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(54) **Title:** COATED OPTICAL ARTICLES DEMONSTRATING ANTI-FOGGING PROPERTIES AND METHODS OF PROVIDING AN OPTICAL ARTICLE WITH ANTI-FOGGING PROPERTIES

(57) **Abstract:** Coated optical articles demonstrating anti-fogging properties are provided. The coated articles comprise: (1) an optical substrate; and (2) a coating layer applied as a topmost layer over a surface of the substrate. The coating layer is formed from a treatment composition comprising: (A) a polymer comprising carboxylic acid groups, pyrrolidone groups and alkoxysilane groups; (B) an alkoxysilane comprising an amino functional group, an ammonium functional group, an epoxy functional group, or ethylenic unsaturation; and (C) polyvinyl pyrrolidone.

COATED OPTICAL ARTICLES DEMONSTRATING ANTI-FOGGING PROPERTIES AND METHODS OF PROVIDING AN OPTICAL ARTICLE WITH ANTI-FOGGING PROPERTIES

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to coated optical articles such as eyeglass lenses, comprising substrates coated with a coating layer that exhibits anti-fogging properties.

BACKGROUND

[0002] When a person wears optical articles such as eyeglasses or face goggles, lens fogging often occurs in high humidity or high temperature conditions, or at interfacial boundaries where there is a significant temperature or humidity difference, such as when wearing swimming goggles in a pool, or along a bottom edge of a lens when a person is also wearing a face mask. Anti-fogging coatings have been developed to reduce the fogging.

[0003] Several different types of hydrophilic anti-fog coatings for optical articles are known. However, these coatings often have issues with effectiveness or durability. Optical articles with currently available anti-fog coatings often become saturated with moisture, making them uncomfortable or affecting the wearer's vision. Certain coatings may be scratched easily, which results in decreased durability, reduced vision, or unacceptable appearance.

[0004] It would be desirable to provide an alternative optical article with anti-fogging properties while mitigating or avoiding at least some of the drawbacks of the prior art.

SUMMARY

[0005] Coated optical articles demonstrating anti-fogging properties are provided. The coated articles comprise: (1) an optical substrate; and (2) a coating layer applied as a topmost layer over a surface of the substrate. The coating layer is formed from a treatment composition comprising: (A) a polymer

comprising carboxylic acid groups, pyrrolidone groups and alkoxysilane groups; (B) an alkoxysilane comprising an amino functional group, an ammonium functional group, an epoxy functional group, or ethylenic unsaturation; and (C) polyvinyl pyrrolidone.

[0006] Also provided are methods of providing an optical article with anti-fogging properties, the method comprising: applying a coating layer as a topmost layer over a surface of an optical substrate, wherein the coating layer is formed from the treatment composition described above.

DETAILED DESCRIPTION

[0007] Other than in any operating examples, or where otherwise indicated, all numbers expressing quantities of ingredients, reaction conditions and so forth 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. 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.

[0008] 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 contain certain errors necessarily resulting from the standard deviation found in their respective testing measurements.

[0009] 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.

[0010] As used in this specification and the appended claims, the articles "a," "an," and "the" include plural referents; i. e., are understood to mean “at least one”, unless expressly and unequivocally limited to one referent.

[0011] The various examples of the coated optical article as presented herein are each understood to be non-limiting with respect to the scope of the disclosure.

[0012] As used in the following description and claims, the following terms have the meanings indicated below:

[0013] The term “reactive” refers to a functional group such as an alkoxysilane or silanol group, capable of undergoing a chemical reaction with itself and/or other functional groups spontaneously or upon the application of heat or in the presence of a catalyst or by any other means known to those skilled in the art.

[0014] The term "optical quality", as used for example in connection with polymeric materials, e.g., a "resin of optical quality" or "organic polymeric material of optical quality" means that the indicated material, e.g., a polymeric material, resin, or resin composition, is or forms a substrate, layer, film or coating that can be used as an optical article, such a glazing, or in combination with an optical article.

[0015] The term "rigid", as used for example in connection with an optical substrate, means that the specified item is self-supporting.

[0016] The term "optical substrate" means that the specified substrate exhibits a light transmission value (transmits incident light) of at least 4 percent, such as at least 50 percent, or at least 70 percent, or at least 85 percent. As used herein, optical substrates and coatings may demonstrate a light transmittance (% Transmission, as defined by Equation 1 below using visible light) of at least 70%. A test article is mounted between electromagnetic radiation transmitter and receiver antennas with the coated side of the substrate facing the transmitter. Water may be spray applied to the coated substrates prior to measurement. The insertion loss (IL) is measured and refers to the amount of

transmitted signal that was not detected at the receiver. This method assumes a “lossless” condition in which the substrate either does not absorb or absorbs an insignificant amount of the incident radar frequency.

Equation 1. $\%\,Transmission = 100\,x\,10^{IL/10}$

[0017] The term "optical substrate" further means that the specified substrate exhibits a haze value of less than 5 percent, e.g., less than 1 percent or less than 0.5 percent, when the haze value is measured at 550 nanometers by, for example, a Haze Gard Plus Instrument. Optical substrates include, but are not limited to, optical articles such as lenses, optical layers, e.g., optical resin layers, optical films and optical coatings, and optical substrates having a light influencing property.

