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(54) Title: COMPOSITIONS AND USE OF CIS-1,1,1,4,4,4-HEXAFLUORO-2-BUTENE FOAM-FORMING COMPOSITION IN THE PREPARATION OF POLYISOCYANATE-BASED FOAMS

(57) Abstract: A foam-forming composition is disclosed which includes both cis-1,1,1,4,4,4-hexafluoro-2-butene and a poorly compatible active hydrogen-containing compound having two or more active hydrogens. Also disclosed is a closed-cell polyurethane or polyisocyanurate polymer foam prepared from reaction of effective amounts of the foam-forming composition and a suitable polyisocyanate. Also disclosed is a process for producing a closed-cell polyurethane or polyisocyanurate polymer foam by reacting an effective amount of the foam-forming composition with a suitable polyisocyanate.



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TITLE

COMPOSITIONS AND USE OF CIS-1,1,1,4,4,4-HEXAFLUORO-2-BUTENE FOAM-FORMING COMPOSITION IN THE PREPARATION OF POLYISOCYANATE-BASED FOAMS

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FIELD OF THE INVENTION

The disclosure herein relates to foam-forming compositions comprising a fluoroolefin blowing agent and an active hydrogen-containing compounds, and using such compositions for producing polyurethane and polyisocyanurate foams. More particularly, the disclosure herein relates to foam-forming compositions comprising cis-1,1,1,4,4,4-hexafluoro-2-butene and a poorly compatible active hydrogen-containing compound having two or more active hydrogens, and using such compositions for producing polyurethane and polyisocyanurate foams.

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BACKGROUND OF THE INVENTION

Closed-cell polyisocyanate-based foams are widely used for insulation purposes, for example, in building construction and in the manufacture of energy efficient electrical appliances. In the construction industry, polyurethane/polyisocyanurate board stock is used in roofing and siding for its insulation and load-carrying capabilities. Poured and sprayed polyurethane foams are widely used for a variety of applications including insulating roofs, insulating large structures such as storage tanks, insulating appliances such as refrigerators and freezers, insulating refrigerated trucks and railcars, etc.

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All of these various types of polyurethane/polyisocyanurate foams require blowing agents for their manufacture. Insulating foams depend on the use of halocarbon blowing agents, not only to foam the polymer, but primarily for their low vapor thermal conductivity, a very important characteristic for insulation value. Historically, polyurethane foams used CFCs (chlorofluorocarbons, for example CFC-11, trichlorofluoromethane) and HCFCs (hydrochlorofluorocarbons, for example HCFC-141b, 1,1-

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dichloro-1-fluoroethane) as the primary blowing agent. However, due to the implication of chlorine-containing molecules such as the CFCs and HCFCs in the destruction of stratospheric ozone, the production and use of CFCs and HCFCs has been restricted by the Montreal Protocol. More recently, hydrofluorocarbons (HFCs), which do not contribute to the destruction of stratospheric ozone, have been employed as blowing agents for polyurethane foams. An example of an HFC employed in this application is HFC-245fa (1,1,1,3,3-pentafluoropropane). The HFCs do not contribute to the destruction of stratospheric ozone, but are of concern due to their contribution to the "greenhouse effect", i.e., they contribute to global warming. As a result of their contribution to global warming, the HFCs have come under scrutiny, and their widespread use may also be limited in the future.

Hydrocarbons have also been proposed as foam blowing agents. However, these compounds are flammable, and many are photochemically reactive, and as a result contribute to the production of ground level ozone (i.e., smog). Such compounds are typically referred to as volatile organic compounds (VOCs), and are subject to environmental regulations.

There is need for producing foams that provide low flammability, good thermal insulation and high dimensional stability by using a blowing agent that has substantially no ozone depletion potential (ODP) and no or very low global warming potential (GWP). Cis-1,1,1,4,4,4-hexafluoro-2-butene is one of the good candidates.

Japanese Patent No. 05179043 discloses the use of cis-1,1,1,4,4,4-hexafluoro-2-butene as the blowing agent together with highly compatible polyether polyols to form polyurethane foams.

