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(54) Title: THERMALLY RESISTANT HOT MELT MOISTURE CURE POLYURETHANE ADHESIVE COMPOSITION, METHODS OF USING THE SAME, AND SOLAR PANEL ASSEMBLY INCLUDING THE SAME

(57) Abstract: A one-part, moisture curable hot melt adhesive composition and solar panel assemblies including the same. The adhesive composition includes a thermoplastic polymer having a softening point of at least 120°C, an atmospheric curing prepolymer, and a silane adhesion promoter having a flash point greater than 100°C at atmospheric pressure and a boiling point greater than 100°C at from 0.5 mmHg to 15 mmHg.

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THERMALLY RESISTANT HOT MELT MOISTURE CURE POLYURETHANE ADHESIVE COMPOSITION, METHODS OF USING THE SAME, AND SOLAR PANEL ASSEMBLY INCLUDING THE SAME

This application claims priority to U.S. Serial No. 61/310,928 filed March, 5, 2010, and U.S. Serial No. 61/310,792, filed March 5, 2010 and U.S. 61/310,834, filed March 5, 2010, which are incorporated herein.

BACKGROUND OF THE INVENTION

The invention is directed to maintaining adhesion between two substrates under challenging environmental conditions.

Solar panels and solar panel fields have unique requirements in that they must maintain their integrity under conditions of high humidity, because they are often positioned out doors and exposed to rain, freezing rain, and snow, and under conditions of widely varying temperature extremes because they are often positioned in hot deserts, on hot asphalt rooftops, and in climates that experience extremely high temperatures, extremely low temperatures, and strong winds. Thus, any mechanism used to secure and maintain solar panels in a fixed position must function under a difficult set of environmental conditions.

SUMMARY OF THE INVENTION

In one aspect, the invention features a one-part, moisture curable hot melt adhesive composition that includes a thermoplastic polymer having a softening point of at least 120°C, an atmospheric curing prepolymer, and a silane adhesion promoter having a flash point greater than 100°C at atmospheric pressure and a boiling point greater than 100°C at from 0.5 mmHg (millimeters of mercury) to 15 mmHg.

In one embodiment, the moisture curable adhesive composition exhibits an initial lap shear of at least 1 psi at 23 °C.

In another embodiment, the atmospheric curing prepolymer includes a polyisocyanate prepolymer.

In one embodiment, the thermoplastic polymer having a softening point of at least 120°C includes a polyester polyether block copolymer having a softening point of at least 120°C.

In one embodiment, the adhesive composition further includes a tackifying agent, a thermoplastic polymer having a softening point of lower than 120°C, and combinations thereof.

In one embodiment, the adhesive composition further includes a spacer in a form of spheres, cylinders, tubes, strips, ropes, or any other suitable forms.

In some embodiments, the polyester polyether block copolymer includes a hydroxy functional polyester polyether block copolymer having a hydroxyl number of from 2 mg KOH/g to 50 mg KOH/g.

In other embodiments, the polyester polyether block copolymer includes the reaction product of a hydroxy functional polyester polyether block copolymer having a hydroxyl number of from 2 mg KOH/g to 50 mg KOH/g, and a polyisocyanate.

In another embodiment, the polyisocyanate prepolymer includes the reaction product of a polyisocyanate and at least one of a polyether polyol, a polyester polyol, and combinations thereof.

In another aspect, the invention features a solar panel assembly that includes a solar panel, a support, and a moisture curable adhesive composition disclosed herein, the support being bonded to the solar panel through the adhesive composition. In some embodiments, the solar panel includes a substrate that includes glass, and a superstrate, the adhesive composition being in contact with the glass of the substrate. In one embodiment, the solar panel includes a substrate that includes polymer, and the adhesive composition is in contact with the polymer of the substrate. In another embodiment, the support is metal.

In other embodiments, the support remains bonded to the substrate of the solar panel through the adhesive composition after undergoing the at least one of the Simulated Aging Tests set forth in UL 1703 and the tests set forth in IEC 6646.

In other aspects, the invention features a method of adhering a component of a solar panel assembly to a solar panel, the method including contacting at least one of a first component and a second component with an adhesive composition disclosed herein, the first component including a component of the solar panel assembly other than the solar panel, and the second component including the solar panel, and allowing the adhesive composition to cure to bond the first component to the second component. In one embodiment, the first component includes at least one of a back rail, a frame and a junction box, and the second component includes a substrate of the solar panel, the substrate including at least one of polymer and glass. In other embodiments, the first component includes a metal back rail and the second component includes a substrate of the solar panel, the substrate including at least one of polymer and glass.

The one-part moisture curable hot melt adhesive composition exhibits a rapid rate of set (e.g., from instant grab to set time in less than one minute) allowing for good line speeds and good production efficiency.

The adhesive composition exhibits good green strength (e.g., a solar panel assembly that includes the adhesive composition can be handled shortly after application of the adhesive composition thereto), and, when cured, good durability in a wide range of environmental conditions. The adhesive composition can also be applied using an automated process.

Other features and advantages will be apparent from the following description of the preferred embodiments, from the drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plane view a back rail of a solar panel assembly bonded to a substrate of a solar panel through an adhesive composition disclosed herein.

FIG. 2 is a plane view of a junction box of a solar panel assembly bonded to a substrate of a solar panel through an adhesive composition disclosed herein.

FIG. 3 is a plane view of an end bracket a solar panel assembly bonded to a solar panel through an adhesive composition disclosed herein.

FIG. 4 is a perspective view of a framed solar panel assembly.

FIG. 5 is view taken in cross section along line A-A of the framed solar panel assembly of FIG. 4.

FIG. 6 is a perspective view of a solar panel.

FIG. 7 is an enlarged view of a portion of a framed solar panel assembly with an adhesive/sealant composition configured according to another embodiment.

GLOSSARY

In reference to the invention, these terms have the meanings set forth below:

The terms "dicarboxylic acid" and "diacid" as used in the specification and the claims are meant to include dicarboxylic acids, diacids, and their equivalents.

"Polyol" as used here in the specification and the claims includes both diols and triols.

DETAILED DESCRIPTION OF THE INVENTION

The one-part hot melt moisture cure adhesive composition includes a thermoplastic polymer having a Ring and Ball softening point of at least 120°C, an atmospheric curing prepolymer, and a silane adhesion promoter having a flash point greater than 100°C at atmospheric pressure (as measured according to ASTM D93) and a boiling point greater than 100°C at from 0.5 mmHg to 15 mmHg. To the extent the adhesive composition includes free or unreacted isocyanate monomer, the adhesive composition preferably includes no greater than 5 % by weight, no greater than 1 % by weight, no greater than 0.1 % by weight, based on the weight of isocyanate monomer in the final composition.

The one-part, hot melt moisture cure adhesive composition cures upon exposure to atmospheric moisture (e.g., water vapor) in an ambient atmosphere to form a cross-linked thermoset elastomer. The as applied, uncured hot melt adhesive composition is stable in the melt as a one-part composition. The hot melt adhesive composition is in a liquid phase at a temperature above 120°C, reversibly solidifies upon cooling to room temperature, and irreversibly solidifies upon subsequent exposure to ambient atmospheric moisture.

The adhesive composition rapidly cools to a solid allowing for immediate handling of articles constructed therewith, exhibits good bond strengths, and good temperature (i.e., heat and cold) resistance. The adhesive composition also exhibits a rapid rate of set.

The adhesive composition preferably exhibits an initial lap shear strength (i.e., green strength) of at least 1 psi, at least 2 psi, or even at least 4 psi at 23°C, and a final lap shear of at least 1 psi, at least 2 psi, or even at least 4 psi at 85°C.

The adhesive composition also exhibits a tensile strength after 7 days of at least 1750 psi at 23°C, or even at least 2000 psi at 23°C. The cured adhesive composition preferably exhibits an elongation after 7 days of at least 300 %, at least 500 %, at least 1000 %, or even at least 1500 % at 23°C.

The cured adhesive composition also preferably exhibits cold temperature flexibility. The cured adhesive composition is creep resistant and preferably passes the creep resistance test method at 85°C.

Solar panel assemblies that include the cured adhesive composition preferably pass the Simulated Aging Tests set forth in UL 1703, or even the tests of IEC 6646. The cured adhesive composition preferably maintains a support bonded to a solar panel after undergoing the Simulated Aging Tests set forth in UL 1703, or even the tests of IEC 6646.

