ACOUSTICAL INSULATING FOAM FROM COMPATIBILIZED BLENDS OF POLY (VINYL AROMATIC) POLYMERS AND POLY (ALPHA-OLEFIN) POLYMERS

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Foams made from a ternary blend of an alkenyl aromatic polymer such as polystyrene, an olefin polymer such as polyethylene, and a compatibilizer, are used as acoustical insulation in building constructions. These foams exhibit an unusual combination of low creep and low dynamic stiffness. They are especially useful in floating floor installations.
ACOUSTICAL INSULATING FOAM FROM COMPATIBILIZED BLENDS OF POLY (VINYL AROMATIC) POLYMERS AND POLY (ALPHA-OLEFIN) POLYMERS

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0001] The research and development leading to the subject matter disclosed herein was not federally sponsored.

BACKGROUND OF THE INVENTION

[0002] This invention relates to acoustical insulation for a variety of applications such as buildings, and especially for floors.

[0003] In subdivided buildings such as apartment buildings, townhouses, condominiums, hotels and office buildings, it is important to provide good acoustical insulation between adjoining units and/or between floors. In many jurisdictions, building codes mandate certain standards of acoustical insulation between adjoining tenants and/or adjoining floors. To meet these standards, insulating materials are often incorporated into walls, ceilings and floors.

[0004] To minimize the transmission of noise between floors, so-called “floating floor” constructions are becoming common. A “floating floor” construction includes a structural subfloor, which is weight-bearing. A “floating floor” sits atop of the structural subfloor but is not affixed to it and it is also separated from the connecting side walls. A flexible material separates the structural floor and the side walls from the floating floor. This flexible material is selected to have a low stiffness, leading to a low resonance frequency of the floating floor system. This provides insulation against ambient sounds that have higher frequencies.

[0005] The acoustical insulation in a floating floor installation must satisfy several simultaneous demands. It must be soft enough that the system’s natural resonance frequency is low. It must bear the weight of the floating floor and additional weight such as furniture and building occupants. As it will usually be walked over as it is installed and the floating floor is installed above it, the insulating material must withstand high, temporary, localized pressures without substantial permanent deformation. As insulating material is normally in place for years or decades, it must maintain its acoustical insulating properties for long periods of time. It must also be chemically stable, and not decompose or release harmful or irritating compounds to the surrounding environment.

[0006] A commonly used insulating material in floating floor installations are foam boards made from expanded polystyrene (EPS) beads. In order to be soft enough to provide acceptable acoustical insulation, these EPS boards are made in such a way that the individual expanded EPS beads are only weakly adhered to each other. As a result of the poor bead adhesion, the boards are very fragile unless they are thicker than about 17 millimeters (mm). This fragility leads to difficulties in handling the EPS boards. The thickness of the EPS boards also increases the cost and takes up otherwise habitable space.

[0007] When thinner insulating material is desired, polyethylene foam sheets are often used instead of expanded EPS sheet. However, these sheets are not satisfactory in long-term creep behavior. Thus, it would be desirable to provide an alternative acoustical insulating material for use in building walls and, especially floors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The FIGURE is a cross-section of a floating floor construction containing a layer of acoustical insulation according to the invention.

SUMMARY OF THE INVENTION

[0010] In a first aspect, this invention is an improvement in a building construction wherein foam acoustical insulation is installed in a wall, ceiling or floor of said building construction, the improvement comprising using as said acoustical insulation a polymeric foam of a polymer blend including (a) at least one alkyl aromatic polymer, (b) at least one α-olefin polymer and (c) an effective amount of a compatibilizer to compatibilize said alkyl aromatic polymer and said α-olefin polymer at the relative proportions thereof that are present in said polymer blend.

[0011] In a second aspect, this invention is an improvement to a floating flooring system. The flooring system comprises a structural subfloor having a floating floor overlaid upon it and a polymeric foam underlayment installed between said structural subfloor and said floating floor. The polymeric foam is a cellular polymer blend including (a) at least one alkyl aromatic polymer, (b) at least one α-olefin polymer and (c) an effective amount of a compatibilizer to compatibilize said alkyl aromatic polymer and said α-olefin polymer at the relative proportions thereof that are present in said polymer blend.

[0012] In a third aspect, this invention is the use as acoustical insulation in a building construction of a cellular polymer blend including (a) at least one alkyl aromatic polymer, (b) at least one α-olefin polymer and (c) an effective amount of a compatibilizer to compatibilize said alkyl aromatic polymer and said α-olefin polymer at the relative proportions thereof that are present in said polymer blend.

[0013] In a fourth aspect, this invention is an acoustical foam comprising (a) at least one alkyl aromatic polymer, (b) at least one α-olefin polymer and (c) an effective amount of a compatibilizer to compatibilize said alkyl aromatic polymer and said α-olefin polymer at the relative proportions thereof that are present in said polymer blend, said foam having a density of from about 10-60 kg/m³, a dynamic stiffness of from about 9-500 MN/m², a thickness of 3-20 mm, and a width of from about 0.1 to 2 meters.

[0014] In a fifth aspect, this invention is a method for improving the acoustical performance of a building construction, comprising installing a wall, polymeric foam in a wall, ceiling or floor of said building construction, wherein the polymeric foam of a polymer blend including (a) at least one alkyl aromatic polymer, (b) at least one α-olefin polymer and (c) an effective amount of a compatibilizer to compatibilize said alkyl aromatic polymer and said α-olefin polymer at the relative proportions thereof that are present in said polymer blend.

DETAILED DESCRIPTION OF THE INVENTION

[0015] In this invention, a polymeric foam made from a blend of an alkyl aromatic polymer and an α-olefin...
polymer may be used as acoustical insulation in a building construction. The blend also contains a polymeric compatibilizer for the alkenyl aromatic polymer and the \( \alpha \)-olefin polymer.

[0016] Any numerical values recited herein include all values from the lower value to the upper value in increments of one unit provided that there is a separation of at least 2 units between any lower value and any higher value. As an example, if it is stated that the amount of a component or a value of a process variable such as, for example, temperature, pressure, time and the like is, for example, from 1 to 90, preferably from 20 to 80, more preferably from 30 to 70, it is intended that values such as 15 to 85, 22 to 68, 43 to 51, 30 to 32 etc. are expressly enumerated in this specification. For values which are less than one, one unit is considered to be 0.0001, 0.001, 0.01 or 0.1 as appropriate. These are only examples of what is specifically intended and all possible combinations of numerical values between the lowest value and the highest value enumerated are to be considered to be expressly stated in this application in a similar manner. Unless otherwise stated, all ranges include both endpoints and all numbers between the endpoints.

[0017] All references herein to elements or metals belonging to a certain Group refer to the Periodic Table of the Elements published and copyrighted by CRC Press, Inc., 1989. Any reference to the Group or Groups shall be to the Group or Groups as reflected in this Periodic Table of the Elements using the IUPAC system for numbering groups.

[0018] “Hydrocarbyl” means any aliphatic, cycloaliphatic, aromatic, aryl substituted aliphatic, aryl-substituted cycloaliphatic, aliphatic substituted aromatic, or aliphatic substituted cycloaliphatic groups. “Hydrocarbyloxy” means a hydrocarbyl group having an oxygen linkage between it and the carbon atom to which it is attached. “Aliphatic” means a compound having a straight- or branched-chain arrangement of its carbon atoms.

[0019] “Copolymer” means a polymer having polymerized therein monomeric units derived from two different monomers.

[0020] “Interpolymer” means a polymer having polymerized therein monomeric units derived from at least two different monomers. This includes, for example, copolymers, terpolymers and tetrapolymers. “Monomeric unit” refers to a polymer backbone portion that is derived from a single monomer.

[0021] Alkenyl Aromatic Polymer

[0022] For purposes of this invention, an alkenyl aromatic polymer is a melt-processable polymer or melt processable impact-modified polymer in the form of polymerized monovinylidene aromatic monomers as represented by the structure:

\[
\text{H}_2\text{C} = \text{C} - \text{C}_x \text{Ar}
\]

[0023] wherein R is hydrogen or an alkyl radical that preferably has no more than three carbon atoms and Ar is an aromatic group. R is preferably hydrogen or methyl, most preferably hydrogen. Aromatic groups Ar include phenyl and naphthyl groups. The aromatic group Ar may be substituted. Halogen (such as Cl, F, Br), alkyl (especially \( \text{C}_3-\text{C}_5 \) alkyl such as methyl, ethyl, propyl and \( \text{t}-\text{butyl} \), \( \text{C}_1-\text{C}_5 \) haloalkyl (such as chloromethyl or chloroethyl) and alkoxyl (such as methoxyl or ethoxyl) substituents are all useful. Styrene, para-vinyl toluene, \( \alpha \)-methyl styrene, 4-methoxy styrene, \( \text{t}-\text{butyl} \) styrene, chlorostyrene, vinyl naphthalene and the like are all useful monovinylidene aromatic monomers. Styrene is especially preferred.

