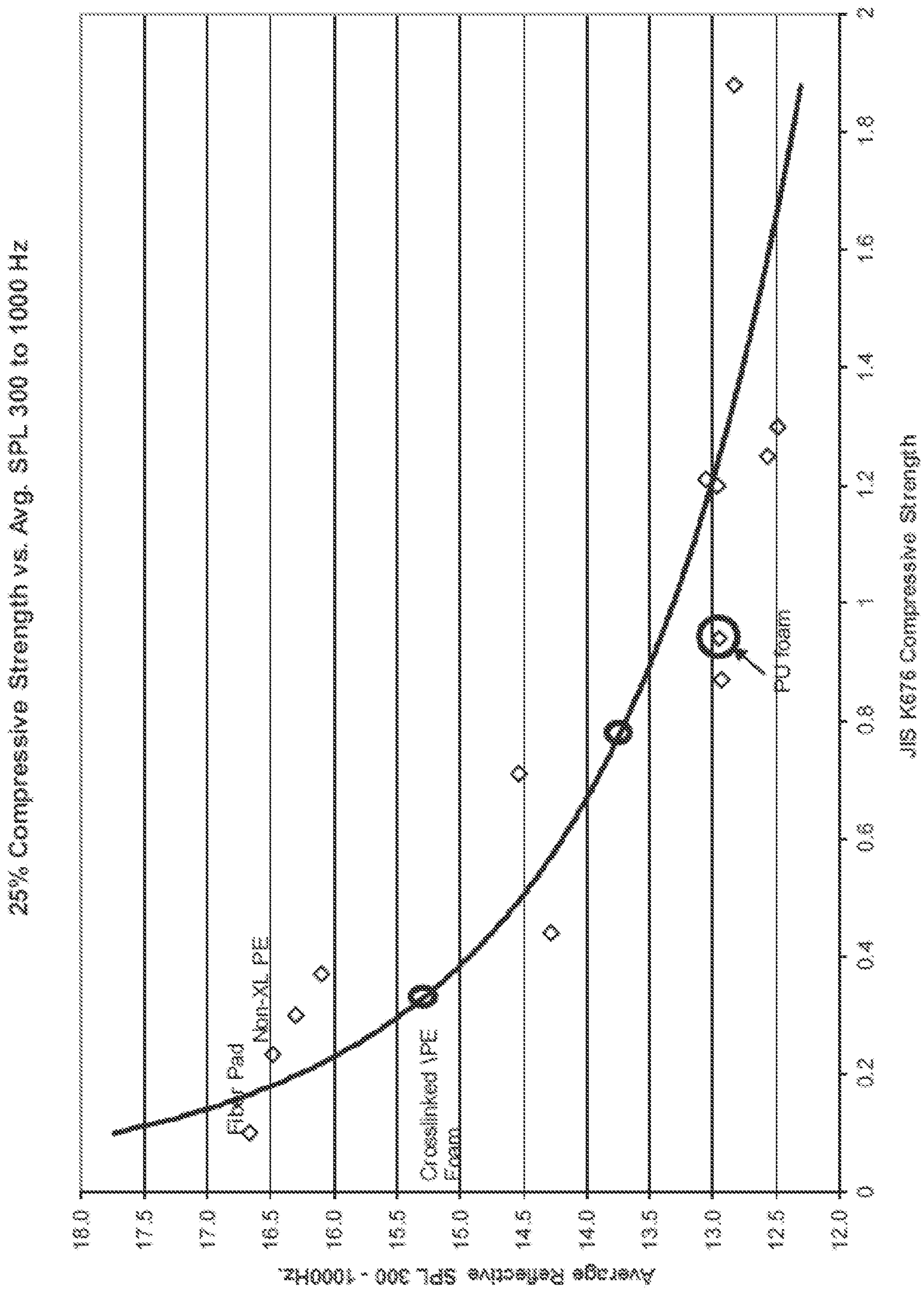

25% Compressive Strength vs. Avg. SPL 300 to 1000 Hz
Average Reflective SPL 300 - 1000Hz.
18.0
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
JIS K676 Compressive Strength
Fiber Pad
Non-XL PE
Crosslinked \PE Foam
PU foam

