

Description

Title of Invention: Acrylic Conformal Coating

Technical Field

5 The present invention relates to a polymer composition comprising a polymer having repeating units of a bulk monomer, a flexibilizing monomer, a cross-linking monomer; a fluoromonomer; an adhesion promoting monomer; and a leveling monomer; and optionally a fluorophore. The present invention also relates to a method of synthesizing the polymer composition, a polymer composition obtainable by the method, a coating comprising the polymer composition, a method for coating a substrate with the coating and a substrate that is at least partially coated
10 with the coating.

Background Art

Conformal coatings are a proven method for protecting sensitive electronics and solder joints from corrosive electrochemical effects. Originally used almost exclusively for aerospace and military applications, the use of these coatings is increasing as electronics assemblies
15 increasingly pervade modern life – from toys to cars and medical to white goods – and are more frequently used in what can be considered ‘hostile’ situations in terms of such parameters as vibration, thermal cycling and exposure to moisture.

Conformal coatings are thin layers of synthetic resins or organic polymers applied to printed circuit boards (PCBs) and electronic components for protection against environmental,
20 mechanical, electrical, and chemical assaults including contaminants such as dust, dirt, fungus, moisture, chemicals, thermo-mechanical stress, mechanical shock, and vibration. Conformal coatings can be formed from polymers including urethanes, silicone, acrylics, epoxies, and poly(p-xylylene) polymers.

The selection of a conformal coating material is generally based upon desired performance and processing requirements for a specific application. For example, silicones are known for high
25 temperature operating capability and can typically be used at operating temperatures up to 200 °C, whereas many other conformal coatings can typically only be used at 130 °C. Silicones, however, exhibit a high coefficient of thermal expansion and relatively poor adhesion to many materials. In addition, silicones are known to migrate within the coating which can cause the
30 failure of electronic components on a printed circuit board. Acrylics, on the other hand, are generally the easiest of the coating materials to handle and rework, and typically provide better adhesion properties than silicones. However, they often suffer from temperature limitation.

There is therefore a need to provide a polymer composition that overcomes or at least ameliorates, one or more of the disadvantages described above.

Summary

In an aspect, there is provided a polymer composition comprising:

a polymer having repeating units of: a bulk monomer, a flexibilizing monomer, a fluoromonomer; an adhesion promoting monomer; and a leveling monomer;

5 optionally a cross-linking monomer; and

optionally a fluorophore.

Advantageously, the polymer composition is cured to comprise 100% solids, as it may be free of solvents. The polymer composition may advantageously have low volatile organic compounds (VOC). Despite this, the polymer composition may have superior wetting and low viscosity for ease of application to a variety of substrates. Further advantageously, the polymer composition may be substantially free of silicon.

Further advantageously, the polymer composition may have a high flash point, and therefore low flammability, making it safe to use. More advantageously, the formulation that is cured at 100-120 °C for 1 hour may exhibit superior scratch resistance, conformability, levelling, and adhesion to a variety of substrates. Further advantageously, the polymer composition may experience low shrinkage during curing. More advantageously, the polymer composition may have a wide working temperature, excellent corrosion protection, an extended shelf-life of approximately six months and may be easy to apply to substrates. In addition, the polymer composition may have superior electrical and thermal properties, including high resistance to thermal shock in the temperature range of about -65 °C to about 125 °C, allowing for excellent thermal cycling properties.

The flexibilizing monomer may advantageously impart high moisture barrier, flexibility and conformability, as well as lower cure shrinkage to the polymer composition. The cross-linking monomer may increase cross-link density which in turn may increase the interpenetrating polymer network (IPN) structure, thereby improving the film properties and corrosion resistance. The fluoromonomer may impart corrosion resistance and minimize defects in the coating. The adhesion promoter may facilitate adhesion of the polymer composition to various substrates, and the levelling agent may level the coating to eliminate defects such as craters, orange peel effect, Bernard cells. The fluorophore may advantageously give colour to the film to facilitate visual analysis of the quality of the film.

The polymer composition may therefore have a combination of advantageous properties, whereby it may be free of solvent, may be free of silicon, may comprise a fluoromonomer and may be cured both thermally and by UV.

In another aspect, there is provided a method for synthesizing the polymer composition as defined above, comprising the step of contacting a bulk monomer, a flexibilizing monomer, an

adhesion promoting monomer, a levelling agent, optionally a cross-linking monomer and optionally a fluorophore.

Advantageously, the polymer composition may have dual-curing properties, whereby the composition may be cured both by heat and UV-irradiation. The dual curing property may advantageously mitigate shadow-curing defects, wherein the preliminary UV-curing may be unable to cure areas that are in a shadow during UV-irradiation. The secondary thermal curing may eliminate this issue. Advantageously, thermal curing may be performed in the temperature range of about 90 °C to about 150 °C.

In another aspect, there is provided a polymer composition obtainable by contacting a bulk monomer, a flexibilizing monomer, an adhesion promoting monomer, a levelling agent, optionally a cross-linking monomer and optionally a fluorophore. Advantageously, the composition may be easy to formulate.

In another aspect, there is provided a coating comprising the polymer composition as defined above.

Advantageously, the coating may have a thickness of less than 2 mm, or less than 50 µm.

In another aspect, there is provided a method for coating a substrate with the coating as defined above, comprising the step of applying the coating composition onto at least part of a substrate surface.

Advantageously, the coating may be applied to a substrate by various methods including dip coating, spray coating, brush coating and flow coating techniques.

In another aspect, there is provided a substrate that is at least partially coated with the coating composition as defined above.

Advantageously, a substrate such as a printed circuit board (PCB) coated with the polymer composition may have the following advantageous properties: reliability under humid conditions may be improved, it may eliminate the need to hermetically seal the PCB, the conductor spacing may be reduced, the PCB may be protected from the environment/particulates, the coating may have superior dielectrics, with improved insulation and moisture resistance, as well as higher breakdown voltage, improved flexibility which prevents stress on the components, the PCB may become repairable, and/or extended product life.

Definitions

The following words and terms used herein shall have the meaning indicated:

"Alkyl" as a group or part of a group refers to a straight or branched aliphatic hydrocarbon group, preferably a C₁–C₅₀ alkyl, preferably a C₁–C₁₂ alkyl, more preferably a C₁–C₁₀ alkyl, most preferably C₁–C₆ unless otherwise noted. Examples of suitable straight and branched

C₁-C₆ alkyl substituents include methyl, ethyl, n-propyl, 2-propyl, n-butyl, sec-butyl, t-butyl, hexyl, and the like. The group may be a terminal group or a bridging group.

The word “substantially” does not exclude “completely” e.g. a composition which is “substantially free” from Y may be completely free from Y. Where necessary, the word
5 “substantially” may be omitted from the definition of the invention.

Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As used herein, the term "about", in the context of concentrations of components of the
10 formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It
15 should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have
20 specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Certain embodiments may also be described broadly and generically herein. Each of the narrower species and subgeneric groupings falling within the generic disclosure also form
25 part of the disclosure. This includes the generic description of the embodiments with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein.

Detailed Disclosure of Optional Embodiments

There is provided a polymer composition comprising:

- 30 a polymer having repeating units of: a bulk monomer; a flexibilizing monomer; a fluoromonomer; an adhesion promoting monomer; and a leveling monomer;
- optionally a cross-linking monomer, and
- optionally a fluorophore.

The polymer composition may be substantially free of solvent, and/or may be substantially free
35 of silicon. The polymer composition may not comprise any solvent and/or any silicon. The

solvent may be any liquid which does not form part of the polymer network after polymerization. The silicon may be in the form of silica or silanes.

The polymer composition may consist essentially of:

- 5 a polymer having repeating units of: a bulk monomer, a flexibilizing monomer, a fluoromonomer; an adhesion promoting monomer; and a leveling monomer.

The polymer composition may consist essentially of:

- a polymer having repeating units of: a bulk monomer, a flexibilizing monomer, a cross-linking monomer; a fluoromonomer; an adhesion promoting monomer; and a leveling monomer; and
- 10 a cross-linking agent and/or a fluorophore.

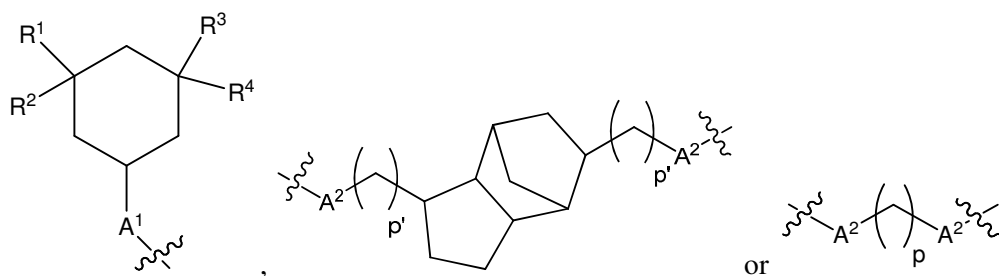
The polymer may consist essentially of repeating units of: a bulk monomer, a flexibilizing monomer, a fluoromonomer; an adhesion promoting monomer; and a leveling monomer.

