

FAST-CURED INTUMESCENT COATINGS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority of U.S. Provisional Application No. 63/513,698, filed July 14, 2023, filed under 35 U.S.C 119, titled “Fast-Cured Intumescent Coatings”; which is incorporated herein by reference.

FIELD

[0002] This disclosure generally relates to intumescent coating composition and methods for making and using same.

BACKGROUND

[0003] Intumescent coating compositions with faster drying times are desired.

SUMMARY

[0004] The present disclosure is directed to intumescent coating compositions that include (a) a molecule that includes one or more acylacyloxy groups; (b) an epoxy resin; (c) a molecule that includes a ketimine group; and (d) an intumescent agent.

FIGURES

[0005] Figure 1 shows a potential reaction mechanism for some intumescent coatings described herein.

DETAILED DESCRIPTION

[0006] For the purposes of the following detailed description, it is to be understood that the disclosure may assume various alternative variations and step sequences, except where expressly specified to the contrary. Moreover, other than in any operating examples, or where otherwise indicated, all numbers expressing, for example, quantities of ingredients used in the specification and claims are to be understood as being modified in all instances by the term “about”. Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that may vary depending upon the desired properties to be obtained by the present disclosure. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope

of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

[0007] Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the disclosure are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard variation found in their respective testing measurements.

[0008] Also, it should be understood that any numerical range recited herein is intended to include all sub-ranges subsumed therein. For example, a range of “1 to 10” is intended to include all sub-ranges between (and including) the recited minimum value of 1 and the recited maximum value of 10, that is, having a minimum value equal to or greater than 1 and a maximum value of equal to or less than 10.

[0009] In this application, the use of the singular includes the plural and plural encompasses the singular, unless specifically stated otherwise. In addition, in this application, the use of “or” means “and/or” unless specifically stated otherwise, even though “and/or” may be explicitly used in certain instances. Further, in this application, the use of “a” or “an” means “at least one” unless specifically stated otherwise. For example, “a” polymer, “an” acid, and the like refer to one or more of any of these items.

[0010] Unless otherwise indicated, ambient conditions of temperature and pressure are ambient temperature (20-25 °C) and standard pressure of 101.3 kPa (1 atm).

[0011] The present disclosure is directed to intumescent coating compositions that include (a) a molecule that includes one or more acylacyloxy (ACAC) groups, such as an acetoacetoxy group; (b) an epoxy resin; (c) a molecule that includes a ketimine and/or an aldimine group; and (d) an intumescent agent.

[0012] The present intumescent coating compositions are fast-cured and include a polyacylacyloxy (ACAC)-ketimine/aldimine-epoxy-based binder and intumescent agents. The present intumescent coating compositions can be fast cured/dried in order to be handled within 2 hours at 23 °C. The present intumescent coating composition is suitable for fire protection, as a coating of metallic and/or non-metallic substrates, as nonlimiting examples, steel components such as pillars, beams, or truss members, to increase the fire resistance time.

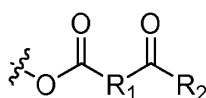
[0013] The present intumescent coating composition can be substantially free (less than 1 weight percent), essentially free (less than 0.1 weight percent) or completely free

(undetectable) of an independent gas source. For example, melamine or melamine containing compounds can be excluded or not included in the intumescent coating composition.

Molecule that includes one or more ACAC groups

[0014] The present intumescent coating composition includes a molecule that includes one or more acylacyloxy (ACAC) groups. The ACAC groups can be end groups on the molecule.

The ACAC groups can conform to the following formula:



where R¹ is a difunctional C₁-C₄ alkyl radical, such as methylene, and R² is C₁-C₄ alkyl, such as methyl. When R¹ and R² are C₁, the ACAC group is an acetoacetoxo group.

[0015] The molecule that includes one or more ACAC groups can be an oligomer or polymer. A nonlimiting example of a polymer that includes one or more ACAC groups is one where R¹ is CH₂, R² is methyl, and an ester group is provided pendant to the main chain of the oligomer or polymer. The acylacyloxy-functional groups can be terminal, branched or side chained or mixtures thereof. As a nonlimiting example, at least one branch of the oligomer or polymer terminates with acylacyloxy-functionality. The acylacyloxy-functional group may be bonded to a polyester functional block or directly to a polyol functional block as needed for a particular application.

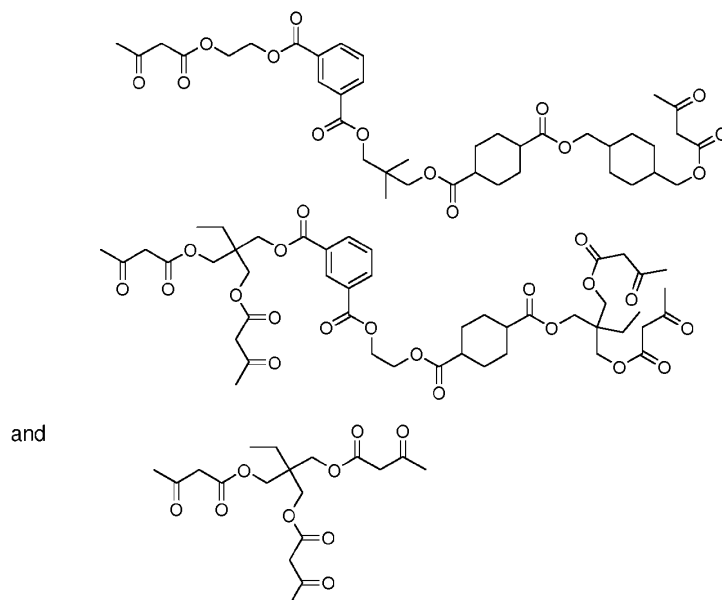
[0016] Derivative of the ACAC containing oligomers or polymers described above can include but are not limited to (a) polypropylene glycol based (e.g., co-reacted with polypropylene glycol), poly-diol based (e.g., co-reacted with a polycarbonate diol, polypropylene glycol, polyether diol, polyester diol, etc.), (b) urethane backbone and/or urethane modified (e.g., co-reacted with isocyanate) iterations thereof (c) silicones, silanes, (meth) acrylates, acrylics, but not limited to. Such molecule that includes one or more ACAC groups can be used on their own or mixed with epoxy resin binders as described herein.

[0017] The ACAC containing oligomers or polymers can, as a nonlimiting example, include acetoacetate functional dimer fatty acid based polyol/polyester block copolymers, such as an AcAc functional polymer initially formed from caprolactones.

[0018] The ACAC containing oligomers or polymers can be flexible block copolymers that may include, as a nonlimiting example, at least a hydrophobic polyol block; functional endcaps provided by epoxy groups, acetoacetate groups, or both. As a nonlimiting example, the endcaps can have a functionality greater than 1. The oligomer or polymer may also include optional functional extension groups such as isocyanates or silicones for flexibility. To provide flexibility, the block copolymer may, without limitation, either include select polyalkylene glycol diol blocks having a molecular weight to impart flexibility or, if the hydrophobic polyol block includes epoxy and/or fatty acid derived polyol groups, then the flexible copolymer may also include one or more lactone-derived flexibility blocks each having the residue of at least 3 or more repeating lactone groups. The optional functional groups may include hydroxyl and other groups that do not create unfavorable reactions/conditions with the remaining constituents in the intumescent coating composition.

[0019] The molecule that includes one or more ACAC groups can have a molecular weight of less than 5,000 g/mol, such as less than 3,000 g/mol, less than 1500 g/mol, less than 1250 g/mol or less than 1000 g/mol, and can be from 300 to 5,000 g/mol, such as from 500 to 3,000 g/mol, from 350 to 1,500 g/mol, or 500 to 1,000 g/mol.

[0020] The molecules that include one or more ACAC groups that can be used in the present intumescent coating composition can be prepared by reacting 1,4-cyclohexanedicarboxylic acid, isophthalic acid, ethylene glycol, 2,2 dimethyl-1,3 propanediol, 1,4 cyclohexane dimethanol, trimethylolpropane and tert-butyl acetoacetate in the presence of butyl stannic acid and the triphenyl ester of phosphorous acid as catalysts. The resulting product can include one or more compounds according to the following formulas:

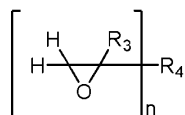


[0021] The molecule that includes one or more ACAC groups can be present in the intumescent coating composition in an amount of at least 5, such as at least 10, at least 15, or at least 20 percent by weight, based on the total weight of the intumescent coating composition and can be present in an amount of up to 30, such as up to 20, or up to 10 percent by weight, based on the total weight of the intumescent coating composition, the molecule comprising one or more acylacetoxy end groups can be present in the intumescent coating composition in an amount in the range of from 5 to 30 percent by weight, from 5 to 25 percent by weight, from 5 to 20 percent by weight, from 10 to 30 percent by weight, from 10 to 25 percent by weight, from 15 to 30 percent by weight, from 15 to 20 percent by weight, from 20 to 30 percent by weight, from 20 to 25 percent by weight, or from 25 to 30 percent by weight based on the total weight of the intumescent coating composition.

The epoxy resin

[0022] The epoxy resin (b) in the intumescent coating composition can include the reaction product of polyhydroxy compounds, such as polyvalent phenols or phenol-aldehyde condensates, with epihalohydrins or the precursors thereof.

[0023] The epoxy resin can be a polyepoxide resin, as a nonlimiting example can be one which contains at least two oxirane groups in the molecule, i.e.,



where n is at least two, R₃ is hydrogen or methyl, and R₄ broadly represents an organic based molecule or polymer typically composed of carbon, hydrogen, oxygen, and optionally nitrogen and or sulfur. Hydroxyl substituent groups can also be present and frequently are, as well as halogen and ether groups. Generally, the epoxide equivalent weight ranges from about 60 to about 1000, such as from about 100 to about 500, or from about 150 to about 250. These resins can be broadly categorized as being aliphatic, aromatic, cyclic, acyclic, alicyclic, or heterocyclic.

[0024] Polyepoxide resins that can be used herein include, without limitation, the epoxy novolac resins. These resins can be prepared by reacting an epihalohydrin with the condensation product of an aldehyde with a monohydric or polyhydric phenol. A nonlimiting example includes the reaction product of epichlorohydrin with a phenolformaldehyde condensate.