FIG. 4

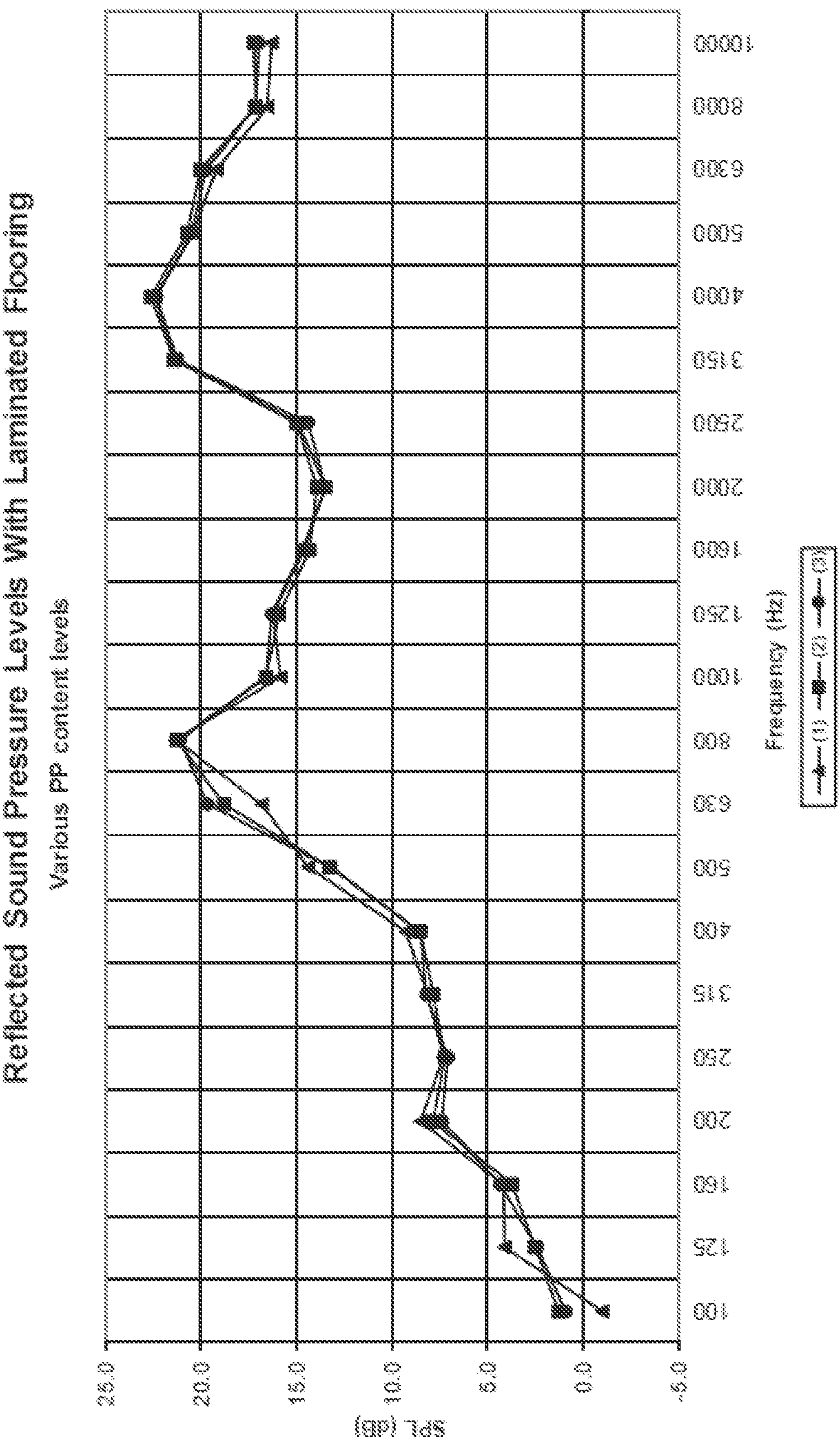