Bulk monomer

- 15 The bulk monomer may have good miscibility and compatibility with the other monomers in the polymer composition. The bulk monomer may act to modify the viscosity of the polymer composition. The bulk monomer may additionally act as a cross-linker in the polymer. The bulk monomer may further facilitate the formulation to be homogeneous.

- The bulk monomers disclosed herein may have been selected on the basis of their ability to adjust viscosity of the polymer composition, and on the basis that they are able to dissolve the
- 20 other components of the polymer composition.

The bulk monomer may comprise the following structure:



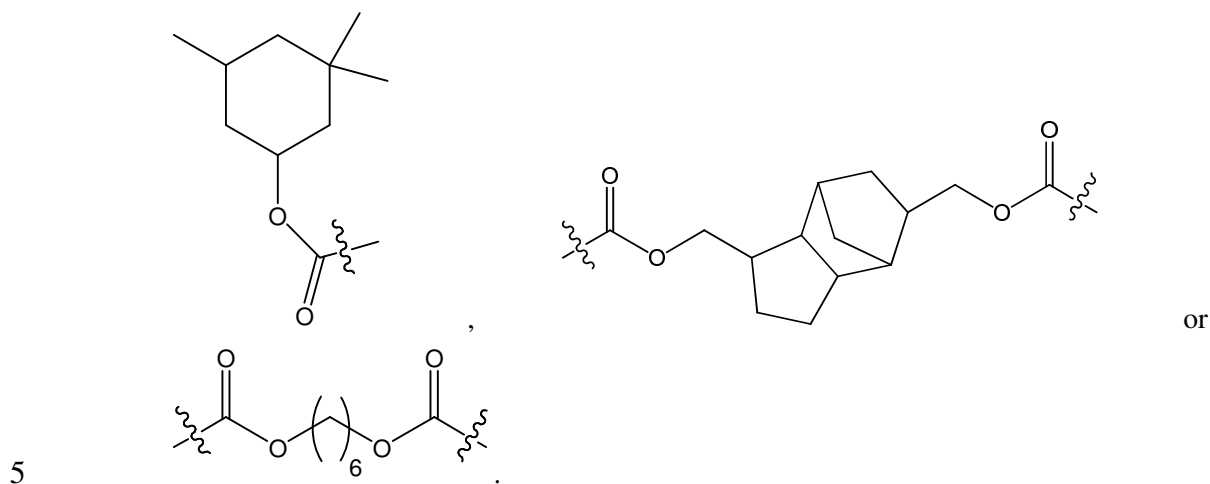
wherein A¹ and A² may independently be absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof;

- 25 R¹, R², R³ and R⁴ may independently be hydrogen or alkyl, and

p and p' may independently be an integer in the range of from 1 to 10.

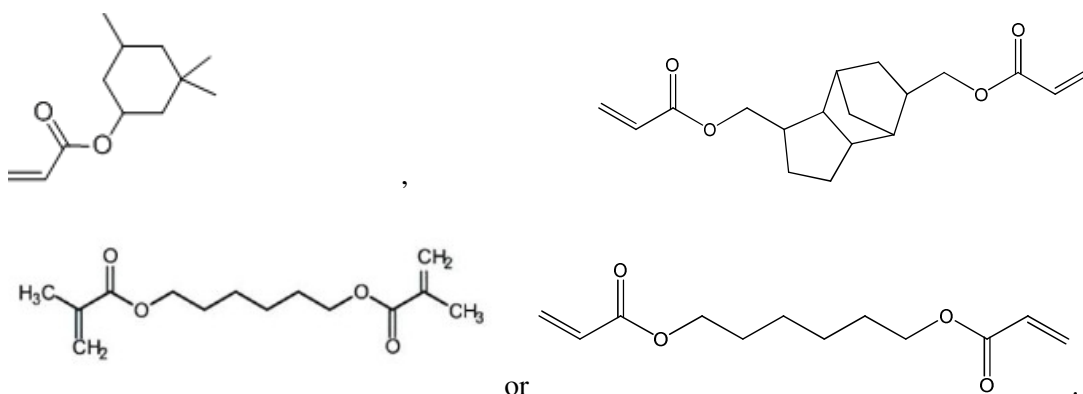
A^1 or A^2 may be ester, R^1 may be hydrogen, R^2 , R^3 and R^4 may be methyl, p may be 6 and p' may be 1.

The bulk monomer may comprise the following structure:



The bulk monomer may comprise a vinyl group.

The bulk monomer may have the following structure:



- 10 The cyclic monomers may provide rigidity to the polymer, whereas the linear monomers may provide more flexibility. Cyclic monomers after polymerization may phase separate, but linear monomers may not phase separate after polymerization. The type of bulk monomer may be selected depending on the desired property of the polymer.

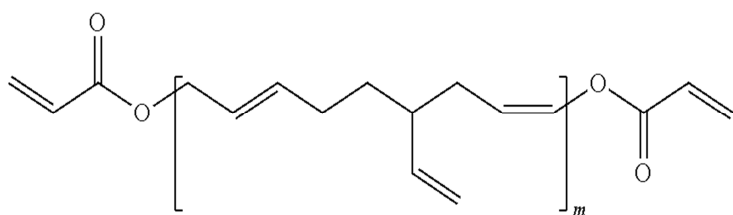
Flexibilizing monomer

- 15 The flexibilizing monomer may impart a high moisture barrier, flexibility and conformability to the polymer composition. The flexibilizing monomer may further facilitate lower cure shrinkage.

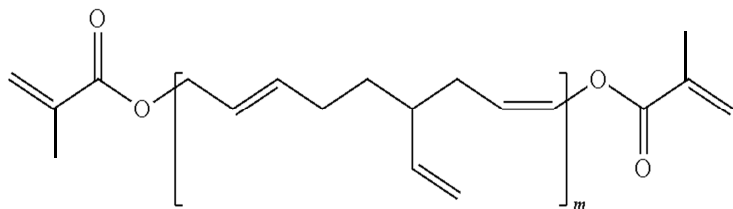
The flexibilizing monomer may comprise at least one diene group. The flexibilizing monomer may comprise butadiene. The flexibilizing monomer may comprise a polybutadiene oligomer. The flexibilizing monomer may comprise a vinyl group. The flexibilizing monomer may be a polybutadiene diacrylate or a polybutadiene dimethacrylate.

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The flexibilizing monomer may have the following structure:



or



of 1 to 50.

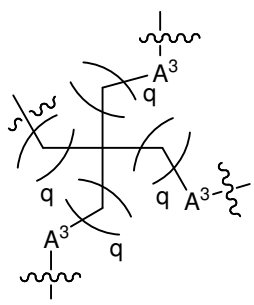
where m is an integer in the range

- 5 The flexibilizing monomer may be a hydrogenated polybutadiene diacrylate or polybutadiene dimethacrylate.

Cross-linking monomer

- 10 The polymer composition may further or optionally comprise a cross-linking monomer. The cross-linking monomer may increase cross-linking density, which in turn may increase the interpenetrating polymer network structure, thereby improving the properties of the polymer composition and corrosion resistance.

The cross-linking monomer may comprise the following structure:

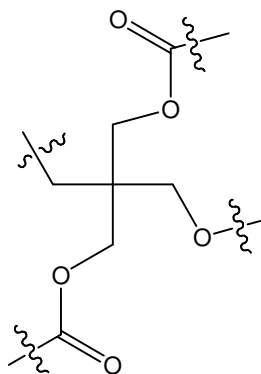


- 15 wherein A^3 may independently be absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof; and

q may independently be an integer in the range of from 1 to 10.

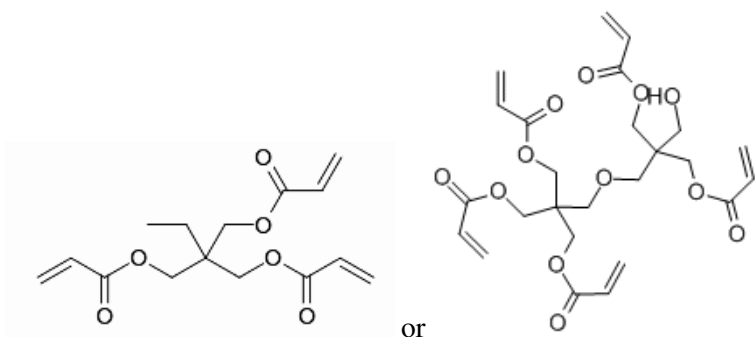
q may be 1 and A^3 may be ester.