THERMOPLASTIC POLYMER HAVING A SOFTENING POINT OF AT LEAST 120°C

The adhesive composition includes a thermoplastic polymer having a softening point of at least 120°C. Suitable classes of such thermoplastic polymers include, e.g., thermoplastic elastomers including, e.g., block copolymers (e.g., A-B-A triblock copolymers, A-B diblock copolymers, A-B-A-B-A-B multiblock copolymers, Y block copolymers, radial block copolymers and grafted versions thereof, where the A block is styrene and the B block is isoprene, butadiene, ethylene/butylene, ethylene/propylene and combinations thereof). Particularly useful thermoplastic polymers include isobutylene-isoprene rubber compounds, which are often referred to as butyl rubber compounds, ethylene-propylene rubber compounds and mixtures thereof.

Other useful thermoplastic polymers include polyamides; homopolymers, copolymers and terpolymers of ethylene; homopolymers, copolymers and terpolymers of propylene, homopolymers and copolymers of isobutylene; hydrogenated versions of the aforementioned, and mixtures thereof.

Other useful thermoplastic polymers also include reactive functionalized versions of any of the aforementioned polymers, which react with isocyanate group, and mixtures thereof.

Useful commercially available thermoplastic polymers include, e.g., amorphous polyalphaolefins available from Evonik under the trade designations VESTOPLAST 308, VESTOPLAST 608, and VESTOPLAST 703, atactic polypropylene polymers available under the REXTAC series of trade designations including, e.g., REXTAC RT 2535 and RT 2585, from REXtac LLC (Odessa, Texas) and the EASTOFLEX series of trade designations including, e.g., EASTOFLEX E1060, from Eastman Chemical Co. (Kingsport, Tennessee); polyethylene polymers available under the EPOLENE C-17 trade designation from Westlake Chemical Corporation; ethylene methyl acrylate copolymers available under the OPTEMA series of trade designations from ExxonMobil Chemical Co. (Houston, Texas); butylene/poly(alkylene ether) phthalate polymers available under the HYTREL trade designations from DuPont; and ethylene-octene block copolymers available under the INSITE trade designation including e.g., INSITE D9807.15 from Dow Chemical Company.

The thermoplastic polymer is preferably present in the adhesive composition in an amount of from about 5 % by weight, or from about 10% by weight, or from about 15% by weight to about 90 % by weight, or to about 80 % by weight, or to about 50 % by weight, or to about 30 % by weight, based on the weight of the composition.

One particularly useful class of the thermoplastic polymer includes polyester polyether block copolymers. A variety of polyester polyether block copolymers are suitable for use in the adhesive composition including, e.g., modified polyester polyether block copolymers that include reactive groups, e.g., hydroxyl groups, (e.g., grafted on to a polyester polyether copolymer), modified polyester polyether block copolymers that are the reaction product of a polyisocyanate and polyester polyether block copolymer, modified polyester polyether block copolymers that are the reaction product of a polyisocyanate and hydroxyl grafted polyester polyether block copolymer, modified polyester polyether block copolymers that are the reaction product of a polyisocyanate prepolymer and a polyester polyether block copolymer, and combinations thereof. Preferably the polyester polyether block copolymer has a softening point of at least 120°C and is a thermoplastic elastomer.

One class of useful polyester polyether block copolymers includes polyester polyether block copolymers having the formula set forth below and including hard segments and soft segments

$-CO-Nu-COO-R_1$

wherein Nu is a predominately cyclic nucleus, and

R_1 is randomly selected from either a C_{2-6} alkylene or an amorphous, long-chain polyether subunit that includes a polyoxyalkylene group. Preferably the polyester polyether thermoplastic elastomer includes from 15 % by weight to 75 % by weight short chain ester units and from 25 % by weight to 85 % by weight long chain ester units joined through ester linkages.

The nucleus (Nu) can be derived from aromatic dicarboxylic acids, aliphatic dicarboxylic acids, and combinations thereof. Suitable aromatic dicarboxylic acids include, e.g., terephthalic acid, isophthalic acid, phthalic acid, substituted dicarboxy compounds with benzene nuclei such as bis(p-carboxy-phenyl) methane, p-oxy(p-carboxyphenyl) benzoic acid, ethylene-bis(p-oxybenzoic acid), ethylene-bis-(p-benzoic acid), tetramethylene-bis(p-oxybenzoic acid), 1,5-naphthalene dicarboxylic acid, 2,6-naphthalene dicarboxylic acid, 2,7-naphthalene dicarboxylic acid, phenanthrene dicarboxylic acid, anthracene dicarboxylic acid, 4,4'-sulfonyl dibenzoic acid, and indene dicarboxylic acid, as well as ring substituted derivatives thereof including, e.g., C_{2-10} alkyl, halo, alkoxy or aryl derivatives. Hydroxy acids such as p(β-hydroxyethoxy) benzoic acid can also be used providing an aromatic dicarboxylic acid is also present.

Useful precursors to the nucleus include methyl esters of a dicarboxylic acid. The nucleus can be derived from dimethyl isophthalate, dimethyl terephthalate, dimethyl cyclohexane dicarboxylate, and mixtures thereof.

The characteristics of R_1 determine whether the segment is a hard segment or a soft segment. In a hard segment, R_1 is a C_{2-6} alkylene group, and is derived from aliphatic, alicyclic, and aromatic short chain diols having molecular weights of less than about 250. Useful diols include those diols having from 2 carbon atoms to 15 carbon atoms, or even from 2 carbon atoms to 6 carbon atoms, including, e.g., ethylene, propylene, tetramethylene, isobutylene, pentamethylene, 2,2-dimethyltrimethylene, hexamethylene, and decamethylene glycols, dihydroxycyclohexane, cyclohexane dimethanol, resorcinol, hydroquinone, 1,5-dihydroxynapthalene, bisphenols, and combinations thereof. Suitable bisphenols include, e.g., bis(p-hydroxydiphenyl), bis(p-hydroxyphenyl) methane, bis(p-hydroxyphenyl) methane, bis(p-hydroxyphenyl) propane, 2,2-bis(p-hydroxyphenyl) propane, and combinations thereof. Equivalent ester forming derivatives of diols are also useful. Such diol derivatives can be used to form the diol *in situ* prior to forming the hard segment.

In a soft segment, R_1 is an amorphous, long chain polyether subunit. The polyether subunit has a number average molecular weight (Mn) of from about 350 to about 6,000, from about 350 to about 3,000, or even from about 1,000 to about 3,000, a melting point of less than about 55°C, and a carbon:oxygen ratio of greater than about 2.5:1. Suitable polyethers include, e.g., poly(alkylene oxide) glycols in which the alkylene is C_{2-6} (e.g., poly(1,2-and 1,3-propylene oxide) glycol, poly(tetramethylene-oxide) glycol, poly(pentamethylene oxide) glycol, poly(hexamethylene oxide) glycol and poly (1,2-butylene oxide) glycol), random and block copolymers of ethylene oxide and 1,2-propylene oxide (used in proportions such that the carbon to oxygen mole ratio in the glycol exceeds 2.5:1), and poly-formals prepared by reacting formaldehyde with glycols (e.g., pentamethylene glycol, mixtures of glycols (e.g., a mixture of tetramethylene glycol and pentamethylene glycol), and combinations thereof). Derivatives of the aforementioned polyols can also be used to form a polyether subunit *in situ* prior to formation of the polyester polyether thermoplastic elastomer. One example of a suitable polyether subunit is a polyoxyalkylene polyol having from 2 carbon atoms to 6 carbon atoms in the alkylene group (e.g., polytetramethylene ether glycol (PTMEG)).

When present in the adhesive composition, the polyester polyether block copolymer is preferably in an amount of from about 5 % by weight to about 80 % by weight, from about 5 % by weight to about 50 % by weight, or even from about 5 % by weight to about 35 % by weight, based on the weight of the composition.

One useful polyester polyether block copolymers consist essentially a multiplicity of recurring short chain ester units and long chain ester units joined through ester linkages, the short chain ester units amounting to from about 15 % by weight to 75 % by weight of the copolyester and being of the formula

$$-CO-R_2CO-OR_3-$$

and the long chain ester units amounting to from about 25 % by weight to 85 % by weight of the copolyester and being of the formula

$$-CO-R_2CO-OR_4-$$

where

R_2 is the divalent aromatic radical remaining after removal of the carboxyl groups from aromatic dicarboxylic acid having a molecular weight of less than about 350,

R_3 is the divalent radical remaining after removal of the hydroxyl groups from organic diol having a molecular weight of less than about 250, and

R_4 is the divalent radical remaining after removal of the terminal hydroxyl groups from long chain glycol or polyalkylene glycol having an average weight molecular weight of from about 350 to about 6000, the copolyester having a melt index of less than about 150 g/10 minutes (as measured according to ASTM D 1238-65T at 190°C with a 2160 gram load) and a melting point of at least about 125°C.

