

Low speed cross-linking catalyst for silane-grafted plastomers

Field of the invention

The present invention is concerned with silane crosslinking catalysts for crosslinking grafted plastomers to be used as EPDM replacements.

5 Background of the invention

EPDM is mostly used rubber in sealing applications. Generally speaking, EPDM is a very versatile material. However, the handling and processing of EPDM requires many steps and is labour and energy intensive process. This is one reason why there is interest for polyolefin based rubbery materials. Soft, cross-linkable polymers can indeed be used in many applications instead of EPDM or other classical rubbers. Immediate applications for those polyolefins based rubbery materials can be found on the automotive and building industry. The relatively complex production process of EPDM is also very challenging for guaranteeing absence of production related variations.

One way of controlling the properties of polyolefin-derived plastomers is to graft polyolefins with silanes in a first step and cross-link the grafted products using a condensation catalyst in a second step. In the second step, the silane-grafted polymer is subjected to a silanol forming condensation catalyst and then exposed to humidity and/or heat to effect crosslinking. The crosslinking then takes place via formation of backbone-Si-O-Si-backbone' bonds. The provision of the grafted plastomer is a two-step process; i.e. the plastomer is polymerised first and grafted in a second processing step.

In automotive applications, the required extreme reliability in very long term asks for decreased process related variation. This is particularly true for all fluid transfer systems, i.e. usually hoses in automotive applications. In addition to that, there is an increasing demand in the automotive field for low weight components, including also low weight fluid transfer systems, such as low weight hoses.

Moreover, silane crosslinking catalysts as known in the art suffer from the opportunities of controlling reaction rate upon the industrial needs. For example, car manufactures ask for crosslinking catalysts that allow very low curing speeds at room temperatures for 2 or even 4 days but allow achieving full curing within a maximum of 20 minutes at 140°C or full curing within 10 minutes at similar temperature at elevated pressure. It is the object of the present invention to address these needs.

Summary of the invention

The present invention is based on the finding that excellent EPDM replacement is possible by grafting a polyolefin with alkoxy silane groups and crosslinking the grafted intermediate with a specific catalyst. The present invention is further based on the finding that the needs for
5 controlling the crosslinking reaction rates can be met by a specific crosslinking catalyst.

The present invention insofar provides a silane crosslinking catalyst comprising

- 75 to 85 wt.-% of an olefin acrylate interpolymers and
- 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a
10 number average molecular weight M_n of 1500 to 4000 g/mol; and
- optionally up to 5 wt.-% wax,

wherein the silane crosslinking catalyst is free of tin, carboxylic acid(s) and
sulphonic acid(s),

all weight percentages with respect to the total weight of the silane
crosslinking catalyst.

15 The present invention further provides
a crosslinkable formulation comprising

(1) a grafted ethylene alpha olefin plastomer comprising silane crosslinker in an
amount of 1.0 to 10.0 wt.-% with respect to the grafted ethylene alpha olefin
plastomer, wherein the grafted ethylene alpha olefin plastomer is obtained by

- 20 - grafting an ethylene alpha olefin plastomer
and/or
- grafting a plastomer having a density of from 850 kg/m³ to 870 kg/m³
and/or
- 25 - grafting a plastomer having a melt flow rate (ISO 1133, 2.16kg, 190°C)
of 0.40 to 1.5 g/10min

(2) and a silane crosslinking catalysts comprising

- 5
- 75 to 85 wt.-% of an olefin acrylate interpolymers and
 - 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight M_n of 1500 to 4000 g/mol; and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid(s) and sulphonic acid(s),

all weight percentages with respect to the total weight of the silane crosslinking catalyst.

In a further aspect, the present invention provides

- 10 a process of crosslinking an ethylene alpha olefin plastomer, the process comprising the steps of

(a) providing an ethylene alpha olefin plastomer having one or more of the following characteristics:

- 15
- being an ethylene octene plastomer;
 - having a density of from 850 kg/m³ to 870 kg/m³;
 - having an melt flow rate (ISO 1133, 2.16kg, 190°C) of 0.40 to 1.5 g/10min;

(b) grafting the ethylene alpha olefin plastomer and thereby providing a grafted ethylene alpha olefin plastomer such that the content of silane cross-linker is in an amount of 0.1 to 10.0 wt.-% with respect to the grafted ethylene alpha olefin plastomer;

20

(c) contacting said grafted ethylene alpha olefin plastomer with a silane crosslinking catalyst comprising

- 25
- 75 to 85 wt.-% of an olefin acrylate interpolymers and
 - 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight M_n of 1500 to 4000 g/mol; and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid and sulphonic acid;

all weight percentages with respect to the total weight of the silane crosslinking catalyst

5 at a temperature sufficient for at least partial crosslinking, thereby providing an at least partially crosslinked ethylene alpha olefin plastomer.

In yet a further aspect, the present invention provides a process for providing a fluids transport product comprising the steps of

- 10 (a) providing a grafted ethylene alpha olefin plastomer having a content of silane crosslinker of 0.1 to 10.0 wt.-% with respect to the grafted ethylene alpha olefin plastomer;
(b) extruding said grafted ethylene alpha olefin plastomer into a tubular structure

in the presence of a silane crosslinking catalyst comprising

- 15 - 75 to 85 wt.-% of an olefin acrylate interpolymers and
- 15 to 25 wt.-% of a hindered amine light stabilizer (HALS)
having a number average molecular weight M_n of 1500 to 4000 g/mol; and
- optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid and sulphonic acid,

20 all weight percentages with respect to the total weight of the silane crosslinking catalyst;

- 25 (c) optionally reinforcing the tubular structure by fabric and further optionally covering the fabric with the same or a different grafted ethylene alpha olefin plastomer also having a content silane crosslinker of 0.1 to 10.0 wt.-%;
(d) optionally labelling the outer surface;
(e) optionally fixing the labelling if present by using UV rays;
(f) washing the structure obtained;
(g) cutting the structure into semi-finished products

- (h) maintaining the semi-finished products at a temperature of from 10 to 25 °C and relative humidity of from up to 60 %;
- (i) placing the semi-finished products on shaped mandrels;
- (j) subjecting the semi-finished products placed on the shaped mandrels to curing by increasing temperature and optionally increasing pressure, and further optionally increasing relative humidity thereby obtaining cured semi-finished fluids transport products having a predetermined shape;
- (k) optionally washing and further optionally trimming the cured semi finished fluids transport products to yield the fluids transport products.