[0025] Another group of useful polyepoxide resins include, without limitation, the polyglycidyl ethers of polyhydric aromatic alcohols, such as for example, dihydric phenols. The phenol can be at least dihydric. Suitable, nonlimiting examples, include resorcinol, catechol, hydroquinone, bis(4-hydroxyphenyl)-1, 1-isobutane; 4,4-dihydroxybenzophenone; bis(4-hydroxyphenyl)l, 1-isobutane; bis(4-hydroxyphenyl)-1, 1-ethane; bis(2-hydroxynaphenyl)methane; 1,5-hydroxynaphthalene and 4,4'-isopropylidenediphenol, i.e., bisphenol A, which can be utilized. Epichlorohydrin can be used although epibromohydrin can also be used. The polyglycidyl ethers useful herein can be obtained by reacting epichlorohydrin and bisphenol A in the presence of an alkali, such as sodium or potassium hydroxide. The EPON series of epoxy resins sold by Hexion can be used herein.

[0026] Another group of useful polyepoxide resins include, without limitation, the polyglycidyl ethers derived from such polyhydric alcohols as ethylene glycol; diethylene

glycol; triethylene glycol; 1,2-propylene glycol; 1,4butylene glycol; 1,5-pentanediol; 1,2,6-hexanetriol; glycerol and trimethylolpropane.

[0027] Also useful herein, without limitation, are the polyepoxide resins that are polyglycidyl ethers of polycarboxylic acids. These materials are produced by the reaction of an epoxy compound such as epichlorohydrin with an aliphatic or aromatic polycarboxylic acid such as oxalic acid; succinic acid; glutaric acid; terephthalic acid; 2,6-naphthalene dicarboxylic acid and dimerized linoleic acid.

[0028] Still another group of polyepoxide resins that can be used include, without limitation, those derived from epoxidation of olefinically unsaturated alicyclic materials. Among these are the epoxy alicyclic ethers and esters well known in the art.

[0029] In addition to the materials discussed above and referring to the structure of the polymer containing oxirane groups above, useful epoxy resin can also include, without limitation, those containing oxyalkylene groups, i.e., wherein R^3 is hydrogen or C_1 to C_6 alkyl, m is an integer from 1 to 4 and n is an integer from 2 to 50. Such groups can be pendant from the backbone of the epoxide resin, or they can be included as part of the backbone. The proportion of oxyalkylene groups in the polyepoxide resin depends upon several factors, among them the size of the oxyalkylene group and the nature of the epoxy resin. Mixtures of polyepoxide resins are also useful herein.

[0030] The epoxy resin can include, without limitation, one or more of:

- a) reaction products of epichlorohydrin with bisphenol A, F, or S;
 - b) reaction products of epichlorohydrin with bisphenol S
 - c) epoxy novolac resins based on phenol or cresol;
 - d) aromatic glycidyl amine resins;
 - e) epoxy resins which do not have aromatic structural units;
 - f) an aliphatic or cycloaliphatic polyepoxide;
- and combinations or mixtures thereof.

[0031] The epoxy resin can have an epoxide equivalent weight in the range of from 60 to 1000, such as from 100 to 500, or from 150 to 250 moles of epoxy groups per 100g resin.

[0032] The epoxy resin can be present in the intumescent coating composition in an amount of at least 3, such as at least 5, or at least 7 percent by weight, and can be present at up to 9.9, such as up to 9.2, or up to 8.5 percent by weight, based on the total weight of the intumescent coating composition, the epoxy resin may be present in the intumescent coating composition in an amount in the range of from 3 to 9.9 percent by weight, such as from 3 to 9.2 percent by weight, from 3 to 8.5 percent by weight, from 5 to 9.9 percent by weight, from 5 to 9.2

percent by weight, from 5 to 8.5 percent by weight, from 7 to 9.9 percent by weight, from 7 to 9.2 percent by weight, or from 7 to 8.5 percent by weight.

The molecule that includes a ketimine and/or aldimine group

[0033] The molecule that includes a ketimine group can be, without limitation, a ketimine containing polyepoxide and/or aliphatic ketimine. The ketimine containing polyepoxide can be prepared as known in the art by ketone modifying a polyamine followed by the reaction of the remaining nucleophilic group(s) with polyepoxides. The aliphatic ketimine may be prepared as known in the art by reacting an aliphatic diamine with an aliphatic ketone. The polyepoxide in the ketimine containing polyepoxide can be the same or different from the epoxy resin (b) in the intumescent coating composition.

[0034] The molecule that includes a ketimine group can be the reaction product of a polyamine with a ketone containing molecule.

[0035] The molecule that includes a ketimine group can be the reaction product of a polyamine with a ketone containing molecule to form a polyamine/ketone product followed by reacting the polyamine/ketone product with an epoxide containing molecule to form the molecule that includes a ketimine group.

[0036] The polyepoxide resin which is utilized in the preparation of the ketimine containing polyepoxide resin can be selected from a variety of materials, such as the epoxy resins described above.

[0037] The epoxide containing molecule can include an epoxy resin that has an epoxide equivalent weight in the range of from 60 to 1000, such as from 100 to 500, or from 150 to 250 moles of epoxy group per 100g of resin.

[0038] The molecule that includes a ketimine group can be a ketimine containing polyepoxide that can be prepared from any one of the above polyepoxides in the following manner. First a polyhydric amine compound having an average of at least two amine groups per molecule, such as a polyamine modified by reaction with a ketone to form a ketimine. As a nonlimiting example, one mole of diethylenetriamine can be reacted with two moles of methylisobutyl ketone to produce a diketimine with secondary amine functionality plus two moles of water. As another nonlimiting example, an aldehyde can be used in place of or in conjunction with the ketone to form a modified amine referred to as an aldimine. The resulting ketimine, or aldimine, modified amine is then reacted with a polyepoxide, effectively depleting all of the oxirane groups of the polyepoxide and resulting in a ketimine, or aldimine, containing polyepoxide units which can be essentially free of oxirane groups. By

"essentially free of oxirane groups" is meant that the epoxy equivalent weight of the ketimine and/or aldimine containing polyepoxide is measured to be about at least 5000 (g/equivalent of epoxy), in other words, the ketimine and/or aldimine containing polyepoxide is calculated to contain, on average, less than 1, such as less than 0.5 oxirane groups per molecule.

[0039] Representative polyamines that can be used in the practice of the present disclosure can be described as aliphatic or cycloaliphatic amines having from 2 to 10 primary and/or secondary amino groups, such as from 2 to 4 primary amino groups and from 2 to 200 carbon atoms. Examples of suitable polyamines include without limitation ethylenediamine, propylenediamine, butylenediamine, pentamethylenediamine, hexamethylenediamine, decamethylenediamine, 4,7-dioxadecane-1, 10-diamine, dodecamethylenediamine, 4,9-dioxadodecane-1,12-diamine, 7-methyl-4, 10-dioxatridecane-1,13-diamine, 1,2-diaminocyclohexane, 1,4-diaminocyclohexane, 4,4'-diaminodicyclohexyl methane, isophorone diamine, bis(3-methyl-4-aminocyclohexyl)methane, 2,2-bis(4-aminocyclohexyl)propane, nitrile tris(ethane amine), bis(3-aminopropyl) methylamine, 2-amino-i(methylamino) propane, 3-amino-1-(cyclohexylamino)propane and N-(2-hydroxyethyl)ethylene diamine, isophorone diamine, 1,2-diaminopropane, 1,3-diaminopropane, 1,4-diaminobutane, 1,5-diaminopentane, 1,6-diaminohexane, 1,8-diaminooctane, 2-methyl-1,5-pentane diamine, 2,5-diamino-2,5- dimethylhexane, 2,2,4-trimethyl-1,6-diamino-hexane, 2,4,4-trimethyl-1,6- diamino-hexane, 1,11-diaminoundecane, 1,12-diaminododecane, 1,3- cyclohexane diamine, 1,4-cyclohexane diamine, 1-amino-3,3,5-trimethyl-5- aminomethyl-cyclohexane, 2,4'-diamino-dicyclohexyl methane, 4,4'-diamino-dicyclohexyl methane, 3,3'-dimethyl-4,4'-diamino-dicyclohexyl methane and/or 3,3'-diethyl-4,4'-diamino-dicyclohexyl methane and combinations thereof.

[0040] A group of polyamines that can be used according to this disclosure can be represented by the following structural formula;



where the group R^5 and R^6 can be the same or different and represent an alkylene group containing from 2 to 6, such as from 2 to 4 carbon atoms and n is a number from 1 to 6, such as from 1 to 3. By an alkylene group is meant a cycloalkylene group, an alkylene group, or an alkylene group containing an ether-oxygen atom. Examples of representative polyalkylene polyamines include diethylenetriamine, dipropylenetriamine and dibutylenetriamine. These polyamines have two primary amino groups and one secondary amino group.

[0041] The ketone used in modifying the polyamine can be represented by the following structural formula:



wherein R and R' are independently alkanes having between 1 and 12 carbon atoms.

Aldehydes, according to the structure R-C(O)H, where R is defined as above, can also be used.

[0042] Examples of suitable ketones and aldehydes used as modifiers or blocking agents for the amine groups of this disclosure include, without limitation, acetone, diethyl ketone, methylisobutyl ketone, isobutyraldehyde, hydroxybutyraldehyde, pentanone, cyclohexanone, ethylamyl ketone, hydroxycitronellal, isophorone and decanone.