[0024] The alkenyl aromatic polymer may be a homopolymer of a monovinylidene aromatic monomer as described above. Polystyrene homopolymers are the most preferred alkenyl aromatic polymers. Interpolymers of two or more monovinylidene aromatic monomers are also useful.

[0025] Although not critical, the alkenyl aromatic polymer may have a high degree of syndiotactic configuration; i.e., the aromatic groups are located alternately at opposite directions relative to the main chain that consists of carbon-carbon bonds. Homopolymers of monovinylidene aromatic polymers that have syndiotacticity of 75% \( \tau \) diad or greater or even 90% \( \tau \) diad or greater as measured by \( ^{13}\text{C} \) NMR are useful herein.

[0026] The alkenyl aromatic polymer may also contain repeating units derived from one or more other monomers that are copolymerizable with the monovinylidene aromatic monomer. Suitable such monomers include N-phenyl maleimide; acrylamide; ethylenically unsaturated nitriles such as acrylonitrile and methacrylonitrile; ethylenically unsaturated carboxylic acids and anhydrides such as acrylic acid, methacrylic acid, fumaric anhydride and maleic anhydride; esters of ethylenically unsaturated acids such as \( \text{C}_3-\text{C}_5 \) alkyl acrylates and methacrylates, for example \( \text{n}-\text{butyl} \) acrylate and \( \text{methyl} \) methacrylate; and conjugated dienes such as butadiene or isoprene. The interpolymers of these types may be random, block or graft interpolymers. Blends of interpolymers of this type with homopolymers of a monovinylidene aromatic monomer can be used. For example, styrene/\( \text{C}_3-\text{C}_5 \) alkyl acrylate interpolymers and styrene-buta diene interpolymers are particularly suitable as impact modifiers when blended into polystyrene. Such impact-modified polystyrenes are useful herein.

[0027] In addition, the alkenyl aromatic polymers include those modified with rubbers to improve their impact properties. The modification can be, for example, through blending, grafting or polymerization of a monovinylidene aromatic monomer (optionally with other monomers) in the presence of a rubber compound. Examples of such rubbers are homopolymers of \( \text{C}_3-\text{C}_5 \) conjugated dienes such as butadiene or isoprene; ethylene/propylene interpolymers; interpolymers of ethylene, propylene and a nonconjugated diene such as 1,6-hexadiene or ethylidene norbornene; \( \text{C}_3-\text{C}_5 \) alkyl acrylate homopolymers or interpolymers, including interpolymers thereof with a \( \text{C}_3-\text{C}_5 \) alkyl acrylate. The rubbers are conveniently prepared by anionic solution polymerization techniques or by free radical initiated solution, mass or suspension polymerization processes. Rubber polymers that are prepared by emulsion polymerization may be agglomerated to produce larger particles having a multimodal particle size distribution.

[0028] Preferred impact modified alkenyl aromatic polymers are prepared by dissolving the rubber into the monovinylidene aromatic monomer and any comonomers and polymerizing the resulting solution, preferably while agitating the solution so as to prepare a dispersed, grafted impact modified polymer having rubber domains containing occlusions of the matrix polymer dispersed throughout the result-
ing polymerized mass. In such products, polymerized monovinyldiene aromatic monomer forms a continuous polymeric matrix. Additional quantities of rubber polymer may be blended into the impact modified polymer if desired.

[0029] Commercial PS (poly styrene), HIPS (high impact poly styrene), ABS (acylonitrile-butadiene-styrene) and SAN (styrene-acrylonitrile) resins that are melt processable are particularly useful in this invention.

[0030] The alkenyl aromatic polymer has a molecular weight such that it can be melt processed with a blowing agent to form a cellular foam structure. Preferably, the alkenyl aromatic polymer has a melting temperature of about 60°C to about 310°C. A number average molecular weight of about 60,000 to about 350,000, preferably from about 100,000 to about 300,000, is particularly suitable. In the case of an impact modified polymer, these molecular weight numbers refer to molecular weight of the matrix polymer (i.e., the continuous phase polymer of a monovinyldiene aromatic monomer).

[0031] α-Olefin Polymer

[0032] The α-olefin polymer is a polymer or interpolymer containing repeated units derived by polymerizing an α-olefin. The α-olefin polymer contains essentially no polymerized monovinyldiene aromatic monomers and no sterically hindered aliphatic or cycloaliphatic vinyl or vinylidene monomers. Particularly suitable α-olefins have from 2 to about 20 carbon atoms, preferably from 2 to about 8 carbon atoms, and include ethylene, propylene, 1-butene, 4-methyl-1-pentene, 1-hexene, 1-octene and the like. Preferred α-olefin polymers are homopolymers of ethylene or propylene and interpolymers of ethylene with a C2-C6 α-olefin. The α-olefin polymer may also contain, in polymerized form, one or more other non-aromatic monomers that are interpolymerizable with the α-olefin and which are neither aromatic nor contain a aliphatic or cycloaliphatic group. Such monomers include, for example, vinyl acetate, acrylic acid, methacrylic acid, esters of acrylic or methacrylic acid and acid anhydrides such as maleic anhydride. The α-olefin polymer preferably contains at least 75% by weight, preferably at least 95% by weight, of polymerized α-olefin monomers. More preferably, the α-olefin polymer contains at least 85% by weight polymerized ethylene, with polymerized α-olefin monomers constituting the remainder of the polymer.

[0033] Particularly suitable α-olefin polymers include low density polyethylene (LDPE), which term is used herein to designate polyethylene homopolymers made in a high pressure, free radical polymerization process. These LDPE polymers are characterized by having a high degree of long chain branching. LDPE useful in this invention preferably has a density of about 0.910 to 0.940 g/cc (ASTM D792) and a melt index from about 0.02 to about 100 grams per 10 minutes, preferably from 0.1 to about 50 grams per 10 minutes (as determined by ASTM Test Method D1238, condition 190°C, 2.16 kg).

[0034] The so-called linear low density polyethylene (LLDPE) and high density polyethylene (HDPE) products are also useful herein. These polymers are homopolymers of polyethylene or copolymers thereof with one or more higher α-olefins and characterized by the near or total absence (less than 0.01/1000 carbon atoms) of long chain branching. LLDPE and HDPE are made in a low pressure process employing conventional Ziegler-Natta type catalysts, as described in U.S. Pat. No. 4,076,698. LLDPE and HDPE are generally distinguished by the level of α-olefin comonomer in the production, with LLDPE containing higher levels of comonomer and accordingly lower density. Suitable LLDPE polymers having a density of about 0.85 to about 0.940 g/cc (ASTM D792) and a melt index (ASTM D1238, condition 190°C, C/2.16 kg) of about 0.01 to about 100 grams/10 minutes. Suitable HDPE polymers have a similar melt index, but have a density of greater than about 0.940 g/cc.

[0035] Another suitable α-olefin polymer includes propylene. High melt strength polypropylene resins are preferred. The propylene polymer material may be comprised solely of one or more propylene homopolymers, one or more propylene copolymers, and blends of one or more of each of polypropylene homopolymers and copolymers; propylene homopolymers are preferred. The propylene polymer preferably has a weight average molecular weight (Mw) of at least 100,000. Mw can be measured by known procedures. Preferred propylene polymers include those that are branched or lightly cross-linked. Branching (or light cross-linking) may be obtained by those methods generally known in the art, such as chemical or irradiation branching/light cross-linking. One such resin which is prepared as a branched/lightly cross-linked polypropylene resin prior to using the polypropylene resin to prepare a finished polypropylene resin product and the method of preparing such a polypropylene resin is described in U.S. Pat. No. 4,916,198, which is hereby incorporated by reference. Another method to prepare branched/lightly cross-linked polypropylene resin is to introduce chemical compounds into the extruder, along with a polypropylene resin and allow the branching/lightly cross-linking reaction to take place in the extruder. This method is illustrated in U.S. Pat. No. 3,250,731 with a polyfunctional azide, U.S. Pat. No. 4,714,716 (and published International Application WO 99/10424) with an azido functional silane and EP 879,844-A1 with a peroxide in conjunction with a multi-vinyl functional monomer. The aforementioned U.S. patents are incorporated herein by reference. Irradiation techniques are illustrated by U.S. Pat. Nos. 5,605,936 and 5,883,151, which are also incorporated by reference.