There is need for producing polyurethane/polyisocyanurate foams by using cis-1,1,1,4,4,4-hexafluoro-2-butene as the blowing agent together with poorly compatible active hydrogen-containing compounds having two or more active hydrogens.

SUMMARY OF THE INVENTION

This disclosure provides a foam-forming composition comprising cis-1,1,1,4,4,4-hexafluoro-2-butene and a poorly compatible active hydrogen-containing compound having two or more active hydrogens.

5 This disclosure also provides a closed-cell polyurethane or polyisocyanurate polymer foam prepared from reaction of effective amounts of the foam-forming composition and a suitable polyisocyanate.

This disclosure also provides a method for producing a closed-cell polyurethane or polyisocyanurate polymer foam. The method comprises
10 reacting an effective amount of the foam-forming composition and a suitable polyisocyanate.

DETAILED DESCRIPTION

The composition of this disclosure is a foam-forming composition
15 comprising cis-1,1,1,4,4,4-hexafluoro-2-butene and a poorly compatible active hydrogen-containing compound having two or more active hydrogens, in the form of hydroxyl groups. In this disclosure, cis-1,1,1,4,4,4-hexafluoro-2-butene is used as a blowing agent.

Cis-1,1,1,4,4,4-hexafluoro-2-butene is a known compound, and its
20 preparation method has been disclosed, for example, in U.S. Patent Application No. 60/926293 [FL1346 US PRV] filed April/26/2007, hereby incorporated by reference in its entirety.

By "poorly compatible", it is meant to refer to an active hydrogen-containing compound in which the solubility of cis-1,1,1,4,4,4-hexafluoro-
25 2-butene does not exceed 25 wt %.

By "highly compatible", it is meant to refer to an active hydrogen-containing compound in which the solubility of cis-1,1,1,4,4,4-hexafluoro-2-butene is more than 40 wt %.

By "cream time", it is meant to refer to the time period starting from
30 the mixing of the active hydrogen-containing compound with polyisocyanate, and ending at when the foaming starts to occur and color of the mixture starts to change.

By "rise time", it is meant to refer to the time period starting from the mixing of the active hydrogen-containing compound with polyisocyanate, and ending at when the foam rising stops.

By "tack free time", it is meant to refer to the time period starting
5 from the mixing of the active hydrogen-containing compound with polyisocyanate, and ending at when the surface of the foam is no longer tacky.

By "initial R-value", it is meant to refer to the polymer foam's insulation value (thermal resistance) measured at a mean temperature of
10 75 °F within 24 hours after the foam is formed and becomes tack free.

The active hydrogen-containing compounds of this invention can comprise compounds having two or more groups that contain an active hydrogen atom reactive with an isocyanate group, such as described in U.S. Patent No. 4,394,491; hereby incorporated by reference. Examples
15 of such compounds have at least two hydroxyl groups per molecule, and more specifically comprise polyols, such as polyether or polyester polyols. Examples of such polyols are those which have an equivalent weight of about 50 to about 700, normally of about 70 to about 300, more typically of about 90 to about 270, and carry at least 2 hydroxyl groups, usually 3 to 8
20 such groups.

Examples of suitable polyols comprise polyester polyols such as aromatic polyester polyols, e.g., those made by transesterifying polyethylene terephthalate (PET) scrap with a glycol such as diethylene glycol, or made by reacting phthalic anhydride with a glycol. The resulting
25 polyester polyols may be reacted further with ethylene - and/or propylene oxide - to form an extended polyester polyol containing additional internal alkyleneoxy groups.

Examples of suitable polyols also comprise polyether polyols such as polyethylene oxides, polypropylene oxides, mixed polyethylene-
30 propylene oxides with terminal hydroxyl groups, among others. Other suitable polyols can be prepared by reacting ethylene and/or propylene oxide with an initiator having 2 to 16, generally 3 to 8 hydroxyl groups as present, for example, in glycerol, pentaerythritol and carbohydrates such as sorbitol, glucose, sucrose and the like polyhydroxy compounds.

Suitable polyether polyols can also include aliphatic or aromatic amine-based polyols.