[0043] The aliphatic ketimine and/or aldimine may be prepared as known in the art by reacting an aliphatic diamine with an aliphatic ketone or aliphatic aldehyde. Examples of suitable diamines include, without limitation, isophorone diamine, ethylene diamine, 1,2-diaminopropane, 1,3-diaminopropane, 1,4-diaminobutane, 1,5-diaminopentane, 1,6-diaminohexane, 1,8-diaminooctane, 2-methyl-1,5-pentane diamine, 2,5-diamino-2,5-dimethylhexane, 2,2,4-trimethyl-1,6-diamino-hexane, 1,11-diaminoundecane, 1,12-diaminododecane, 1,3-cyclohexane diamine, 1,4-cyclohexane diamine, 1-amino-3,3,5-trimethyl-5-aminomethyl-cyclohexane, 2,4'-diamino-dicyclohexyl methane, 4,4'-diamino-dicyclohexyl methane, 3,3'-dimethyl-4,4'-diamino-dicyclohexyl methane and/or 3,3'-diethyl-4,4'-diamino-dicyclohexyl methane. Suitable ketones include, but are not limited to, acetone, methyl ethyl ketone, methyl isobutyl ketone, and/or methyl amyl ketone. Suitable aldehydes include, but are not limited to, isobutyraldehyde, hydroxybutyraldehyde and hydroxycitronellal. The aliphatic ketimine can be prepared, as a nonlimiting example, from a reaction mixture that includes isophorone diamine and methyl isobutyl ketone.

[0044] The polyketimine and/or aldimine resin can have a weight average molecular weight of from 300 to 10,000 g/mol, such as from about 500 to about 5,000 g/mol or from about 600 to about 1200 g/mol as determined by gel permeation chromatography (GPC), using a polystyrene standard. Further the ketimine and/or aldimine containing polyepoxide resin can be described as having an average of at least two ketimine and/or aldimine groups per molecule, such as an average of about 2 to about 25 ketimine and/or aldimine groups per molecule, or from about 3 to about 6 ketimine and/or aldimine groups per molecule.

[0045] The molecule that includes a ketimine and/or aldimine group can be present in the present invention in an amount of at least 10, such as at least 20, or least 25, or at least 30 percent by weight, based on the total weight of paint composition. The polyketimine and/or aldimine may be present in the present invention in an amount of at most 40, such as at most 30, or at most 20 percent by weight, based on the total weight of composition. Thus, the polyketimine and/or aldimine may be present in the intumescent coating composition in an amount, the range of 10 to 40 percent by weight, such as a range of 10 to 30 percent by weight, or a range of 10 to 20 percent by weight, or a range of 15 to 40 percent by weight, or a range of 10 to 30 percent by weight, or a range of 15 to 20 percent by weight, or a range of 20 to 40 percent by weight, or a range of 20 to 30 percent by weight, or a range of 25 to 40 percent by weight, or a range of 25 to 30 percent by weight.

Intumescent agents

[0046] The intumescent agent used in the intumescent coating composition can include one or more of a gas source, a carbon source, an acid source, a reinforcing fiber, other inorganic additive, and combinations thereof. The intumescent agents can be present, in total, at from 5 to 55, such as from 6 to 50 weight percent based on the total weight of the intumescent coating composition.

[0047] As indicated above, the intumescent coating composition can be substantially free (less than 1 weight percent), essentially free (less than 0.1 weight percent) or completely free (undetectable) of an independent gas source. For example, melamine or melamine containing compounds can be excluded or not included in the intumescent coating composition. As used herein, the term “independent gas source” refers to one or more molecules in the intumescent coating composition that act as a blowing agent by degrading and releasing an inflammable gas, which can expand a layer of the intumescent coating composition causing the formation of a swollen multicellular layer.

[0048] Common gas sources are nitrogen-containing, including compounds like ammonium polyphosphate, azodicarbonamide, p-toluene sulfonylsemicarbazide, 4,4'-oxybis(benzenesulfonyl hydrazide), dinitrosopentamethylenetetramine, p-toluene hydrazide, 5-phenyltetrazole, diazonium benzenesulfonate, melamine and melamine derivatives, as well as urea or urea derivatives.

[0049] When the intumescent agent includes melamine and/or melamine derivatives, the intumescent agent can include, salts of melamine, melamine formaldehyde, hydroxymethylated melamine, hexmethoxymethyl melamine, melamine monophosphate,

di(melamine phosphorate), melamine dihydric phosphorate, melem (-2,5,8-triamino 1,3,4,6,7,9,9b-heptaazaphenalene) and melon (poly[8-amino-1,3,4,6,7,9,9b-heptaazaphenalene -2,5-diyl]imino and melam (1,3,5-triazine-2,4,6-triamine-n-(4,6-diamino-1,3,5-triazine-2-yl) and mixtures or combinations thereof.

[0050] Additional gas sources include, but are not limited to, diisocyanate-(hydroxyethyl) isocyanurate (THEIC), boric Acid, trichloroethyl phosphate (TCEP), trichloropropyl phosphate (TCPP), or chlorinated paraffins. The resin itself can also act as a gas source through decomposition. Melamine can be the gas source.

[0051] When the intumescent agent includes a gas source, intumescent coating composition can include a boron containing compound, such as boric acid, and borates, such as ammonium pentaborate, zinc borate, sodium borate, lithium borate, aluminum borate, magnesium borate and borosilicate, and mixtures or combinations thereof.

[0052] When the intumescent agent includes a carbon source, the carbon source can include a tall oil fatty acid and/or an aromatic compound that includes at least one aromatic ring, such as 2, 3, or 4 aromatic rings, such as a benzene ring, a naphthalene ring, an anthracene ring, or a phenanthrene ring, and where the aromatic compound can optionally include at least one functional substituent, such as hydroxy, carboxy, mercapto, and/or amino. As a nonlimiting example, the aromatic compound can include one or more of bisphenol A, bisphenol B and bisphenol F. As a nonlimiting example, the aromatic compound can include an aromatic compound having a long chain hydrocarbyl substituent, such as a saturated or unsaturated hydrocarbyl having a linear or branched alkyl and/or alkenyl and/or alkynyl group having 6 to 20 carbon atoms, such as 6 to 18 carbon atoms, or 6 to 15 carbon atoms; where the long chain hydrocarbyl optionally includes 1 to 3 unsaturated bonds, such as double bond and/or an acetylenic bond.

[0053] Many types of compounds can be used as a carbon source or carbonizing agent, including pentaerythritol (monomer, dimer, and trimer), sorbitol, mannitol, dextrans, starch, phenol-formaldehyde resins, and charring polymers such as nylon 6, polyurethane, and polycarbonates.

[0054] When the intumescent agent includes a carbon source, the carbon source can be present in the intumescent coating composition in a range of from 0.5 to 50 weight percent, such as a range of from 10 to 18 weight percent, a range of from 11 to 17 weight percent or a range of from 12 to 16 weight percent based on the total weight of the intumescent coating composition.

[0055] When the intumescent agent includes an acid source, the acid source can include one or more of phosphorates, such as phosphoric acid, sodium phosphate, potassium phosphate or ammonium phosphate, ammonium polyphosphate (APP), monoammonium phosphate, diammonium phosphate, trichloroethyl phosphate (TCEP), trichloropropyl phosphate (TCPP), ammonium pyrophosphate, and triphenyl phosphate; sulfonates, such as sulphonic acid, sodium sulfonate, potassium sulfonate, ammonium sulfonate, and paratoluene sulfonate; and sulphates, such as sodium sulphate, potassium sulphate and ammonium sulphate.

[0056] When the intumescent agent includes an acid source, the acid source can be present in the intumescent coating composition in an amount in the range of 5 to 30 weight percent, such as a range of 5 to 25 weight percent, a range of 5 to 20 weight percent, or a range of 5 to 15 weight percent based on the total weight of the intumescent coating composition.

[0057] When the intumescent agent includes reinforcing fibers, the reinforcing fibers can include one or both of inorganic fibers and organic fibers. The inorganic fibers can include one or more of carbide fibers, such as boron carbide fibers, silicon carbide fibers, and niobium carbide fibers; nitride fibers, such as silicon nitride fibers; boron containing fibers, such as boron fibers and boride fibers; silicon containing fibers, such as silicon fibers, alumina-boron-silica fibers, non-base aluminum borate fibers, non-base or low base sodalime-aluminumborosilicate fibers, base-sodalime-silicate fibers, S-glass fibers, inorganic glass fibers, quartz fibers; ceramic fibers; basalt fibers and combinations thereof.

[0058] When the intumescent agent includes reinforcing fibers, the reinforcing fibers can be present in the intumescent coating composition in a range of from 0 to 5 weight percent, such as a range of from 1 to 4 weight percent or a range of from 2 to 5 weight percent based on the total weight of the intumescent coating composition.

[0059] When the intumescent agent includes other inorganic additives to enhance their fireretardant properties, the other inorganic additives can include one or more of titanium dioxide (TiO_2); aluminum hydroxide; expandable graphite and combinations thereof.

[0060] When the intumescent agent includes inorganic additives, the inorganic additives can be present in the intumescent coating composition in an amount in the range of 0 to 50 weight percent, such as a range of 15 to 40 weight percent, a range of 15 to 35 weight percent, a range of 15 to 30 weight percent, or a range of 15 to 25 weight percent based on the total weight of the intumescent coating composition.

Application of the intumescent coating composition to a substrate

[0061] Not being bound to any particular theory and as a nonlimiting example as shown in Fig. 1, when the intumescent coating composition of this disclosure is applied to at least a portion of a substrate and comes in contact with ambient moisture, the ketimine and/or aldimine component decomposes (i.e. deblocks) to generate a primary amine, which reacts rapidly with the (ACAC) group to form an imine. The final product is an enamine, which is formed by tautomerization of the imine over time and is thermodynamically favored. Although rapid cross-linking of the ketimine and/or aldimine and acylacyloxy group occurs readily, the enamine is reversible in the presence of water and can convert back to primary amine and acylacyloxy group. The extent of this reaction is determined by equilibrium, and rate determined by the pH of the intumescent coating composition and the presence or absence of other catalysts (e.g. ionic species). A secondary cross-linking reaction can be incorporated by the addition of a polyepoxide resin. This is believed to form an irreversible bond through reaction with the enamine product as well as primary and tertiary amine components of the binder.

[0062] The intumescent coating composition according to this disclosure can have a dry to handle time (ASTM-D1640 -2014) at 23°C and 40% relative humidity of less than or equal to 200 minutes, such as less than or equal to 175 minutes, less than or equal to 150 minutes or less than or equal to 125 minutes and the dry to handle time can be in a range from 50 to 200 minutes, such as a range from 60 to 175 minutes, a range from 70 to 150 minutes or a range from 50 to 125 minutes. The dry to handle time can be achieved without including a catalyst to the intumescent coating composition described herein.