[0036] Another suitable type of α-olefin polymer is LLDPE polymers having a homogeneous distribution of the comonomer, as are described, for example, in U.S. Pat. No. 3,645,992 to Elston and U.S. Pat. Nos. 5,026,798 and 5,059,438 to Canic. This also describes, for example, in U.S. Pat. No. 5,272,236 and 5,278,272, incorporated herein by reference. The substantially linear olefin polymer is advantageously a homopolymer of a C2-C20 α-olefin or, preferably, an interpolymer of ethylene with at least one C2-C20 α-olefin and/or a C4-C10 diolefin. These polymers contain a small amount of long-chain branching (i.e., about 0.01 to 3, preferably 0.01-1 and more preferably 0.3-1 long chain branch per 1000 carbon atoms) and typically exhibit only a single melting peak by differential scanning calorimetry. Particularly suitable substantially linear olefin polymers have a melt index (ASTM D1238, Condition 190°C, C/2.16 kg) of from about
0.01 to about 1000 g/10 min, and a density of from 0.85 to 0.97 g/cc, preferably 0.85 to 0.95 g/cc and especially 0.85 to 0.92 g/cc.

[0038] In addition, α-olefin polymers that have been subjected to coupling or light crosslinking treatments are useful herein, provided that they remain melt processable. Such grafting or light crosslinking techniques include silane grafting as described in U.S. Pat. No. 4,714,716 to Park; peroxide coupling as described in U.S. Pat. No. 4,578,431 to Shaw et al., and irradiation as described in U.S. Pat. No. 5,736,618 to Poloso. Preferably, the treated polymer has a gel content of less than 10%, more preferably less than 5%, most preferably less than 2% by weight, as determined by gel permeation chromatography. Treatment of this type is of particular interest for HDPE, LLDPE or substantially linear polyethylene copolymers, as it tends to increase the melt tension and melt viscosity of those polymers to a range that improves their ability to be processed into foam in an extrusion process.

[0039] Polymeric Compatibilizer

[0040] The polymer blend further contains a polymeric compatibilizer for the alkylenyl aromatic polymer and the α-olefin polymer. The polymeric compatibilizer can be of any type, provided that it prevents macroscopic phase separation of the polymer blend, and the polymer blend is melt processable to form a foam. Without the compatibilizer, the alkylenyl aromatic polymer and the α-olefin polymer are difficult to blend and difficult to foam. The compatibilizer enhances the mixing between the polymeric components. Suitable compatibilizers include certain aliphatic α-olefin- monovinylidene aromatic interpolymer, hydrogenated or non-hydrogenated monovinylidene aromatic/conjugated diene block (including diblock and triblock) copolymers, and styrene/olefin graft copolymers.

[0041] Examples of suitable aliphatic α-olefin/monovinylidene interpolymer include the substantially random interpolymer prepared by polymerizing i) ethylene and/or one or more α-olefin monomers and ii) one or more vinyl or vinylidene aromatic monomers and/or one or more sterically hindered aliphatic or cyclic aliphatic vinyl or vinylidene monomers, and optionally iii) other polymerizable ethylenically unsaturated monomer(s). The interpolymer contains, for example, in polymerized form, from about 35 to about 99 mole percent of monomer type i), about 1 to about 65 mole percent of monomer type ii), and up to 30 mole percent of monomer type iii). Preferably, the interpolymer contains from about 45-97 mole percent of monomer type i), about 3-55 mole percent of monomer type ii) and no more than 20 mole percent of monomer type iii). The interpolymer advantageously has a melt flow index (190°C/2.16 kg) of about 0.1 to 50 g/10 min and a molecular weight distribution which is a weight average molecular weight/number average molecular weight (Mw/Mn) of about 1.5 to about 20.

[0042] Examples of suitable α-olefins include for example, α-olefins containing from 3 to about 20, preferably from 3 to about 12, more preferably from 3 to about 8 carbon atoms. Particularly suitable are ethylene, propylene, butene-1, 4-methyl-1-pentene, hexene-1 or octene-1 or ethylene in combination with one or more of propylene, butene-1, 4-methyl-1-pentene, hexene-1 or octene-1. These α-olefins do not contain an aromatic, hindered aliphatic or cycloaliphatic moieties.

[0043] Other optional polymerizable ethylenically unsaturated monomer(s) include norbornene and C10-alkyl or C10-aryl substituted norbornenes, with an exemplary interpolymer being ethylene/styrene/norbornene.

[0044] Vinyl or vinylidene aromatic monomers which can be employed to prepare the interpolymer include, for example, those represented by the following formula:

\[
\begin{align*}
&\text{Ar} \\
&\text{CH}_2 \\
&R^1 \rightarrow \text{C} = \text{C}(R^2) \\
\end{align*}
\]

[0045] wherein R1 is selected from the group of radicals consisting of hydrogen and alkyl radicals containing from 1 to about 4 carbon atoms, preferably hydrogen or methyl; each R2 is independently selected from the group of radicals consisting of hydrogen and alkyl radicals containing from 1 to about 4 carbon atoms, preferably hydrogen or methyl; Ar is a phenyl group or a phenyl group substituted with from 1 to 5 substituents selected from the group consisting of halo, C1-4-alkyl, and C1-4-haloalkyl and n has a value from zero to about 4, preferably from zero to 2, most preferably zero. Exemplary vinyl aromatic monomers include styrene, vinyl toluene, α-methylstyrene, t-butyl styrene, chlorostyrene, including all isomers of these compounds, and the like. Particularly suitable such monomers include styrene and lower alkyl- or halogen-substituted derivatives thereof. Preferred monomers include styrene, α-methyl styrene, the lower alkyl-(C1-C4) or phenyl-ring substituted derivatives of styrene, such as for example, ortho-, meta-, and para-methylstyrene, the ring halogenated styrenes, para-vinyl toluene or mixtures thereof, and the like. A more preferred aromatic vinyl monomer is styrene.

[0046] By the terms "sterically hindered aliphatic or cycloaliphatic vinyl or vinylidene compounds", it is meant addition polymerizable vinyl or vinylidene monomers corresponding to the formula:

\[
\begin{align*}
&\text{A}^1 \\
&R^1 \rightarrow \text{C} = \text{C}(R^2) \\
\end{align*}
\]

[0047] wherein A1 is a sterically bulky, aliphatic or cycloaliphatic substituent of up to 20 carbons, R1 is selected from the group of radicals consisting of hydrogen and alkyl radicals containing from 1 to about 4 carbon atoms, preferably hydrogen or methyl; each R2 is independently selected from the group of radicals consisting of hydrogen and alkyl radicals containing from 1 to about 4 carbon atoms, preferably hydrogen or methyl; or alternatively R2 and A1 together form a ring system. Preferred aliphatic or cycloaliphatic vinyl or vinylidene compounds are monomers in which one or the carbon atoms bearing ethylenic unsaturation is tertiary or quaternary substituted. Examples of such substituents include cyclic aliphatic groups such as cyclohexyl, cyclohexyl, cyclooctenyl, or ring alkyl or aryl substituted derivatives thereof, tert-butyl, norbornyl, and the like. Most preferred aliphatic or cycloaliphatic vinyl or vinylidene compounds are the various isomeric vinyl-ring substituted
derivatives of cyclohexene and substituted cyclohexenes, and 5-ethylidene-2-norbornene. Especially suitable are 1-, 3-, and 4-vinylcyclohexene. Simple linear non-branched \( \alpha \)-olefins including for example, \( \alpha \)-olefins containing from 3 to about 20 carbon atoms such as propylene, butene-1, 4-methyl-1-pentene, hexene-1 or octene-1 are not examples of sterically hindered aliphatic or cycloaliphatic vinyl or vinylidene compounds.

[0048] The substantially random interpolymeromers include the pseudo-random interpolymeromers as described in EP-A-0, 416,815 by James C. Stevens et al., (equivalent to U.S. Pat. No. 5,872,201) and U.S. Pat. No. 5,703,187 by Francis J. Timmers, both of which are incorporated herein by reference in their entirety. The substantially random interpolymeromers are conveniently made by polymerizing a mixture of polymerizable monomeromers in the presence of one or more metallocone or constrained geometry catalysts in combination with various cocatalysts. Preferred operating conditions for such polymerization reactions are pressures from atmospheric up to 3000 atmospheres and temperatures from -30\( ^\circ \) C. to 200\( ^\circ \) C. Polymerizations and unreacted monomeromers removal at temperatures above the autopolymerization temperature of the respective monomeromers may result in formation of some amounts of homopolymer polymerization products resulting from free radical polymerization.