The cross-linking monomer may comprise the following structure:



The cross-linking monomer may comprise a vinyl group.

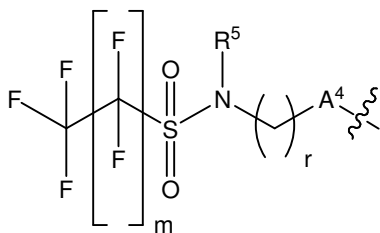
The cross-linking monomer may have the following structure:



5 Fluoromonomer

The fluoromonomer may confer corrosion resistance to the polymer composition, particularly against salt water and sulfur. It may further minimize defects in the polymer composition.

The fluoromonomer may comprise the following structure:



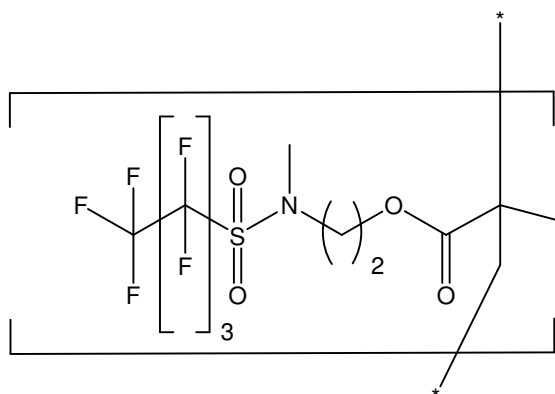
10 wherein m and r may independently be an integer in the range of from 1 to 10,

R^5 may be hydrogen or alkyl, and

A^4 may be absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

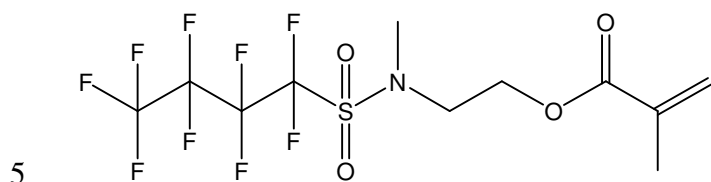
m may be 4, r may be 2, R^5 may be methyl and A^4 may be ester.

The repeating unit of the fluoromonomer may have the following structure:



The fluoromonomer may comprise a vinyl group.

The fluoromonomer may have the following structure:



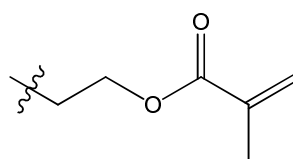
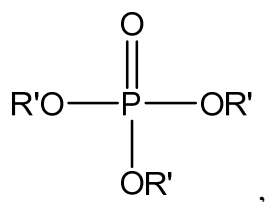
Adhesion promoting monomer

The adhesion promoting monomer may facilitate the adhesion of the polymer composition to various substrates.

The adhesion promoting monomer may comprise a carboxylic acid or a phosphonate ester.

10 The adhesion promoting monomer may be acrylic acid.

The adhesion promoter may have the following structure:

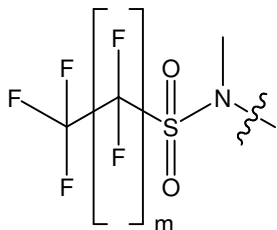


wherein R' may independently be hydrogen or

Leveling monomer

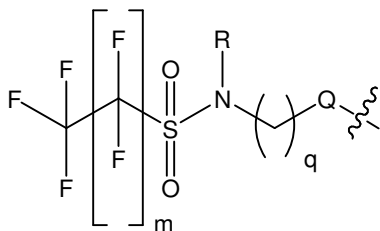
The leveling monomer may act to eliminate defects such as crates, orange peel effect and Bernard cells in the polymer composition. The leveling monomer may have good compatibility with both fluorocarbon and hydrocarbon monomers.

- 5 The leveling monomer may comprise a fluoroacrylate polymer comprising the following



structure: , wherein m may be an integer in the range of 1 to 50.

The leveling monomer may comprise the following structure:



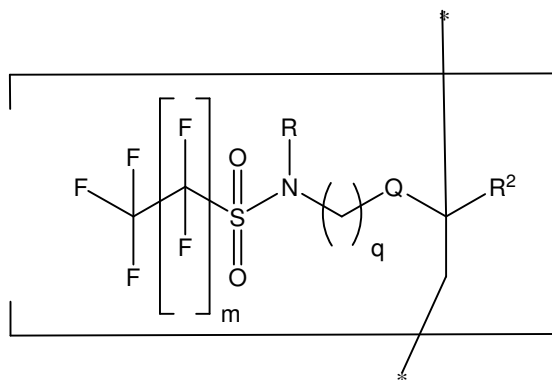
wherein q may be an integer in the range of 1 to 50,

- 10 m may be an integer in the range of 1 to 50,

R may be hydrogen or alkyl; and

Q may be absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

The leveling monomer may comprise the following structure:



- 15

wherein q, m and R are as defined above and R² may be hydrogen or alkyl.

Q may be ester, m may be 3, q may be 2 and R² may be hydrogen or methyl.

The leveling monomer may be a copolymer of MeFBSEA (C₄F₉SO₂N(CH₃)CH₂CH₂OOCCH=CH₂) and a polaxamer (Pluronic ®) surfactant. The leveling monomer may comprise:

- 5 A) 2-(methyl(nonafluorobutyl)sulfonyl)amino) ethyl ester 2-propenoic acid, telomere with methyloxirane polymer with oxirane di-2-propenoate and methyloxirane polymer with oxirane mono-propenoate at about 85 to 95 wt%,
- B) Polyether polymer at about 5 to 10 wt%,
- C) 2-methoxymethylethoxypropanol at about 0-5 wt%,
- 10 D) 1,1,2,2,3,3,4,4,4-nonafluoro-N-(2-hydroxyethyl)-N-methyl-1-butanesulfonamide at less than 1 wt%,
- E) 1,1,2,2,3,3,4,4,4-nonafluoro-N-methyl-1-butanesulfonamide at less than 1 wt%,
- F) 2-(methyl(nonafluorobutyl)sulfonyl)amino) ethyl ester 2-propeonic acid at less than 1 wt%, and
- 15 G) Toluene at less than 1 wt%.

Fluorophore

The fluorophore may be soluble in and therefore compatible with the other monomers. The fluorophore may be evenly distributed throughout the polymer composition after polymerization, without any phase separation or aggregation. The fluorophore may not impart significant colour to the polymer composition. The fluorophore may not have any colour in the visible spectrum, but be highly fluorescent in the UV range.

The fluorophore may be 2,5-bis-(5-ter-butyl-benzoxazolyl-)thiophene.

Polymerization initiator

The polymerization initiator may have a high half-life ($t_{1/2}$) to improve the shelf life of the polymer composition. Using a mixture of thermal- and UV-polymerization initiators may enable the polymer composition to have a dual-cure system, whereby the curing can be done by both heat and UV-irradiation.

Typical UV curing is exothermic and the temperature may reach up to 70 °C to 80°C. The thermal curing may be a secondary mode for curing, hence the thermal initiator should still be active after UV curing. The 10-hour half-life temperature of the thermal initiator may therefore be chosen to be greater than 80 °C, so that the secondary thermal curing may be performed after UV curing. Secondary thermal curing may be performed to prevent shadow curing, whereby the UV radiation is unable to reach the hidden areas under the components and the coating cannot be cured efficiently.

The polymerization initiator may be selected from the group consisting of 1,1'-azo-bis(cyanocyclohexane), di-tert-amyl peroxide, 1-benzoylcyclohexanol and any mixture thereof.

1,1'-azo-bis(cyanocyclohexane) and di-tert-amyl peroxide may be a thermal polymerization initiator and 1-benzoylcyclohexanol may be a UV polymerization initiator. Composition

The components and amount of each of the components of the polymer composition may be selected based on the compatibility of the monomers with each other after polymerization such that no phase separation occurs, and the properties achieved, such as flexibility, toughness, water transmission and viscosity.