[0063] The intumescent coating composition of this disclosure can be applied to any suitable substrate. Such substrates include, without limitation, one or more of concrete, wood, plastic, fiberglass, and rigid metal substrates such as ferrous metals, aluminum, aluminum alloys, and copper. The ferrous metal can include one or more of cold rolled steel, galvanized (zinc coated) steel, electrogalvanized steel, stainless steel, pickled steel, zinc-iron alloys, and combinations or composites of ferrous and non-ferrous metals. The intumescent coating composition can be applied by a method selected from brush coating, flow coating, and spray coating.

[0064] The intumescent coating composition according to this disclosure can be applied by optionally cleaning and/or degreasing at least a portion of a surface of the substrate followed by applying the intumescent coating composition as described above.

[0065] The intumescent coating composition can be a single component composition or a multicomponent composition. When the intumescent coating composition is a multicomponent composition, it can include a first component and a second component, such as where the first component includes (a) the molecule comprising one or more acylacyloxy (ACAC) groups and (b) the epoxy resin; and the second component includes (c) the molecule that includes a ketimine and/or aldimine group. The first component and the second component are combined prior to being applied to the substrate.

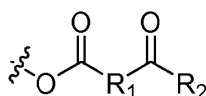
[0066] Prior to applying the present intumescent coating composition, a second coating compositions, such as a primer or a sealer can be applied to the surface of the substrate. The second coating composition can be applied by a method selected from electrodeposition, spraying, dip coating, roll coating, and curtain coating.

[0067] When applied to a substrate, the intumescent coating composition can form a coating layer on the substrate having a dry film thickness in a range of from 0.1 to 20 mm, such as a range of from 0.5 to 20 mm, a range of from 0.5 to 18 mm, or a range of from 0.8 to 16 mm measured according to ASTM D1005-95 (2020).

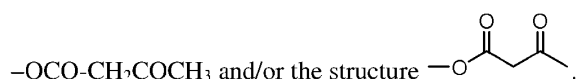
[0068] As indicated above, once applied to a substrate, the intumescent coating composition can have a dry to handle time (ASTM-D1640 -2014) at 23 °C and 40% relative humidity of less than or equal to 200 minutes, such as less than or equal to 175 minutes, less than 150 or equal to minutes or less than or equal to 125 minutes and the dry to handle time can be in a range from 50 to 200 minutes, such as a range from 60 to 175 minutes, a range from 70 to 150 minutes or a range from 50 to 125 minutes.

[0069] The substrate can be part of a larger structure that includes the intumescent coating composition applied to a substrate as described herein.

[0070] As used herein, the terms “acylacyloxy” or “ACAC” group refers to a functional group in a molecule according to the formula:



where R^1 is a difunctional C_1 - C_4 alkyl radical, such as methylene, and R^2 is C_1 - C_4 alkyl, such as methyl. When R^1 and R^2 are C_1 , the ACAC group conforms to the formula



[0071] As used herein, the term “aldimine” refers to compounds characterized by the presence of a double bond linking carbon and nitrogen atoms, formed by the condensation of an aldehyde with ammonia or a primary amine.

[0072] As used herein, the term “dry to handle time” refers to the length of time from applying a coating until it hardens such that the coated surface or film does not show any unwanted marks, detachment, loosening, wrinkling or other forms of distortion when subjected to tests, as a nonlimiting example, those specified in ASTM-D1640 (2014).

[0073] As used herein, the terms “dry film thickness” or “DFT” refer to the measured thickness of dried and/or cured films of coatings determined according to ASTM D1005-95 (2020).

[0074] As used herein, the term “epoxide equivalent weight” refers to the epoxy content of an epoxy resin or epoxy reactive diluent, or glycidyl ether. The epoxide equivalent weight can be measured first and done by titration according to ASTM D1652 (2019). The epoxy equivalent weight reflects the number of grams of epoxy resin required to give 1 mole of epoxy groups. (g/equivalent of epoxy).

[0075] As used herein, the term “intumescent agent” refers to flame retardant agents that can be included in intumescent coatings to provide, without limitation, low smoke, low toxicity, carbonizing, coating strength and/or foaming.

[0076] As used herein, the term “intumescent coating” refers to a layer of protective substance which works by chemical reaction generated by heat, resulting in swelling and formation of an insulating layer on the surface for, as nonlimiting examples, fire protection and corrosion protection of structures.

[0077] As used herein, the term “ketimine” refers to compounds characterized by the presence of a double bond linking carbon and nitrogen atoms, formed by the condensation of a ketone with ammonia or a primary amine.

[0078] As used herein, the term “molecular weight” unless described differently, refers to the weight average molecular weight of a polymer or oligomer, determined by gel permeation chromatography (GPC), using appropriate polystyrene standards.

[0079] As used herein, the term “novolac resin” refers to phenol formaldehyde resins that can be made from reacting phenol and formaldehyde to provide amorphous (not crystalline) thermoplastics.

[0080] As used herein, the terms “oligomer”, “oligomeric”, “polymer” or “polymeric” refers to large or macromolecular compounds, i.e., compounds having a relatively high molecular mass (e.g., 500 Da or more), the structure of which comprises multiple repeat units derived,

actually or conceptually, from chemical species of relatively lower molecular mass, and includes as nonlimiting examples prepolymers, oligomers, and both homopolymers and copolymers. The term “resin” is used interchangeably with “polymer”. The term “monomer” or “monomeric” is meant to refer to a compound which can contribute constitutional units to the structure of an oligomer or polymer.

[0081] As used herein, the term “thermoplastic” refers to resins where the polymer chains are not joined together by covalent bonds and, thereby, can undergo liquid flow upon heating and can be soluble in certain solvents.

Aspects

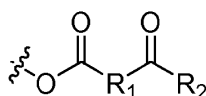
[0082] Aspect 1: An intumescent coating composition comprising:

- (a) a molecule comprising one or more acylacyloxy groups;
- (b) an epoxy resin;
- (c) a molecule comprising a ketimine and/or an aldimine group; and
- (d) an intumescent agent.

[0083] Aspect 2: The intumescent coating composition according to aspect 1, wherein the intumescent coating composition is substantially free (less than 1 weight percent), essentially free (less than 0.1 weight percent) or completely free (undetectable) of an independent gas source.

[0084] Aspect 3: The intumescent coating composition according to either of aspects 1 or 2, wherein melamine or melamine containing compounds are not included in the intumescent coating composition.

[0085] Aspect 4: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising one or more acylacyloxy end groups comprises acetoacetoxy end groups according to the following formula:



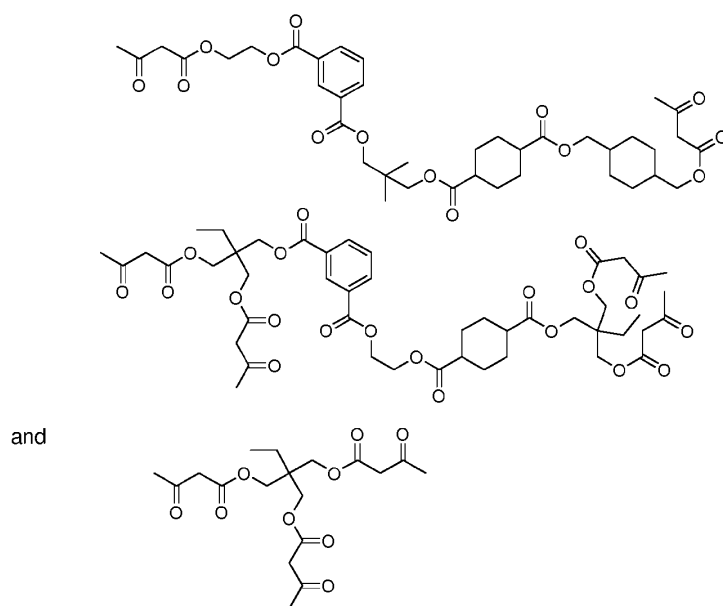
wherein R₁ is a difunctional C₁-C₄ alkyl radical, such as methylene, and R₂ is C₁-C₄ alkyl, such as methyl.

[0086] Aspect 5. The intumescent coating composition according to any preceding aspect, wherein the molecule comprising one or more acylacyloxy end groups has a molecular weight of from 300 to 5,000 g/mol.

[0087] Aspect 6. The intumescent coating composition according to any preceding aspect, wherein the molecule comprising one or more acylacyloxy end groups has a molecular weight of less than 5,000 g/mol, such as less than 3,000 g/mol, less than 1500 g/mol, less than 1250 g/mol or less than 1000 g/mol.

[0088] Aspect 7. The intumescent coating composition according to any preceding aspect, wherein the molecule comprising one or more acylacyloxy end groups has a molecular weight of from 500 to 3,000 g/mol, such as from 350 to 1,500 g/mol, or 500 to 1,000 g/mol.

[0089] Aspect 8. The intumescent coating composition according to any preceding aspect, wherein the molecule comprising one or more acylacyloxy end groups comprises one or more compounds according to the following formulas:



[0090] Aspect 9: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising one or more acylacyloxy end groups is present in the intumescent coating composition in an amount in the range of from 5 to 30 percent by weight based on the total weight of the intumescent coating composition.

[0091] Aspect 10: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising one or more acylacyloxy end groups is present in the intumescent coating composition in an amount of at least 5, such as at least 10, at least 15, or at least 20 percent by weight, based on the total weight of the intumescent coating composition and can be present in an amount of up to 30, such as up to 20, or up to 10 percent by weight, based on the total weight of the intumescent coating composition.

[0092] Aspect 11: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising one or more acylacyloxy end groups can be present in the intumescent coating composition in an amount in the range of from 5 to 25 percent by weight, such as from 5 to 20 percent by weight, from 10 to 30 percent by weight, from 10 to 25 percent by weight, from 15 to 30 percent by weight, from 15 to 20 percent by weight, from 20 to 30 percent by weight, from 20 to 25 percent by weight, or from 25 to 30 percent by weight based on the total weight of the intumescent coating composition.