A useful polyester polyether block copolymer according to the above formulas includes R_2 derived from terephthalic acid or a mixture of terephthalic acid and isophthalic acid, R_3 derived from an organic diol such as butanediol, and R_4 derived from a long chain glycol such as polytetramethylene ether glycol (PTMEG).

The polyester polyether block copolymer of the above formulas can be combined with a low molecular weight thermoplastic prepolymer that forms compatible mixtures with the polyester polyether block copolymer, is thermally stable at 150°C, and has a melt viscosity of less than about 10,000 centipoises at 200°C, including, e.g., hydrocarbon resins, bituminous asphalts, coal tar pitches, rosins, resin based alkyd resins, phenolic resins, chlorinated aliphatic hydrocarbon waxes, chlorinated polynuclear aromatic hydrocarbons, and combinations thereof. Such compositions are disclosed in, e.g., U.S. patent no. 3,832,314; 3,932,326; and 3,959,062 and incorporated herein.

Another useful class of polyester polyether block copolymers includes the modified polyester polyether block copolymers having an increased level of hydroxyl functionality relative to the hydroxyl functionality inherently present in polyester polyether block copolymers formed as described above an in U.S. patent no. 3,832,314; 3,932,326; and 3,959,062. Suitable hydroxyl-modified polyester polyether block copolymers have hydroxyl numbers of from 2 mg KOH/g to 50 mg KOH/g, from 4 mg KOH/g to 20 mg KOH/g, or even from 5 mg KOH/g to 10 mg KOH/g (as measured according to ASTMD 4274-88).

The increased hydroxyl functionality can be achieved by grafting hydroxyl groups onto the polyester polyether block copolymer, e.g., by combining a hydroxy-functional grafting agent and the polyester polyether block copolymer under appropriate reaction conditions. One such grafting method is described in U.S. patent no. 7,053,152, which is incorporated herein. Suitable grafting agents include, e.g., allyl alcohol, hydroxyethyl (meth)acrylate, hydroxypropyl (meth)acrylate, mercapto functional alcohols (e.g., mercaptoethanol, mercaptopropanol and mercaptobutanol), cinnamyl alcohol, 1-butene-3,4-diol, 3-butene-1-ol, 2-butene-1,4-diol, 2,5-dimethyl-2,5-bis(tert.-butylperoxy)-hexyne-3, and bis-hydroxyalkyl disulfides (e.g., bis-(hydroxyethyl) disulfide and bis-(hydroxypropyl) disulfide), and mixtures thereof. The amount of grafting agent to be employed is governed by the desired hydroxyl number of the grafted polyester polyether block copolymer and the molecular weight of the grafting agent. Preferably from about 0.5 % by weight to about 15 % by weight, or even from about 1 % by weight to about 10 % by weight of grafting agent based on the weight of the block copolymer is used to form the hydroxyl modified block copolymer having a hydroxyl number of from about 1.5 mg/KOH to about 10 mg/KOH.

When present in the adhesive composition, the hydroxyl-modified polyester polyether block copolymers are preferably in an amount of from about 2 % by weight to about 70 % by weight, from about 5 % by weight to about 50 % by weight, or even from about 10 % by weight to about 30 % by weight, based on the weight of the composition.

Another useful class of polyester polyether block copolymers includes the reaction product of a polyisocyanate and at least one of the polyester polyether block copolymer and the modified hydroxy-functional polyester polyether block copolymer. Suitable polyisocyanates for reaction with the polyester polyether block copolymer and the modified hydroxy-functional polyester polyether block copolymer include the polyisocyanates useful for forming the polyisocyanate prepolymer as described below.

When used in the adhesive composition, the polyester polyether block copolymers that include the reaction product of a polyisocyanate and at least one of the polyester polyether block copolymer and the modified hydroxy-functional polyester polyether block copolymer are preferably in an amount of from about 1.5 % by weight to about 70 % by weight, from about 5 % by weight to about 50 % by weight, from about 5 % by weight to about 30 % by weight, or even from about 10 % by weight to about 20 % by weight, based on the weight of the composition.

ATMOSPHERIC CURING PREPOLYMER

The adhesive composition includes an atmospheric curing prepolymer. The atmospheric curing prepolymer is a prepolymer that cures upon exposure to moisture. Useful atmospheric curing prepolymers include, e.g., polyisocyanates, polyurethanes (e.g., polyether urethanes), polydimethylsiloxanes, alkoxy-, acetoxy-, and oxyamino- silane terminated polyethers, alkyl siloxane polymers crosslinked with alkoxy-, acetoxy-, and oxyamino-organo functional silanes, and combinations thereof.

In the embodiments where the atmospheric curing prepolymer is a polyisocyanate prepolymer, a variety of polyisocyanate prepolymers can be included in the adhesive composition.

Useful polyisocyanate prepolymers include the reaction product of a polyfunctional isocyanate having an isocyanate functionality of at least 2 and a polyol (e.g., a polyester polyol, a polyether polyol, or combinations thereof). Useful polyisocyanates include, e.g., aromatic isocyanates, aliphatic isocyanates, cycloaliphatic isocyanates, and combinations thereof. Useful aromatic isocyanates include, e.g., diphenyl methylene diisocyanate, 2,2'-diphenyl methylene diisocyanate, 4,4'-diphenyl dimethylmethylene diisocyanate, diphenyl methylene 2,4'-diisocyanate, tetramethyl xylene diisocyanate, isophorone diisocyanate, toluene diisocyanate, naphthalene diisocyanate (e.g., naphthalene 1,5-diisocyanate), di- and tetraalkyl diphenylmethane diisocyanate, 4,4'-dibenzyl diisocyanate, 1,3-phenylene diisocyanate, 1,4-phenylene diisocyanate, and combinations thereof.

Suitable cycloaliphatic polyisocyanates include, e.g., the hydrogenation products of the aforementioned aromatic diisocyanates including, e.g., 4,4'-dicyclo-hexylmethane diisocyanate (H_{12}MDI), 1-isocyanatomethyl-3-isocyanato-1,5,5-trimethylcyclohexane (isophorone diisocyanate, IPDI), cyclohexane 1,4-diisocyanate, hydrogenated xylylene diisocyanate (H_6XDI), 1-methyl-2,4-diisocyanatocyclohexane, m- and p-tetramethylxylene diisocyanate (m-TMXDI, p-TMXDI), dimer fatty acid diisocyanate, and combinations thereof.

Suitable aliphatic diisocyanates include, e.g., hexamethylene diisocyanate, hydrogenated MDI, dodecane isocyanate, dimer diisocyanate, tetramethoxybutane 1,4-diisocyanate, butane 1,4-diisocyanate, hexane 1,6-diisocyanate (HDI), 1,6-diisocyanato-2,2,4-trimethylhexane, 1,6-diisocyanato-2,4,4-trimethylhexane, 1,12-dodecane diisocyanate (C_{12}DI), polymeric isocyanates, trimeric isocyanates, and combinations thereof.

Preferably the isocyanate and the polyol are combined at an NCO:OH ratio of from about 4.0:1.0 to about 4.0:1.5 to obtain an %NCO in the polyisocyanate prepolymer of from about 0.1 % by weight to about 10 % by weight. One useful method of determining residual NCO concentration is ASTM D-2572-80 "Standard Method for Isocyanate Group and Urethane Materials or Prepolymers."

Useful isocyanates are also disclosed, e.g., in U.S. 4,775,719; U.S. 4,808,255; and U.S. 4,820,368; all of which are incorporated herein. One example of a useful commercially available polyisocyanate is ISONATE 2125M pure diphenylmethane diisocyanate (MDI) from Dow Chemical Co. (Midland, Michigan).

Suitable polyols include polyhydroxy compounds having at least two hydroxyl groups per molecule, and a number average molecular weight of from about 400 to about 20,000, or even from about 1000 to about 6000. Useful polyols include polyols that are glass-like (i.e., amorphous), solid, crystalline, or liquid at room temperature. Useful polyols include, e.g., polyester polyols, polyether polyols, polyalkylene polyols, and mixtures thereof. Suitable polyester polyols include those polyester polyols described in U.S. 4,808,255, which is incorporated herein. Useful polyether polyols include those polyether polyols described in U.S. 5,441,808, which is incorporated herein. Useful polyalkylene polyols include those polyalkylene polyols described in U.S. 4,820,368, which is incorporated herein. Useful polyols are also described in Doyle, E. N., The Development and Use of Polyurethane Products, McGraw-Hill Book Co., 1971, pages 44 to 62.

The polyol is preferably formed from a diacid and a diol. Suitable diacids have greater than about 10 carbon atoms. Some useful polyester polyols include the reaction product of a dimer acid (e.g., EMPOL 1061 and EMPOL 1018 dimer acids available from the Cognis Chemical. (Cincinnati, Ohio)) and at least one of neopentyl glycol, ethylene glycol, propylene glycol, cyclohexanel,4-butanediol, and 1,6-hexanediol.