The present invention also relates to processes for producing a closed-cell polyurethane or polyisocyanurate polymer foam by reacting an effective amount of the foam-forming compositions with a suitable polyisocyanate.

Typically, before reacting with a suitable polyisocyanate, the active hydrogen-containing compound described hereinabove and optionally other additives are mixed with the blowing agent cis-1,1,1,4,4,4-hexafluoro-2-butene to form a foam-forming composition. Such foam-forming composition is typically known in the art as an isocyanate-reactive preblend, or B-side composition. The foam-forming composition of this invention can be prepared in any manner convenient to one skilled in this art, including simply weighing desired quantities of each component and, thereafter, combining them in an appropriate container at appropriate temperatures and pressures.

When preparing polyisocyanate-based foams, the polyisocyanate reactant is normally selected in such proportion relative to that of the active hydrogen-containing compound that the ratio of the equivalents of isocyanate groups to the equivalents of active hydrogen groups, i.e., the foam index, is from about 0.9 to about 10 and in most cases from about 1 to about 4.

While any suitable polyisocyanate can be employed in the instant process, examples of suitable polyisocyanates useful for making polyisocyanate-based foam comprise at least one of aromatic, aliphatic and cycloaliphatic polyisocyanates, among others. Representative members of these compounds comprise diisocyanates such as meta- or paraphenylene diisocyanate, toluene-2,4-diisocyanate, toluene-2,6-diisocyanate, hexamethylene-1,6-diisocyanate, tetramethylene-1,4-diisocyanate, cyclohexane-1,4-diisocyanate, hexahydrotoluene diisocyanate (and isomers), naphthylene-1,5-diisocyanate, 1-methylphenyl-2,4-phenyldiisocyanate, diphenylmethane-4,4-diisocyanate, diphenylmethane-2,4-diisocyanate, 4,4'-biphenylenediisocyanate and 3,3'-dimethoxy-4,4'-biphenylenediisocyanate and 3,3'-

dimethyldiphenylpropane-4,4-diisocyanate; triisocyanates such as toluene-2,4,6-triisocyanate and polyisocyanates such as 4,4 - dimethyldiphenylmethane-2,2,5,5-tetraisocyanate and the diverse polymethylenepoly-phenylopolyisocyanates, mixtures thereof, among
5 others.

A crude polyisocyanate may also be used in the practice of this invention, such as the crude toluene diisocyanate obtained by the phosgenating a mixture comprising toluene diamines, or the crude diphenylmethane diisocyanate obtained by the phosgenating crude
10 diphenylmethanediamine. Specific examples of such compounds comprise methylene-bridged polyphenylpolyisocyanates, due to their ability to crosslink the polyurethane.

It is often desirable to employ minor amounts of additives in preparing polyisocyanate-based foams. Among these additives comprise
15 one or more members from the group consisting of catalysts, surfactants, flame retardants, preservatives, colorants, antioxidants, reinforcing agents, filler, antistatic agents, among others well known in this art.

Depending upon the composition, a surfactant can be employed to stabilize the foaming reaction mixture while curing. Such surfactants
20 normally comprise a liquid or solid organosilicone compound. The surfactants are employed in amounts sufficient to stabilize the foaming reaction mixture against collapse and to prevent the formation of large, uneven cells. In one embodiment of this invention, about 0.1% to about 5% by weight of surfactant based on the total weight of all foaming
25 ingredients (i.e. blowing agents + active hydrogen-containing compounds + polyisocyanates + additives) are used. In another embodiment of this invention, about 1.5% to about 3% by weight of surfactant based on the total weight of all foaming ingredients are used.

One or more catalysts for the reaction of the active hydrogen-
30 containing compounds, e.g. polyols, with the polyisocyanate may be also employed. While any suitable urethane catalyst may be employed, specific catalyst comprise tertiary amine compounds and organometallic compounds. Exemplary such catalysts are disclosed, for example, in U.S. Patent No. 5,164,419, which disclosure is incorporated herein by

reference. For example, a catalyst for the trimerization of polyisocyanates, such as an alkali metal alkoxide, alkali metal carboxylate, or quaternary amine compound, may also optionally be employed herein. Such catalysts are used in an amount which measurably increases the rate of
5 reaction of the polyisocyanate. Typical amounts of catalysts are about 0.1% to about 5% by weight based on the total weight of all foaming ingredients.