A silane crosslinking catalyst is a catalyst promoting the hydrolysis of the silicium alkoxy groups to silicium hydroxyl groups and subsequently the formation of intermolecular, irreversible Si-O-Si crosslink sites.

- 15 Olefin acrylate interpolymer stands for ethylene acrylate copolymer, ethylene acrylate terpolymer, ethylene acrylate quaterpolymer, i.e. a polymer containing units derived from ethylene and acrylate containing olefin(s), whereby the number of different acrylate containing olefin(s) can be higher than 1.

Wax denotes an organic compound that melts within the temperature range of 35°C to 65°C without deterioration.

- 20 Butylated reaction products of p-cresol and dicyclopentadiene are well known in the art and are frequently used as antioxidants for rubber products.

Ethylene- α -olefin plastomer

Plastomer denotes a polymer material that combines qualities of elastomers and plastics.

- 25 The optional ethylene- α -olefin plastomer may have a density in the range of from 860 to 900 kg/m³, preferably in the range of from 865 to 895 kg/m³ and more preferably in the range of from 870 to 890 kg/m³.

The MFR2 (190°C/2.16kg) measured according to ISO 1133 of the optional ethylene- α -olefin plastomer is in the range of from 0.5 to 50.0 g/10min, preferably in the range

of from 0.8 to 45.0 g/10min and more preferably in the range of from 1.0 to 35.0 g/10min.

Suitable ethylene-based plastomers may have an ethylene content from 60.0 to 95.0 wt%, preferably from 65.0 to 90.0 wt% and more preferably from 70.0 to 88.0 wt%.

- 5 The comonomer contribution preferably is up to 40.0 wt%, more preferably up to 35.0 wt%. The comonomer contents of conventional ethylene plastomers are familiar to the person skilled in the art.

- 10 The ethylene-based plastomer may be a copolymer of ethylene and propylene or a C4 -C10 alpha-olefin. Suitable C4 - C10 alpha-olefins include 1-butene, 1-hexene and 1-octene, preferably 1-butene or 1-octene and more preferably 1-octene. Preferably, copolymers of ethylene and 1-octene are used.

- 15 The melting points (measured with DSC according to ISO 11357-3:1999) of suitable ethylene based plastomers can be below 130°C, preferably below 120°C, more preferably below 110°C and most preferably below 100°C. A reasonable lower limit for the melting points of suitable ethylene based plastomers may be 30°C. A typical melting point range is from 33 to 115°C.

Furthermore suitable ethylene based plastomers may have a glass transition temperature T_g (measured by DMTA according to ISO 6721-7) of below -40°C, preferably below -54°C, more preferably below -58°C.

- 20 The M_w/M_n value of the ethylene based plastomer, representing the broadness of the molecular weight distribution (MWD), is preferably in the range of from 1.5 to 5.0, more preferably in the range of from 2.0 to 4.5, even more preferably in the range of from 2.5 to 4.0.

The ethylene-based plastomer can be unimodal or multimodal, preferably unimodal. 25

Preferably, the PE plastomer is a metallocene catalysed polymer although Ziegler-Natta based polyethylene plastomers are also possible.

Suitable ethylene based plastomers can be any copolymer of ethylene and propylene or ethylene and C4 - C10 alpha olefin having the above defined properties, which are commercial available, i.e. from Borealis AG (AT) under the tradename Queo, from

DOW Chemical Corp (USA) under the tradename Engage or Affinity, or from Mitsui under the tradename Tafmer.

Alternatively, the ethylene based plastomer can be prepared by known processes, in a one stage or two stage polymerization process, comprising solution polymerization, 5 slurry polymerization, gas phase polymerization or combinations therefrom, in the presence of suitable catalysts, like vanadium oxide catalysts or single-site catalysts, e.g. metallocene or constrained geometry catalysts, known to the art skilled persons.

Preferably, these ethylene-based plastomers are prepared by a one stage or two-stage solution polymerization process, especially by high temperature solution 10 polymerization process at temperatures higher than 100°C.

Such processes are essentially based on polymerizing the monomer and a suitable comonomer in a liquid hydrocarbon solvent in which the resulting polymer is soluble. The polymerization is carried out at a temperature above the melting point of the polymer, as a result of which a polymer solution is obtained. This solution is flashed 15 in order to separate the polymer from the unreacted monomer and the solvent. The solvent is then recovered and recycled in the process.

Preferably, the solution polymerization process is a high temperature solution polymerization process, using a polymerization temperature of higher than 100°C. Preferably, the polymerization temperature is at least 110°, more preferably at least 20 150°C. The polymerization temperature can be up to 250°C.

The pressure in such a solution polymerization process is preferably in a range of 10 to 100 bar, preferably 15 to 100 bar and more preferably 20 to 100 bar.

The liquid hydrocarbon solvent used is preferably a C5-12-hydrocarbon which may be unsubstituted or substituted by a C1-4 alkyl group such as pentane, methyl 25 pentane, hexane, heptane, octane, cyclohexane, methylcyclohexane and hydrogenated naphtha. More preferably, unsubstituted C6-10-hydrocarbon solvents are used.