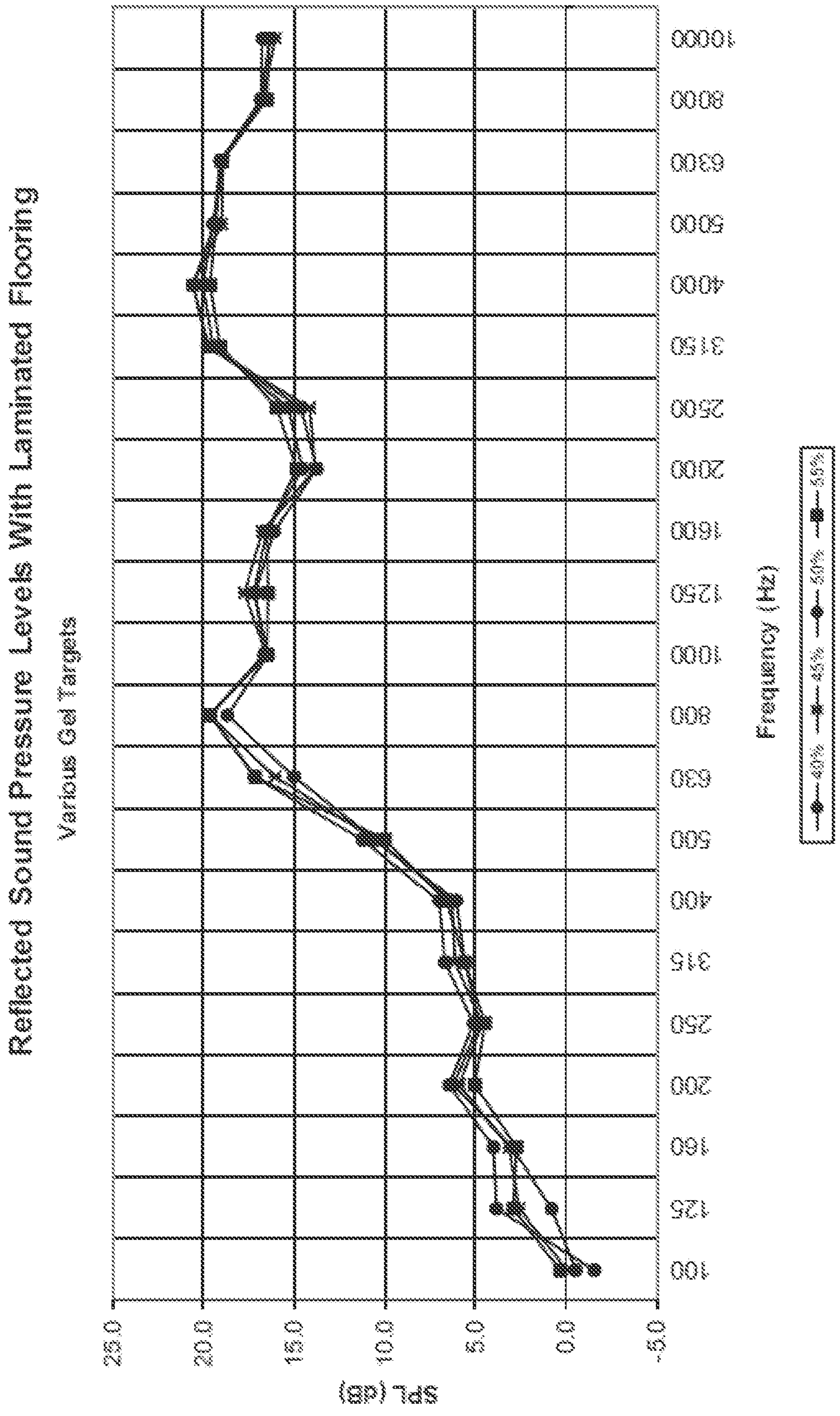