[0093] Aspect 12: The intumescent coating composition according to any preceding aspect, wherein the epoxy resin comprises the reaction product of polyhydroxy compounds, such as polyvalent phenols or phenol-aldehyde condensates, with epihalohydrins or the precursors thereof.

[0094] Aspect 13: The intumescent coating composition according to any preceding aspect, wherein the epoxy resin comprises one or more of:

- a) reaction products of epichlorohydrin with bisphenol A, F, or S;
 - b) reaction products of epichlorohydrin with bisphenol S
 - c) epoxy novolac resins based on phenol or cresol;
 - d) aromatic glycidyl amine resins;
 - e) epoxy resins which do not have aromatic structural units;
 - f) an aliphatic or cycloaliphatic polyepoxide;
- and combinations or mixtures thereof.

[0095] Aspect 14: The intumescent coating composition according to any preceding aspect, wherein the epoxy resin has an epoxide equivalent weight in the range of from 60 to 1000 moles of epoxy group per 100g resin.

[0096] Aspect 15: The intumescent coating composition according to any preceding aspect, wherein the epoxy resin has an epoxide equivalent weight in the range of from 100 to 500, such as from 150 to 250 moles of epoxy group per 100g resin.

[0097] Aspect 16: The intumescent coating composition according to any preceding aspect, wherein the epoxy resin is present in the intumescent coating composition in a range of from 3 to 9.9 percent by weight, based on the total weight of the intumescent coating composition.

[0098] Aspect 17: The intumescent coating composition according to any preceding aspect, wherein the epoxy resin is present in the intumescent coating composition in an amount of at least 3, such as at least 5, or at least 7 percent by weight, and can be present at up to 9.9, such as up to 9.2, or up to 8.5 percent by weight, based on the total weight of the intumescent coating composition.

[0099] Aspect 18: The intumescent coating composition according to any preceding aspect, wherein the epoxy resin is present in the intumescent coating composition in an amount of at from 3 to 9.2 percent by weight, such as from 3 to 8.5 percent by weight, from 5 to 9.9 percent by weight, from 5 to 9.2 percent by weight, from 5 to 8.5 percent by weight, from 7 to 9.9 percent by weight, from 7 to 9.2 percent by weight, or from 7 to 8.5 percent by weight, based on the total weight of the intumescent coating composition.

[0100] Aspect 19. The intumescent coating composition according to any preceding aspect, wherein the epoxide resin comprises a polyepoxide comprising one or more of novolac resins, such as the reaction product of an epihalohydrin with the condensation product of an aldehyde with a monohydric or polyhydric phenol; polyglycidyl ethers of polyhydric aromatic alcohols, such as dihydric phenols comprising resorcinol, catechol, hydroquinone, bis(4-hydroxyphenyl)-1, 1-isobutane, 4,4-dihydroxybenzophenone, bis(4-hydroxyphenyl)l, 1-isobutane, 4,4-dihydroxybenzophenone, bis(4-hydroxyphenyl)-1, 1-ethane; bis(2-hydroxynaphenyl)methane, 1,5-hydroxynaphthalene and/or 4,4'-isopropylidenediphenol; polyglycidyl ethers derived from polyhydric alcohols such as ethylene glycol, diethylene glycol, triethylene glycol, 1,2-propylene glycol, 1,4butylene glycol, 1,5-pentanediol, 1,2,6-hexanetriol, glycerol and/or trimethylolpropane; polyglycidyl ethers of polycarboxylic acids such as those produced by the reaction of an epoxy compound such as epichlorohydrin with an aliphatic or aromatic polycarboxylic acid such as oxalic acid, succinic acid, glutaric acid, terephthalic acid, 2,6-naphthalene dicarboxylic acid and/or dimerized linoleic acid; and/or polyepoxide resins derived from epoxidation of olefinically unsaturated alicyclic materials.

[0101] Aspect 20: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising a ketimine group is the reaction product of a polyamine with a ketone containing molecule.

[0102] Aspect 21: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising a ketimine group is the reaction product of a polyamine with a ketone containing molecule to form a polyamine/ketone product followed by reacting the remaining nucleophilic group(s) in the polyamine/ketone product with an epoxide containing molecule to form the molecule comprising a ketimine group.

[0103] 1Aspect 22: The intumescent coating composition according to either of aspects 20 or 21, wherein the ketone containing molecule comprises a ketone represented by the following formula:



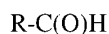
wherein R and R' are independently alkanes having between 1 and 12 carbon atoms

[0104] Aspect 23: The intumescent coating composition according to any of aspects 20 through 22 wherein the ketone containing molecule comprises one or more of acetone, diethyl ketone, methylisobutyl ketone, pentanone, cyclohexanone, ethylamyl ketone, isophorone and decanone.

[0105] Aspect 24: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising an aldimine group is the reaction product of a polyamine with an aldehyde containing molecule.

[0106] Aspect 25: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising an aldimine group is the reaction product of a polyamine with an aldehyde containing molecule to form a polyamine/aldehyde product followed by reacting the remaining nucleophilic group(s) in the polyamine/aldehyde product with an epoxide containing molecule to form the molecule comprising an aldimine group.

[0107] Aspect 26: The intumescent coating composition according to either of aspects 24 or 25, wherein the aldehyde containing molecule comprises an aldehyde represented by the following formula:



wherein R is an alkane having between 1 and 12 carbon atoms.

[0108] Aspect 27: The intumescent coating composition according to any of aspects 24 through 26, wherein the aldehyde containing molecule comprises one or more of isobutyraldehyde, hydroxybutyraldehyde and hydroxycitronellal.

[0109] Aspect 28: The intumescent coating composition according to any of aspects 20 through 27, wherein the polyamine comprises a compound according to the formula:



wherein R⁵ and R⁶ can independently be an alkylene group containing from 2 to 6, such as from 2 to 4 carbon atoms and

wherein n is an integer from 1 to 6, such as from 1 to 3.

[0110] Aspect 29: The intumescent coating composition according to aspect 28, wherein the alkylene group comprises a cycloalkylene group or an alkylene group containing an ether-oxygen atom, such as diethylenetriamine, dipropylenetriamine and dibutylenetriamine.

[0111] Aspect 30: The intumescent coating composition according to any of aspects 20 through 25, wherein the polyamine modified by the ketone is the reaction product of

an aliphatic diamine comprising isophorone diamine, ethylene diamine, 1,2-diaminopropane, 1,3- diaminopropane, 1,4-diaminobutane, 1,5-diaminopentane, 1,6-diaminohexane, 1,8-diaminooctane, 2-methyl-1,5-pentane diamine, 2,5-diamino-2,5-dimethylhexane, 2,2,4- trimethyl-1,6-diamino-hexane, 2, 4, 4-trimethyl-1,6- diamino-hexane, 1,11-diaminoundecane, 1,12-diaminododecane, 1,3- cyclohexane diamine, 1,4-cyclohexane diamine, 1 -amino-3, 3, 5-trimethyl-5- aminomethyl-cyclohexane, 2,4'-diamino-dicyclohexyl methane, 4,4'-diamino- dicyclohexyl methane, 3,3'-dimethyl-4,4'-diamino-dicyclohexyl methane and/or 3,3'-diethyl-4,4'-diamino-dicyclohexyl methane;

with an aliphatic ketone comprising acetone, methyl ethyl ketone, methyl isobutyl ketone, and/or methyl amyl ketone.

[0112] Aspect 31: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising a ketimine and/or an aldimine group has a weight average molecular weight in the range of from 300 g/mol to 10,000 g/mol, such as from 500

g/mol to 5,000 g/mol or in a range of from 600 g/mol to 1200 g/mol as determined by gel permeation chromatography using polystyrene standards.

[0113] Aspect 32: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising a ketimine and/or an aldimine group has at least two ketimine and/or aldimine groups per molecule, such as a range of from 2 to 25 ketimine and/or aldimine groups per molecule or a range of from 3 to 6 ketimine and/or aldimine groups per molecule.

[0114] Aspect 33: The intumescent coating composition according to any of aspects 21 through 28, wherein the epoxide containing molecule comprises an epoxy resin having an epoxide equivalent weight in the range of from 60 to 1000, such as from 100 to 500, or from 150 to 250 moles of epoxy group per 100g resin.

[0115] Aspect 34: The intumescent coating composition according to any of aspects 21 through 33, wherein the epoxide containing molecule comprises an epoxy resin comprising the reaction product of polyhydroxy compounds, such as polyvalent phenols or phenol-aldehyde condensates, with epihalohydrins or the precursors thereof.

[0116] Aspect 35: The intumescent coating composition according to any of aspects 21 through 34, wherein the epoxide containing molecule comprises an epoxy resin comprising:

- a) reaction products of epichlorohydrin with bisphenol A, F, or S;
 - b) reaction products of epichlorohydrin with bisphenol S
 - c) epoxy novolac resins based on phenol or cresol;
 - d) aromatic glycidyl amine resins;
 - e) epoxy resins which do not have aromatic structural units;
 - f) an aliphatic or cycloaliphatic polyepoxide;
- and combinations or mixtures thereof.

[0117] Aspect 36: The intumescent coating composition according to any of aspects 21 through 35, wherein the epoxide containing molecule comprises an epoxide resin comprising a polyepoxide comprising one or more of novolac resins, such as the reaction product of an epihalohydrin with the condensation product of an aldehyde with a monohydric or polyhydric phenol; polyglycidyl ethers of polyhydric aromatic alcohols, such as dihydric phenols comprising resorcinol, catechol, hydroquinone, bis(4-hydroxyphenyl)-1, 1-isobutane, 4,4-dihydroxybenzophenone, bis(4-hydroxyphenyl)l, 1-isobutane, 4,4-dihydroxybenzophenone, bis(4-hydroxyphenyl)-1, 1-ethane; bis(2-hydroxynaphenyl)methane, 1,5-hydroxynaphthalene and/or 4,4'-isopropylidenediphenol; polyglycidyl ethers derived from polyhydric alcohols

such as ethylene glycol, diethylene glycol, triethylene glycol, 1,2-propylene glycol, 1,4-butylene glycol, 1,5-pentanediol, 1,2,6-hexanetriol, glycerol and/or trimethylolpropane; polyglycidyl ethers of polycarboxylic acids such as those produced by the reaction of an epoxy compound such as epichlorohydrin with an aliphatic or aromatic polycarboxylic acid such as oxalic acid, succinic acid, glutaric acid, terephthalic acid, 2,6-naphthalene dicarboxylic acid and/or dimerized linoleic acid; and/or polyepoxide resins derived from epoxidation of olefinically unsaturated alicyclic materials.