Fluids transport product denotes any article being suitable for transporting fluids.

Hose denotes a flexible tube for conveying a liquid or a gas. In contrast to pipes, hoses show flexibility during conventional use conditions.

Fluid transport products denotes fluid transport products other than hoses such as fittings or pipes.

- 5 The present invention allows adaptation of the crosslinking rates according to the industrial need of the final applications. In other words, the silane crosslinking catalysts according to the present invention are extremely versatile and can particularly promote both very low curing speed at room temperature and high curing speed when high temperature, maybe further combined with water bath are applied.
- 10 The final articles, particularly hoses and fluid transfer systems also qualify by good surface finish, shore A hardness, compression set, tear strength and long-term heat aging even at elevated temperatures of $\sim 175^{\circ}\text{C}$.

Silane Crosslinker

A silane crosslinker can be used to covalently graft silane moieties onto the first and 15 second polyolefins and the silane crosslinker may include alkoxysilanes, silazanes, siloxanes, or a combination thereof. The grafting and/or coupling of the various potential silane crosslinkers or silane crosslinker molecules is facilitated by the reactive species formed by the grafting initiator reacting with the respective silane crosslinker.

- 20 In some aspects, the silane crosslinker is a silazane where the silazane may include, for example, hexamethyldisilazane (HMDS) or Bis(trimethylsilyl)amine. In some aspects, the silane crosslinker is a siloxane where the siloxane may include, for example, polydimethylsiloxane (PDMS) and octamethylcyclotetrasiloxane.

- In some aspects, the silane crosslinker is an alkoxysilane. As used herein, the term 25 "alkoxysilane" refers to a compound that comprises a silicon atom, at least one alkoxy group and at least one other organic group, wherein the silicon atom is bonded with the organic group by a covalent bond. Preferably, the alkoxysilane is selected from alkylsilanes; acryl-based silanes; vinyl-based silanes; aromatic silanes; epoxy-based silanes; amino-based silanes and amines that possess —NH_2 , —NHCH_3 or $\text{—N(CH}_3)_2$; ureide-based silanes; mercapto-based silanes; and 30

alkoxysilanes which have a hydroxyl group (i.e., —OH). An acryl-based silane may be selected from the group comprising beta-acryloxyethyl trimethoxysilane; beta-acryloxy propyl trimethoxysilane; gamma-acryloxyethyl trimethoxysilane; gamma-acryloxypropyl trimethoxysilane; beta-acryloxyethyl triethoxysilane; beta-acryloxypropyl triethoxysilane; gamma-acryloxyethyl triethoxysilane; gamma-acryloxypropyl triethoxysilane; beta-methacryloxyethyl trimethoxysilane; beta-methacryloxypropyl trimethoxysilane; gamma-methacryloxyethyl trimethoxysilane; gamma-methacryloxypropyl trimethoxysilane; beta-methacryloxyethyl triethoxysilane; beta-methacryloxypropyl triethoxysilane; gamma-methacryloxyethyl triethoxysilane; gamma-methacryloxypropyl triethoxysilane; 3-methacryloxypropylmethyl diethoxysilane. A vinyl-based silane may be selected from the group comprising vinyl trimethoxysilane; vinyl triethoxysilane; p-styryl trimethoxysilane, methylvinyl dimethoxysilane, vinyl dimethylmethoxysilane, divinyl dimethoxysilane, vinyltris(2-methoxyethoxy)silane, and vinylbenzylethylenediaminopropyltrimethoxysilane. An aromatic silane may be selected from phenyltrimethoxysilane and phenyltriethoxysilane. An epoxy-based silane may be selected from the group comprising 3-glycidoxypropyl trimethoxysilane; 3-glycidoxypropylmethyl diethoxysilane; 3-glycidoxypropyl triethoxysilane; 2-(3,4-epoxycyclohexyl)ethyl trimethoxysilane, and glycidyl oxypropylmethyl dimethoxysilane. An amino-based silane may be selected from the group comprising 3-aminopropyl triethoxysilane; 3-aminopropyl trimethoxysilane; 3-aminopropyl dimethyl ethoxysilane; 3-aminopropylmethyl diethoxysilane; 4-aminobutyl triethoxysilane; 3-aminopropyl diisopropyl ethoxysilane; 1-amino-2-(dimethylethoxysilyl)propane; (aminoethylamino)-3-isobutyl dimethyl methoxysilane; N-(2-aminoethyl)-3-aminoisobutylmethyl dimethoxysilane; (aminoethylaminomethyl)phenetyl trimethoxysilane; N-(2-aminoethyl)-3-aminopropylmethyl dimethoxysilane; N-(2-aminoethyl)-3-aminopropyl trimethoxysilane; N-(2-aminoethyl)-3-aminopropyl triethoxysilane; N-(6-aminoethyl)aminomethyl trimethoxysilane; N-(6-aminoethyl)aminopropyl trimethoxysilane; N-(2-aminoethyl)-1,1-aminoundecyl trimethoxysilane; 1,1-aminoundecyl triethoxysilane; 3-(m-aminophenoxy)propyl trimethoxysilane; m-aminophenyl trimethoxysilane; p-aminophenyl trimethoxysilane; (3-trimethoxysilylpropyl)diethylenetriamine; N-methylaminopropylmethyl dimethoxysilane; N-methylaminopropyl trimethoxysilane; dimethylaminomethyl ethoxysilane; (N,N-dimethylaminopropyl)trimethoxysilane; (N-acetylglucosyl)-3-