Reflected Sound Pressure Levels With Laminated Flooring
Various PP content levels
SPL (dB)
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
Frequency (Hz)
(1)
(2)
(3)

FIG. 5A



Reflected Sound Pressure Levels With Laminated Flooring
Various Gel Targets
SPL (dB)
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
Frequency (Hz)
40%
45%
50%
55%

FIG. 5B

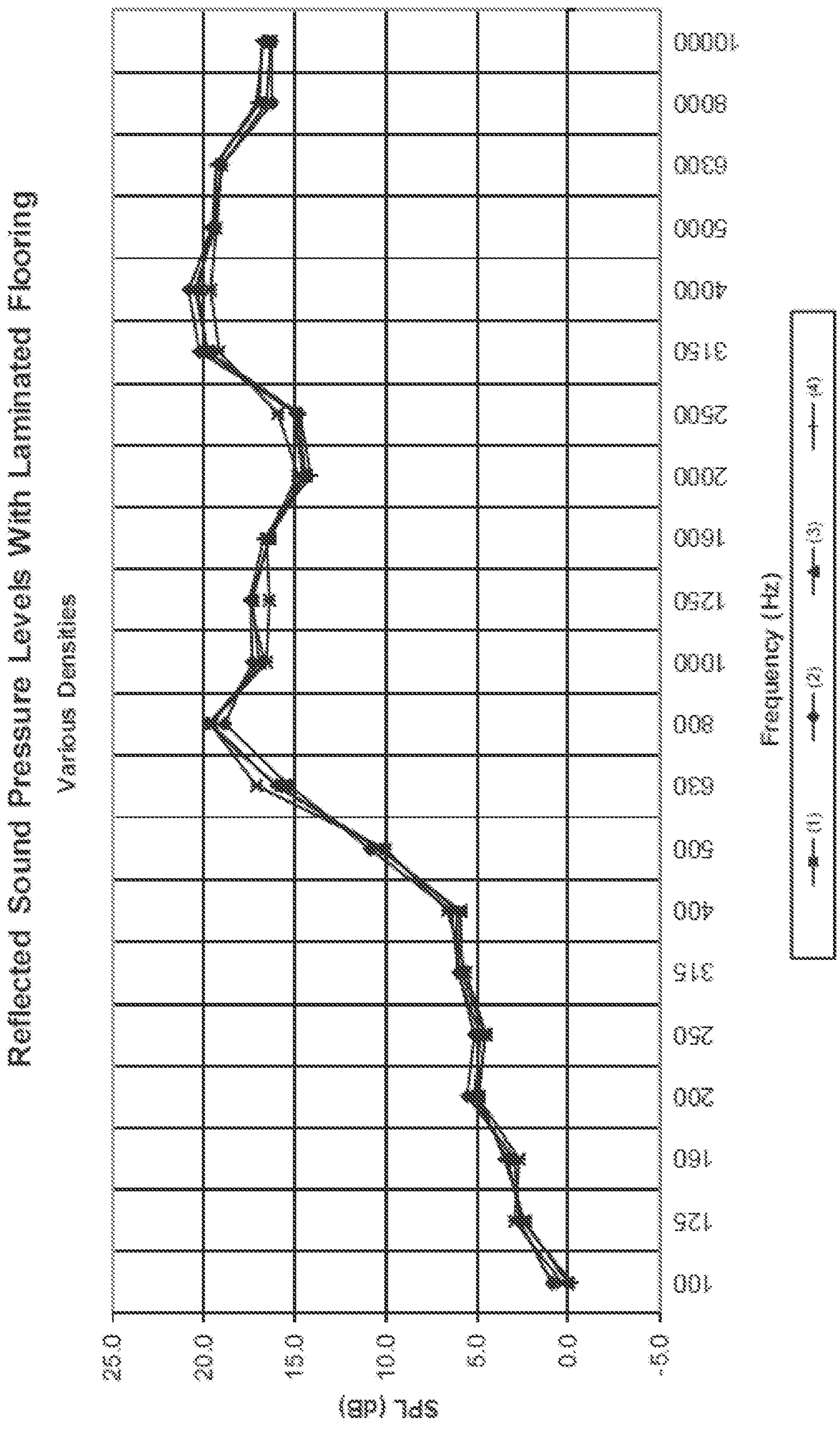

Reflected Sound Pressure Levels With Laminated Flooring
Various Densities
SPL (dB)
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
Frequency (Hz)
(1)
(2)
(3)
(4)