[0049] Examples of catalysts and methods for preparing the substantially random interpolymeromers are disclosed in European Application Nos. EP-A-416,815; EP-A-514,828; allowed U.S. application Ser. No. 09/302,067; as well as U.S. Pat. Nos. 5,053,438; 5,057,475; 5,068,967; 5,064,802; 5,132,380; 5,189,192; 5,211,106; 5,247,024; 5,350,723; 5,374,696; 5,399,635; 5,470,993; 5,703,187; 5,721,185; 5,929,154; 6,013,819; and 6,048,909. All of the foregoing are fully incorporated herein by reference.

[0050] The substantially random \( \alpha \)-olefin/vinyl aromatic interpolymeromers can also be prepared by the methods described in JP 07/278230 employing as catalysts compounds shown by the general formula:

\[
\text{Cp}^1 \quad \text{R} \quad \text{M} \quad \text{R'}
\]

[0051] where \( \text{Cp}^1 \) and \( \text{Cp}^2 \) are cyclopentadienyl groups, indenyl groups, fluoroenyl groups, or substituents of these, independently of each other; \( \text{R} \) and \( \text{R'} \) are hydrogen atoms, halogen atoms, hydrocarbon groups with carbon numbers of 1-12, alkoxyl groups, or aryloxyl groups, independently of each other; \( \text{M} \) is a group IV metal, preferably Zr or Hf, most preferably Zr; and \( \text{R} \) is an alkylene group or silanediyl group used to cross-link \( \text{Cp}^1 \) and \( \text{Cp}^2 \).

[0052] The substantially random \( \alpha \)-olefin/vinyl aromatic interpolymeromers can also be prepared by the methods described by John G. Bradfute et al. (W. R. Grace & Co.) in WO 95/32095; by R. B. Pannell (Exxon Chemical Patents, Inc.) in WO 94/00500; and in Plastics Technology, p. 25 (September 1992), all of which are incorporated herein by reference in their entirety.

[0053] Also of interest are the substantially random interpolymeromers which comprise at least one \( \alpha \)-olefin/vinyl aromatic \( \alpha \)-olefin/vinyl aromatic/\( \alpha \)-olefin tetrads disclosed in WO 98/09999 by Francis J. Timmers et al. These interpolymeromers contain additional signals in their carbon-13 NMR spectra with intensities greater than three times the peak to peak noise. These signals appear in the chemical shift range 43.70-44.25 ppm and 38.0-38.5 ppm. Specifically, major peaks are observed at 44.1, 43.9, and 38.2 ppm. A proton test NMR experiment indicates that the signals in the chemical shift region 43.70-44.25 ppm are methine carbons and the signals in the region 38.0-38.5 ppm are methylene carbons.

[0054] It is believed that these new signals are due to sequences involving two head-to-tail vinyl aromatic monomeromers insertions preceded and followed by at least one \( \alpha \)-olefin insertion, e.g. an ethylene/styrene/styrene/ethylene tetrad wherein the styrene monomeromer insertions of said tetrads occur exclusively in a 1,2 (head to tail) manner. It is understood by one skilled in the art that for such tetrads involving a vinyl aromatic monomeromer other than styrene and an \( \alpha \)-olefin other than ethylene that the ethyleny/vinyl aromatic monomeromer/vinyl aromatic monomeromer/ethylene tetrad will give rise to similar carbon-13 NMR peaks but with slightly different chemical shifts.

[0055] These interpolymeromers can be prepared by conducting the polymerization at temperatures of from about -30\( ^\circ \) C. to about 250\( ^\circ \) C. in the presence of such catalysts as those represented by the formula:

\[
\text{ER}_3\text{M} = \text{R}_2
\]

[0056] wherein: each \( \text{C} \) is independently, each occurrence, a substituted cyclopentadienyl group \( \pi \)-bound to \( \text{M} \); \( \text{E} \) is \( \text{C} \) or \( \text{Si} \); \( \text{M} \) is a group IV metal, preferably Zr or Hf, most preferably Zr; each \( \text{R} \) is independently, each occurrence, \( \text{H} \), hydrocarbyl, silahydrocarbyl, or hydrocarbylsilyl, containing up to about 30 preferably from 1 to about 20 more preferably from 1 to about 10 carbon or silicon atoms; each \( \text{R} \) is independently, each occurrence, \( \text{H} \), halo, hydrocarbyl, hydrocarboxyloxy, silahydrocarbyl, hydrocarbylsilyl containing up to about 30 preferably from 1 to about 20 more preferably from 1 to about 10 carbon or silicon atoms or two \( \text{R} \) groups together can be a \( \text{C}_{1-10} \) hydrocarbyl substituted 1,3-butadiene; \( \text{m} \) is 1 or 2; and optionally, but preferably in the presence of an activating cocatalyst. Particularly suitable substituted cyclopentadienyl groups include those illustrated by the formula:

\[
\text{C}_{1-10}\text{R}
\]

[0057] wherein each \( \text{R} \) is independently, each occurrence, \( \text{H} \), hydrocarbyl, silahydrocarbyl, or hydrocarbylsilyl, containing up to about 30 preferably from 1 to about 20 more preferably from 1 to about 10 carbon or silicon atoms or two \( \text{R} \) groups together form a di- or tri-valent derivative of such group. Preferably, \( \text{R} \) independently each occurrence is (including
where appropriate all isomers) hydrogen, methyl, ethyl, propyl, butyl, pentyl, hexyl, benzyl, phenyl or silyl or (where appropriate) two such R groups are linked together forming a fused ring system such as indenyl, fluorenyl, tetrahydronindenyl, tetrahydrofluorenyl, or octa hydrofluorenyl.

[0058] Particularly preferred catalysts include, for example, racemic-(dimethylsilanediyl)-bis-(2-methyl-4-phenylindeny) zirconium dichloride, racemic-(dimethylsilanediyl)-bis-(2-methyl-4-phenylindenyl) zirconium dimethyl, racemic-(4,4-diphenyl-1,3-butadiene, racemic-(dimethylsilanediyl)-bis-(2-methyl-4-phenylindenyl) zirconium di-C1-4 alkyl, racemic-(dimethylsilanediyl)-bis-(2-methyl-4-phenylindenyl) zirconium di-C1-4 alkoxides, or any combination thereof and the like.

[0059] It is also possible to use the following titanium-based constrained geometry catalysts, [N-(1,1-dimethyl-ethyl)-1,1-dimethyl-1-[(2,2,3,4,5-6,7-tetrahydro-s-indacen-1-yl) amino] (N)-N titaniam dimethyl; (1-indenyl)( tert-butylamido) dimethylsilane titanium dimethyl; (1,1,3,5-tetramethyl-1,3,5-7-tetrahydro-s-indacen-1-indenyl)(1,1,3,5-tetramethyl-1,3,5-7-tetrahydro-s-indacen-1-indenyl)(1,1,3,5-tetramethyl-1,3,5-7-tetrahydro-s-indacen-1-amido) dimethylsilane titanium dimethyl; or any combination thereof and the like.

[0060] Further preparative methods for the interpolymerizations employed in the present invention have been described in the literature. Longo and Grassi (Makromol. Chem., Volume 191, pages 2387 to 2396 [1990]) and D’Anniello et al. (Journal of Polymer Science, Volume 58, pages 1701-1706 [1995]) reported the use of a catalytic system based on methylaluminoxane (MAO) and cyclopentadienyltitanium trichloride (CpTiCl3) to prepare an ethylene-styrene copolymer. Xu and Lin (Polymer Preprints, Am. Chem. Soc., Div. Polym. Chem.) Volume 35, pages 686, 687 [1994]) have reported copolymerization using a MgCl2/TiCl4/NdCl3/Al(iBu)3 catalyst to give random copolymers of styrene and propylene. Lu et al (Journal of Applied Polymer Science, Volume 53, pages 1453 to 1460 [1994]) have described the copolymerization of ethylene and styrene using a TiCl4/NdCl3/MgCl2/Al(Et3)3 catalyst. Sennitz and Mullhaupt, (Macromol. Chem. Phys., v. 197, pp. 1071-1083, 1997) have described the influence of polymerization conditions on the copolymerization of styrene with ethylene using Me2Si(Me-Cp)(N-tert-butyl)Cl2/methylaluminoxane Ziegler-Natta catalysts. Copolymers of ethylene and propylene produced by bridged metallocene catalysts have been described by Arao, Toshikazu and Suzuki (Polymer Preprints, Am. Chem. Soc., Div. Polym. Chem.) Volume 36, pages 349, 350 [1997]) and in U.S. Pat. No. 5,652,315, issued to Mitsui Toatsu Chemicals, Inc. the manufacture of olefin/propylene or vinyl aromatic monomer interpolymer such as propylene/styrene and butene/styrene are described in U.S. Pat. No. 5,244,996, issued to Mitsui Petrochemical Industries Ltd or U.S. Pat. No. 5,652,315 also issued to Mitsui Petrochemical Industries Ltd or as disclosed in DE 197 11 339 A1 to Denki Kagaku Kagyo KK. All the above methods described for preparing the interpolymer component are incorporated herein by reference. Also, although of high isotacticity and therefore not “substantially random”, the random copolymers of ethylene and styrene as disclosed in Polymer Preprints Vol 39, No. 1, March 1998 by Toru Aria et al. can also be employed as compatibilizers in the present invention.