aminopropyl trimethoxysilane, N-phenyl-3-aminopropyltrimethoxysilane, N-phenyl-3-aminopropyltriethoxysilane, phenylaminopropyltrimethoxysilane, aminoethylaminopropyltrimethoxysilane, and aminoethylaminopropylmethyldimethoxysilane. An ureide-based silane may be 3-ureidepropyl triethoxysilane. A mercapto-based silane may be selected from the group comprising 3-mercaptopropylmethyl dimethoxysilane, 3-mercaptopropyl trimethoxysilane, and 3-mercaptopropyl triethoxysilane. An alkoxysilane having a hydroxyl group may be selected from the group comprising hydroxymethyl triethoxysilane; N-(hydroxyethyl)-N-methylaminopropyl trimethoxysilane; bis(2-hydroxyethyl)-3-aminopropyl triethoxysilane; N-(3-triethoxysilylpropyl)-4-hydroxy butylamide; 1,1-(triethoxysilyl)undecanol; triethoxysilyl undecanol; ethylene glycol acetal; and N-(3-ethoxysilylpropyl)gluconamide.

In some aspects, the alkylsilane may be expressed with a general formula: $R_nSi(OR')^{4-n}$ wherein: n is 1, 2 or 3; R is a C1-20 alkyl or a C2-20 alkenyl; and R' is an C1-20 alkyl. The term "alkyl" by itself or as part of another substituent, refers to a straight, branched or cyclic saturated hydrocarbon group joined by single carbon-carbon bonds having 1 to 20 carbon atoms, for example 1 to 10 carbon atoms, for example 1 to 8 carbon atoms, preferably 1 to 6 carbon atoms. When a subscript is used herein following a carbon atom, the subscript refers to the number of carbon atoms that the named group may contain. Thus, for example, C1-6 alkyl means an alkyl of one to six carbon atoms. Examples of alkyl groups are methyl, ethyl, propyl, isopropyl, butyl, isobutyl, sec-butyl, t-butyl, 2-methylbutyl, pentyl, iso-amyl and its isomers, hexyl and its isomers, heptyl and its isomers, octyl and its isomer, decyl and its isomer, dodecyl and its isomers. The term "C2-20 alkenyl" by itself or as part of another substituent, refers to an unsaturated hydrocarbyl group, which may be linear, or branched, comprising one or more carbon-carbon double bonds having 2 to 20 carbon atoms. Examples of C2-6 alkenyl groups are ethenyl, 2-propenyl, 2-butenyl, 3-butenyl, 2-pentenyl and its isomers, 2-hexenyl and its isomers, 2,4-pentadienyl and the like.

In some aspects, the alkylsilane may be selected from the group comprising methyltrimethoxysilane; methyltriethoxysilane; ethyltrimethoxysilane; ethyltriethoxysilane; propyltrimethoxysilane; propyltriethoxysilane; hexyltrimethoxysilane; hexyltriethoxysilane; octyltrimethoxysilane; octyltriethoxysilane; decyltrimethoxysilane; decyltriethoxysilane;

dodecyltrimethoxysilane; dodecyltriethoxysilane; tridecyltrimethoxysilane;
dodecyltriethoxysilane; hexadecyltrimethoxysilane; hexadecyltriethoxysilane;
octadecyltrimethoxysilane; octadecyltriethoxysilane, trimethylmethoxysilane,
methylhydrodimethoxysilane, dimethyldimethoxysilane, diisopropyldimethoxysilane,
5 diisobutyldimethoxysilane, isobutyltrimethoxysilane, n-butyltrimethoxysilane, n-
butylmethyldimethoxysilane, phenyltrimethoxysilane, phenyltrimethoxysilane,
phenylmethyldimethoxysilane, triphenylsilanol, n-hexyltrimethoxysilane, n-
octyltrimethoxysilane, isooctyltrimethoxysilane, decyltrimethoxysilane,
hexadecyltrimethoxysilane, cyclohexylmethyldimethoxysilane,
10 cyclohexylethyldimethoxysilane, dicyclopentyldimethoxysilane, tert-
butylethyldimethoxysilane, tert-butylpropyldimethoxysilane,
dicyclohexyldimethoxysilane, and a combination thereof.

In some aspects, the alkylsilane compound may be selected from
triethoxyoctylsilane, trimethoxyoctylsilane, and a combination thereof.

15 Additional examples of silanes that can be used as silane crosslinkers include, but
are not limited to, those of the general formula $\text{CH}_2=\text{CR}-(\text{COO})_x(\text{C}_n\text{H}_{2n})_y\text{SiR}'_3$,
wherein R is a hydrogen atom or methyl group; x is 0 or 1; y is 0 or 1; n is an integer
from 1 to 12; each R' can be an organic group and may be independently selected
from an alkoxy group having from 1 to 12 carbon atoms (e.g., methoxy, ethoxy,
20 butoxy), aryloxy group (e.g., phenoxy), araloxy group (e.g., benzyloxy), aliphatic
acyloxy group having from 1 to 12 carbon atoms (e.g., formyloxy, acetyloxy,
propanoyloxy), amino or substituted amino groups (e.g., alkylamino, arylamino), or a
lower alkyl group having 1 to 6 carbon atoms. x and y may both equal 1. In some
aspects, no more than one of the three R' groups is an alkyl. In other aspects, not
25 more than two of the three R' groups is an alkyl.

Any silane or mixture of silanes known in the art that can effectively graft to and
crosslink an olefin polymer can be used in the practice of the present disclosure. In
some aspects, the silane crosslinker can include, but is not limited to, unsaturated
silanes which include an ethylenically unsaturated hydrocarbyl group (e.g., a vinyl,
30 allyl, isopropenyl, butenyl, cyclohexenyl or a gamma-(meth)acryloxy allyl group) and
a hydrolyzable group (e.g., a hydrocarbyloxy, hydrocarbonyloxy, or hydrocarbylamino
group). Non-limiting examples of hydrolyzable groups include, but are not limited to,
methoxy, ethoxy, formyloxy, acetoxo, propionyloxy, and alkyl, or arylamino groups.