FIG. 5C

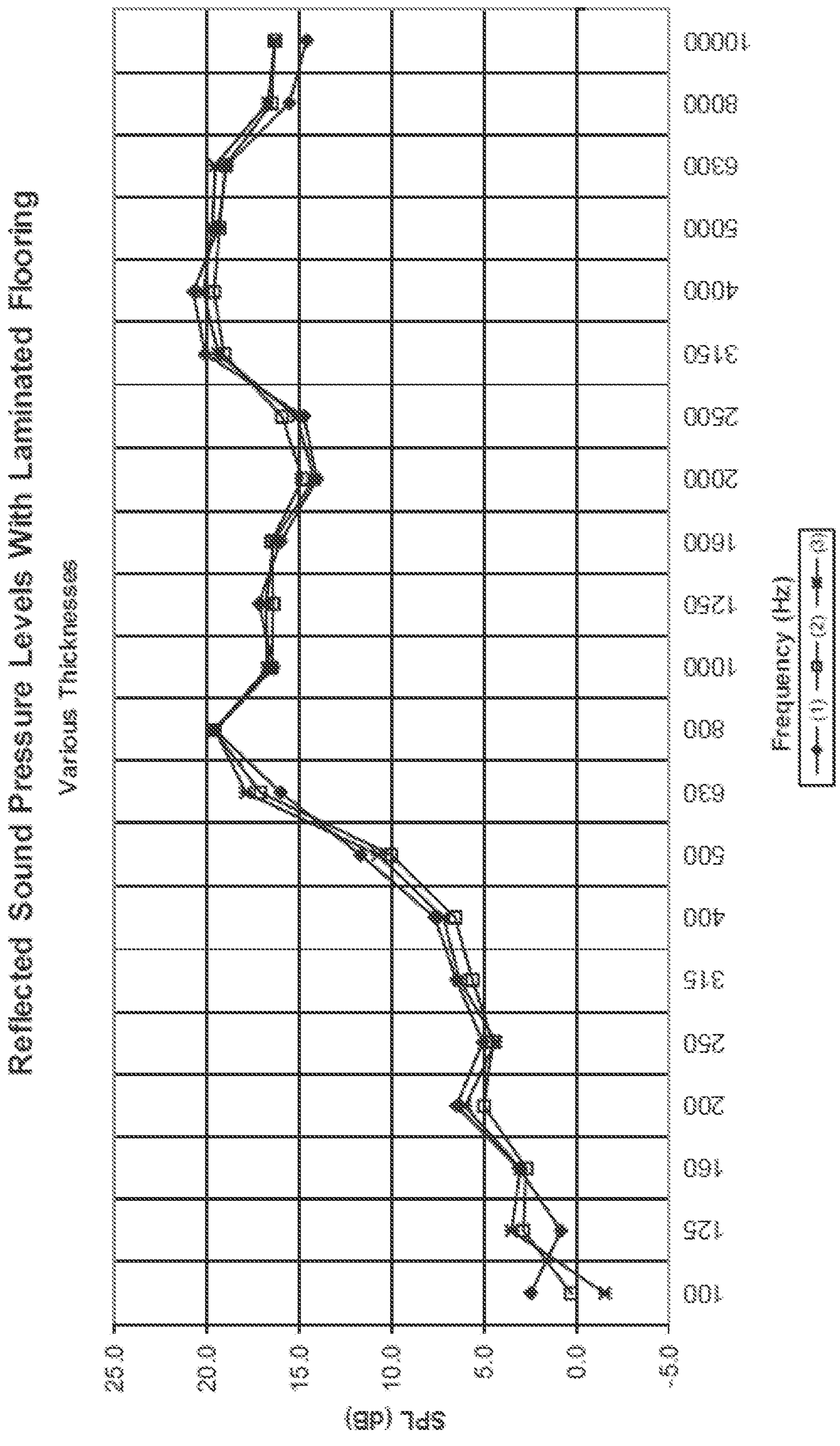

Reflected Sound Pressure Levels With Laminated Flooring
Various Thicknesses
SPL (dB)
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
Frequency (Hz)
(1)
(2)
(3)