In the process of the invention for making a polyisocyanate-based foam, the active hydrogen-containing compound (e.g. polyol),
10 polyisocyanate and other components are contacted, thoroughly mixed, and permitted to expand and cure into a cellular polymer. The mixing apparatus is not critical, and various conventional types of mixing head and spray apparatus are used. By conventional apparatus is meant apparatus, equipment, and procedures conventionally employed in the
15 preparation of isocyanate-based foams in which conventional isocyanate-based foam blowing agents, such as fluorotrichloromethane (CCl_3F , CFC-11), are employed. Such conventional apparatus are discussed by: H. Boden et al. in chapter 4 of the Polyurethane Handbook, edited by G. Oertel, Hanser Publishers, New York, 1985; a paper by H. Grunbauer et al. titled "Fine Celled CFC-Free Rigid Foam - New Machinery with Low
20 Boiling Blowing Agents" published in Polyurethanes 92 from the Proceedings of the SPI 34th Annual Technical/Marketing Conference, October 21-October 24, 1992, New Orleans, Louisiana; and a paper by M. Taverna et al. titled "Soluble or Insoluble Alternative Blowing Agents? Processing Technologies for Both Alternatives, Presented by the
25 Equipment Manufacturer", published in Polyurethanes World Congress 1991 from the Proceedings of the SPI/ISOPA September 24-26, 1991, Acropolis, Nice, France. These disclosures are hereby incorporated by reference.

30 In one embodiment of this invention, a preblend of certain raw materials is prepared prior to reacting the polyisocyanate and active hydrogen-containing components. For example, it is often useful to blend the polyol(s), blowing agent, surfactant(s), catalysts(s) and other foaming ingredients, except for polyisocyanates, and then contact this blend with

5 The invention composition and processes are applicable to the production of all kinds of expanded polyurethane foams, including, for example, integral skin, RIM and flexible foams, and in particular rigid closed-cell polymer foams useful in spray insulation, as pour-in-place appliance foams, or as rigid insulating board stock and laminates.

15 EXAMPLES

Polyol A is an aromatic polyester polyol (Stepanpol PS2502-A) purchased from STEPAN Inc. at 22W Frontage Road, Northfield, IL 60093. Polyol A has viscosity of 3,000 centerpoise at 25 °C. The content of hydroxyl groups in Polyol A is equivalent to 240 mg KOH per gram of Polyol A.

Polyol C is a toluene diamine (o-TDA) initiated aromatic polyether polyol (VORANOL 391) purchased from Dow Chemicals Inc. at Midland,

MI, 49641-1206. Polyol C has viscosity of 4740 centipoise at 25 °C. The content of hydroxyl groups in Polyol C is equivalent to 391 mg KOH per gram of Polyol C.

Silicon type surfactant is a mixture of 70%

- 5 polyalkyleneoxidemethylsiloxane and 30% polyalkylene oxide (Niax Silicone L-5440) purchased from Momentive Performance Materials at 187 Danbury Road, Wilton, CT 06897 USA.

- Amine catalyst (Polycat 8) is N,N-dimethylcyclohexylamine purchased from Air Products Inc. at 7201 Hamilton Blvd, Allentown PA
10 18195.

Co-catalyst (Curithane 52) is 2-methyl(n-methyl amino b-sodium acetate nonyl phenol) purchased from Air Products Inc. at 7201 Hamilton Blvd, Allentown PA 18195.

- Polymethylene polyphenyl isocyanate (PAPI 27) is purchased from
15 Dow Chemicals, Inc. at Midland, MI, 49641-1206.

Initial R-value is measured by a LaserComp FOX 304 Thermal Conductivity Meter at a mean temperature of 75 °F. The unit of R-value is ft²-hr-°F/BTU-in.