In other aspects, the silane crosslinkers are unsaturated alkoxy silanes which can be grafted onto the polymer. In still other aspects, additional exemplary silane crosslinkers include vinyltrimethoxysilane, vinyltriethoxysilane, 3-(trimethoxysilyl)propyl methacrylate gamma-(meth)acryloxypropyl trimethoxysilane), and mixtures thereof.

The silane crosslinker may be present in the silane-grafted polyolefin elastomer in an amount of from greater than 0.1 wt % to about 10 wt %, including from about 0.5 wt % to about 5 wt %. The amount of silane crosslinker may be varied based on the nature of the olefin polymer, the silane itself, the processing conditions, the grafting efficiency, the application, and other factors. In still other aspects, the silane crosslinker content is at least 1% based on the weight of the reactive composition.

Cross-linking catalyst

The crosslinking catalyst according to the present invention preferably contains 80 to 84 wt.-% olefin acrylate interpolymers.

The crosslinking catalyst according to the present invention may preferably contain the hindered amine light stabilizer (HALS) in an amount of 15 to 20 wt.-%.

The hindered amine light stabilizer (HALS) may be a single hindered amine light stabilizer (HALS) component or a mixture of two or more hindered amine light stabilizers (HALS) components.

The amount of optional wax in the silane crosslinking catalyst according to the present invention is preferably from 0.5 to 2.0 wt.-%.

The hindered amine light stabilizer (HALS) preferably has a number average molecular weight M_n in the range of 2000 to 3100 g/mol. Such hindered amine light stabilizers are commercially available. As an example, attention is drawn to Chimassorb 944.

The olefin acrylate interpolymers according to the present invention is preferably selected from the group of ethylene butyl acrylate (EBA), ethylene ethyl acrylate (EEA) and ethyl methyl acrylate (EMA). Ethylene butyl acrylate (EBA) is particularly

preferred. As a matter of definition olefin acrylate interpolymers also include mixtures thereof.

Moreover, the olefin acrylate interpolymers according to the present invention preferably have a MFR (2.16 kg, ISO1133) of 3.0 to 15 g/10min.

- 5 The hindered amine light stabilizer (HALS) as contained in the silane crosslinking catalyst according to the present invention preferably has a melting temperature of at least 95°C, more preferably from 100 to 135°C.

In yet a further aspect, the wax is more preferably present in an amount of 0.5 to 1.4 wt.-% with respect to the total weight of the silane crosslinking catalyst.

- 10 The silane crosslinking catalyst according to the present invention preferably does not contain a butylated reaction product of p-cresol and dicyclopentadiene. Such antioxidants have a tendency not to properly disperse.

- 15 In yet a further aspect, the silane crosslinking catalyst according to the present invention preferably shall not contain an alkylalkoxysilane, particularly shall not contain alkylalkoxysilane such as for example hexadecyltrimethoxysilane.

- 20 In the silane crosslinking catalyst according to the present invention the olefin acrylate interpolymers preferably are ethylene butyl acrylate (EBA) having a content of butylate groups $\text{O-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$ of 15 to 20 wt.-% with respect to the total ethylene butyl acrylate (EBA). Most preferably EBA is the only acrylate being present.

As mentioned above olefin acrylate interpolymers according to the present invention preferably have a MFR (2.16 kg, ISO1133, 190°C) of 3.0 to 15 g/10min, more preferably 5.0 to 10.0 g/10min (ISO1133, 2.16 kg load, 190°C).

- 25 The present invention is further concerned with a crosslinkable formulation comprising the silane crosslinking catalysts as described above. All preferred aspects as described herein with respect to the silane crosslinking catalysts shall also hold for the crosslinkable formulation comprising the silane crosslinking catalysts.

Particularly the present invention is concerned with a formulation comprising

5 (1) a grafted ethylene alpha olefin plastomer containing silane cross-linker in an amount of 0.1 to 10.0 wt.-% with respect to the grafted ethylene alpha olefin plastomer, wherein the grafted ethylene alpha olefin plastomer is obtained by

- grafting an ethylene octene plastomer

and/or

- grafting a plastomer having a density of from 850 kg/m³ to 870 kg/m³

and/or

10 - grafting a plastomer having an melt flow rate (ISO 1133, 2.16kg, 190°C) of 0.40 to 1.5 g/10min; and

(2) a silane crosslinking catalysts comprising

15 - 75 to 85 wt.-% of an olefin acrylate interpolymers and
- 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight M_n of 1500 to 4000 g/mol; and
- optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid(s) and sulphonic acid(s),

all weight percentages with respect to the total weight of the silane crosslinking catalyst.

20 In a preferred aspect, the grafted ethylene alpha olefin plastomer is preferably obtained by grafting an ethylene octene plastomer having a density of from 850 kg/m³ to 870 kg/m³ and further having an melt flow rate (ISO 1133, 2.16kg, 190°C) of 0.40 to 1.5 g/10min.

25 The grafted ethylene alpha olefin plastomer preferably contains silane crosslinker in an amount of 1.4 to 2.3 wt.-% with respect to the grafted ethylene alpha olefin plastomer.

Suitable ethylene alpha olefin plastomers to be used as reactants in the grafting step are commercially available and well known in the art.