FIG. 5D

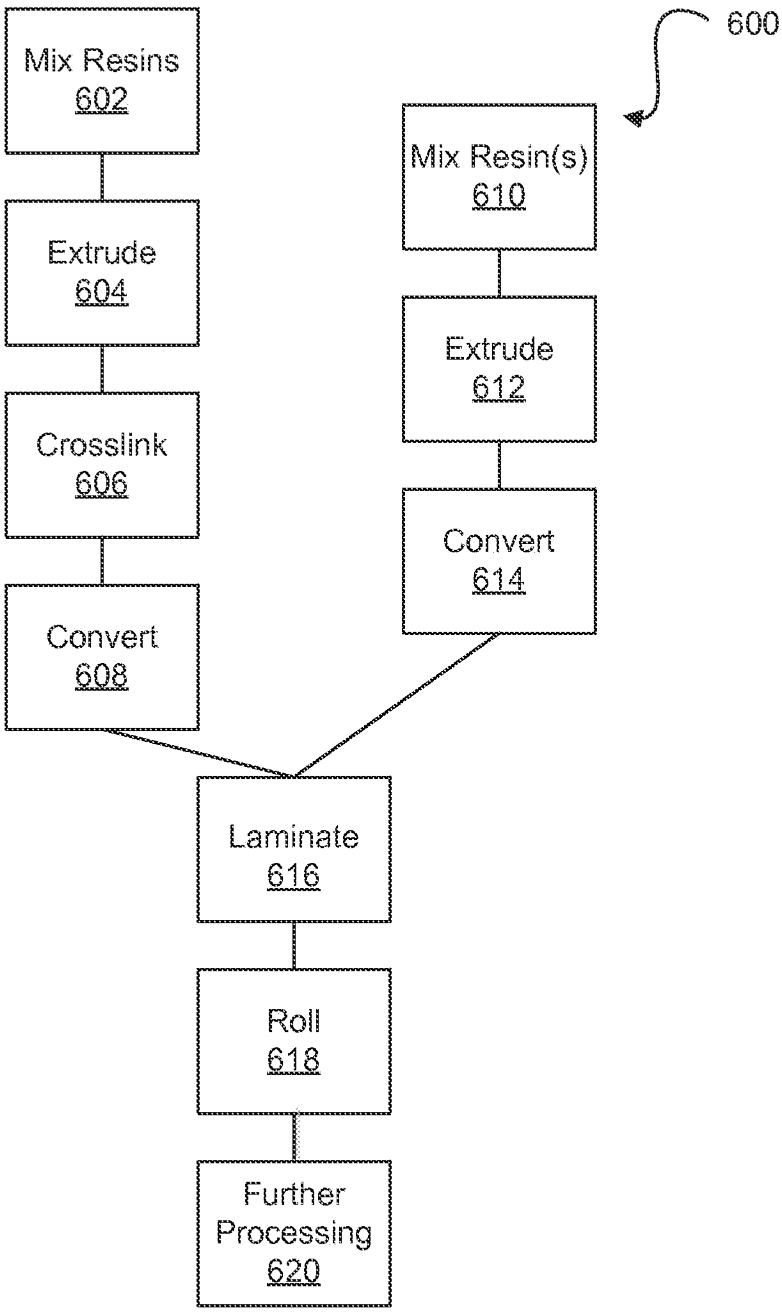

600
Mix Resins 602
Extrude 604
Crosslink 606
Convert 608
Mix Resin(s) 610
Extrude 612
Convert 614
Laminate 616
Roll 618
Further Processing 620

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 15/20169

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E04F 11/16, E04F 15/22, E04B 5/00, E04C 1/00, A63C 19/00 (2015.01)
CPC - E04F 11/16, E04F 15/22, E04B 5/00, E04C 1/00, A63C 19/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): E04F*. E04B*. E04C*. A63B* (2015.01)
CPC: E04F*, E04B\ E04C*, A63B*

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8): E04* (2015.01)
CPC: E04*

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patents, Google Web
Keywords: keane, craig, patrick, cross-linked, non-crosslinked, foam, open, diameter, polyolefin, polyethylene, cell, structure, flooring

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 8,056,292 B2 (SWANSON et al.) 15 November 2011 (15.11.2011), entire document	1-4, 7, 9-11, 13-17, 19-21
Y		5, 6, 8, 12, 18
Y	WO 2000/015700 A1 (PARK) 23 March 2000 (23.03.2000), entire document	5, 6, 8, 12, 18
A	US 5,132,171 A (YOSHIZAWA et al.) 21 July 1992 (21.07.1992), entire document	1-21
A	US 2009/0069457 A1 (BROWN et al.) 12 March 2009 (12.03.2009), entire document	1-21
A	US 2012/0291387 A1 (KEANE) 22 November 2012 (22.11.2012), entire document	1-21

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 May 2015 (08.05.2015)	16 JUN 2015

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774