One useful class of polyether polyols includes polyoxyalkylene polyols in which the alkylene is C_{2-8}. Other useful polyoxyalkylene polyols include, e.g., and polytetramethylene ether glycols (e.g., polytetramethylene glycols having an number average molecular weight of from about 600 and about 6000, or even from about 800 to about 5000), poly(alkyleneoxide) glycols wherein alkylene is C_{2-8} including poly(1,2- and 1,3-propylene oxide) glycol, poly(tetramethylene oxide) glycol, poly(pentamethylene oxide) glycol, poly(hexamethylene oxide) glycol, poly(heptamethylene oxide) glycol, poly(octamethylene oxide) glycol, poly(nonamethylene oxide) glycol, and poly (1,2-butylene oxide) glycol, difunctional polypropylene glycols, trifunctional polypropylene glycols, random and block copolymers of ethylene oxide and 1,2-propylene oxide (used in proportions such that the carbon to oxygen mole ratio in the glycol is greater than 2.5), and poly-formals prepared by reacting formaldehyde with glycols (e.g., pentamethylene glycol, mixtures of glycols (e.g., a mixture of tetramethylene glycol and pentamethylene glycol). Additionally, the dicarboxymethyl acids of polyoxyalkylene polyols can be used to form long chain polyols *in situ*. The polyol used to form the polyisocyanate prepolymer can be the same polyol used in the preparation of the polyether polyester block copolymer.

Useful polyester polyols include those that are the reaction product of various polyols (e.g., diols and triols) with aromatic acids, aliphatic dicarboxylic acids, tricarboxylic acids, polymers of lactones (e.g., ε-caprolactone) (e.g., polycaprolactone), and combinations thereof.

Polyols suitable for forming the polyester polyol include, e.g., ethylene glycol, butane diol (e.g., 1,4-butanediol), neopentyl glycol, hexane diol, propylene glycol, dipropylene glycol, diethylene glycol, triethylene glycol, cyclohexane dimethanol, 1,6-hexanediol, 1,8-octanediol, 1,10-decanediol, 1,12-dodecanediol, dimeric fatty alcohol, glycerol, trimethylolpropane, and combinations thereof. Suitable aromatic acids for forming the polyester polyol include, e.g., teraphthalic acid, isophthalic acid, hexahydrophthalic acid, phthalic anhydride, and combinations thereof. Suitable aliphatic acids for forming the polyester polyol include, e.g., sebasic acid, adipic acid, glutaric acid, azelaic acid, succinic acid, suberic acid, undecanedioic acid, dodecanedioic acid, 3,3-dimethylglutaric acid, dimeric fatty acids, and combinations thereof .

Other useful polyester polyols include, e.g., polyols derived from oleochemicals, and the complete ring opening of epoxidized triglycerides of an at least partially olefinically unsaturated fatty acid-containing fat mixture and at least one alcohol containing from 1 carbon atom to 12 carbon atoms, followed by partial transesterification of the triglyceride derivatives to form alkyl ester polyols having from 1 carbon atom to 12 carbon atoms in the alkyl radical. Further suitable polyols include polycarbonate polyols, dimeric diols, castor oil and its derivatives, and hydroxyfunctional polybutadienes.

Also suitable as polyols are linear and slightly branched acrylic ester copolymer polyols, which may be produced according to a number of methods including, e.g., by free-radical copolymerization of at least one of an acrylic acid ester and a methacrylic acid ester, and at least one of a hydroxyfunctional acrylic acid compound and a methacrylic acid compound (e.g., hydroxyethyl (meth)acrylate and hydroxypropyl (meth)acrylate).

When mixtures of polyols are used in the in the preparation of the polyisocyanate prepolymer, the polyols preferably have at least partial compatibility with the polyether polyester block copolymer when it is used as the thermoplastic polymer.

The polyisocyanate prepolymer may be stripped to less than 0.5 % free isocyanate monomer. One device useful for stripping unreacted isocyanate monomer is a wipe film evaporator. The use of stripped isocyanate prepolymer can result in improved safety in handling the adhesives.

The adhesive composition preferably includes the atmospheric curing prepolymer in an amount of from about 5 % by weight to about 95 % by weight, from about 5 % by weight to about 50 % by weight, from about 10 % by weight to about 85 % by weight, from about 15 % by weight to about 70 % by weight, or even from about 20 % by weight to about 50 % by weight, based on the weight of the composition.

In the embodiments where the adhesive composition includes polyester polyether block copolymers that include the reaction product of a polyisocyanate and at least one of the polyester polyether block copolymer and the modified hydroxy-functional polyester polyether block copolymer, the atmospheric curing prepolymer is preferably present in the adhesive composition in an amount of from about 2.5 % by weight to about 60 % by weight, or even from about 10 % by weight to about 40 % by weight, based on the weight of the composition.

SILANE ADHESION PROMOTER

The adhesive composition includes a silane adhesion promoter. The silane adhesion promoter has a flash point greater than 100°C at atmospheric pressure and a boiling point greater than 100°C at from 0.5 mmHg to 15 mmHg. Silane adhesion promoters are compounds or monomers that have an average molecular weight of from about 300 to about 1000, or from about 300 to about 800, or to about 500 to 700. Useful silane adhesion promoters include silyl groups such as alkoxysilyls, acryloxysilyls, alkyloxyiminosilyls, oxime silyls, amino silyls, and combinations thereof. Examples of useful alkoxysilyl groups include methoxysilyl, ethoxysilyl, propoxysilyl, butoxysilyl, and acyloxysilyl reactive groups including, e.g., silyl ester of various acids including, e.g., acetic acid, 2-ethylhexanoic acid, palmitic acid, stearic acid, and oleic acid, and combinations thereof.

Suitable silane adhesion promoters include, e.g., methacryloxy propyl triethoxy-silane, M-aminophenyltriethoxy-silane, P-aminophenyltriethoxy-silane, N-(2-aminoethyl)-3-aminopropyl triethoxy-silane, n-butylaminopropyltrimethoxy-silane, bis(triethoylsilylpropyl)amine, bis(trimethoylsilylpropyl) amine, 3-(trimethoxylsilyl) propyl succinic anhydride, (3-glycidoxypropyl) methyldiethoxy-silane, (3-glycidoxypropyl) methyldimethoxy-silane, tris(3-trimethoxysilylpropyl) isocyanurate, bis(triethoxysilyl)ethane, bis(trimethoxysilyl) benzene, and combinations thereof.

Suitable silane adhesion promoters are commercially available under the SILQUEST A-1170 and SILQUEST SILQUEST A-LINK 597 trade designations from Momentive Performance Materials, Inc. (Albany, New York).

The silane adhesion promoter preferably is present in the adhesive composition in an amount from about 0.01 % by weight to about 5 % by weight, from about 0.01 % by weight to about 3% by weight, or to about 2 % by weight, or even from about 0.01 % by weight to about 1 % by weight, based on the weight of the composition.

THERMOPLASTIC POLYMERS HAVING A SOFTENING POINT OF LOWER THAN 120°C

The adhesive composition optionally includes a thermoplastic polymer having a softening point of lower than 120°C. Classes of such suitable thermoplastic polymers include, e.g., thermoplastic polyurethanes, thermoplastic polyester block copolymers, , thermoplastic polyetheramides, low molecular weight polymers of ethylenically unsaturated monomers (e.g., (co)polymers of at least one of the following monomers: C_1-C_{18} alkyl esters of acrylic acid and methacrylic acid (e.g., ethylene acrylate, ethylene methacrylate, ethylene butylacrylate, ethylene hydroxyethyl acrylate, and combinations thereof), acrylic acid, methacrylic acid, vinyl versatate, and vinyl ethers), vinyl polymers (e.g., ethylene vinyl acetate copolymers, and vinyl propionate), alkyl fumarates, alkyl maleates, styrene, alkylstyrene, acrylonitrile, butadiene, isoprene, hydrogenation products of butadiene and isoprene copolymers, such as styrene-ethylene-propylene and styrene-ethylene-butylene diblock and triblock copolymers. The thermoplastic polymer preferably has a number average molecular weight less than about 60,000, or even from about 10,000 to about 40,000. One useful example of the optional thermoplastic polymers includes a vinyl acetate-ethylene copolymer that includes from about 18 % by weight to about 80 % by weight vinyl acetate.

The thermoplastic polymer having a softening point of lower than 120°C is preferably present in the adhesive composition in an amount of from 0 % by weight to about 20 % by weight, or even from about 0 % by weight to about 10 by weight, based on the weight of the composition.