[0118] Aspect 37: The intumescent coating composition according to any preceding aspect, wherein the molecule comprising a ketimine and/or an aldimine group is present in the intumescent coating composition in an amount of at least 10, such as at least 20, at least 25, or at least 30 percent by weight, based on the total weight of the intumescent coating composition and the molecule comprising a ketimine and/or an aldimine group is present in the intumescent coating composition in an amount of up to 40, such as up to 30, or up to 20 percent by weight, based on the total weight of the intumescent coating composition, the molecule comprising a ketimine and/or an aldimine group is present in the intumescent coating composition in an amount in the range of 10 to 40 percent by weight, such as in a range of 10 to 30 percent by weight, in a range of 10 to 20 percent by weight, in a range of 15 to 40 percent by weight, in a range of 10 to 30 percent by weight, in a range of 15 to 20 percent by weight, in a range of 20 to 40 percent by weight, in a range of 20 to 30 percent by weight, in a range of 25 to 40 percent by weight, or in a range of 25 to 30 percent by weight.

[0119] Aspect 38: The intumescent coating composition according to any of aspects 1 or 4 through 30, wherein the intumescent agent comprises one or more of melamine and/or melamine derivatives, such as, salts of melamine, melamine formaldehyde, hydroxymethylated melamine, hexmethoxymethyl melamine, melamine monophosphate, di(melamine phosphate), melamine dihydric phosphate, and mixtures or combinations thereof.

[0120] Aspect 39: The intumescent coating composition according to any of aspects 1 or 3 through 38, wherein the intumescent agent comprises a boron containing compound, such as boric acid, and borates, such as ammonium pentaborate, zinc borate, sodium borate, lithium borate, aluminum borate, magnesium borate and borosilicate, and mixtures or combinations thereof.

[0121] Aspect 40: The intumescent coating composition according to any preceding aspect, wherein the intumescent agent comprises one or more of a carbon source comprising

an aromatic compound and/or a tall oil fatty acid, an acid source, a reinforcing fiber, and/or an inorganic additive.

[0122] Aspect 41: The intumescent coating composition according aspect 36, wherein the carbon source is an aromatic compound comprising at least one aromatic ring, such as 2, 3, or 4 aromatic rings, such as a benzene ring, a naphthalene ring, an anthracene ring, or a phenanthrene ring, and

wherein the aromatic compound optionally comprises at least one functional substituent, such as hydroxy, carboxy, mercapto, and/or amino.

[0123] Aspect 42: The intumescent coating composition according aspect 41, wherein the aromatic compound comprises one or more of bisphenol A, bisphenol B and bisphenol F.

[0124] Aspect 43: The intumescent coating composition according to any of aspects 40 through 42, wherein the aromatic compound comprises an aromatic compound having a long chain hydrocarbyl substituent, such as a saturated or unsaturated hydrocarbyl having a linear or branched alkyl and/or alkenyl and/or alkynyl group having 6 to 20 carbon atoms, such as 6 to 18 carbon atoms, or 6 to 15 carbon atoms;

wherein the long chain hydrocarbyl optionally comprises 1 to 3 unsaturated bonds, such as double bond and/or an acetylenic bond.

[0125] Aspect 44: The intumescent coating composition according to any of aspects 40 through 43, wherein the carbon source is present in the intumescent coating composition in a range of from 0.5 to 50 weight percent, such as a range of from 10 to 18 weight percent, a range of from 11 to 17 weight percent or a range of from 12 to 16 weight percent based on the weight of the intumescent coating composition.

[0126] Aspect 45: The intumescent coating composition according to any of aspects 40 through 44, wherein the acid source comprises one or more of phosphorates, such as sodium phosphate, potassium phosphate or ammonium phosphate, ammonium polyphosphate (APP), monoammonium phosphate, diammonium phosphate, trichloroethyl phosphate (TCEP), trichloropropyl phosphate (TCPP), ammonium pyrophosphate, and triphenyl phosphate; sulfonates, such as sodium sulfonate, potassium sulfonate, ammonium sulfonate, and paratoluene sulfonate; and sulphates, such as sodium sulphate, potassium sulphate and ammonium sulphate.

[0127] Aspect 46: The intumescent coating composition according to any of aspects 40 through 42, wherein the acid source is present in the intumescent coating composition in an amount in the range of 5 to 30 weight percent, such as a range of 5 to 25 weight percent, a

range of 5 to 20 weight percent, or a range of 5 to 15 weight percent based on the total weight of the intumescent coating composition.

[0128] Aspect 47: The intumescent coating composition according to any of aspects 40 through 46, wherein the reinforcing fiber comprises one or both of inorganic fibers and organic fibers.

[0129] Aspect 48: The intumescent coating composition according to aspect 47, wherein the inorganic fibers comprise one or more of carbide fibers, such as boron carbide fibers, silicon carbide fibers, and niobium carbide fibers; nitride fibers, such as silicon nitride fibers; boron containing fibers, such as boron fibers and boride fibers; silicon containing fibers, such as silicon fibers, alumina-boron-silica fibers, non-base aluminum borate fibers, non-base or low base sodalime-aluminumborosilicate fibers, base-sodalime-silicate fibers, S-glass fibers, inorganic glass fibers, quartz fibers; ceramic fibers and basalt fibers.

[0130] Aspect 49: The intumescent coating composition according to any of aspects 40 through 48, wherein the reinforcing fiber is present in the intumescent coating composition in a range of from 0 to 5 weight percent, such as a range of from 1 to 4 weight percent or a range of from 2 to 5 weight percent based on the total weight of the intumescent coating composition.

[0131] Aspect 50: The intumescent coating composition according to any of aspects 40 through 49, wherein the inorganic additive is present in the intumescent coating composition at an amount in the range of 0 to 50 weight percent, such as a range of 15 to 40 weight percent, a range of 15 to 35 weight percent, a range of 15 to 30 weight percent, or a range of 15 to 25 weight percent based on the total weight of the intumescent coating composition.

[0132] Aspect 51: The intumescent coating composition according to any preceding aspect, wherein the intumescent coating composition has a dry to handle time (ASTM-D1640-2014) at 23°C and 40% relative humidity of less than or equal to 200 minutes, such as less than or equal to 175 minutes, less than 150 or equal to minutes or less than or equal to 125 minutes and the dry to handle time can be in a range from 50 to 200 minutes, such as a range from 60 to 175 minutes, a range from 70 to 150 minutes or a range from 50 to 125 minutes.

[0133] Aspect 52: A coated substrate, wherein at least a portion of a surface of the substrate is coated with the intumescent coating composition according to any of aspects 1 through 51.

[0134] Aspect 53: The coated substrate according to aspect 52, wherein the substrate comprises one or more of concrete, wood, plastic, fiberglass, and rigid metal substrates such as ferrous metals, aluminum, aluminum alloys, and copper.

[0135] Aspect 54: The coated substrate according to aspect 53, wherein the ferrous metal comprises one or more of cold rolled steel, galvanized (zinc coated) steel, electrogalvanized steel, stainless steel, pickled steel, zinc-iron alloys, and combinations or composites of ferrous and non-ferrous metals.

[0136] Aspect 55: A method of applying an intumescent coating composition comprising: applying the intumescent coating composition according to any of aspects 1 through 51 to a substrate.

[0137] Aspect 56: The method according to aspect 55 comprising cleaning and/or degreasing at least a portion of a surface of the substrate prior to applying the intumescent coating composition.

[0138] Aspect 57: The method according to either of aspects 55 or 56, wherein the intumescent coating composition is a multicomponent composition comprising a first component and a second component, wherein the first component comprises (a) the molecule comprising one or more acylacyloxy end groups and (b) the epoxy resin; and a second component comprises (c) the molecule comprising a ketimine and/or an aldimine group; and wherein the first component and the second component are combined prior to being applied to the substrate.

[0139] Aspect 58: The method according to any of aspects 55 through 57, wherein prior to applying the intumescent coating composition, a second coating compositions, such as a primer or a sealer is applied to the surface of the substrate.

[0140] Aspect 59: The method according to aspect 58, wherein the second coating composition is applied by a method selected from electrodeposition, spraying, dip coating, roll coating, and curtain coating.

[0141] Aspect 60: The method according to any of aspects 55 through 59, wherein the intumescent coating composition is applied to the substrate using one or more methods selected from brush coating, flow coating, and spay coating.

[0142] Aspect 61: The method according to any of aspects 55 through 60, wherein the intumescent coating composition forms a coating layer on the substrate having a dry film thickness in a range of from 0.1 to 20 mm, such as a range of from 0.5 to 20 mm, a range of from 0.5 to 18 mm, or a range of from 0.8 to 16 mm measured according to ASTM D1005-95 (2020).

[0143] Aspect 62: The method according to any of aspects 55 through 61, wherein the intumescent coating composition has a dry to handle time (ASTM-D1640 -2014) at 23°C

and 40% relative humidity of less than or equal to 200 minutes, such as less than or equal to 175 minutes, less than or equal to 150 minutes or less than or equal to 125 minutes and the dry to handle time can be in a range from 50 to 200 minutes, such as a range from 60 to 175 minutes, a range from 70 to 150 minutes or a range from 50 to 125 minutes.

[0144] Aspect 63: A structure, wherein at least a portion of a substrate of the structure comprises the intumescent coating composition applied according to any method of aspects 55 through 62.

Examples

[0145] The following examples are presented to demonstrate the general principles of the disclosure. The disclosure should not be considered as limited to the specific examples presented.