The polymer composition may comprise:

about 7 wt% to about 70 wt%, about 7 wt% to about 12 wt%, about 7 wt% to about 20 wt%, about 7 wt% to about 35 wt%, about 7 wt% to about 45 wt%, about 7 wt% to about 55 wt%, about 7 wt% to about 65 wt%, about 12 wt% to about 65 wt%, about 12 wt% to about 20 wt%, about 12 wt% to about 35 wt%, about 12 wt% to about 45 wt%, about 12 wt% to about 55 wt%, about 12 wt% to about 70 wt%, about 20 wt% to about 35 wt%, about 20 wt% to about 45 wt%, about 20 wt% to about 55 wt%, about 20 wt% to about 65 wt%, about 20 wt% to about 70 wt%, about 35 wt% to about 45 wt%, about 35 wt% to about 55 wt%, about 35 wt% to about 65 wt%, about 35 wt% to about 70 wt%, about 45 wt% to about 55 wt%, about 45 wt% to about 65 wt%, about 45 wt% to about 70 wt%, about 55 wt% to about 65 wt%, about 55 wt% to about 70 wt%, or about 65 wt% to about 70 wt% of the bulk monomer,

about 3 wt% to about 55 wt%, about 3 wt% to about 8 wt%, about 3 wt% to about 20 wt%, about 3 wt% to about 30 wt%, about 3 wt% to about 40 wt%, about 3 wt% to about 50 wt%, about 8 wt% to about 50 wt%, about 8 wt% to about 20 wt%, about 8 wt% to about 30 wt%, about 8 wt% to about 40 wt%, about 8 wt% to about 55 wt%, about 20 wt% to about 30 wt%, about 20 wt% to about 40 wt%, about 20 wt% to about 50 wt%, about 20 wt% to about 55 wt%, about 30 wt% to about 40 wt%, about 30 wt% to about 50 wt%, about 30 wt% to about 55 wt%, about 40 wt% to about 50 wt%, about 40 wt% to about 55 wt% or about 50 wt% to about 55 wt% of the flexibilizing monomer,

about 0 wt% to about 15 wt%, about 0 wt% to about 1.5 wt%, about 0 wt% to about 5 wt%, about 0 wt% to about 7.5 wt%, about 0 wt% to about 10 wt%, about 1.5 wt% to about 10 wt%, about 1.5 wt% to about 5 wt%, about 1.5 wt% to about 7.5 wt%, about 1.5 wt% to about 15 wt%, about 5 wt% to about 7.5 wt%, about 5 wt% to about 10 wt%, about 5 wt% to about 15 wt%, about 7.5 wt% to about 10 wt%, about 7.5 wt% to about 15 wt% or about 10 wt% to about 15 wt% of the cross-linking monomer,

about 1 wt% to about 40 wt%, about 1 wt% to about 5 wt%, about 1 wt% to about 15 wt%, about 1 wt% to about 25 wt%, about 1 wt% to about 35 wt%, about 5 wt% to about 35 wt%, about 5 wt% to about 15 wt%, about 5 wt% to about 25 wt%, about 5 wt% to about 40 wt%, about 15 wt% to about 25 wt%, about 15 wt% to about 35 wt%, about 15 wt% to about 40 wt%, about 25 wt% to about 35 wt%, about 25 wt% to about 40 wt%, or about 35 wt% to about 40 wt% of the fluoromonomer;

about 1 wt% to about 10 wt%, about 1 wt% to about 5 wt%, about 1 wt% to about 2.5 wt%, about 2.5 wt% to about 5 wt%, about 2.5 wt% to about 10 wt% or about 5 wt% to about 10 wt% of the adhesion promoting monomer;

5 about 0.1 wt% to about 5 wt%, about 0.1 wt% to about 1 wt%, about 0.1 wt% to about 0.2 wt%, about 0.1 wt% to about 0.5 wt%, about 0.2 wt% to about 0.5 wt%, about 0.2 wt% to about 1 wt%, about 0.2 wt% to about 5 wt%, about 0.5 wt% to about 1 wt%, about 0.5 wt% to about 5 wt% or about 1 wt% to about 5 wt% of the leveling monomer; and

10 about 0 wt% to about 5 wt%, about 0 wt% to about 0.5 wt%, about 0 wt% to about 0.2 wt%, about 0.2 wt% to about 0.5 wt%, about 0.2 wt% to about 5 wt%, or about 0.5 wt% to about 5 wt% of the fluorophore,

wherein the total wt% is 100%.

The polymer may be a branched copolymer. The polymer may be a random copolymer.

15 There is also provided a polymer composition obtainable by contacting a bulk monomer, a flexibilizing monomer, an adhesion promoting monomer, a levelling agent and optionally a fluorophore.

Method

20 There is provided a method for synthesizing the polymer composition as defined above, comprising the step of contacting a bulk monomer, a flexibilizing monomer, an adhesion promoting monomer, a levelling agent and optionally a cross-linking monomer and optionally a fluorophore.

25 The method may not comprise contacting a solvent and/or silicon with the polymer composition. The method may not comprise the step of adding a solvent and/or silicon to the polymer composition. The solvent may be any liquid which does not form part of the polymer network after polymerization. The silicon may be in the form of silica or silanes.

The bulk monomer, the flexibilizing monomer, the adhesion promoting monomer, the levelling agent and optionally the cross-linking monomer and optionally the fluorophore may be mixed sequentially in that order to form a mixture.

30 The method may further comprise the step of pre-mixing the flexibilizing monomer, the cross-linking monomer, the adhesion promoting monomer, the levelling agent or the fluorophore with the bulk monomer before adding to the mixture.

The mixture may be heated to a temperature in the range of about 30 °C to about 60 °C, about 30 °C to about 40 °C, about 30 °C to about 50 °C, about 40 °C to about 40 °C, about 40 °C to about 50 °C, about 40 °C to about 60 °C, or about 50 °C to about 60 °C.

The method may comprise the step of adding a polymerization initiator.

- The method may comprise the step of UV-curing the polymer composition under UV radiation using a D-bulb at a power in the range of about 400 W to about 800 W, about 400 W to about 500 W, about 400 W to about 600 W, about 400 W to about 700 W, about 500 W to about 600W, about 500 W to about 700 W, about 500 W to about 800 W, about 600 W to about 700 W, about 600 W to about 800 W or about 700 W to about 800W.

The step of UV-curing of the polymer composition may be performed at a radiation intensity in the range of about 15 ft/min to about 25 ft/min, about 15 ft/min to about 20 ft/min or about 20 ft/min to about 25 ft/min.

- The method may comprise the step of thermal curing the polymer composition at a temperature in the range of about 90 °C to about 150 °C, about 90 °C to about 110 °C, about 90 °C to about 120 °C, about 90 °C to about 130 °C, about 90 °C to about 140 °C, about 100 °C to about 110 °C, about 100 °C to about 120 °C, about 100 °C to about 130 °C, about 100 °C to about 140 °C, about 100 °C to about 150 °C, about 110 °C to about 120 °C, about 110 °C to about 130 °C, about 110 °C to about 140 °C, about 110 °C to about 150 °C, about 120 °C to about 130 °C, about 120 °C to about 140 °C, about 120 °C to about 150 °C, about 130 °C to about 140 °C, about 130 °C to about 150 °C, or about 140 °C to about 150 °C.

- The step of thermal curing of the polymer composition may be performed for a duration in the range of about 30 minutes to about 90 minutes, about 30 minutes to about 45 minutes, about 30 minutes to about 60 minutes, about 30 minutes to about 75 minutes, about 45 minutes to about 60 minutes, about 45 minutes to about 75 minutes, about 45 minutes to about 90 minutes, about 60 minutes to about 75 minutes, about 60 minutes to about 90 minutes, or about 75 minutes to about 90 minutes.

- The curing may be done sequentially, whereby the polymer composition is first cured by UV-curing, followed by thermal curing.

Coating

There is also provided a coating comprising the polymer composition as defined above.

- The thickness of the coating may be in the range of about 20 µm to about 50 µm., about 20 µm to about 30 µm, about 20 µm to about 40 µm, about 30 µm to about 40 µm, about 30 µm to about 50 µm, about 40 µm to about 50 µm, about 50 µm to about 100 µm, about 50 µm to about 200 µm, about 50 µm to about 500 µm, about 50 µm to about 1000 µm, about 50 µm to about 2000 µm, about 100 µm to about 200 µm, about 100 µm to about 500 µm, about 100 µm to about 1000 µm, about 100 µm to about 2000 µm, about 200 µm to about 500 µm, about 200 µm to about 1000 µm, about 200 µm to about 2000 µm, about 500 µm to about 1000 µm, about 500 µm to about 2000 µm, or about 500 µm to about 2000 µm.

There is also provided a method for coating a substrate with the coating as defined above, comprising the step of applying the coating composition onto at least part of a substrate surface.

The applying step may be performed by dip coating, spin coating, spray coating, brush coating, flow coating or airless spray dispensing.