Additives

The adhesive composition optionally includes a variety of additives including, e.g., tackifying agents, fillers, plasticizers, catalysts, dyes, inhibitors, antioxidants, stabilizers, UV absorbers, waxes, and other additives. The adhesive composition optionally includes a catalyst to improve the speed at which the composition cures. The catalyst is preferably selected to maintain the desired green strength and thermal stability of the adhesive composition. Useful classes of catalysts include, e.g., ethylene diamine catalysts, organo tin catalysts (e.g., dibutyl tin dilaurate and dibutyl tin diacetate), bismuth catalysts (e.g., bismuth octoate), and catalysts that include ether and morpholine functional groups, examples of which include 2,2-dimorpholinoethyl ether, di(2,6-dimethyl morpholinoethyl)ether, and 4,4'-(oxydi-2,1-ethanediyl)bis-morpholine, which is otherwise known as DMDEE and is commercially available under the JEFFCAT DMDEE trade designation from Huntsman Corp. (Houston, Texas). Other catalysts include aliphatic titanates having from 1 carbon atom to 12 carbon atoms such as lower alkyl titanates including tetrabutyl titanate and tetraethyl titanate, and amines. Useful catalysts are also disclosed in U.S. 6,355,317, which is incorporated herein. The catalysts can be present in the adhesive composition in an amount of from about 0 % by weight to about 2 % by weight, or even from about 0.01 % by weight to 2 % by weight, based on the weight of the composition. The adhesive composition optionally includes a tackifying agent. Suitable tackifying agents have a ring and ball softening point of at least about 80°C, or even from about 85°C to about 150°C. Useful classes of tackifying agents include, e.g., rosin esters, aliphatic, cycloaliphatic, and aromatic hydrocarbon resins, and modified versions and hydrogenated derivatives thereof; and terpenes (polyterpenes), styrenated terpenes, modified terpenes, and hydrogenated derivatives thereof, and combinations thereof. Examples of useful rosin esters include glycerol rosin ester, pentaerythritol rosin ester, and hydrogenated version of the above. Examples of useful aromatic resins include alphamethyl styrene resin, styrene monomer, polystyrene, coumorone, indene, vinyl toluene, and combinations thereof. Other useful tackifying agents include, e.g., abietic acid, abietic esters, terpene resins, styrenated terpene resins, terpene-phenolic resins, poly-α-methylstyrene, aliphatic hydrocarbon resins, aromatic hydrocarbon resins, aromatic-aliphatic hydrocarbon resins, coumarone-indene resins, and combinations thereof. The tackifying agent optionally includes active hydrogen atoms (e.g., hydroxy-functional esters of abietic acid and hydroxylated terpene-phenolic resins).

Suitable commercially available tackifying agents include, e.g., cycloaliphatic hydrocarbon resins and aromatic-modified, cycloaliphatic hydrocarbon resins available under the ESCOREZ 5637 and ESCOREZ 5340 trade designations from ExxonMobil Chemical Company; partially hydrogenated cycloaliphatic petroleum hydrocarbon resins available under the EASTOTAC series of trade designations (e.g., EASTOTAC H-130 and H-142) from Eastman Chemical Co. (Kingsport, Tennessee) available in grades E, R, L and W, which have differing levels of hydrogenation from least hydrogenated (E) to most hydrogenated (W), the ESCOREZ series of trade designations including, e.g., ESCOREZ 5320 and ESCOREZ 5400, from ExxonMobil Chemical Co. (Houston, Texas), and under the HERCOLITE 2100 trade designation from Eastman Chemical Co.; partially hydrogenated aromatic modified petroleum hydrocarbon resins available under the ESCOREZ 5600 trade designation from ExxonMobil Chemical Co.; aromatic hydrogenated hydrocarbon resins available under the trade designation REGALREZ 1126 and alphamethyl styrene resins available under the trade designation KRISTALEX 5140 from Eastman Chemical Co. (Kingsport, Tennessee).

The tackifying agent is preferably present in the adhesive composition in an amount of from 0 % by weight to about 35 % by weight, from about 0 % by weight to about 20% by weight, or from 0% by weight to about 15 % by weight, based on the weight of the composition.

The adhesive composition optionally includes filler. Useful fillers include, e.g., particulate matter, fibers, and powders. Preferably the filler does not interfere with the other components in the adhesive composition. Suitable fillers include, e.g., talc, clay, and silica, and treated versions thereof, carbon blacks and micas, calcium carbonate, ceramics, glass, silica, quartz, mica, treated clay, titanium dioxide, boron nitrides, graphite, asbestos, metals, barium, sulfate, nano-sized particles (e.g., nano-clays, nano-silicas, and combinations thereof), and combinations thereof.

Suitable fillers are commercially available under a variety of trade designations including, e.g., MISTRON VAPOR talc from Luzenac America, Inc. (Englewood, Colorado), NYTAL 200, 300 and 400, different particle size grades of talc from R.T. Vanderbilt Co. (Norwalk, Connecticut), SNOBRITE clay, a Kaolin clay available from Evans Clay Co. (Mcintyre, Georgia), CAB-O-SIL TS-720 fumed silica available from Cabot Corp. (Tuscol, Illinois) and MINERALITE 3X and 4X micas, high compression strength glass beads and spheres, available from Mineral Mining Corp. (Kershaw, South Carolina).

Calcium carbonates are also suitable provided they are first dried and the pH compensated for to prevent the filler from leaching into the adhesive composition and catalyzing unintended reactions.

The adhesive composition optionally includes plasticizer. The plasticizer preferably has a boiling point of greater than about 85°C, and improves at least one of extrudability, flexibility, workability, and stretchability of the adhesive composition. Useful plasticizers include, e.g., liquid aromatic ester plasticizers including dioctyl phthalate esters, solid plasticizers including dicyclohexyl phthalate, benzoate plasticizers (e.g., cyclohexane dimenthanol dibenzoate), bitumen, oil (e.g., mineral based oils, petroleum based oils (e.g., hydrocarbon oils, low aromatic content oils, paraffinic oils, naphthenic oils, and 500 second and 1200 second naphthenic process oils), liquid resins, liquid elastomers, polybutene, polyisobutylene, phthalate plasticizers, benzoate plasticizers, epoxidized soya oil, olefin oligomers, low molecular weight polymers, vegetable oils and their derivatives, solid plasticizers, and combinations thereof.

Useful commercially available plasticizers include, e.g., CALSOL 5120, a naphthenic petroleum based oil available from Calumet Lubricants Co. (Indianapolis, Indiana), KAYDOL WHITE MINERAL OIL, a paraffinic mineral oil available from Witco Corp.

(New York, New York), PARAPOL 1300, a liquid butene homopolymer available from Exxon Chemical Co. (Houston, Texas), INDOPOL H-300, a liquid butene homopolymer available from BPAmoco Corp. (Chicago, Illinois), ESCOREZ 2520, a liquid aromatic petroleum based hydrocarbon resin with a pour point of 20°C available from ExxonMobil Chemical Co., and REGALREZ 1018, a liquid hydrogenated aromatic hydrocarbon resin with a pour point of 18°C available from Eastman Chemical Co.

One example of a useful solid plasticizer is dicylcohexylphthalate. Useful solid plasticizers are commercially available under the BENZOFLEX series of trade designations including BENZOFLEX 352, a 1,4-cyclohexane dimethanol dibenzoate, BENZOFLEX S-404, a glyceryl tribenzoate, and BENZOFLEX S-552, a pentaerythritol tetrabenzoate, from Velsicol Chemical Corp. (Rosemont, Illinois).

Plasticizer is preferably present in the adhesive composition in an amount of from 0 % by weight to about 20% by weight, or to about 10 % by weight, or to about 5% by weight, based on the weight of the composition.

The adhesive composition optionally includes a small amount of wax. Examples are paraffin, ethylene, propylene, hydrogenated natural oils, and chlorinated waxes e.g., CHLOREZ 700 DD, which is a chlorinated paraffin wax from Dover Chemical Corp. (Dover, Ohio).

The adhesive composition also optionally includes a stabilizer, an antioxidant, and combinations thereof. Suitable hindered phenolic antioxidants are commercially available from Ciba-Geigy (Hawthorne, New York) under the trade designations IRGANOX 565, IRGANOX 1010 and IRGANOX 1076. These antioxidants can be used alone or in combination with other antioxidants including, e.g., phosphite antioxidants (e.g., IRGAFOS 168 available from Ciba-Geigy). Other suitable antioxidants include CYANOX LTDP thioether antioxidant available from Cytec Industries (Stamford, Connecticut), and ETHANOX 330 hindered phenolic antioxidant available from Albemarle (Baton Rouge, Louisiana). Antioxidant can be present in the adhesive composition in an amount of from 0 % by weight to about 2 % by weight, based on the weight of the composition.