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EXAMPLE 1

Compatibility Test

- The polyol - blowing agent (cis-1,1,1,4,4,4-hexafluoro-2-butene) compatibility test was performed in a 3 OZ aerosol sealed glass vessels manufactured by Aerotech Lab. 50 grams of polyol were loaded into the
25 glass vessel. The glass vessel was then sealed at room temperature under atmospheric pressure. Before adding cis-1,1,1,4,4,4-hexafluoro-2-butene into polyol, the glass vessel containing 50 grams of polyol was kept at 25±2 °C for 15 minutes and was visually confirmed for clear appearance. Cis-1,1,1,4,4,4-hexafluoro-2-butene was then injected to the
30 glass vessel at 2.5 (5 wt % based on weight of polyol) grams increment. After each injection, the vessel was shaken for 15 minutes to insure the complete mixing. The vessel was then kept at 25±2 °C for 15 minutes and visually checked for separation and/or emulsion. The above steps were

repeated until stable emulsion or separation was observed, or a total of 30 grams (60 wt % based on weight of polyol) of cis-1,1,1,4,4,4-hexafluoro-2-butene was added.

The test indicated that Polyol B had good compatibility with cis-1,1,1,4,4,4-hexafluoro-2-butene, remaining clear in appearance without any sign of emulsion or separation after a total of 30 grams (60 wt % based on weight of polyol) of cis-1,1,1,4,4,4-hexafluoro-2-butene was injected. Polyol A had poor compatibility with cis-1,1,1,4,4,4-hexafluoro-2-butene, showing a stable emulsion after a total of 12.5 grams (25 wt % based on weight of polyol) of cis-1,1,1,4,4,4-hexafluoro-2-butene was injected. Polyol C also had poor compatibility with cis-1,1,1,4,4,4-hexafluoro-2-butene, showing a phase separation from the blowing agent after a total of 2.5 grams (5 wt % based on weight of polyol) of cis-1,1,1,4,4,4-hexafluoro-2-butene was injected.

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EXAMPLE 2

Polyurethane Foam Made from Highly Compatible

Polyether Polyol (Polyol B)

Polyol B, surfactant, catalyst, water and cis-1,1,1,4,4,4-hexafluoro-2-butene were pre-mixed by hand and then mixed with polyisocyanate. The resulting mixture was poured into a 8"x8"x2.5" paper box to form the polyurethane foam. The formulation and properties of the foam are shown in Tables 1 and 2 below.

Table 1 Polyurethane formulation - Polyol B

Component	Parts by weight
Polyol B	100
Silicon type surfactant	2.0
Amine catalyst	1.5
Co-catalyst	0.5
Water	1.0
Cis-1,1,1,4,4,4-hexafluoro-2-butene blowing agent	29.4
Polymethylene polyphenyl isocyanate	123

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Table 2. Polyurethane foam properties – Polyol B

Foam Index	1.22
Cream time(second)	15
Rise time (seconds)	220
Tack free time(seconds)	240
Foam density (pounds-per-cubic-feet)	2.2
Initial R-value (ft ² -hr-°F/BTU-in)	6.9

EXAMPLE 3Polyurethane Foam Made from the Foam-Forming Composition5 Containing Poorly Compatible Polyether Polyol (Polyol C)

Polyurethane foam was made using polyol C in the same way as described in Example 2. The polyurethane formulation and properties are shown in Tables 3 and 4 below. By using a foam-forming composition comprising cis-1,1,1,,4,4,4-hexafluoro-2-butene and a poorly compatible polyol(Polyol C), the R-value of the foam was improved from 6.9 of
10 Example 2 to 7.2.

Table 3 Polyurethane formulation - Polyol C

Component	Parts by weight
Polyol C	100
Silicon type surfactant	2.0
Aminecatalyst	1.5
Co-catalyst	0.5
Water	1.0
Cis-1,1,1,4,4,4-hexafluoro-2-butene blowing agent	29.4
Polymethylene polyphenyl isocyanate	132

Table 4. Polyurethane foam properties – Polyol C

Foam Index	1.22
Cream time(second)	9
Rise time (seconds)	105
Tack free time(seconds)	105
Foam density (pounds-per-cubic-feet)	2.1
Initial R-value (ft ² -hr-°F/BTU-in)	7.2

EXAMPLE 4

5 Use of Foam-forming Composition to Improve Polyurethane Foam Made
 from a Highly Compatible Polyol B

Poorly compatible polyester (polyol A) and polyether polyols (Polyol C) was added to the formulation containing highly compatible polyol B as described in Example 2. Incorporating the poorly compatible polyol A and
 10 C into the foam-forming composition of Example 2 improved R-value from 6.9 of Example 2 to 7.4. The polyurethane formulation and properties are shown in Tables 5 and 6 below.