- 5 The coating may be applied by dipping, the pull speed may be in the range of about 6"/min to about 20"/min, about 6"/min to about 10"/min, about 6"/min to about 12"/min, about 6"/min to about 17"/min, about 10"/minute to about 12"/minute, about 10"/minute to about 17"/minute, about 10"/minute to about 20"/minute, about 12"/minute to about 17"/minute, about 12"/minute to about 20"/minute, or about 17"/minute to about 20"/minute.

The dwell time during dip coating may be in the range of about 30 seconds to about 90 seconds, about 30 seconds to about 60 seconds, or about 60 seconds to about 90 seconds.

- 10 The dwell time may be selected in order to remove trapped gases. Further agitation may be required in order to remove the trapped gasses. There is also provided a substrate that is at least partially coated with the coating composition as defined above. The substrate may be selected from the group consisting of metal, glass, aluminium coupon, and printed circuit board. The printed circuit board may further comprise of FR-4, which is a composite material composed of
- 15 fiberglass and epoxy resin, solders, ceramics and any mixture thereof.

Examples

Non-limiting examples of the invention will be further described in greater detail by reference to specific Examples, which should not be construed as in any way limiting the scope of the invention.

20 Example 1: Materials and Methods

The 100% solids acrylic formulation consists of the following components. The monomers and suppliers are given in Table 1.

Table 1. Monomers used

Monomer	Monomers/additives	Supplier
Bulk Monomer	CD 420	Sartomer of Colombes Cedex, France
	SR 239	
Flexibilizer	Hexanediol diacrylate (HDDA)	Sartomer of Colombes Cedex, France
	SR833S	
	CN 307	
Cross-Linker	CN 301	Shin-A T&C, Seoul, Korea
	SU-H8130	
Fluoro Monomer	SR 351 NS	Sartomer of Colombes Cedex, France
	SR 399	
Adhesion Promoter	MeFBSEA (C4 Acrylate)	3M Company of St. Paul, Minnesota of the United States of America
Adhesion Promoter	Acrylic Acid	Sigma Aldrich of St. Lous, Missouri of the United States of America
	CD 9053	Sartomer of Colombes Cedex, France

	SAM-HS100	Shin-A T&C, Seoul, Korea
Levelling Agent	FC 4430	3M Company of St. Paul, Minnesota of the United States of America
Thermal Initiator	VAZO 88 Luperox DTA	Sigma Aldrich of St. Lous, Missouri of the United States of America
UV Initiator	Irgacure 184	Ciba Specialty Chemicals, Basel, Switzerland
Fluorescent Dye	Fluorescent Brightener OB	Ciba Specialty Chemicals, Basel, Switzerland

Coatings were carried out by the dip coating technique using a withdrawal speed of 11"/min. Substrates included glass, aluminium coupon and standard printed circuit board (PCB).

- 5 IPC –CC- 830 Standard test methods were followed for qualification of PCB conformal coatings. This included a flexibility test using a conical mandrel, and electrical measurements for the dielectric withstand voltage. Pencil Hardness and Scratch Resistance Tests were also conducted.

Flexibility Mandrel Test

- 10 Conical Mandrel Tester, consisting of a metal cone, a rotating panel-bending arm, and panel clamps, all mounted on a metal base, was used to measure the flexibility of the coating. With the operating lever of the apparatus in a horizontal position, the test specimen was placed between the mandrel and the drawbar with the finish side towards the drawbar. The specimen was rigidly clamped in a vertical position adjacent to the mandrel by placing the long edge behind the clamping bar in such a manner that the panel was always set up to the narrow end of the
- 15 mandrel. The 0.3175 cm (1/8") mandrel was placed in a stationary position, in the center of the test panel. One end of the test panel was selected and within 1 second, the panel was bent 180° over the mandrel. The test panel was then examined with 10X magnification for cracking and creasing.

Linear Taber Abrader - Abrasion Test

- 20 Linear abrasion test was done to investigate the scratch resistance of the coating. The abrasion test was performed using a Taber Abrader using the ASTM standard D1044.3470. Scratches were examined visually by using an optical microscope at 5X magnification.

Pencil Hardness Test

- 25 Pencil hardness test was conducted to determine the hardness of the coating. This also measured the scratch resistance of the coating. Scratches were examined using an optical microscope with 5x magnification.

Thermal Shock

Thermal Shock measurements were taken to determine the physical endurance of applied coatings to sudden changes of temperature. Testing was performed on five coated IPC-B-25A boards. The boards were placed in a thermal shock test chamber and the parameters were set.

- 5 The coatings were tested for 100 cycles at -65°C to 125°C with dwell times of 15 minutes at each temperature extreme. The transfer times were typically two minutes maximum. Following the test exposure, the boards are removed and maintained at $25 \pm 5^{\circ}\text{C}$ with a relative humidity of $50 \pm 5\%$ for 24 hours. Whether the initial requirements established for Appearance and Dielectric Withstanding Voltage criteria were met was investigated.

10 ***Dielectric Withstanding Voltage***

- Dielectric Withstanding Voltage was measured to prove that the coated printed circuit board will operate at its rated voltage, as well as to determine that the coating is adequate during voltage applications. The test was performed on five coated IPC-B-25A boards. Insulated wires were attached to the finger tabs of the “D” pattern. A test voltage of 1500 VAC was applied in
15 increments of 100VAC per second and held for one minute. The leakage current was monitored during testing. The specimens were considered adequate if they did not exhibit spark over, flashover, or breakdown during testing, and if the leakage rate did not exceed 10 microamperes.

Moisture and Insulation Resistance

- Moisture and insulation resistance measurement was performed to evaluate, in an accelerated
20 manner, the resistance of materials to the deteriorative effects of high temperature/humidity conditions (typical of tropical environments). Test specimens utilized for insulation resistance testing (same as dielectric test) were subjected to cyclic temperatures of 25°C and 65°C with 85% minimum relative humidity. The specimens were electrically biased with 50V DC while
25 inside the test chamber. The bias was removed before taking measurements inside the test chamber. A test voltage of 100 volts was applied to each of the individual test points 1-2, 2-3, 3-4, and 4-5 for one minute before obtaining the insulation resistance measurement. The specimens were placed in an oven maintained at $50 \pm 2^{\circ}\text{C}$ for 24 hours. The specimens were cooled to ambient conditions of 25° ($+2$, -5°C) with 40-50% relative humidity prior to obtaining
30 initial insulation resistance measurements. Electrical measurements were also taken during exposure inside the test chamber and were measured at the first, fourth, seventh, and tenth cycles (during the high phase of each cycle). Upon completion of accelerated cycling (20 cycles), the boards were maintained at 25° ($+2$, -5°C) with 40-50% relative humidity and insulation resistance measurements were obtained within 1-2 hours of removal from the test chamber. The specimens were then held for an additional 24 hours at ambient test conditions of
35 25° ($+2$, -5°C) with 40-50% relative humidity and the final insulation resistance values were then obtained. Whether the initial requirements established for Appearance and Dielectric Withstanding Voltage were met, was investigated.

Example 2: Formulations

The rationale for selecting the various monomers is described in Table 2.

Table 2. Properties of the monomers

Monomer	Monomers/additives	Function
Bulk Monomer	CD 420 SR 239 Hexanediol diacrylate (HDDA) SR833S	Base polymer and viscosity modifier, compatibility with other monomers
Flexibilizer	CN 307 CN 301 SU-H8130	Imparts high moisture barrier, flexibility/conformability, lower cure shrinkage.
Cross-Linker	SR 351 NS SR 399	Increase cross-link density. This increases the interpenetrating polymer network (IPN) structure, thereby improving the coating properties and corrosion resistance.
Fluoro Monomer	MeFBSEA (C4 Acrylate)	Corrosion resistance (particularly to salt water and sulfur) and water repellency and/or water proofing, minimize defects in the coating.
Adhesion Promoter	Acrylic Acid CD 9053 SAM-HS100	Facilitate adhesion to different substrates
Levelling Agent	FC 4430	Levels the coating to eliminate defects such as craters, orange peel effect, Bernard cells
Initiator	VAZO 88 Luperox DTA Irgacure 184	Initiate polymerization
Fluorescent Dye	Fluorescent Brightener OB	Gives colour to the film, facilitating visual analysis using UV

The formulations tried are given in Tables 3 and 4 below.