The adhesive composition can optionally include other components including, e.g., color agents (e.g., pigments), fluorescing agents, ultraviolet (UV) absorbers (e.g., TINUVIN P 327 and 328 from Ciba-Geigy), UV scavengers (e.g., TINUVIN 770 from Ciba-Geigy), odor masking agents, and combinations thereof.

The adhesive composition can be made according to a variety of methods including, e.g., preparing the atmospheric curing prepolymer (e.g., an isocyanate capped prepolymer) and then blending the atmospheric curing prepolymer with the thermoplastic polymer, silane adhesion promoter, and any other optional ingredient.

USE

The adhesive composition is useful for bonding a variety of substrates to each other including substrates made from, e.g., glass, polymer (e.g., polymer composites), metal (e.g., stainless steel, aluminum (e.g., anodized aluminum), galvanized steel and cold-rolled steel), and combinations thereof, treated and coated substrates (e.g., substrates treated for corrosion resistance, aluminum and zinc coated substrates, and combinations thereof), painted substrates and combinations thereof.

The adhesive composition is useful for bonding the various components of solar assemblies to each other including such components as, e.g., solar panel frames (e.g., C-shaped channels), junction boxes (e.g., polymeric junction boxes), back rails for supporting solar panels (e.g., metal back rails), brackets (e.g., end brackets), solar panels, components of solar panels (e.g., superstrate, substrate and edges), components used in mounting the solar panels, components used in supporting the solar panels, and combinations thereof. Useful solar panel superstrates include a layer of an ultraviolet light transparent material (e.g., glass), and useful solar panel substrates include a layer of polymer, polymer composite, and combinations thereof.

In one embodiment, the aforesaid adhesive composition is particularly used for sealing and mounting frames on a solar panel to form a framed solar panel assembly.

Solar panels are often surrounded by a frame and adhered to the frame with a structural adhesive. It is often necessary to include both a structural adhesive and a moisture vapor barrier to achieve a framed solar panel that will maintain its integrity under the rigorous conditions to which it is often exposed including, e.g., high humidity, widely varying temperature extremes, and strong winds.

In the embodiments where it is used for framing solar panels, the aforesaid adhesive composition can function as both an adhesive and a moisture vapor barrier, therefore, is referred to as an adhesive/sealant composition. In some embodiments, the adhesive/sealant composition exhibits a moisture vapor transmission rate (MVTR) of no greater than 2 g/m^2/day. In some embodiments, the adhesive/sealant composition exhibits a MVTR of no greater than 1 g/m^2/day. In some embodiments, the adhesive/sealant composition exhibits a MVTR of no greater than 0.2 g/m^2/day.

In one embodiment, the invention provides a framed solar panel assembly. The solar panel assembly includes a solar panel that includes edges; a peripheral frame including an interior surface; and any one of the aforesaid adhesive/sealant compositions disposed between the interior surface of the frame and the edges of the solar panel, the panel being bonded to the frame through the adhesive/sealant composition.

In another embodiment, the invention provides a method of framing a solar panel. The method includes contacting at least one of the interior surfaces of a frame and the solar panel with any one of the adhesive/sealant compositions disclosed herein, and affixing the frame to the solar panel. In some embodiments the method further includes allowing the adhesive/sealant composition to cure such that the frame is bonded to the solar panel through the cured adhesive/sealant composition.

The framed solar panel assemblies exhibit good protection against moisture, which can adversely affect the efficiency of the solar panel. The method provides an efficient framing process and enables the manufacture of a framed solar panel assembly using an adhesive/sealant composition that functions as both an adhesive composition and a sealant composition at the same time, especially as an edge sealant composition.

Other features and advantages of the invention will be apparent from the following description of the preferred embodiments, the drawings, and from the claims.

Turning to FIG. 1, a back rail 10 of a solar panel assembly 5 is bonded to a substrate 8 of a solar panel 12 through an adhesive composition 6.

FIG. 2 illustrates a junction box 20 bonded to a substrate 8 of a solar panel 12 through an adhesive composition 6.

Referring to FIG. 3, an end bracket 30 is bonded to an edge 22, substrate 8 and superstrate 24 of a solar panel 12 through an adhesive composition 6.

FIGS. 4-6 illustrate a framed solar panel assembly 11 includes a solar panel 12 and a peripheral frame 14. The solar panel 12 is surrounded by the frame 14 along edges 16, 18, 20, and 22. An adhesive/sealant composition 4 is disposed between the edges 16, 18, 20 and 22 and the interior surface 28 of the frame 14 so as to seal the solar panel 12, which provides a barrier to moisture entering the solar panel 12, and to adhere the frame 14 to the edges 16, 18, 20 and 22 of the solar panel 12. A continuous bead of the adhesive/sealant composition 4 is in continuous contact with the edge of the solar panel 12 to form a vapor barrier.

The frame 14 defines a U-shaped channel 32 that receives an edge of the solar panel 12. The channel 32 includes a back wall 34, a top wall 36, and a bottom wall 38. The adhesive/sealant composition 4 is in contact with at least one component of the channel 32 of the frame 14, e.g., the back wall 34, a top wall 36, and a bottom wall 38 of the frame 14, and at least one component of the solar panel 12, e.g., the edges 16, 18, 20, and 22 of the panel 12, the superstrate 24 (e.g., a glass superstrate) of the panel 12, and the substrate 8 (e.g., a polymer substrate or a glass substrate) of the solar panel 12, as shown in FIG. 6.

Turning to FIG. 7, the adhesive/sealant composition 4 is positioned in a discontinuous manner on the bottom wall 38, back wall 34, and top wall 36 of the channel 32 of the frame 14 that receives the solar panel 12. The adhesive/sealant composition 4 bonds the frame 14 to the solar panel 12 and preferably provides a vapor barrier. The adhesive/sealant composition 4 preferably exhibits a moisture vapor transmission rate (MVTR) of no greater than 2 $g/m^2/day$, when in the form of a 60 mil film.

Other solar panel assemblies in which the adhesive composition is particularly useful include those constructions described in, e.g., U.S. 2009/0205703 and U.S. 2010/0018570, which are incorporated herein.

The invention will now be described by way of the following examples. All parts, ratios, percents and amounts stated in the Examples are by weight unless otherwise specified.

EXAMPLES

Test Procedures

Test procedures used in the examples include the following.

Tensile Strength Test Method

The tensile strength at break is determined according to ASTM-D638-00 entitled, "Standard Test Method for Tensile Properties of Plastics." A homogeneous film of the adhesive composition is pressed at 100°C to a thickness of from 40 mil to 60 mil. The film is conditioned at 23°C and 50 % relative humidity for 4 weeks to cure. Specimens are cut from the film and tested for tensile strength at break according to ASTM D638-00.

Lap Shear Strength Test Method

The lap shear strength is determined according to ASTM C-961-01 entitled, "Standard Test Method for Lap Shear Strength of Hot Applied Sealants," with the exception that the test specimen is prepared as follows. A 1 in x 1 in film of adhesive composition having a bondline thickness of from 50 mil to 60 mil is placed on a 4 in x 1 in piece of a first substrate (stainless steel). Another 1 in x 4 in piece of a second substrate (stainless steel) is then placed on top of the film and pressed hard against the film using maximum hand pressure. The test specimen is then heated to a temperature of from 120°C-150°C for 10 minutes to achieve good wet out of the adhesive composition.

Initial lap shear (i.e., green strength) is measured within about one to two hours after preparing the bond sample.

Final lap shear is measured 4 weeks after preparing the bond sample and is recorded as the average of at least three samples.

Cold Temperature Flexibility Test Method

Flexibility is measured according to ASTM D3111 entitled, "Flexibility Determination of Hot Melt Adhesive by Mandrel Bend Test Method" (which is incorporated herein) using a free film. The results are reported as pass or fail according to the criteria set forth in ASTM D3111.

Creep Resistance Test Method

Creep resistance is determined as follows. A 1 in x 1 in film of adhesive composition having a thickness of from 50 mil to 60 mil is placed on a 4 in x 1 in piece of aluminum. A 1 in x 3 in piece of glass is then placed on top of the film and pressed hard against the film using maximum hand pressure. The test specimen is then heated to a temperature of from 120°C to 150°C for 10 minutes to achieve good wet out of the adhesive composition. The test specimen is allowed to cure for at least 4 weeks.

A one pound load is then hung from an end of the test specimen and placed in an oven at a specified temperature, e.g., at 85°C or even a higher temperature. The time to failure is recorded. The test specimen is recorded as pass at the test temperature if there is no failure after seven days.