In yet a further aspect, the present invention provides a process of crosslinking an ethylene alpha olefin plastomer, the process comprising the steps of

- 5 (a) providing an ethylene alpha olefin plastomer having one or more of the following characteristics:
- 10 - being an ethylene octene plastomer;
 - having a density of from 850 kg/m³ to 870 kg/m³;
 - having an melt flow rate (ISO 1133, 2.16kg, 190°C) of 0.40 to 1.5 g/10min;
- (b) grafting the ethylene alpha olefin plastomer and thereby providing a grafted ethylene alpha olefin plastomer such that the content of silane crosslinker is in an amount of 0.1 to 10 wt.-% with respect to the grafted ethylene alpha olefin plastomer;
- 15 (c) contacting said grafted ethylene alpha olefin plastomer with a silane crosslinking catalyst comprising
- 20 - 75 to 85 wt.-% of an olefin acrylate interpolymers and
 - 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight Mn of 1500 to 4000 g/mol;
 and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid and sulphonic acid;
- all weight percentages with respect to the total weight of the silane crosslinking catalyst
- 25 at a temperature sufficient for at least partial crosslinking, thereby providing an at least partially crosslinked ethylene alpha olefin plastomer.

All preferred ranges and aspects as disclosed for the silane crosslinking catalyst or the plastomer shall also hold for the process.

In yet a further embodiment, the present invention provides a process for providing a fluids transport product comprising the steps of

- 5
- (a) providing a grafted ethylene alpha olefin plastomer having a content of silane crosslinker of 0.1 to 10 wt.-% with respect to the grafted ethylene alpha olefin plastomer;
- (b) extruding said grafted ethylene alpha olefin plastomer into a tubular structure
- 10
- in the presence of a silane crosslinking catalyst comprising
- 75 to 85 wt.-% of an olefin acrylate interpolymers and
 - 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight M_n of 1500 to 4000 g/mol; and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid and sulphonic acid,
- 15
- all weight percentages with respect to the total weight of the silane crosslinking catalyst;
- 20
- (c) optionally reinforcing the tubular structure by fabric and further optionally covering the fabric with the same or a different grafted ethylene alpha olefin plastomer also having a content of silane crosslinker of 0.1 to 10 wt.-%;
- (d) optionally labelling the outer surface;
- (e) optionally fixing the labelling if present by using UV rays;
- (f) washing the structure obtained;
- (g) cutting the structure into semi-finished products
- 25
- (h) maintaining the semi-finished products at a temperature of from 10 to 25 °C and relative humidity of from up to 60 %;
- (i) placing the semi-finished products on shaped mandrels;
- (j) subjecting the semi-finished products placed on the shaped mandrels to curing by increasing temperature and optionally increasing pressure, and further optionally increasing relative humidity thereby
- 30
- obtaining cured semi-finished fluids transport products having a predetermined shape;

- (k) optionally washing and further optionally trimming the cured semi finished fluids transport products to yield the fluids transport products.

Preferably, the semi-finished products are maintained at a temperature of from 10 to 25 °C and at a relative humidity of up to 60 % [step (h)]. More preferably, the relative humidity during step (h) is less than 55%. More preferably and independent therefrom, step (h) lasts for at least 24h. Usually step (h) will not last longer than 100 hours. Step (h) and particularly its relatively long duration provides excellent flexibility for industrial processes.

The fluid transport product of the process described above is preferably a hose. In a further embodiment, the present invention is also concerned with a fluid transport product or hose as obtained by the process described herein. The specific process features including also the inventive catalyst guarantee a combination of properties. Particularly the fluid transport product or hose as obtained by the process described herein can easily meet shore hardness A, good compression set, tear strength and long-term heat aging as well as low weight.

In yet a further embodiment, the present invention concerns vehicles comprising a fluid transport product or hose as described herein. The inventive low weight materials contribute significantly to the weight savings versus standard materials such as EPDM.

The present invention is further concerned with crosslinkable formulations

(1) a grafted ethylene alpha olefin plastomer containing silane crosslinker in an amount of 0.1 to 10 wt.-% with respect to the grafted ethylene alpha olefin plastomer, wherein the grafted ethylene alpha olefin plastomer is obtained by

- grafting an ethylene octene plastomer

and/or

- grafting a plastomer having a density of from 850 kg/m³ to 870 kg/m³

and/or

- grafting a plastomer having an melt flow rate (ISO 1133, 2.16kg, 190°C) of 0.40 to 1.5 g/10min; and

(2) a silane crosslinking catalysts comprising

- 5
- 75 to 85 wt.-% of an olefin acrylate interpolymers and
 - 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight Mn of 1500 to 4000 g/mol; and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid(s) and sulphonic acid(s),

10 all weight percentages with respect to the total weight of the silane crosslinking catalyst

for replacing EPDM.

Such use is preferably characterized by the lower weight of the articles versus the same articles made from EPDM.

15 The preparation of fluid transport products, preferably hoses is per se known in the art. A preferred process for the preparation of hoses is described in WO2016004204 inter alia at paragraphs [0089] to [0093] which are incorporated by reference herewith. WO2016004204 further describes optional basic layouts for hoses inter alia in paragraphs [0026] to [0039] which are incorporated by reference herewith.

20 In the following, several particularly preferred embodiments shall be described.

In a first particularly preferred embodiment, the silane crosslinking catalyst according to the present invention comprises

- 75 to 85 wt.-% of an olefin acrylate interpolymers having an MFR (2.16kg load, ISO1133) of 5 to 15 g/10min wherein

25 the olefin acrylate interpolymers is selected from the group of ethylene butyl acrylate (EBA), ethylene ethyl acrylate (EEA) and ethyl methyl acrylate (EMA)

and

- 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight M_n of 1500 to 4000 g/mol

and having a melting temperature of at least 95°C; and

- 5
- optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid(s) and sulphonic acid(s),

all weight percentages with respect to the total weight of the silane crosslinking catalyst.