Table 3. Formulations tested – Group 1

No.	CD 420 (g)	CN 307 (g)	SR 351	MeFBSEA	Acrylic Acid	FC 4430	Vazo88	Dye
1	30		4	14	2	0.25	0.5	0.15
2	5	16.5	2.7	10	0.6	0.1	0.2	0.05
3	3	0.5	0.25	1	0.06	-	0.05	-

5

Table 4. Formulations tested – Group 2

No.	SR 239 (g)	CN 301(g)	SR 399	MeFBSEA	CD 9053	FC 4430	Vazo88	Dye
4	36	20	1.2	4	1.2	0.3	0.5	0.15
5	80	45	3	12	3	0.7	1.2	0.3

Formulation 6

SR 239	40g
CN 301	20g
SR 399	1.2g
MeFBSEA	4g
CD 9053	1.2g
Vazo 88	0.9g
Irgacure 184	1.0
FC 4430	0.3g
Dye	0.2g

Formulation 8

SR 239	40g
SUO H8310	15g
SR 399	1.2g
MeFBSEA	4g
SAM HA100	1.2g
Vazo 88	0.9g
Irgacure 184	1.0
FC 4430	0.3g
Dye	0.2g

Formulation 7

SR 238	40g
CN 301	20g
SR 399	1.2g
MeFBSEA	4g
CD 9053	1.2g
Vazo 88	0.9g
Irgacure 184	1.0
FC 4430	0.3g
Dye	0.2g

Formulation 9

SR 238	40g
SUO H8310	15g
SR 399	1.2g
MeFBSEA	4g
SAM HA100	1.2g
Vazo 88	0.9g
Irgacure 184	1.0g
FC 4430	0.3g
Dye	0.2g

Formulation 10

SR 238	30g
SR 833S	10g
SUO H8310	15g
SR 399	1.2g
MeFBSEA	4g
SAM HA100	1.2g
Vazo 88	0.9g
Irgacure 184	1.0g
FC 4430	0.3g
Dye	0.2g

The formulations were tuned, based on the following factors:

- 5 i. Miscibility of monomers – in liquid state as well as post-polymerization, with no phase separation.
- ii. Flexibility and Toughness – It is necessary for a conformal coating to be flexible. In addition, the coating needs to be scratch resistant. A balanced amount of flexibilizer was required to achieve both the desired properties.
- iii. High $t_{1/2}$ initiator to improve the shelf life of the coating.

For the bulk monomer, CD 420 and SR 239 were chosen. These monomers have high flash point and low viscosity with excellent miscibility with other monomers. SR 239 gave a better film as compared to CD 420. CD 420 partially evaporated during the curing process and gave off a typical acrylate smell. SR 833S provided better rigidity and scratch resistance to the films.

- 5 Flexibilizers CN 310 and 307 are amber coloured butadiene dimethacrylates with very high viscosity. Both were miscible with the bulk monomers. Both CN 310 and 307 could be copolymerized with other monomers. SU-H8130 has high viscosity and very low color, which makes it suitable for LED applications.

- 10 Cross-linkers were added at a weight % of about 1-2% to improve the cross-link density. SR 399 was preferred due to high viscosity and the additional cross-linking sites.

Acrylic acid was used as typical adhesion promoter for acrylic formulations. However, due to heat curing and the low boiling point of acrylic acid, CN 9053 and SAM-HS100 which are phosphonate ester based adhesion promoter was also used. CN 9053 and SAM-HS100 gave excellent adhesion on metal substrates.

- 15 Fluorescent dye OB has only 0.3% solubility in the bulk formulation. However, this was sufficient to impart fluorescence properties to the polymer under UV/black light.

Different levelling agents were tried from Evonik's Tego series and BYK. Excellent performance was obtained using 3M surfactant FC 4430 which itself is fluoroacrylate polymer. 0.5 wt% addition of FC 4430 gave an excellent film without defects.

- 20 The fluoromonomer was used to impart corrosion resistance to the polymer composition, in particular against salt water and sulfur corrosion. It is only possible to protect against sulfur corrosion using a fluorinated polymer. Sulfur corrosion is most catastrophic for printed circuit boards (PCBs) due to exposure to the environment, for example due to sulfur emission from vehicle pollution.

- 25 The components were mixed sequentially by heating to 40-50 °C with agitation. The fluorescent dye was dissolved in a small amount of bulk monomer before mixing into the formulation. Finally, the initiator was dissolved in the bulk monomer and added into the formulation at room temperature.

- 30 The coating was applied via a dip coating method using a dwell time of 1 minute and a pull speed of 12"/minute. The thermal curing was performed at 100 °C for 1 hour, and UV-curing was performed using a D bulb at 600 W and an intensity of 20 ft/minute.

Example 3: Properties of the Coatings

The properties of the inventive coatings are summarised in Table 5.

Table 5. Properties of the coatings

Coating	Viscosity (cps)	Shelf life	Cure Condition	Flexibility
1	40	> 6 months	Thermal - 100 °C , 1 hour UV – D bulb, 600W, 20ft/min	Poor
2	250	> 6 months		Excellent
3	80	> 6 months		Moderate
4	180	> 6 months*		Good
5	210	> 6 months*		Good
6	40	> 6 months		Poor
7	250	> 6 months		Excellent
8	80	> 6 months		Moderate
9	180	> 6 months*		Good
10	210	> 6 months*		Good

Example 4: Flexibility

Flexibility is one of the major pre-screening properties of a coating formulation. A conformal coating must pass the Conical Mandrel test as an initial qualification. CD-420-based formulations 1 and 3 showed failure in the flexibility test although coating 2 was shown to be excellent due to an increase in rubber content. The limitation in increasing the amount of flexibilizing monomer is that it will decrease the hardness and scratch resistance of the coating. The SR-239 based coating gave a better balance between the flexibility and hardness properties.

10 Example 5: Taber Abrasion and Pencil Hardness Test

The Linear Taber abrasion test was performed on coatings applied on aluminium coupons. This technique was a modified version of Rotatory Taber Abrader with CS-10 wheels in accordance with ASTM standard D1044.3470. This is also a prescribed method for UL 746E standard.

Table 6. Scratch Resistance Performance and Pencil Hardness values.

Coating	Scratch Resistance	Pencil Hardness
1	100 cycles	3H
2	5 cycles	B
3	20 cycles	H
4	100 cycles	3H
5	100 cycles	3H
6	100 cycles	3H
7	5 cycles	B
8	20 cycles	H
9	100 cycles	3H
10	100 cycles	3H

As shown in Table 6, coatings 1, 4 and 5 showed a pencil hardness of 3H with 500g of force. In addition, these coatings showed superior scratch resistance over the other coatings.

Addition of SR 833S improved the scratch resistance for formulation 10.

Based on the above screening, Coatings 4 and 5 were further analyzed exhaustively.

Example 6: Thermal Shock

It was found that all tested coatings 1 to 10 withstood the 100 thermal shock cycles in the temperature range -65°C to 125°C. No flaking off or breakage of the films was observed.

5 Example 7: Electrical Measurements

As Coatings 1, 2, 3 6, 7, and 8 failed in initial experiments, Coatings 4, 5, 9 and 10 were subjected to a Dielectric Withstand Voltage (DWV) test.

Table 7. Results of the DWV test with respect to coating thickness.

Coating	Thickness - micron	DWV – VAC
4	30	1500
5	42	1500
9	30	1500
10	42	1500

- 10 Coatings 4 and 5 were dip coated onto standard PCB with a pull speed of 11"/min. This gave an approximate thickness as shown in Table 7. The coatings that were thicker (25 to 50 microns) typically passed the DWV test.

Example 8: Moisture Insulation Resistance

Table 8. Moisture insulation resistance

Coating	Moisture Insulation Resistance (GigaOhms)			Dielectric Withstand Voltage
	Initial	10 th cycle	Recovery	
6	2320	10	1490	Passed
7	2200	7.1	1080	Passed
8	2310	7.9	1110	Passed
9	2400	6.8	1030	Passed
10	2940	9.8	1460	Passed

15

IPC standard acceptance limit for moisture insulation resistance is 0.1 GigaOhms.

Industrial Applicability

The polymer composition may be useful in moisture protection and water proofing applications in printed circuit boards and sensors.

- 5 The polymer composition may be useful for protecting sensitive electronics and solder joints from corrosive electrochemical effects. The polymer composition may therefore be useful as a coating to protect printed circuit boards.

The polymer composition may also be useful as a coating to ensure long term reliability of automobiles, control drives, fire alarms, and in military/aerospace applications. The polymer composition may also be useful in protecting toys, cars, medical equipment and white goods.