Examples 1-3

Moisture curable hot melt adhesive compositions of Examples 1- 3 are prepared according to Table 1 by mixing thermoplastic polymer(s), polyols, and tackifier (if added) in a molten state until uniformly blended. The MDI is then added and mixed under vacuum for 1-3 hours. Catalyst and silane adhesion promoter and any other additives are added and mixed for an additional 30 minutes to one hour. The adhesive compositions are tested according to the aforesaid test methods, and the results are listed in Table 2.

Table 1

Ingredient	Example 1	Example 2	Example 3
HYTREL 3078 (block copolymer (SP > 120°C)	20	10	---
INSITE D9807.15 (block copolymer SP >120°C)	---	---	15
ELVAX 46L (EVA, SP < 120°C)	---	10	---
REXTAC RT-2730 (APAO, SP < 120°C)	---	---	34.5
KRISTALEX 3100 (tackifier)	39	39	
ZONATAC NG98 (tackifier)	---	---	25
MDI	10	10	6.2
PRIPLAST 3187 (polyol)	---	---	18.8
TERATHANE 2000 (polyol)	15	15	---
DYNACOLL 7380 (polyol)	15	15	---
SILQUEST A-link 597 (silane adhesion promoter)	0.25	0.25	0.5
ELFTEX 8 (pigment)	0.75	0.75	---

Table 2

	Example 2	Example 3
Ultimate Tensile	2433 psi	170 psi
Ultimate Elongation	708 %	166%
Final Lap Shear	671 psi	n/a
Creep Resistance at 85°C	Pass	n/a

n/a: not available

The relevant portions of all documents disclosed herein are hereby incorporated by reference in their entirety.

Other embodiments are within the claims.

We claim:

1. A one-part, moisture curable hot melt adhesive composition comprising:

a thermoplastic polymer having a softening point of at least 120°C;

an atmospheric curing prepolymer; and

a silane adhesion promoter having a flash point greater than 100°C at atmospheric pressure and a boiling point greater than 100°C at from 0.5 mmHg to 15 mmHg.

2. The moisture curable adhesive composition of claim 1, wherein the composition exhibits an initial lap shear of at least 1 psi at 23 °C.

3. The moisture curable hot melt adhesive composition of claim 1, wherein the atmospheric curing prepolymer comprises a polyisocyanate prepolymer.

4. The moisture curable hot melt adhesive composition of claim 1, wherein the thermoplastic polymer comprises a polyester polyether block copolymer having a softening point of at least 120°C.

5. The moisture curable hot melt adhesive composition of claim 4, wherein the polyester polyether block copolymer comprises a hydroxy functional polyester polyether block copolymer having a hydroxyl number of from 2 mg KOH/g to 50 mg KOH/g.

6. The moisture curable hot melt adhesive composition of claim 4, wherein the polyester polyether block copolymer comprises the reaction product of a hydroxy functional polyester polyether block copolymer having a hydroxyl number of from 2 mg KOH/g to 50 mg KOH/g, and a polyisocyanate.

7. The moisture curable hot melt adhesive composition of claim 1, wherein the polyisocyanate prepolymer comprises the reaction product of a polyisocyanate and at least one of a polyether polyol, a polyester polyol, and combination thereof.

8. The moisture curable hot melt adhesive composition of claim 1, further comprising a tackifying agent, a non-reactive thermoplastic polymer having a softening point of lower than 120°C, and combinations thereof.

9. A solar panel assembly comprising:
a solar panel;
a support; and
the moisture curable adhesive composition of any one of claims 1-8,
the support being bonded to the solar panel through the adhesive composition.

10. The solar panel assembly of claim 9, wherein the solar panel comprises a substrate comprising glass and a superstrate, the adhesive composition being in contact with the glass of the substrate.

11. The solar assembly of claim 9, wherein the solar panel comprises a substrate comprising polymer, the adhesive composition being on contact with the polymer of the substrate.

12. The solar assembly of claim 11, wherein the support is metal.

13. The solar assembly of claim 9, wherein the support remains bonded to the substrate of the solar panel through the adhesive composition after undergoing at least one of the Simulated Aging Tests set forth in UL 1703 and the tests of EIC 6646.

14. A method of adhering a component of a solar panel assembly to a solar panel, the method comprising:

contacting at least one of a first component and a second component with the adhesive composition of any one of claims 1-8, the first component comprising a component of the solar module other than the solar panel, and the second component comprising the solar panel, and

allowing the adhesive composition to cure to bond the first component to the second component.

15. The method of claim 14, wherein the first component comprises at least one of a back rail, a frame, a junction box, and combinations thereof, and the second component comprises a substrate of the solar panel, the substrate comprising at least one of polymer and glass.

16. The method of claim 15, wherein the first component comprises a metal back rail and the second component comprises a substrate of the solar panel, the substrate comprising at least one of polymer and glass.

17. A framed solar panel assembly, comprising:

a solar panel comprising edges;

a peripheral frame comprising an interior surface; and

a moisture curable adhesive/sealant composition disposed between the interior surface of the frame and the edges of the panel, the panel being bonded to the frame through the adhesive/sealant composition, the adhesive/sealant composition comprising

a thermoplastic polymer having a softening point of at least 120°C;

an atmospheric curing prepolymer;

a silane adhesion promoter having a flash point greater than 100°C at atmospheric pressure and a boiling point greater than 100°C at from 0.5 mmHg to 15 mmHg; and optionally, a thermoplastic tackifying agent having a softening point greater than 80°C.

18. The framed solar panel assembly of claim 17, wherein the adhesive/sealant composition exhibits an MVTR of no greater than 2 g/m^2/day.

19. The framed solar panel assembly of claim 17, wherein the adhesive/sealant composition exhibits a final lap shear of at least 4 psi at 85°C.

20. A method of framing a solar panel, the method comprising:

contacting at least one of the interior surfaces of a frame with a solar panel by means of a moisture curable adhesive/sealant composition, and

affixing the frame to the solar panel,

the adhesive/sealant composition comprising

a thermoplastic polymer having a softening point of at least 120°C;

an atmospheric curing prepolymer;

a silane adhesion promoter having a flash point greater than 100°C at atmospheric pressure and a boiling point greater than 100°C at from 0.5 mmHg to 15 mmHg; and

optionally, a thermoplastic tackifying agent having a softening point greater than 80°C.

21. The method of claim 20, further comprising allowing the adhesive/sealant composition to cure such that the frame is bonded to the solar panel through the cured adhesive/sealant composition.