[0061] While preparing the substantially random interpolymer, an amount of atactic vinyl aromatic homopolymer may be formed due to homopolymerization of the vinyl aromatic monomers at elevated temperatures. The presence of vinyl aromatic homopolymer is in general not detrimental for the purposes of the present invention and can be tolerated. The vinyl aromatic homopolymer may be separated from the interpolymer, if desired, by extraction techniques such as selective precipitation from solution with a non solvent for either the interpolymer or the vinyl aromatic homopolymer. For the purpose of the present invention it is preferred that no more than 30 weight percent, preferably less than 20 weight percent based on the total weight of the interpolymers of atactic vinyl aromatic homopolymer is present.

[0062] Blends of an alkyl vinyl aromatic polymer with an α-olefin polymer using an α-olefin/monovinylidene aromatic interpolymer as a compatibilizer are described in U.S. Pat. No. 5,460,818 incorporated herein by reference. These blends are suitable for use herein.

[0063] Monovinylidene aromatic/conjugated diene block copolymers include diblock and triblock copolymers of, for example, styrene and one or more conjugated dienes such as butadiene, isoprene or norbornene. The proportion of units derived from the monovinylidene aromatic monomer is, for example, from 10 to 80% by weight and preferably from 30 to 60% by weight. These advantageously have a molecular weight, as measured by viscosity against a polystyrene standard, of about 3,000 to 600,000 and preferably from 10,000 to 100,000. These block copolymers can be hydrogenated, as described in U.S. Pat. No. 4,020,025, and the hydrogenated forms can also be used. The double bonds in the backbone of the polymer may be hydrogenated to the extent of 90% or more. Suitable styrene/olefin graft copolymers are also described in U.S. Pat. No. 4,020,025 and in German Published Application 1,495,813, both included herewith by reference.

[0064] Preferred interpolymers are substantially random ethylene-styrene interpolymer. Such polymers preferably have a styrene content from about 20 to about 70 wt % as measured as described, for example, in U.S. Pat. No. 6,048,909 to Chaudhry. Most preferred are interpolymers such as those marketed by The Dow Chemical Company under the INDEX™ trade name. These interpolymers have a higher damping ratio than either the ethylene or the styrene components alone. A damping ratio, also called loss tangent (tgε), is a ratio between loss modulus (viscous component of the deformation) versus storage modulus (elastic component of the deformation.)

[0065] The polymer blend contains, for example, from about 10%, preferably from about 20%, more preferably from about 25%, most preferably from about 35% up to about 90%, preferably up to about 80%, and more preferably up to about 75%, and even more preferably up to about 70% by weight alkyl aromatic polymer. A high concentration of alkyl aromatic polymer tends to improve mechanical properties but decrease softness. The blend contains, for example, from about 10%, preferably from about 20%, more preferably from about 25%, most preferably from about 35% up to about 75%, preferably up to about 60%, more preferably up to about 50% by weight of the α-olefin polymer. A high concentration of α-olefin polymer tends to improve
softness but may hinder post-load recovery and creep performance. The blend preferably contains from about 1%, more preferably from about 2%, most preferably from about 3%, even more preferably from about 5%, preferably from about 10% to about 60%, preferably to about 50%, more preferably to about 40%, even more preferably to about 30% by weight of the compatibilizer. The polymeric compatibilizer tends to improve damping properties, but a high concentration may decrease strength. All percentages in this paragraph are based on the combined weight of alkyl aromatic polymer, α-olefin polymer, and compatibilizer. The polymer blend can be prepared by simple melt blending. If desired, the individual polymers can be separately charged into an extruder together with blowing agent and other auxiliaries to form the polymer blend as part of the forming process. Alternatively, the polymer blend can be made separately prior to the foam forming. The dispersion of the polymer components should be uniform.

[0066] The polymer blend or any component thereof can contain additives that do not undesirably interfere with the foaming process or the acoustical properties of the resulting foam. Antioxidants, colorants, fillers, dyes, slip agents, flame retardants and the like are common such additives.

[0067] A foam for use in this invention is conveniently made from the polymer blend through an extrusion process. The polymer blend or the individual constituents thereof are advantageously fed into the heated barrel of an extruder, which is maintained above the crystalline melting temperature of the constituents of the blend. Optionally, auxiliary components such as nucleating agents are mixed into the blend. An expanding agent is mixed with the molten polymer blend under pressure and the resulting mixture extruded through a die into an area of lower pressure where the mixture expands and cools to form a cellular structure. Generally, the mixture is cooled to within +/−20° C. of the highest crystalline melting point or glass transition temperature of the components of the polymer blend before extrusion. Optionally, the extruded foam is made using an accumulating extrusion process as described in U.S. Pat. No. 4,323,528 to Collins et al.

[0068] Expanding agents include both physical and chemical blowing agents. Physical blowing agents include gasses and liquids that volatilize under the conditions of the foaming process, whereas chemical blowing agents produce a gas under the condition of the foaming process through some chemical means, usually decomposition. Particularly suitable physical blowing agents include halocarbons containing 1 or 2 carbon atoms such as methyl chloride, ethyl chloride, dichloromonomethane, dichlorodifluoromethane, monochlorodifluoromethane, 1,1,2-trifluoro-1,2-dichloroethane, 1,1,2,2-tetrafluoroethane, 1,2,2,2-tetrafluoroethane, and 1,2,2-trifluoroethane. Also suitable are saturated or unsaturated hydrocarbons containing from 3 to 8 carbon atoms such as propane, n-butane, isobutane, pentane, hexane, octane, propene, 1-butenes, 1-pentene, iso-pentane and 2,2-dimethylbutane. Carbon dioxide, nitrogen, argon, water and the like are also useful. Mixtures of these physical expanding agents can be used. Chemical blowing agents include, for example, azodicarbonamide, dinitrosopentamethylenetetramine, benzenesulfonyl Hydrazone and toluene sulfonyl hydrazide. Isobutane is a highly preferred blowing agent.

[0069] A nucleating agent (or cell control agent) can be used to control the size of the cells. Cell control agents include finely particulate solids such as talc as well as mixtures of sodium bicarbonate with citric acid or sodium citrate. The foam advantageously has a cell size in the range of from 0.1 mm, preferably from 0.2 mm, more preferably from about 0.3 mm, to about 10 mm, preferably to about 5 mm, more preferably to about 2.5 mm as measured by ASTM D 3756.

[0070] In addition, a stability control agent such as glyceryl monostearate, stearyl stearamide or the like can be used to modify the rate at which the blowing agent escapes from the cells of the foam after the foam is cooled. The use of such stability control agents is described, for example, in U.S. Pat. Nos. 3,644,230 to Cronin and 4,395,510 to Park.

[0071] As the foam may be used in buildings, for example as acoustical insulation, it preferably will also contain a flame retardant which functions to extinguish flames or at least slow the spread of fire in the flame. Flame retardants are well known, and include brominated organic compounds such as are described in U.S. Pat. No. 4,446,254 to Nakae. Preferred flame retardants include hexabromocyclododecane and blends with a chlorinated paraffin and/or a synergist such as antimony trioxide, dicumyl and polycumyl.

[0072] It is often desirable to accelerate the aging of the foam in order to remove the blowing agent from the cells before shipping or using the foam. This is particularly true with hydrocarbon or other flammable blowing agents. Accelerated aging can be accomplished through perforation techniques as described in U.S. Pat. No. 5,242,016 to Kolesowski, through heat aging (including but not limited to the conditions described in U.S. Pat. No. 5,059,376 to Pontiff), or a combination of both techniques.