- 10 It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. A polymer composition comprising:

a polymer having repeating units of:

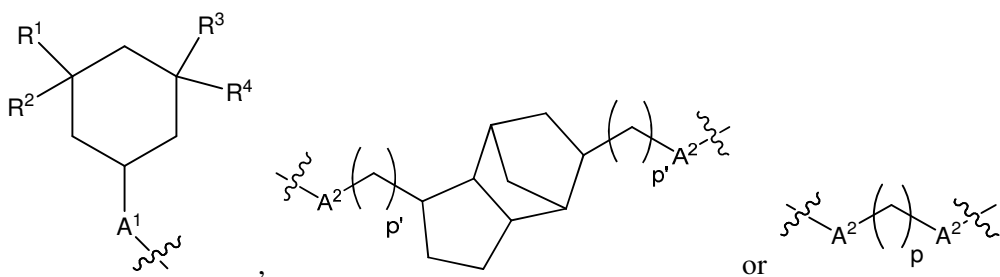
a bulk monomer, a flexibilizing monomer, a fluoromonomer; an adhesion promoting monomer; and a leveling monomer;

optionally a cross-linking monomer; and

optionally a fluorophore.

2. The polymer composition of claim 1, wherein the polymer composition is substantially free of solvent, and/or is substantially free of silicon.

3. The polymer composition of claim 1 or 2, wherein the bulk monomer comprises the following structure:



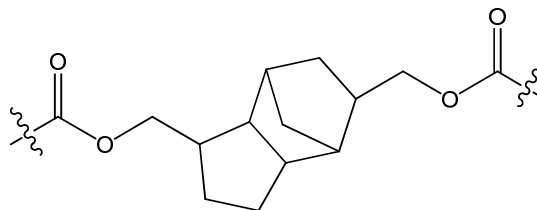
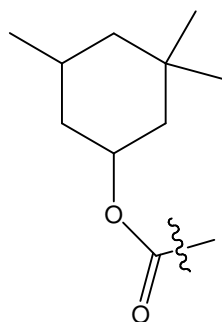
wherein A¹ and A² are independently absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof;

R¹, R², R³ and R⁴ are independently hydrogen or alkyl, and

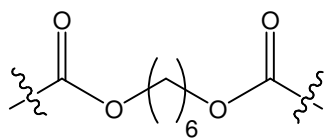
p and p' are independently an integer in the range of from 1 to 10.

4. The polymer composition according to claim 3, wherein A¹ or A² are ester, R¹ is hydrogen, R², R³ and R⁴ are methyl, p is 6 and p' is 1.

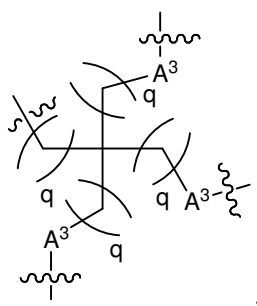
5. The polymer composition according to claim 3 or 4, wherein the bulk monomer comprises the following structure:



or



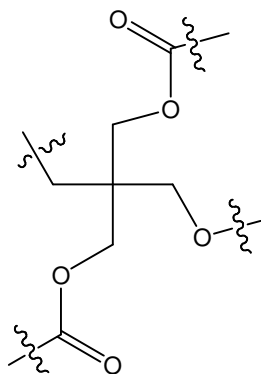
6. The polymer composition according to any one of the preceding claims, wherein the flexibilizing monomer comprises at least one diene group.
- 5 7. The polymer composition according to claim 6, wherein the flexibilizing monomer comprises butadiene.
8. The polymer composition according to claim 6 or 7, wherein the flexibilizing monomer comprises a polybutadiene oligomer.
9. The polymer composition according to any one of the preceding claims, wherein the cross-linking monomer comprises the following structure:
- 10



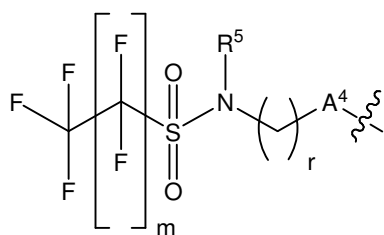
wherein A^3 is independently absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof; and

q is independently an integer in the range of from 1 to 10.

- 15 10. The polymer composition according to claim 9, wherein q is 1 and A^3 is ester.
11. The polymer composition according to claim 9 or 10, wherein the cross-linking monomer comprises the following structure:



12. The polymer composition according to any one of the preceding claims, wherein the fluoromonomer comprises the following structure:



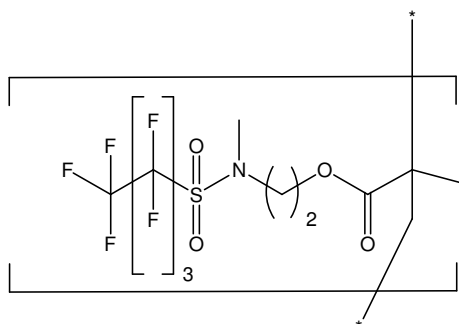
- 5 wherein m and r are independently an integer in the range of from 1 to 10,

R^5 is hydrogen or alkyl; and

A^4 is absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

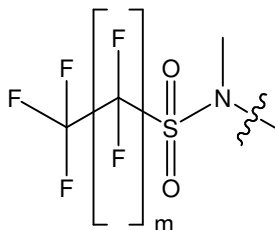
- 10 13. The polymer composition according to claim 12, wherein m is 4, r is 2, R^5 is methyl and A^4 is ester.

14. The polymer composition according to claim 12 or 13, wherein the repeating unit of the fluoromonomer has the following structure:



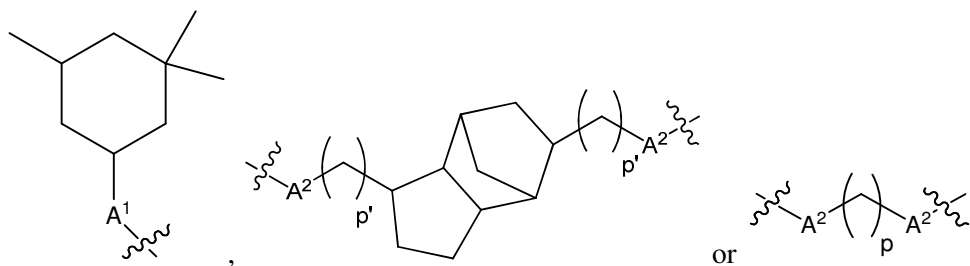
- 15 15. The polymer composition according to any one of the preceding claims, wherein the adhesion promoting monomer comprises a carboxylic acid or a phosphonate ester.

16. The polymer composition according to any one of the preceding claims, wherein the leveling monomer comprises a fluoroacrylate polymer comprising the following structure:



, wherein m is an integer in the range of 1 to 50.

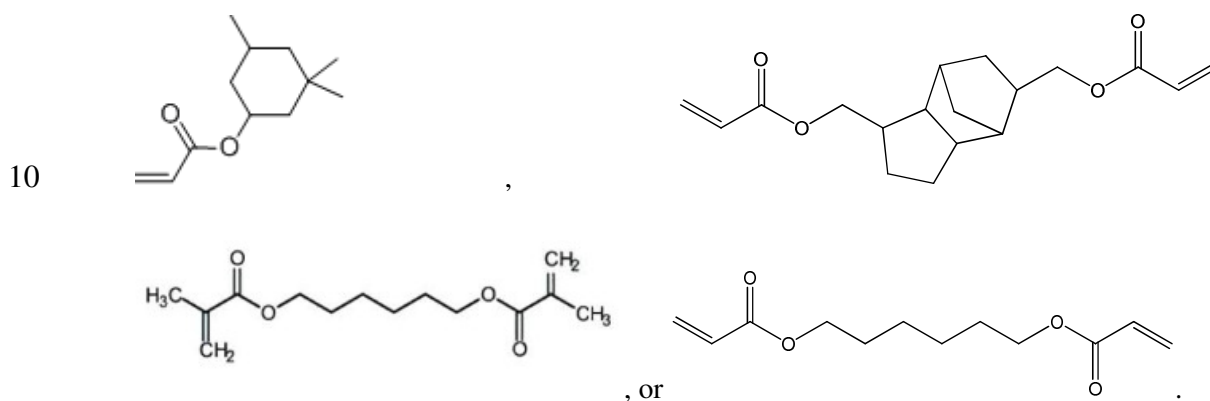
17. The polymer composition according to any one of the preceding claims, wherein the fluorophore is 2,5-bis-(5-ter-butyl-benzoxazolyl-)thiophene.
18. The polymer composition according to any one of the preceding claims, wherein the polymer composition comprises:
- about 7 wt% to about 70 wt% of the bulk monomer,
 - about 3 wt% to about 55 wt% of the flexibilizing monomer,
 - about 0 wt% to about 15 wt% of the cross-linking monomer,
 - about 1 wt% to about 40 wt% of the fluoromonomer;
 - about 1.0 wt% to about 10 wt% of the adhesion promoting monomer;
 - about 0.1 wt% to about 5 wt% of the leveling monomer; and
 - about 0 wt% to about 5 wt% of the fluorophore,
- wherein the total wt% is 100%.
19. The copolymer of any one of the preceding claims, wherein the polymer is a random copolymer.
20. A method for synthesizing the polymer composition according to any one of claims 1 to 18, comprising the step of contacting a bulk monomer, a flexibilizing monomer, an adhesion promoting monomer, a levelling agent and optionally a cross-linking monomer and optionally a fluorophore.
21. The method according to claim 20, wherein the method does not comprise contacting a solvent, and/or silicon with the polymer composition.
22. The method according to claim 20 or 21, wherein the bulk monomer comprises the following structure:



wherein A^1 and A^2 are independently absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof; and

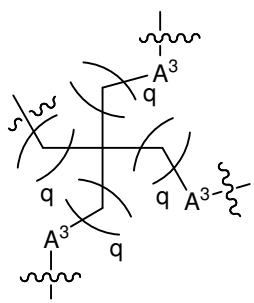
p is an integer in the range of from 1 to 10.