22. The method of claim 14, wherein the adhesive/sealant composition exhibits an MVTR of no greater than 2 g/m^2/day.

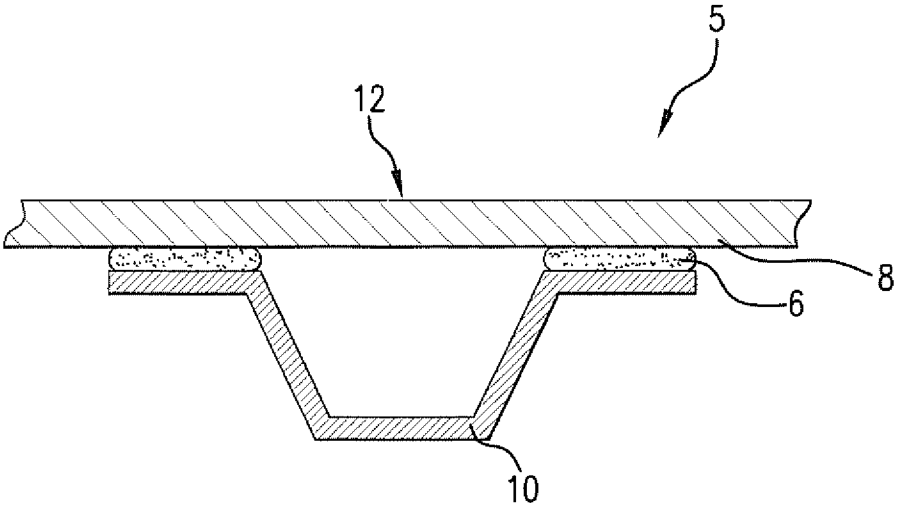

FIG.1

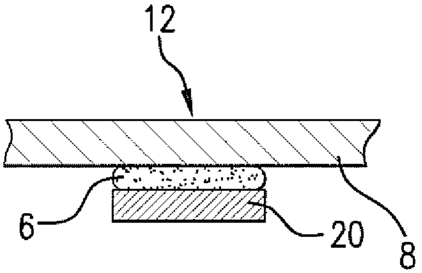

FIG.2

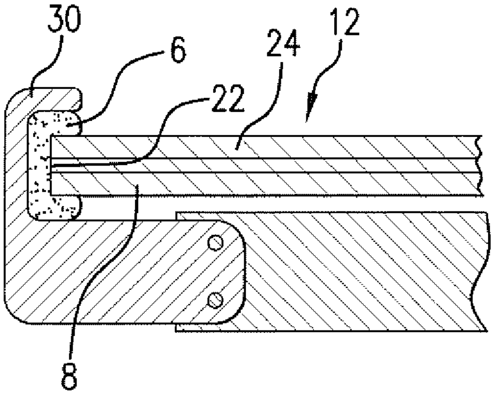

FIG.3

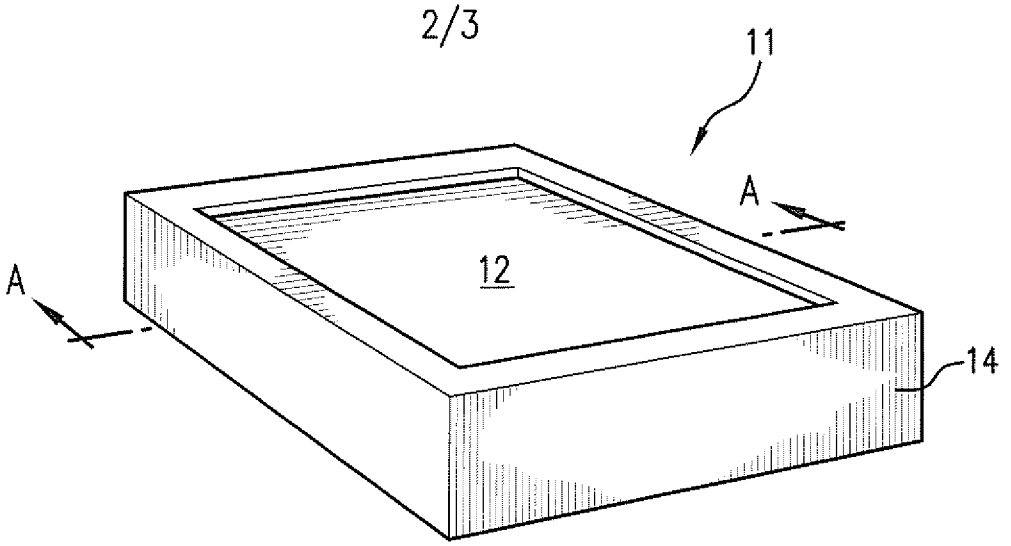

FIG.4

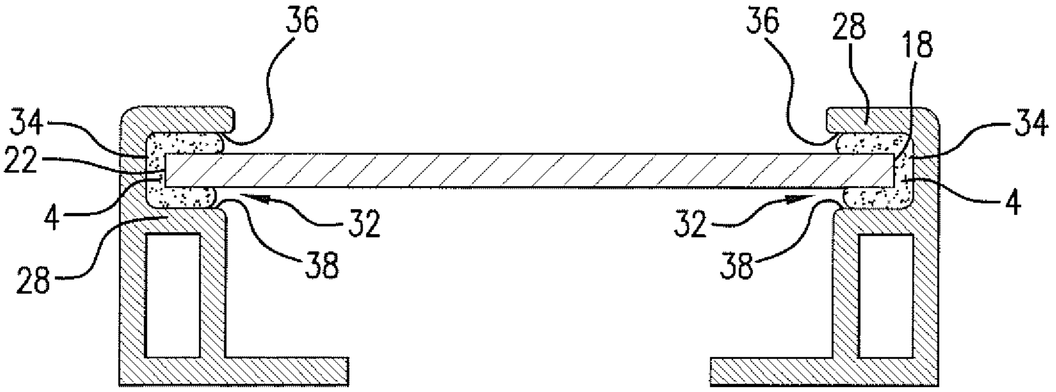

FIG.5

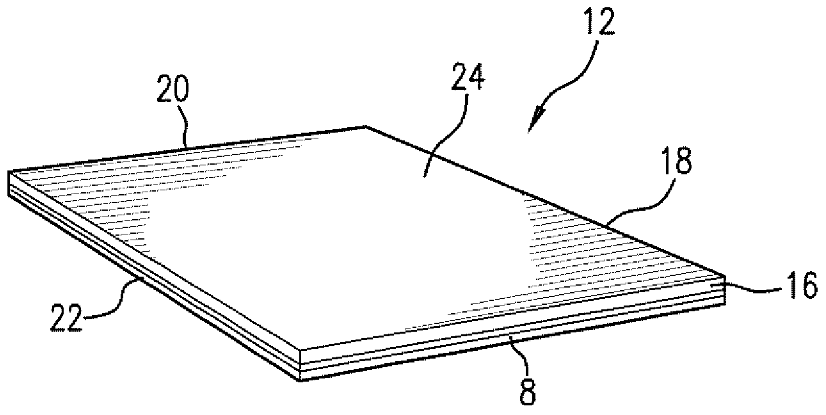

FIG.6

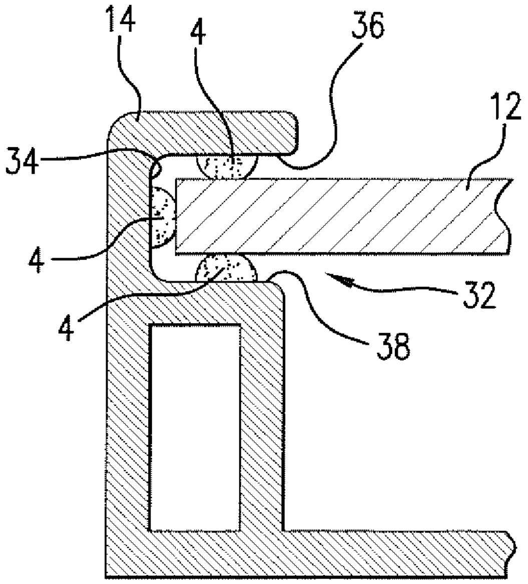

FIG.7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/027045

A. CLASSIFICATION OF SUBJECT MATTER
INV. C08G18/12 C08G18/40 C08G18/48 C08G18/71 C08G18/76
C09J175/06 H01L31/042
ADD. C08L23/08

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)
C08G C09J H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 98/58003 A1 (FULLER H B LICENSING FINANC [US]) 23 December 1998 (1998-12-23) page 6, line 20 - page 7, line 6 page 12, line 21 - page 13, line 9; claims 2,8; examples -----	1-8 9-22
X	WO 91/15530 A1 (FULLER H B LICENSING FINANC [US]) 17 October 1991 (1991-10-17) page 3, line 25 - page 4, line 25 page 5, line 15 - page 10, line 18 page 13, lines 14-16 page 14, line 21 - page 5, line 1; claims; examples II, III, IV, V ----- -/--	1-8

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

☒ See patent family annex.

* 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 document 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 12 May 2011	Date of mailing of the international search report 23/05/2011
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Eigner, Markus

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/027045

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/090454 A1 (HENKEL KGAA [DE]; PRIMKE HARTMUT [DE]; PETRY GERALD [DE]; NIXON ANDREW) 14 November 2002 (2002-11-14)	1-8
A	pages 1,11-12 pages 14, 17; claim 16; example 1 -----	9-22
Y	EP 0 845 816 A1 (SUNSTAR ENGINEERING INC [JP]) 3 June 1998 (1998-06-03) page 4, line 38 - page 5, line 14; figures; example 1 -----	9-22

International application No.
PCT/US2011/027045

INTERNATIONAL SEARCH REPORT

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8

   Moisture-curable hot melt adhesive

   ---

2. claims: 9-22

   Solar panel assembly and production method therefor

International application No

PCT/US2011/027045

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9858003 A1	23-12-1998	AU 8145998 A	04-01-1999
		US 6355317 B1	12-03-2002
WO 9115530 A1	17-10-1991	AT 115973 T	15-01-1995
		CA 2077336 A1	01-10-1991
		DE 69106134 D1	02-02-1995
		DE 69106134 T2	11-05-1995
		EP 0544672 A1	09-06-1993
		JP 3022924 B2	21-03-2000
		JP 5505846 T	26-08-1993
		US 5939499 A	17-08-1999
WO 02090454 A1	14-11-2002	AT 332343 T	15-07-2006
		BR 0210059 A	17-08-2004
		CA 2446919 A1	14-11-2002
		CZ 20033038 A3	14-04-2004
		DE 10122437 A1	28-11-2002
		EP 1397455 A1	17-03-2004
		ES 2268051 T3	16-03-2007
		JP 2004531610 T	14-10-2004
		PL 363680 A1	29-11-2004
		US 2004143034 A1	22-07-2004
EP 0845816 A1	03-06-1998	WO 9707549 A1	27-02-1997
		JP 9055530 A	25-02-1997
		US 6172295 B1	09-01-2001