Table 5 Polyurethane formulation using polyol A, B and C

Component	Parts by weight
Polyol A	25
Polyol B	55
Polyol C	20
Silicon type surfactant	2.0
Aminecatalyst	1.5
Co-catalyst	0.5
Water	1.0
Cis-1,1,1,4,4,4-hexafluoro-2-butene blowing agent	29.4
Polymethylene polyphenyl isocyanate	117

Table 6. Polyurethane foam properties (Polyols A,B and C)

Foam Index	1.22
Cream time(second)	9
Rise time (seconds)	90
Tack free time(seconds)	120
Foam density (pounds-per-cubic-feet)	2.3
Initial R-value (ft ² -hr-°F/BTU-in)	7.4

EXAMPLE 5

5 Polyurethane Foam Made Using the Foam-Forming Composition
 Containing Poorly Compatible Polyols A and C

 Polyurethane foam was made in the same way as described in
 Example 2 using poorly compatible polyether polyol (Polyol C) and poorly
 compatible polyester polyol (Polyol A). The polyurethane formulation and
 10 properties are shown in Tables 7 and 8 below. The foam-forming
 composition produced polyurethane foam with R-value of 7.8, compared to
 6.9 from the foam made using highly compatible polyether polyol(Polyol B)

Table 7 Polyisocyanurate formulation - Polyol A and C

Component	Parts by weight
Polyol A	80
Polyol C	20
Silicon type surfactant	2.0
Aminecatalyst	1.5
Co-catalyst	0.5
Water	1.0
Cis-1,1,1,4,4,4-hexafluoro-2-butene blowing agent	29.4
Polymethylene polyphenyl isocyanate	99

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Table 8. Polyisocyanurate foam properties – Polyol A and C

Foam Index	1.22
Cream time(second)	8
Rise time (seconds)	60
Tack free time(seconds)	60
Foam density (pounds-per-cubic-feet)	2.4
Initial R-value (ft ² -hr-°F/BTU-in)	7.8

Where the terms “comprise”, “comprises”, “comprised” or “comprising” are used in this specification, they are to be interpreted as specifying the presence of the stated features, integers, steps or components referred to, but not to preclude the presence or addition of one or more other feature, integer, step, component or group thereof.

Further, any prior art reference or statement provided in the specification is not to be taken as an admission that such art constitutes, or is to be understood as constituting, part of the common general knowledge in Australia.

The Claims defining the invention are as follows:

- 5 1. A foam-forming composition comprising cis-1,1,1,4,4,4-hexafluoro-2-butene and a poorly compatible active hydrogen-containing compound having two or more active hydrogens, wherein said poorly compatible active hydrogen-containing compound having two or more active hydrogens is a polyether polyol and a highly compatible active hydrogen-containing compound having two or more active hydrogens.
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2. The foam-forming composition of claim 2 wherein said highly compatible active hydrogen-containing compound is a polyol.
3. The foam-forming composition of claim 3 wherein said highly compatible active hydrogen-containing compound is a polyether polyol.
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4. A closed-cell polyurethane or polyisocyanurate polymer foam prepared from reaction of effective amounts of the foam-forming composition of any one of claims 1 to 3 and a suitable polyisocyanate.
- 20 5. The closed-cell polyurethane or polyisocyanurate polymer foam of claim 5 wherein said polymer foam has an initial R-value greater than $6.5 \text{ ft}^2\text{-hr-}^\circ\text{F/BTU-in.}$
- 25 6. A process for producing a closed-cell polyurethane or polyisocyanurate polymer foam comprising: reacting an effective amount of the foam-forming composition of any one of claims 1 to 3 and a suitable polyisocyanate.

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