In a second also particularly preferred embodiment

- 10
- the silane crosslinking catalyst according to the present invention comprises

- 75 to 85 wt.-% of an olefin acrylate interpolpolymer having an MFR (2.16kg load, ISO1133) of 5 to 10 g/10min wherein

the olefin acrylate interpolpolymer is ethylene butyl acrylate (EBA) having a content of butylate groups $\text{O-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$ of 15 to 20 wt.-% with respect to the total ethylene butyl acrylate (EBA),

15

and

- 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight M_n of 1500 to 4000 g/mol

and having a melting temperature of at least 95°C; and

- 20
- optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid(s) and sulphonic acid(s),

all weight percentages with respect to the total weight of the silane crosslinking catalyst.

These particularly preferred embodiments may be combined with the preferred features and ranges as described above as far as appropriate.

Materials

Plastomers P1-P3 are ethylene octene copolymers.

- 5 Reference catalyst 1 (RC1) is Ambicat LE4476.

Reference catalyst 2 (RC2) is a sulphonic acid-based cross-linking catalyst.

Inventive catalyst 1 (IC1) comprises 83 wt% of EBA containing 17 wt% BA units, 1 wt% Licowax and 16 wt% Chimassorb 944.

Measurement methods

- 10 **Degree of crosslinking (Gel Content):**

Degree of crosslinking was measured by decaline extraction according to ASTM D 2765-01, Method A on the crosslinked material.

Sample preparation

The sample preparation was done as following:

- 15 The tested plastomers were dry blended (mixed) with catalyst masterbatches and then extruded into tapes. Tape samples were produced on a Collin extruder (Teach-Line E20T) with a temperature profile of 120-130-140°C. The tape samples had a thickness of 2mm and a width of 40mm.

Cross-linking

- 20 The samples were crosslinked in a conditioned room having 50% humidity at 23°C for 24h.

Results

Example 1

The silane crosslinking catalysts RC1, RC2 and IC2 were tested on plastomers subjected to grafting. The used reactants are indicated in Table 1.

Table 1. Crosslinking degree of the inventive silane crosslinking catalyst IC1 (24h, 48h, 4 days)

Plastomer			VTMS %	IC1	Gel content after crosslinking at RT		
Name	MFR (g/10 min)	Density (kg/m ³)			24 h	48 h	4 days
P1	0.5	863	2.0	5%	8%	8%	22%
P2	1	857	1.8	5%	5%	13%	7%
P3	0.5	861	1.7	5%	11%	20%	32%

- 5 It can be seen the crosslinking degree remained on a surprisingly low level even for up to 4 days.

Table 2. Crosslinking degree of the reference silane crosslinking catalyst RC2 (24h, 48h, 4 days)

Plastomer			VTMS %	RC2	Gel content after crosslinking at RT		
Name	MFR (g/10 min)	Density (kg/m ³)			24 h	48 h	4 days
P1	0.5	863	2.0	5%	96%	96%	96%
P2	1	857	1.8	5%	96%	96%	96%
P3	0.5	861	1.7	5%	96%	96%	96%

Table 3. Crosslinking degree of the reference silane crosslinking catalyst RC1 (24h, 48h, 4 days)

Plastomer			VTMS %	RC1	Gel content after crosslinking at RT		
Name	MFR (g/10 min)	Density (kg/m ³)			24 h	48 h	4 days
P1	0.5	863	2.0	5%	96%	96%	96%
P2	1	857	1.8	5%	96%	96%	96%
P3	0.5	861	1.7	5%	96%	96%	96%

5 It can be seen the crosslinking degree could not be maintained at a low level e.g. for storage.

All tests were made on 2 mm extruded tapes using 95% plastomer (Engage and Queo) and 5% of a catalyst.

Example 2

10 All tapes using IC1 (Table 1) after experimental treatment for 4 days were (as described above) were placed in a water bath using deionized water at 90°C for 24 hours.

Table 4. Crosslinking degree of the inventive silane crosslinking catalyst IC1 after cross-linking in water bath.

Plastomer			VTMS %	IC1	Gel content after crosslinking at 90°C for 24 h
Name	MFR (g/10 min)	Density (kg/m ³)			
P1	0.5	863	2.0	5%	>70%
P2	1	857	1.8	5%	>70%
P3	0.5	861	1.7	5%	>70%

IE1 showed crosslinking of above 70 % gel content, i.e. Cooper Standard specification (minimum 70% gel content) after 24h was met.

- 5 The inventive silane crosslinking catalysts allows modifying reaction rates according to the industrial needs.

Example 3

The production operation included an extrusion of a rubber like tube which is reinforced in another step by a fabric material.

- 10 Cooling and forming was effected under water thereby forming a hose. The hoses were cut to the required length providing semi-finished products. The semi-finished products were maintained at 23°C and 55% relative humidity for 4 days.

After that the semi-finished products were placed on the shaped mandrels and subjected to curing (autoclave, 20 minute curing program consisting of 10 minutes at 140°C at 3.6 bar and 10min at 7.6 bar).

15

Then cured hoses were removed from the mandrels. Shape retention was observed.

Gel content was measured and was well above 70 %.

It could be shown the silane crosslinking catalysts allows an extremely advantageous process for providing a fluids transport products.

1. Silane crosslinking catalyst comprising
 - 5
 - 75 to 85 wt.-% of an olefin acrylate interpolymers and
 - 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight M_n of 1500 to 4000 g/mol; and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid(s) and sulphonic acid(s),
- 10

all weight percentages with respect to the total weight of the silane crosslinking catalyst.
2. Silane crosslinking catalyst according to claim 1, wherein
 - 15
 - the olefin acrylate interpolymers is selected from the group of ethylene butyl acrylate (EBA), ethylene ethyl acrylate (EEA) and ethyl methyl acrylate (EMA)
 - and/or
 - the olefin acrylate interpolymers has a MFR (2.16kg load, ISO1133) of 5 to 15 g/10min
 - and/or
 - 20
 - the hindered amine light stabilizer (HALS) has a melting temperature of at least 95°C;
 - and/or
 - the wax is present in an amount of 2.0 wt.-% or less with respect to the total weight of the silane crosslinking catalyst.