[0073] The foam formulation is advantageously selected so that the foam has a density of from about 5 kg/m³, preferably from about 8 kg/m³, more preferably from about 10 kg/m³, preferably to about 60 kg/m³.

[0074] The foam is conveniently extruded in the form of sheet or plank material having a thickness of from about 1, preferably from about 1.5, more preferably about 2, most preferably about 3 to about 200, preferably to about 100, more preferably to about 50 mm. Due to room height and door height restrictions, the desired thickness requirement is usually less than or equal to about 10 mm when the foam is used as acoustical insulation. Thinner extrusions can be used in multiple layers if desired to achieve desired acoustical insulation. Thicker extrusions can be cut down to lesser thickness. The width of the sheet is not critical, although larger widths tend to reduce labor in installing the foam as acoustical insulation. Widths of up to 3 meters or more are suitable, with preferred widths being from about 0.1 to 2 meters.

[0075] The final foam for use by the consumer, either before or after elastification as described below, preferably has a dynamic modulus of no greater than 1,500 kN/m². More preferably, the dynamic modulus is no greater than about 800, even more preferably no greater than about 600, and most preferably no greater than about 450 kN/m². Dynamic modulus is defined as the dynamic stiffness of the foam in N/m², measured according to ISO 9052-1 or EN 29052-2, multiplied by the thickness of the foam in meters.
For foams having a thickness in the most preferred range of 3-20 mm for acoustic foams, a dynamic modulus of 180-1,500 kN/m² corresponds to a dynamic stiffness in the range of about 9-500 MN/m².

[0076] The dynamic modulus, and therefore the dynamic stiffness, of a foam can be reduced somewhat by mechanically stressing the foam, such as by compression. This process is referred to herein as “elastification”. Elastification tends to open cells and to create cell struts so that the foam is softened and the dynamic stiffness correspondingly reduced. Compression is readily accomplished by, for example, compressing the foam by about 30-95% of its original thickness through a pair of rollers or under any kind of compression system. Multiple compressions may be done in order to achieve a desired softness (as indicated by dynamic modulus).

[0077] The foam advantageously has an open cell content of at least 10 volume %, preferably at least 15 volume %, more preferably at least 20 volume %, up to 100 volume %, preferably up to about 95 volume %, more preferably up to about 90 volume % as measured per ASTM D 2856 Procedure A. In some cases, foams with less than 10 volume % open cells may also be suitable.

[0078] The foam may be used as a layer of acoustical insulation in a floor or wall construction. A layer of the foam is installed in the wall or floor at which acoustical insulation is desired. The foam layer can be installed in the ceiling, wall or floor between weight-bearing structures and exposed surfaces. For vertical installations, the foam can be held in place with adhesives or mechanical devices such as nails, screws, staples or rivets. For horizontal installations, it is often not necessary to secure the foam to the underlying structure, although it may be so secured if desired.

[0079] FIG. 1 illustrates a preferred installation. In FIG. 1, structural subfloor 1 is affixed to structural wall support 2. Interior wall surface 9 is affixed to structural wall support 2 through gypsum 8. Acoustical foam layer 5 lies atop structural subfloor 1. Acoustical foam edge strip 5a is positioned at the interface of screed 3 and structural wall support 2. Optional film layer 4 separates screed 3 from acoustical foam layer 5 and vertical acoustical foam edge strip 5a. Exposed floor surface 6 is positioned atop screed 3. Elastic scaling bead 7 fills any remaining space between the exposed floor surface 6 and the interior wall surface 9.

[0080] Screed 3 and the exposed floor surface 6 are “floating” in the sense that they are not affixed to the structural subfloor 1 or the structural wall support 2.

[0081] The floating floor system illustrated in FIG. 1 is conveniently installed by first building the structural subfloor 1 and structural wall support 2. The structural subfloor 1 can be made of any suitable building material, including concrete, reinforced concrete, wood, steel, aluminum, plywood, particle board, plasterboard, fibrous-reinforced gypsum plates, oriented strand boards and the like. Concrete and reinforced concrete subfloors are preferred. Acoustical foam layer 5 is installed over the subfloor 1. Advantageously, substantially the entire surface of the subfloor is covered with acoustical foam layer 5. Holes may be provided for services such as water, drains, electrical, cables, ducts, vents, and the like. In addition, the periphery of the floor is also lined with acoustical foam edge strip 5a, which extends upward along the structural wall support 2 to a height at least equal to that of the floating floor (i.e., the combined height of acoustical foam layer 5, film layer 4, screed 3 and exposed floor surface 6). As mentioned, acoustical foam layer 5 and acoustical foam edge strip 5a may be simply laid into place, or may be secured to subfloor 1 and/or structural wall support 2 though adhesive or mechanical means.

[0082] As shown in FIG. 1, film layer 4 is then installed over the acoustical foam layer 5 and acoustical foam edge strip 5a. Screed 3 is of a structural material whose purpose is to provide a dimensionally stable support for the exposed floor surface as well as to provide mass that assists in the overall acoustical performance of the floor. Screed 3 is commonly of a concrete-type or reinforced concrete-type that is poured in place over the previously-installed acoustical foam. Film layer 4 provides a continuous surface over which the concrete can be poured, so that the concrete does not leak through spaces between separate pieces of foam that make up acoustical foam layer 5, or between acoustical foam layer 5 and edge strips 5a. This prevents concrete bridges between screed 3 and subfloor 1 from being formed. Such bridges readily transmit sound, so their formation is to be avoided. For the same reason, screed 3 will also contain openings for water, drains, electrical, cables, ducts, vents, and the like, as these also form sound bridges if they are in contact with screed 3. Instead of using film layer 4, acoustical foam layer 5 and edge strips 5a can be taped at all seams, so that those spaces are sealed and leakage of the concrete is prevented.

[0083] Screed 3 can also be made from prefabricated gypsum plates, fiber reinforced gypsum plates or wood (such as a parquet floor or wood particle boards). In this case, it is convenient to attached acoustical layer 5 to the plates or wood pieces prior to installation. In this manner, acoustical layer 5 and screed 3 can be installed simultaneously. Screed 3 can also take the form of ceramic or other tiles embedded in a mortar bed.

[0084] In all cases, screed 3 is installed in such a way that it “floats” over acoustical foam layer 5 and is not affixed to structural subfloor 1 or structural wall support 2.

[0085] Acoustical foam layer 5 and foam edge strip 5a are each advantageously from about 1 to about 30, preferably from about 5 to about 25, more preferably about 5 to about 20 mm thick.

[0086] Because acoustical foam layer 5 bears the weight of screed 3, film 4 and exposed floor surface 6, it is under continuous mechanical pressure throughout the life of the installation. Accordingly, long term deformation performance (creep performance) is sometimes an important performance requirement of the acoustical foam layer 5. Acoustical insulation made from polymer blends in accordance with this invention exhibit excellent creep performance. This property provides an important advantage of using the polymer blends described herein as acoustical insulation in floating floor constructions or other constructions in which the acoustical foam layer is weight-bearing, particularly when compared to the creep performance of extruded polyethylene foams. Creep is conveniently expressed as a loss of thickness when exposed to a load over a period of time. The foam preferably exhibits a loss of thickness when exposed to a load of 2.5 kPa (kN/m²) for 1000 hours of less than 10%, more preferably less than 9%, based on the thickness of the
foam before testing. The foam more preferably exhibits a loss of thickness when exposed to a load of 5 kPa (kN/m²) for 1000 hours of less than 20%, more preferably less than 15%, based on the thickness of the foam before testing.

[0087] The following examples are provided to illustrate the invention but are not intended to limit to scope thereof. All parts and percentages are by weight unless otherwise indicated.

Examples 1-17 and Comparative Examples A & B

[0088] I. Preparation and Testing of Ethylene-styrene Interpolymers (ESI-1 and ESI-2)

[0089] The ESI's may be prepared as described in column 17, line 15 through column 20, line 3 of U.S. Pat. No. 6,048,909 which is herein incorporated by reference. The melt flow or melt index measurements, and analysis of the styrene content in the ESI interpolymers may be determined, for example, as described in column 14, line 28 through column 17, line 11 of U.S. Pat. No. 6,048,909 which is also incorporated by reference.