[0146] Multiple coating formulations (Formulations 1-8) were prepared using the ingredients shown in Table 1. The base for each coating formulation was prepared by dispersing all of the components in a dispersion machine at high rotation speed until the sizes of the particles in the formulation were below 100 microns. The hardener for each coating formulation was prepared by dispersing all of the components under a dispersion machine at high rotation speed until the sizes of the particles in the formulation were below 100 microns. The dispersion speed and disperser plate size used was 1200 rpm and 80 mm, respectively, with a container diameter of 180 mm. Immediately prior to application, the base and hardener were mixed in the relative amounts shown in the tables below.

Comparison example 1

[0147] A commercial fire protection product (PPG Pitt-char NX) based on epoxy amine technology was used as a comparison for the dry-to- handle time.

Comparison example 2

[0148] A single component solvent borne acrylic system (AkzoNobel Interchar 2060) was used to compare the dry-to- handle time.

Comparison example 3

[0149] A single component water borne acrylic system (PPG SteelGuard 651) was used to compare the dry-to- handle time.

Testing methods,**A. Dry film thickness**

[0150] For purposes of this disclosure, the dry film thickness was measured after one day drying by using Elcometer 500 digital coating thickness gauge, ASTM D1005-95 (2020) test method.

B. Dry-to-handle time

[0151] To test for dry-to-handle (also called dry-through) time, a maximum downward pressure was exerted using a thumb onto the film with 90 degrees of twisting. If no loosening, detachment, wrinkling, or other evidence of distortion of the film is observed, then the sample was considered “dry-to-handle”.

C. Shore D Hardness

[0152] For purposes of this disclosure, the Shore D hardness was measured using a Hildebrand HD3000 Shore D Durometer, ASTM D2240, DIN 53 505 or ISO 868 test methods. Other methods and instruments could be used to the extent only a comparative understanding of hardness was required.

[0153] As shown in Table 1, Part A of the intumescent coating included an acetoacetoxym resin as the ACAC resin and epoxy resin were included as binders and reacted to generate the irreversible enamine as described herein. Xylene was included as a solvent, the polyester phosphoric acid ester salt was included as a wetting and dispersing additive, the organophilic phyllosilicates were included as a rheology additive, the castor oil derivative was included as a thixotrope, titanium dioxide was included as a pigment, and the intumescent agent included pentaerythritol as a carbon source, when included, melamine was a gas source, ammonium polyphosphate as an acid source, and the mineral fiber as an engineered mineral fiber for reinforcement. Part B included polyketimine as a hardener.

Table 1. Examples

Component	Amounts (g)							
Example No.	1	2	3	4	5	6	7	8
Part A (Base)								
Acetoacetoxy / polyacetoacetate (AcAc) ¹	8.71	8.92	8.71	8.92	8.71	8.92	8.71	8.92
Epoxy resin derived from a liquid epoxy resin and bisphenol-A ²	6.4	6.56					6.4	6.56
Cycloaliphatic epoxy resin ³			6.4	6.56				
Epoxy resin derived from epichlorohydrin and bisphenol-F ⁴					6.4	6.56		
Xylene	8.13	8.33	8.13	8.33	8.13	8.33	8.13	8.33
Polyester phosphoric acid ester salt ⁴	0.47	0.48	0.47	0.48	0.47	0.48	0.47	0.48
Organophilic phyllosilicates ⁶	1.16	1.19	1.16	1.19	1.16	1.19	1.16	1.19
Castor oil derivative ⁷	0.70	0.72	0.70	0.72	0.70	0.72	0.70	0.72
Titanium dioxide ⁸	10.17	10.40	10.17	10.40	10.17	10.40	10.17	10.40
Pentaerythritol	8.93	9.14	8.93	9.14	8.93	9.14	11.10	11.36
Melamine	8.93	9.14	8.93	9.14	8.93	9.14	0.00	0.00
Ammonium polyphosphate ⁹	27.24	27.89	27.24	27.89	27.24	27.89	34.00	34.80
Mineral fiber ¹⁰	1.94	1.99	1.94	1.99	1.94	1.99	1.94	1.99
Part B (Hardener)								
Polyketimine ¹¹	17.22	15.26	17.22	15.26	17.22	15.26	17.22	15.26

¹ Prepared according to Example A, U.S. Patent No. 5,288,802² EPON 1001-x-75, HEXION INC.³ EPONEX 1510, HEXION INC.⁴ EPOKUKDO YDF-170, Kukdo Chemical⁵ DISPERBYK 103, BYK-CHEMIE GMBH⁶ GARAMITE 1958, BYK-CHEMIE GMBH⁷ THIXATROL ST, ELEMENTIS SPECIALTIES, INC.⁸ KRONOS 2310, Kronos International, Inc.⁹ FR CROS 484, Chemische Fabrik Budenheim KG¹⁰ COATFORCE CF30, ROCKWOOL A/S AKTIESELSKAP¹¹ Prepared according to Example C, U.S. Patent No. 5,288,802

[0154] The base (Part A) and hardener (Part B) were mixed by a mixer or spatula, until the color of the mixture became homogenous and lump-free. The coating formulations were each applied on 150 x 75 x 1.2 mm blasted steel panels with a trowel, and the formed coatings had about 2mm dry film thickness (DFT). The coated panels were tested at 1200°C and -50°C torch fire, with 2 bar gas pressure and burner diameter of 30 mm, for 10 minutes. The expansion coefficient of the coatings, which is defined as the ratio between the thickness of expanded coating and the thickness of the virgin coating, the formed char and its adhesion to the substrate were assessed. The results are summarized in Table 1 and Table 2 below.

Table 2. Characteristics of examples

Example #	1	2	3	4	5	6	7	8	Comparison Example 1	Comparison Example 2	Comparison Example 3
Dry Film Thickness (mm)	1.93	1.78	2.19	2.14	2.36	2.05	1.78	2.04	2	0.7	0.7
ble 2.Dry to handle time (minutes @23C, 40% R.H.)	90	90	90	90	90	90	90	90	420	960	960
The expansion coefficient	18	18	10	10	10	10	18	18	NA	NA	NA

Table 2. Shore D Hardness of examples at 1 day

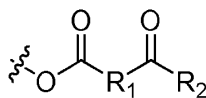
Example #	1	2	3	4	5	6	7	8
Shore D Hardness at 1 day	60	56	49	47	50	59	67	65

[0155] The dry to handle times of examples 1 through 8 were significantly less than the comparison examples 1, 2 and 3. No significant differences were observed with the examples containing melamine (examples 1 through 6) and no melamine (examples 7 and 8) as a gas source.

[0156] Whereas particular embodiments of this disclosure have been described above for purposes of illustration, it will be evident to those skilled in the art that numerous variations of the details of the present disclosure may be made without departing from the disclosure as defined in the appended claims.

We claim:

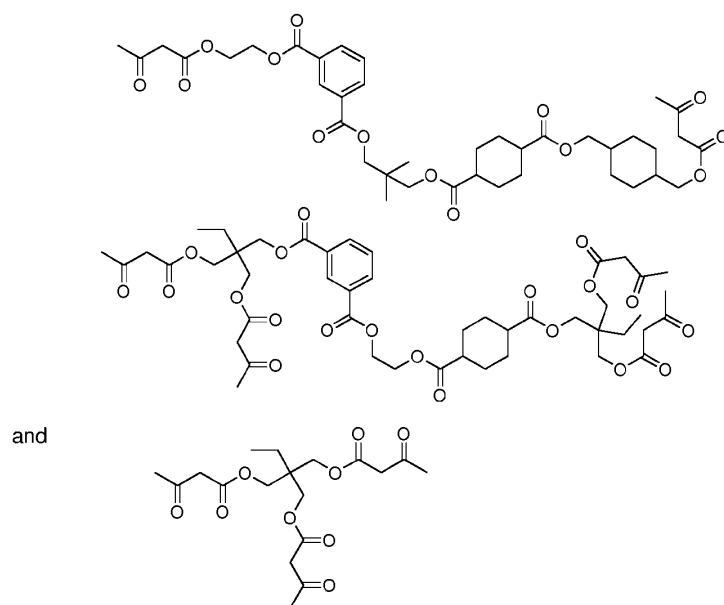
1. An intumescent coating composition comprising:
 - (a) a molecule comprising one or more acylacyloxy groups;
 - (b) an epoxy resin;
 - (c) a molecule comprising a ketimine and/or an aldimine group; and
 - (d) an intumescent agent.
2. The intumescent coating composition according to claim 1, wherein the intumescent coating composition comprises less than 1 weight percent of an independent gas source.
3. The intumescent coating composition according to either of claims 1 or 2, wherein melamine or melamine containing compounds are not included in the intumescent coating composition.
4. The intumescent coating composition according to any preceding claim, wherein the molecule comprising one or more acylacyloxy end groups comprises acetoacetoxy end groups according to the following formula:



wherein R_1 is a difunctional C_1 - C_4 alkyl radical, such as methylene, and R_2 is C_1 - C_4 alkyl, such as methyl.

5. The intumescent coating composition according to any preceding claim, wherein the molecule comprising one or more acylacyloxy end groups has a molecular weight of from 300 to 5,000 g/mol.

6. The intumescent coating composition according to any preceding claim, wherein the molecule comprising one or more acylacyloxy end groups comprises one or more compounds according to the following formulas:



7. The intumescent coating composition according to any preceding claim, wherein the epoxy resin comprises the reaction product of polyhydroxy compounds, such as polyvalent phenols or phenol-aldehyde condensates, with epihalohydrins or the precursors thereof, wherein the epoxy resin optionally comprises one or more of:

- a) reaction products of epichlorohydrin with bisphenol A, F, or S;
- b) epoxy novolac resins based on phenol or cresol;
- c) aromatic glycidyl amine resins;
- d) epoxy resins which do not have aromatic structural units;
- e) an aliphatic or cycloaliphatic polyepoxide;
- f) a polyepoxide comprising one or more of novolac resins, such as the reaction product of an epihalohydrin with the condensation product of an aldehyde with a monohydric or polyhydric phenol; polyglycidyl ethers of polyhydric aromatic alcohols, such as dihydric phenols comprising resorcinol, catechol, hydroquinone, bis(4-hydroxyphenyl)-1,1-isobutane, 4,4-dihydroxybenzophenone, bis(4-hydroxyphenyl)-1,1-isobutane, 4,4-dihydroxybenzophenone, bis(4-hydroxyphenyl)-1,1-ethane; bis(2-hydroxynaphenyl)methane, 1,5-hydroxynaphthalene and/or 4,4'-isopropylidenediphenol; polyglycidyl ethers derived from polyhydric alcohols such as ethylene glycol, diethylene glycol, triethylene glycol, 1,2-propylene glycol, 1,4butylene glycol, 1,5-pentanediol, 1,2,6-hexanetriol, glycerol and/or trimethylolpropane; polyglycidyl ethers of polycarboxylic acids such as those produced by the reaction of an epoxy compound such as epichlorohydrin with an aliphatic or aromatic polycarboxylic acid such as oxalic acid, succinic acid, glutaric acid, terephthalic acid, 2,6-naphthalene dicarboxylic acid and/or dimerized linoleic acid; and/or polyepoxide resins derived from epoxidation of olefinically unsaturated alicyclic materials; and
- h) combinations or mixtures thereof.