3. Silane crosslinking catalyst according to claim 1 or 2, wherein
the silane crosslinking catalyst does not contain a butylated reaction product of p-cresol and dicyclopentadiene.
- 5
4. Silane crosslinking catalyst according to any of the preceding claims, wherein
the silane crosslinking catalyst does not contain an alkoxysilane.
5. Silane crosslinking catalyst according to any of the preceding claims, wherein 10
the olefin acrylate interpolymer is ethylene butyl acrylate (EBA) having a
content of butylate groups $\text{O-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$ of 15 to 20 wt.-% with
respect to the total ethylene butyl acrylate (EBA),
and/or
an melt flow rate of 5.0 to 10.0 g/10min (ISO1133, 2.16 kg load, 190°C).
- 15
6. Crosslinkable formulation comprising
(1) a grafted ethylene alpha olefin plastomer containing silane crosslinker in
an amount of 0.1 to 10 wt.-% with respect to the grafted ethylene alpha olefin
plastomer, wherein the grafted ethylene alpha olefin plastomer is obtained by
- 20
- grafting an ethylene octene plastomer
 - and/or
 - grafting a plastomer having a density of from 850 kg/m³ to 870 kg/m³
 - and/or

- grafting a plastomer having an melt flow rate (ISO 1133, 2.16kg, 190°C) of 0.40 to 1.5 g/10min; and

(2) a silane crosslinking catalyst according to claims 1 to 5 comprising

- 5
- 75 to 85 wt.-% of an olefin acrylate interpolymers and
 - 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight M_n of 1500 to 4000 g/mol; and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid(s) and sulphonic acid(s),

10

all weight percentages with respect to the total weight of the silane crosslinking catalyst.

7. Process of crosslinking an ethylene alpha olefin plastomer, the process comprising the steps of

- 15
- (a) providing an ethylene alpha olefin plastomer having one or more of the following characteristics:
- being an ethylene octene plastomer;
 - having a density of from 850 kg/m³ to 870 kg/m³;
 - having an melt flow rate (ISO 1133, 2.16kg, 190°C) of 0.40 to 1.5 g/10min;
- 20
- (b) grafting the ethylene alpha olefin plastomer and thereby providing a grafted ethylene alpha olefin plastomer such that the content of silane crosslinker is in an amount of 0.1 to 10 wt.-% with respect to the grafted ethylene alpha olefin plastomer;
- 25
- (c) contacting said grafted ethylene alpha olefin plastomer with a silane crosslinking catalyst according to claims 1 to 5 comprising
- 75 to 85 wt.-% of an olefin acrylate interpolymers and

- 5
- 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight Mn of 1500 to 4000 g/mol; and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid and sulphonic acid;

all weight percentages with respect to the total weight of the silane crosslinking catalyst

10 at a temperature sufficient for at least partial crosslinking, thereby providing an at least partially crosslinked ethylene alpha olefin plastomer.

8. Process for providing a fluids transport product comprising the steps of

- 15
- (a) providing a grafted ethylene alpha olefin plastomer having a content of silane crosslinker of 0.1 to 10 wt.-% with respect to the grafted ethylene alpha olefin plastomer;
 - (b) extruding said grafted ethylene alpha olefin plastomer into a tubular structure

in the presence of a silane crosslinking catalyst according to claims 1 to 5 comprising

- 20
- 75 to 85 wt.-% of an olefin acrylate interpolymers and
 - 15 to 25 wt.-% of a hindered amine light stabilizer (HALS) having a number average molecular weight Mn of 1500 to 4000 g/mol; and
 - optionally up to 5 wt.-% wax, wherein the silane crosslinking catalyst is free of tin, carboxylic acid and sulphonic acid,

25 all weight percentages with respect to the total weight of the silane crosslinking catalyst;

- (c) optionally reinforcing the tubular structure by fabric and further optionally covering the fabric with the same or a different grafted

- ethylene alpha olefin plastomer also having a content of silane crosslinker of 0.1 to 10 wt.-%;
- 5 (d) optionally labelling the outer surface;
(e) optionally fixing the labelling if present by using UV rays;
(f) washing the structure obtained;
(g) cutting the structure into semi-finished products
(h) maintaining the semi-finished products at a temperature of from 10 to 25 °C and relative humidity of up to 60 %;
- 10 (i) placing the semi-finished products on shaped mandrels;
(j) subjecting the semi-finished products placed on the shaped mandrels to curing by increasing temperature and optionally increasing pressure, and further optionally increasing relative humidity thereby obtaining cured semi-finished fluids transport products having a predetermined shape;
- 15 (k) optionally washing and further optionally trimming the cured semi finished fluids transport products to yield the fluids transport products.
9. Process according to claim 8, wherein maintaining the semi-finished products at a temperature of from 10 to 25 °C and relative humidity of from up to 60 % [step (h)] lasts at least 24 hours.
- 20 10. Process according to claims 8 or 9, wherein the fluids transport product is a hose.
- 25 11. Fluid transport product or hose as obtained by the process of claims 9 or 10.
12. Vehicle comprising a fluid transport product or hose according to claim 11.
13. Use of a crosslinkable formulation according to claim 6 for replacing EPDM.
14. Use according to claim 13, wherein the weight of articles using the crosslinkable formulation is reduced relative to reference articles using EPDM.
- 30