[0090] For ESI-1, the reactor temperature is 104.9°C, the solvent flow is 665 lb/hr, the ethylene flow is 123 lb/hr, the hydrogen flow is 1525 standard cubic centimeters/minute and the styrene flow is 110 lb/hr. The cocatalyst is tris( pentafluorophenyl)borane. A modified methylaluminoxane (MMAO) commercially available from Akzo Nobel as MMAO-3A (CAS# 146905-79-5) is also used. The boron to titanium ratio in the cocatalyst and catalyst is 3.6:1, and the MMAO/titanium ratio is 6.0. Sufficient catalyst is used to obtain the desired conversion rate. ESI-1 contains 39.9 wt-% (15.2 mole-%) copolymerized styrene and 0.6 weight percent atactic polystyrene homopolymer. Its melt index is 0.63 g/10 minutes (190° C./2.16 kg). ESI-2 contains 44.7 wt-% copolymerized styrene and 10.2 weight percent atactic polystyrene homopolymer. Its melt index is 1.5 g/10 minutes (190° C./2.16 kg).

[0091] II. Foam Preparation

[0092] A foam suitable for use in the present invention is made using a screw type extruder having a feeding zone, a metering, a mixing zone, heating zones, three cooling zones. A rectangular shaped die is mounted at the end of the cooling zones.

[0093] Pellets of polystyrene homopolymer having a Mw of 140,000 and a polydispersity of 3.2, a low density polyethylene resin having a melt index (per ASTM D 1238 at 190° C./2.16 kg) of 1.8 g/10 minutes and a density of 0.923 g/cm³ and ESI-1 are fed into the extruder at a weight ratio of 40:40:20, respectively. The resin blend contains 0.6 parts by weight of a commercial antioxidant (Irganox™ 1010). Talc (0.06 parts by weight) is fed into the extruder with the resins. Twelve parts by weight isobutane are used as the blowing agent. The foam is extruded at a die opening which provides a foam of 10 mm thickness. The foam is cooled to room temperature at ambient conditions. This foam is designated foam Example 1.

[0094] Foam Example 2 is prepared by compressing a portion of foam Example 1 by 70% of its original thickness under a press at a speed of 500 mm/minute and immediately releasing the pressure at the same rate. Foam Example 3 is prepared by compressing a portion of foam Example 1 by 85% in the same way. Foam Example 4 is prepared by compressing a portion of foam Example 1 by 92% in the same way.

[0095] Foam Example 5 is prepared in the same manner as foam Example 1, except the weight ratio of PS/PE/ESI-1 is 40/50/10, and it is compressed by 70% in the manner described for Example 2. Foam Example 6 is prepared in the same way as Foam Example 5, except it is compressed by 90%.

[0096] Foam Examples 7 and 8 are prepared in the same way as Foam Examples 5 and 6, respectively, except that the weight ratio of PS/PE/ESI-1 is 45/45/10.

[0097] Foam Example 9 is prepared in the same way as Foam Example 5, except the PS/PE/ESI-1 ratio is 45/45/10.

[0098] Foam Example 10 is prepared in the same manner as Foam Example 1, except the foam density is somewhat lower. Foam Example 11 is prepared by compressing Foam Example 10 by 70%, using the method described for Foam Example 2.

[0099] Foam Example 12 is prepared in the same manner as Foam Example 10, but at a slightly higher density.

[0100] Foam Examples 13 and 14 are made in the same manner as Examples 1 and 4, respectively, except that ESI-2 is substituted for ESI-1, a 0.7 g/10 min. melt index polyethylene is substituted for the polyethylene, and a polystyrene of MW=192,000 is substituted for the polystyrene used in Examples 1 and 4, the amount of isobutane is 10 parts per hundred parts resin, and 0.06 part per hundred Irganox 1010 is used as the antioxidant.

[0101] The density, cell size, open cell content, dynamic modulus and dynamic stiffness of all Foam Examples are determined. They are as reported in the following table. In addition, creep is measured for each foam after exposure for 1000 hours to loads of 2.5 kPa (kN/m²), 3.75 kPa (kN/m²) and/or 5 kPa (kN/m²). This data is also reported in the following table.

[0102] For comparison, the properties of a polyethylene foam (Comparative Example A) are provided in the following table.

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<th>Ex. No.</th>
<th>PS/PE/ESI</th>
<th>Density</th>
<th>Elastification</th>
<th>Thickness</th>
<th>Cell Size</th>
<th>% Open Cells</th>
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<th>3.5 kPa</th>
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TABLE 1
TABLE 1-continued

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<th>Elastification 3</th>
<th>Thickness 4</th>
<th>% Open Cells 5</th>
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<td>13</td>
<td>40/40/20</td>
<td>27.9</td>
<td>0</td>
<td>10</td>
<td>1.12</td>
<td>39</td>
<td>986</td>
<td>99</td>
<td>6.9</td>
</tr>
<tr>
<td>14</td>
<td>40/40/20</td>
<td>27.8</td>
<td>9.14</td>
<td>10</td>
<td>1.17</td>
<td>57.4</td>
<td>380</td>
<td>42</td>
<td>5.8</td>
</tr>
</tbody>
</table>

*Not an example of this invention. ND = not determined. 1 Weight ratio of polyethylene (PS), ethylene (E) and ESI interpolymer (ESI). In Examples 1-12, the ESI-1 is used. In Examples 13-14, ESI-2 is used. 2 Density in kg/m³. 3 Percentage by which the foam is compressed, based on the original thickness, during an elastification step. 4 Thickness of the sample in mm. 5 Average cell size in mm, derived as the average cell diameter measured in horizontal, vertical and extrusion direction. 6 Open cell content in volume %. 7 Dynamic modulus (DM) in kPa calculated from the dynamic stiffness and tested foam thickness. 8 Dynamic stiffness in MN/m³ measured according to ISO 9052-1 or EN 25052.

Table 2 shows acoustic and mechanical properties of a foam prepared as described in Example 1 at various thicknesses.

<table>
<thead>
<tr>
<th>Comparative Example B</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creep (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (hours)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 kPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>1</td>
<td>7.9</td>
<td>10</td>
</tr>
<tr>
<td>5.1</td>
<td>45</td>
<td>6.7</td>
<td>330</td>
</tr>
<tr>
<td>6.7</td>
<td>330</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>24</td>
<td>9.2</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>5.3</td>
<td>1000</td>
</tr>
<tr>
<td>5.6</td>
<td>56</td>
<td>122</td>
<td>1000</td>
</tr>
<tr>
<td>48</td>
<td>48</td>
<td>10.1</td>
<td>1000</td>
</tr>
<tr>
<td>210</td>
<td>210</td>
<td>5.6</td>
<td>1000</td>
</tr>
<tr>
<td>168</td>
<td>168</td>
<td>12.2</td>
<td>1000</td>
</tr>
<tr>
<td>1056</td>
<td>1056</td>
<td>14.5</td>
<td>1000</td>
</tr>
</tbody>
</table>

Table 3 shows creep data over time (up to about 1000 hours) for a 10 mm thick foam prepared as described in Example 1. For comparison, the properties of a 5 mm thick polyethylene foam (Comparative Example B) are also provided.

Comparative Example B | 15 | 16 | 17
-----------------------|----|----|----
Creep (%)              |    |    |    |
Time (hours)           |    |    |    |
2.5 kPa                |    |    |    |
45                     | 1  | 7.9| 10 |
5.1                    | 45 | 6.7| 330|
6.7                    | 330| 12.0| |
24                     | 24 | 9.2| 100|
100                    | 100| 5.3| 1000|
5.6                    | 56 | 12.2| 1000|
48                     | 48 | 10.1| 1000|
210                    | 210| 5.6| 1000|
168                    | 168| 12.2| 1000|
1056                   | 1056| 14.5| 1000|

As can be seen from the data in the foregoing tables, foam made from the ternary blend in accordance with this invention therefore has a large advantage in long term deformation properties (creep) and typically has a low dynamic modulus, making it more suitable than LDPE foam for use as acoustical insulation in applications that expose the foam to prolonged weight-bearing.

What is claimed is:

1. An improvement in a building construction wherein acoustical insulation is installed in a wall, ceiling or floor of a said building construction, the improvement wherein said acoustical insulation is a foam of a polymer blend including (a) at least one alkynyl aromatic polymer, (b) at least one α-olefin polymer and (c) an effective amount of a compatibilizer for said alkynyl aromatic polymer and said α-olefin polymer at the relative proportions thereof that are present in said polymer blend.

2. The improved building construction of claim 1, wherein said foam has a dynamic modulus of no greater than about 1,500 kN/m² at a thickness of 3-20 mm.
3. The improved building construction of claim 1, wherein said foam has a density of about 10 to about 70 kg/m³ and an open cell content of from about 15 to 95%.

4. The improved building construction of claim 1, wherein said foam has a dynamic modulus of no greater than about 800 kN/m² at a thickness of 3-20 mm.