- 5 23. The method according to claim 22, wherein A^1 or A^2 are ester and p is 6.
24. The method according to claim 22 or 23, wherein the bulk monomer comprises a vinyl group.
25. The method according to any one of claims 20 to 24, wherein the bulk monomer has the following structure:



26. The method according any one claims 20 to 25, wherein the flexibilizing monomer comprises at least one diene group.
27. The method according to claim 26, wherein the flexibilizing monomer comprises butadiene.
- 15 28. The method according to claim 26 or 27, wherein the flexibilizing monomer comprises a polybutadiene oligomer.
29. The method according to any one of claims 26 to 28, wherein the flexibilizing monomer comprises a vinyl group.
- 20 30. The method according to any one of claims 26 to 29, wherein the flexibilizng monomer is a polybutadiene diacrylate or a polybutadiene dimethacrylate.

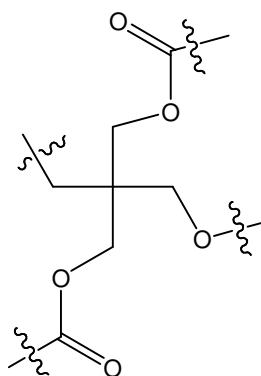
31. The method according to any one of claims 20 to 30, wherein the cross-linking monomer comprises the following structure:



wherein A³ is independently absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof; and

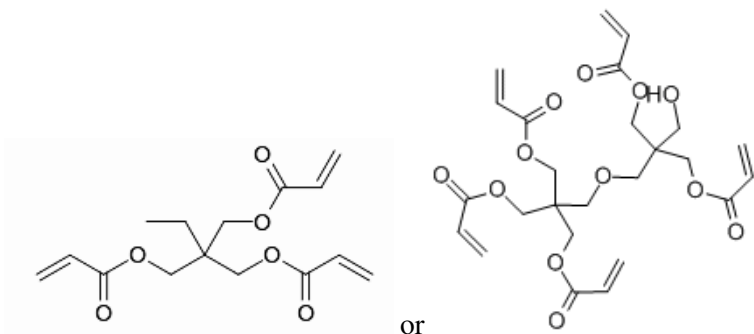
q is independently an integer in the range of from 1 to 10.

32. The method according to claim 31, wherein the cross-linking monomer comprises the following structure:

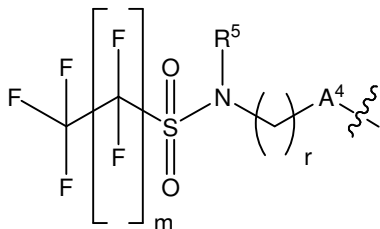


- 10 33. The method according to claim 31 or 32, wherein the cross-linking monomer comprises a vinyl group.

34. The method according to any one of claims 31 to 33, wherein the cross-linking monomer has the following structure:



35. The method according to any one of the claims 20 to 34, wherein the fluoromonomer comprises a carboxylic acid or comprises the following structure:



wherein m and r are independently an integer in the range of from 1 to 10,

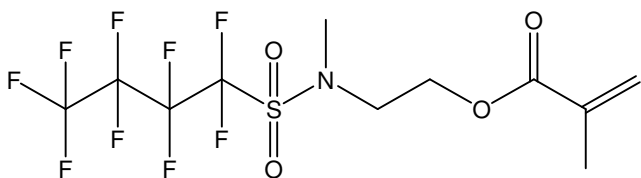
- 5 R^5 is hydrogen or alkyl, and

A^4 is absent or a linker group selected from the group consisting of amide, disulfide, ester, ether, triazole, and any mixture thereof.

36. The method according to claim 35, wherein m is 4, r is 2, R^5 is methyl and A^4 is ester.

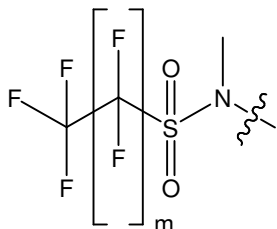
- 10 37. The method according to claim 35 or 36, wherein the fluoromonomer comprises a vinyl group.

38. The method according to any one of claims 35 to 37, wherein the fluoromonomer has the following structure:



- 15 39. The method according to any one of claims 20 to 38, wherein the adhesion promoting monomer comprises a carboxylic acid or a phosphonate ester.

40. The method according to any one of claims 20 to 39, wherein the leveling monomer comprises a fluoroacrylate polymer comprising the following structure:



, wherein m is an integer in the range of 1 to 50.

- 20 41. The method according to any one of claims 20 to 40, wherein the fluorophore is 2,5-bis-(5-ter-butyl-benzoxazolyl-)thiophene.

42. The method according to any one of claims 20 to 41, wherein the bulk monomer, the flexibilizing monomer, the cross-linking monomer, the adhesion promoting monomer, the levelling agent and optionally the fluorophore are contacted at the following weight percentage:
- 5 about 7 wt% to about 70 wt% of the bulk monomer,
- about 3 wt% to about 55 wt% of the flexibilizing monomer,
- about 0 wt% to about 15 wt% of the cross-linking monomer,
- about 1 wt% to about 40 wt% of the fluoromonomer;
- about 1.0 wt% to about 10 wt% of the adhesion promoting monomer;
- 10 about 0.1 wt% to about 5 wt% of the leveling monomer; and
- about 0 wt% to about 5 wt% of the fluorophore,
- wherein the total wt% is 100%.
43. The method according to any one of claims 20 to 42, wherein the bulk monomer, the flexibilizing monomer, the adhesion promoting monomer, the levelling agent, optionally the
- 15 cross-linking monomer and optionally the fluorophore are mixed sequentially in that order to form a mixture.
44. The method according to any one of claims 20 to 42, further comprising the step of pre-mixing the flexibilizing monomer, the cross-linking monomer, the adhesion promoting monomer, the levelling agent or the fluorophore with the bulk monomer before adding to
- 20 the mixture.
45. The method according to any one of claims 20 to 44, wherein the mixture is heated to a temperature in the range of about 30 °C to about 60 °C.
46. The method according to any one of claims 20 to 45, comprising the step of adding a polymerization initiator.
- 25 47. The method according to claim 46, wherein the polymerization initiator is selected from the group consisting of 1,1'-azo-bis(cyanocyclohexane), di-tert-amyl peroxide, 1-benzoylcyclohexanol, and any mixture thereof.
48. The method according to claim 47, comprising the step of UV-curing the polymer composition under UV radiation using a D-bulb at a power in the range of about 400 W to about 800 W and at an intensity in the range of about 15 ft/min to about 25 ft/min.
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49. The method according to claim 47, comprising the step of thermal-curing the polymer composition at a temperature in the range of about 90 °C to about 150 °C for a duration in the range of about 30 minutes to 90 minutes.
50. A polymer composition obtainable by contacting a bulk monomer, a flexibilizing monomer,
5 an adhesion promoting monomer, a levelling agent and optionally a fluorophore.
51. A coating comprising the polymer composition according to any one of claims 1 to 19 or 50.
52. The coating according to claim 51, wherein the thickness of the coating is in the range of about 20 µm to about 2000 µm.
53. A method for coating a substrate with the coating according to claim 51 or 52, comprising
10 the step of applying the coating composition onto at least part of a substrate surface.
54. The method according to claim 53, wherein the applying step is performed by dip coating, spin coating, spray coating, brush coating, flow coating or airless spray dispensing.
55. The method according to claim 54, wherein when the coating is applied by dipping, the
15 pull speed is in the range of about 6"/minute to about 20"/minute with a dwell time in the range of about 30 seconds to 90 seconds.
56. A substrate that is at least partially coated with the coating composition according to claim 51 or 52.