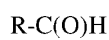
8. The intumescent coating composition according to any preceding claim, wherein the molecule comprising a ketimine group is the reaction product of a polyamine with a ketone containing molecule; optionally comprising a reaction product of a polyamine with a ketone containing molecule to form a polyamine/ketone product followed by reacting the remaining nucleophilic group(s) in the polyamine/ketone product with an epoxide containing molecule

to form the molecule comprising a ketimine group; optionally wherein the ketone containing molecule comprises a ketone represented by the following formula:



wherein R and R' are independently alkanes having between 1 and 12 carbon atoms; such as one or more of acetone, diethyl ketone, methylisobutyl ketone, pentanone, cyclohexanone, ethylamyl ketone, isophorone and decanone.

9. The intumescent coating composition according to any preceding claim, wherein the molecule comprising an aldimine group is the reaction product of a polyamine with an aldehyde containing molecule; optionally wherein the molecule comprising an aldimine group is the reaction product of a polyamine with an aldehyde containing molecule to form a polyamine/aldehyde product followed by reacting the remaining nucleophilic group(s) in the polyamine/aldehyde product with an epoxide containing molecule to form the molecule comprising an aldimine group; and/or wherein the aldehyde containing molecule comprises an aldehyde represented by the following formula:



wherein R is an alkane having between 1 and 12 carbon atoms; and

optionally, wherein the aldehyde containing molecule comprises one or more of isobutyraldehyde, hydroxybutyraldehyde and hydroxycitronellal.

10. The intumescent coating composition according to either of claims 8 or 9, wherein the polyamine comprises a compound according to the formula:



wherein R⁵ and R⁶ can independently be an alkylene group containing from 2 to 6, such as from 2 to 4 carbon atoms and

wherein n is an integer from 1 to 6, such as from 1 to 3; optionally wherein the alkylene group comprises a cycloalkylene group or an alkylene group containing an ether-oxygen atom, such as diethylenetriamine, dipropylenetriamine and dibutylenetriamine.

11. The intumescent coating composition according to any of claims 8 through 10, wherein the polyamine modified by the ketone is the reaction product of

an aliphatic diamine comprising isophorone diamine, ethylene diamine, 1,2-diaminopropane, 1,3- diaminopropane, 1,4-diaminobutane, 1,5-diaminopentane, 1,6-diaminohexane, 1,8-diaminooctane, 2-methyl-1,5-pentane diamine, 2,5-diamino-2,5-dimethylhexane, 2,2,4- trimethyl-1,6-diamino-hexane, 2, 4, 4-trimethyl-1,6- diamino-hexane, 1,11-diaminoundecane, 1,12-diaminododecane, 1,3- cyclohexane diamine, 1,4-cyclohexane diamine, 1 -amino-3, 3, 5-trimethyl-5- aminomethyl-cyclohexane, 2,4'-diamino-dicyclohexyl methane, 4,4'-diamino- dicyclohexyl methane, 3,3'-dimethyl-4,4'-diamino-dicyclohexyl methane and/or 3,3'-diethyl-4,4'-diamino-dicyclohexyl methane;

with an aliphatic ketone comprising acetone, methyl ethyl ketone, methyl isobutyl ketone, and/or methyl amyl ketone.

12. The intumescent coating composition according to any of claims 8 through 11, wherein the epoxide containing molecule comprises an epoxy resin comprising the reaction product of polyhydroxy compounds, such as polyvalent phenols or phenol-aldehyde condensates, with epihalohydrins or the precursors thereof; optionally wherein the epoxide containing molecule comprises an epoxy resin comprising:

- a) reaction products of epichlorohydrin with bisphenol A, F, or S;
- b) epoxy novolac resins based on phenol or cresol;
- c) aromatic glycidyl amine resins;
- d) epoxy resins which do not have aromatic structural units;
- e) an aliphatic or cycloaliphatic polyepoxide;

f) a polyepoxide comprising one or more of novalac resins, such as the reaction product of an epihalohydrin with the condensation product of an aldehyde with a monohydric or polyhydric phenol; polyglycidyl ethers of polyhydric aromatic alcohols, such as dihydric phenols comprising resorcinol, catechol, hydroquinone,

bis(4-hydroxyphenyl)- 1, 1-isobutane, 4,4-dihydroxybenzophenone, bis(4-hydroxyphenyl)l, 1-isobutane, 4,4-dihydroxybenzophenone, bis(4-hydroxyphenyl)-1, 1-ethane; bis(2-hydroxynaphenyl)methane, 1,5-hydroxynaphthalene and/or 4,4'-isopropylidenediphenol; polyglycidyl ethers derived from polyhydric alcohols such as ethylene glycol, diethylene glycol, triethylene glycol, 1,2-propylene glycol, 1,4-butylene glycol, 1,5-pentanediol, 1,2,6-hexanetriol, glycerol and/or trimethylolpropane; polyglycidyl ethers of polycarboxylic acids such as those produced by the reaction of an epoxy compound such as epichlorohydrin with an aliphatic or aromatic polycarboxylic acid such as oxalic acid, succinic acid, glutaric acid, terephthalic acid, 2,6-naphthalene dicarboxylic acid and/or dimerized linoleic acid; and/or polyepoxide resins derived from epoxidation of olefinically unsaturated alicyclic materials;

and

g) and combinations or mixtures thereof.

13. The intumescent coating composition according to any of claims 1 or 3 through 12, wherein the intumescent agent comprises a boron containing compound, such as boric acid, and borates, such as ammonium pentaborate, zinc borate, sodium borate, lithium borate, aluminum borate, magnesium borate and borosilicate, and mixtures or combinations thereof, and/or one or more of a carbon source comprising an aromatic compound and/or a tall oil fatty acid, an acid source, a reinforcing fiber, and/or an inorganic additive, wherein the carbon source optionally comprises an aromatic compound comprising at least one aromatic ring, such as 2, 3, or 4 aromatic rings, such as a benzene ring, a naphthalene ring, an anthracene ring, or a phenanthrene ring, and wherein the aromatic compound optionally comprises at least one functional substituent, such as hydroxy, carboxy, mercapto, and/or amino.

14. The intumescent coating composition according to claim 13, wherein the acid source comprises one or more of phosphorates, such as sodium phosphate, potassium phosphate or ammonium phosphate, ammonium polyphosphate (APP), monoammonium phosphate, diammonium phosphate, trichloroethyl phosphate (TCEP), trichloropropyl phosphate (TCPP), ammonium pyrophosphate, and triphenyl phosphate; sulfonates, such

as sodium sulfonate, potassium sulfonate, ammonium sulfonate, and paratoluene sulfonate; and sulphates, such as sodium sulphate, potassium sulphate and ammonium sulphate; and/or

wherein the reinforcing fiber comprises one or both of inorganic fibers and organic fibers,

wherein the inorganic fibers optionally comprise one or more of carbide fibers, such as boron carbide fibers, silicon carbide fibers, and niobium carbide fibers; nitride fibers, such as silicon nitride fibers; boron containing fibers, such as boron fibers and boride fibers; silicon containing fibers, such as silicon fibers, alumina-boron-silica fibers, non-base aluminum borate fibers, non-base or low base sodalime-aluminumborosilicate fibers, base-sodalime-silicate fibers, S-glass fibers, inorganic glass fibers, quartz fibers; ceramic fibers and basalt fibers.

15. The intumescent coating composition according to any preceding claim, wherein the intumescent coating composition has a dry to handle time (ASTM-D1640 -2014) at 23°C and 40% relative humidity of less than or equal to 200 minutes.

16. A coated substrate, wherein at least a portion of a surface of the substrate is coated with the intumescent coating composition according to any of claims 1 through 15;

wherein the substrate comprises one or more of concrete, wood, plastic, fiberglass, and rigid metal substrates such as ferrous metals, aluminum, aluminum alloys, and copper; and

wherein the ferrous metal comprises one or more of cold rolled steel, galvanized (zinc coated) steel, electrogalvanized steel, stainless steel, pickled steel, zinc-iron alloys, and combinations or composites of ferrous and non-ferrous metals.

17. A method of applying an intumescent coating composition comprising:
applying the intumescent coating composition according to any of claims 1 through 15 to a substrate;

optionally cleaning and/or degreasing at least a portion of a surface of the substrate prior to applying the intumescent coating composition;

optionally prior to applying the intumescent coating composition, a second coating compositions, such as a primer or a sealer is applied to the surface of the substrate;

wherein the intumescent coating composition optionally comprises a multicomponent composition comprising a first component and a second component;

wherein the first component comprises (a) the molecule comprising one or more acylacyloxy end groups and (b) the epoxy resin; and a second component comprises (c) the molecule comprising a ketimine and/or an aldimine group; and

wherein the first component and the second component are combined prior to being applied to the substrate; and

wherein the intumescent coating composition forms a coating layer on the substrate having a dry film thickness in a range of from 0.1 to 20 mm measured according to ASTM D1005-95 (2020).

18. The method according to claim 18, wherein the intumescent coating composition has a dry to handle time according to ASTM-D1640 -2014 at 23 °C and 40% relative humidity in a range from 50 to 200 minutes.

19. A structure, wherein at least a portion of a substrate of the structure comprises the intumescent coating composition applied according to any method of claims 17 through 18.