5. The improved building construction of claim 1, wherein said compatibilizer includes a substantially random interpolymer containing, in polymerized form,

(1) from 1 to 65 mol percent of repeating units derived from;

(a) at least one vinyl or vinylidene aromatic monomer, or

(b) at least one hindered aliphatic or cycloaliphatic vinyl or vinylidene monomer, or

(c) a mixture of (a) and (b);

(2) from 35 to 99 mol percent of repeating units derived from ethylene and/or a C₃₋₂₀ α-olefin; and

(3) no more than 20 mol percent of repeating units derived from ethylenically unsaturated polymerizable monomers other than (1) and (2).

6. The improved building construction of claim 1, wherein said polymer blend contains from about 25 to about 75% by weight of an alkyl aromatic polymer, about 20 to about 50% by weight of an α-olefin polymer and about 2 to about 50% by weight of an acoustical insulation polymer.

7. An improvement in a building construction wherein acoustical insulation is installed in a wall, ceiling or floor of said building construction, the improvement wherein said acoustical insulation is a foam of a polymer blend including (a) about 25 to about 75% by weight polystyrene, (b) about 25 to about 50% by weight polyethylene or a copolymer of ethylene and up to about 15 mole-percent of another α-olefin and (c) about 2 to about 50% by weight of a hydrogenated block copolymer of a monovinylidene aromatic monomer and a conjugated diene, the % by weight of each of components (a), (b) and (c) being based on the total weight of components (a), (b) and (c).

8. The improved building construction wherein acoustical insulation is installed in a wall, ceiling or floor of said building construction, the improvement wherein said acoustical insulation is a foam of a polymer blend including (a) about 25 to about 75% by weight polystyrene, (b) about 25 to about 50% by weight polyethylene or a copolymer of ethylene and up to about 15 mole-percent of another α-olefin and (c) about 2 to about 50% by weight of a hydrogenated block copolymer of a monovinylidene aromatic monomer and a conjugated diene, the % by weight of each of components (a), (b) and (c) being based on the total weight of components (a), (b) and (c).

9. An improvement in a building construction wherein acoustical insulation is installed in a wall, ceiling or floor of said building construction, the improvement wherein said acoustical insulation is a foam of a polymer blend including (a) about 25 to about 75% by weight polystyrene, (b) about 25 to about 50% by weight polyethylene or a copolymer of ethylene and up to about 15 mole-percent of another α-olefin and (c) about 2 to about 50% by weight of a hydrogenated block copolymer of a monovinylidene aromatic monomer and a conjugated diene, the % by weight of each of components (a), (b) and (c) being based on the total weight of components (a), (b) and (c).

10. An improvement in a building construction wherein acoustical insulation is installed in a wall, ceiling or floor of said building construction, the improvement wherein said acoustical insulation is a foam of a polymer blend including (a) about 25 to about 75% by weight polystyrene, (b) about 25 to about 50% by weight polyethylene or a copolymer of ethylene and up to about 15 mole-percent of another α-olefin and (c) about 2 to about 50% by weight of a hydrogenated block copolymer of a monovinylidene aromatic monomer and a conjugated diene, the % by weight of each of components (a), (b) and (c) being based on the total weight of components (a), (b) and (c).

11. The improvement of claim 10, wherein said compatibilizer includes a substantially random interpolymer containing, in polymerized form,

(1) from 1 to 65 mol percent of repeating units derived from;

(a) at least one vinyl or vinylidene aromatic monomer, or

(b) at least one hindered aliphatic or cycloaliphatic vinyl or vinylidene monomer, or

(c) a combination of at least one aromatic vinyl or vinylidene monomer and at least one hindered aliphatic or cycloaliphatic vinyl or vinylidene monomer, and

(2) from 45 to 97 mol percent of repeating units derived from ethylene and/or a C₃₋₂₀ α-olefin; and

(3) no more than 20 mol percent of repeating units derived from ethylenically unsaturated polymerizable monomers other than (1) and (2).

12. The improvement of claim 10, wherein said foam has a density of about 10 to about 70 kg/m³ and an open cell content of from about 15 to 95%.

13. The improvement of claim 10, wherein said foam has a dynamic modulus of no greater than about 450,000 N/m² at a thickness of 3-20 mm.

14. The improvement of claim 10, wherein said compatibilizer includes a substantially random interpolymer containing, in polymerized form,
based on the combined weight of the alkenyl aromatic polymer, \(\alpha\)-olefin polymer and compatibilizer.

16. The improvement of claim 10, wherein the poly(alkenyl aromatic) polymer is poly styrene, the ethylene polymer is polyethylene or a copolymer of ethylene and up to about 10 mole-% of another \(\alpha\)-olefin and said compatibilizer olefin and said compatibilizer includes a substantially random interpolymer having a melt flow index (\(190^\circ\text{C.}/2.16\text{ kg}\)) of 0.1 to 50 g/10 min, an \(M_n/M_w\) of 1.5 to 20; which contains, in polymerized form;

(1) from 3 to 55 mol percent of polymer units derived from;

(a) at least one vinyl or vinylidene aromatic monomer, or

(b) at least one hindered aliphatic or cycloaliphatic vinyl or vinylidene monomer, or

(c) a combination of at least one aromatic vinyl or vinylidene monomer and at least one hindered aliphatic or cycloaliphatic vinyl or vinylidene mono-
mer, and

(2) from 45 to 97 mol percent of repeating units derived from ethylene and/or a \(C_{3-20}\) \(\alpha\)-olefin; and

(3) no more than 20 mol percent of repeating units derived from one or more of ethynically unsaturated polymerizable monomers other than (1) and (2).

17. The improvement of claim 10, wherein said compatibilizer is a hydrogenated block copolymer of monovinylidene aromatic monomer and a conjugated diene, the alkenyl aromatic polymer is poly styrene and the \(\alpha\)-olefin polymer is polyethylene or a copolymer of ethylene and up to about 15 mole-% of another \(\alpha\)-olefin.

18. The improvement of claim 10, wherein said compatibilizer is a block copolymer of styrene and ethylene, the alkenyl aromatic polymer is poly styrene and the \(\alpha\)-olefin polymer is polyethylene or a copolymer of ethylene and up to about 15 mole-% of another \(\alpha\)-olefin.

19. A method for acoustical insulation in a building construction comprising installing in a floor, wall or ceiling a foam of a polymer blend including (a) at least one alkenyl aromatic polymer, (b) at least one \(\alpha\)-olefin polymer and (c) an effective amount of a compatibilizer for said alkenyl aromatic polymer and said \(\alpha\)-olefin polymer at the relative proportions thereof that are present in said polymer blend.

20. An acoustical foam useful for acoustical insulation in a building construction comprising (a) at least one alkenyl aromatic polymer, (b) at least one \(\alpha\)-olefin polymer and (c) an effective amount of a compatibilizer for said alkenyl aromatic polymer and said \(\alpha\)-olefin polymer at the relative proportions thereof that are present in said polymer blend, said foam having a density of from about 10-60 kg/m\(^3\), a dynamic stiffness of from about 9-500 MN/m\(^2\), a thickness of 3-20 mm, and a width of from about 0.1 to 2 meters.

21. An acoustical foam useful for acoustical insulation in a building construction comprising (a) about 25 to about 75% by weight polystyrene, (b) about 25 to about 50% by weight polyethylene or a copolymer of ethylene and up to about 15 mole-percent of another \(\alpha\)-olefin and (c) about 2 to about 50% by weight of a substantially random interpolymer having a melt flow index (\(190^\circ\text{C.}/2.16\text{ kg}\)) of 0.1 to 50 g/10 min, and an \(M_n/M_w\) of 1.5 to 20; which contains, in polymerized form;

(1) from 3 to 55 mol percent of polymer units derived from;

(a) at least one vinyl or vinylidene aromatic monomer, or

(b) at least one hindered aliphatic or cycloaliphatic vinyl or vinylidene monomer, or

(c) a combination of at least one aromatic vinyl or vinylidene monomer and at least one hindered aliphatic or cycloaliphatic vinyl or vinylidene mono-
mer, and

(2) from 45 to 97 mol percent of repeating units derived from ethylene and/or a \(C_{3-20}\) \(\alpha\)-olefin; and

(4) no more than 20 mol percent of repeating units derived from one or more of ethynically unsaturated polymerizable monomers other than (1) and (2) the % by weight of each of components (a), (b) and (c) being based on the total weight of components (a), (b) and (c), said foam having a density of from about 10-60 kg/m\(^3\), a dynamic stiffness of from about 9-500 MN/m\(^2\), a thickness of 3-20 mm, and a width of from about 0.1 to 2 meters.

* * * * *