[0018] The term “substantially free” as used in this disclosure means that if a compound is present in a composition, it is present incidentally in an amount less than 0.1 percent by weight (1000 parts per million (ppm)). “Essentially free” means less than 0.01 percent by weight (100 ppm), and “completely free” means less than 20 parts per billion (ppb) of the compound, based on the total weight of the composition; usually less than trace amounts.

[0019] As mentioned above, coated optical articles demonstrating anti-fogging properties are provided. The coated articles comprise: (1) an optical substrate; and (2) a coating layer applied as a topmost layer over a surface of the substrate. The terms "on", “over” "appended to", "affixed to", "bonded to", "adhered to", or terms of like import means that the designated item, e.g., a coating, film or layer, is either directly connected to the object surface, or indirectly connected to the object surface, e.g., through one or more other coatings, films or layers.

[0020] Substrates suitable for use in the preparation of the coated articles can include glass or any of the plastic optical substrates known in the art. The substrates typically have two opposing surfaces, and the coating layer (2) may be applied to one or both surfaces.

[0021] Suitable glass substrates include soda-lime-silica glass, such as soda-lime-silica slide glass sold from Fisher, or aluminosilicate glass such as Gorilla®

glass from Corning Incorporated, or Dragontrail® glass from Asahi Glass Co., Ltd. The substrate is usually transparent and/or has at least one flat surface. Suitable examples of plastic substrates include polymers prepared from polyol(allyl carbonate) monomers, e.g., allyl diglycol carbonates such as diethylene glycol bis(allyl carbonate), which monomer is sold under the trademark CR-39 by PPG Industries, Inc.; polyurea-polyurethane (polyurea urethane) polymers, which are prepared, for example, by the reaction of a polyurethane prepolymer and a diamine curing agent, a composition for one such polymer being sold under the trademark TRIVEX® by PPG Industries, Inc.; polymers prepared from polyol(meth)acryloyl terminated carbonate monomer, diethylene glycol dimethacrylate monomers, ethoxylated phenol methacrylate monomers, diisopropenyl benzene monomers, ethoxylated trimethylol propane triacrylate monomers, ethylene glycol bismethacrylate monomers, poly(ethylene glycol) bismethacrylate monomers, or urethane acrylate monomers; poly(ethoxylated Bisphenol A dimethacrylate); poly(vinyl acetate); poly(vinyl alcohol); poly(vinyl chloride); poly(vinylidene chloride); polyethylene; polypropylene; polyurethanes; polythiourethanes; thermoplastic polycarbonates, such as the carbonate-linked resin derived from Bisphenol A and phosgene, one such material being sold under the trademark LEXAN; polyesters, such as the material sold under the trademark MYLAR; poly(ethylene terephthalate); polyvinyl butyral; poly(methyl methacrylate), such as the material sold under the trademark PLEXIGLAS, and polymers prepared by reacting polyfunctional isocyanates with polythiols or polyepisulfide monomers, either homopolymerized or co-and/or terpolymerized with polythiols, polyisocyanates, polyisothiocyanates and optionally ethylenically unsaturated monomers or halogenated aromatic-containing vinyl monomers. Also suitable are copolymers of such monomers and blends of the described polymers and copolymers with other polymers, e.g., to form interpenetrating network products. A representative list of substrates used most often includes glass, polymethylmethacrylate, polycarbonate, polyethylene terephthalate (PET), polyurethane, polyurea-urethane, polythiourethane, polyamide,

episulfide, cellulose triacetate (TAC), cyclic olefin polymer (COP), cyclic olefin copolymer (COC) and/or poly (allyl diglycol carbonate). The term "transparent", as used for example in connection with a substrate, film, material and/or coating, means that the indicated substrate, coating, film and/or material has the property of transmitting visible light without appreciable scattering so that objects lying beyond are entirely visible.

[0022] The coated optical article may comprise, for example, a display element such as screens, including touch screens, on devices including cell phones, tablets, GPS, voting machines, POS (Point-Of-Sale), or computer screens; display sheets in a picture frame; window; mirror; active or passive liquid crystal cell element; magnifying lens; ophthalmic lens such as plano (without optical power) and vision correcting (prescription) lenses (finished and semi-finished) including multifocal lenses (bifocal, trifocal, and progressive lenses); contact lens; sun lens; fashion lens; sport mask; face shield; visor; goggle; vehicular headlight; vehicular taillight; instrument panel cover, vehicular signal light; vehicular window; or vehicular windshield. The optical article may also be chosen from glazings such as windows and vehicular transparencies such as automobile windshields and side windows, display elements and devices. As used herein the term "display" means the visible representation of information in words, numbers, symbols, designs or drawings. Examples of display elements and devices include screens, monitors, and security elements. Examples of security elements include security marks and authentication marks that are connected to a substrate, such as and without limitation: access cards and passes, e.g., tickets, badges, identification or membership cards, debit cards etc.; negotiable instruments and non-negotiable instruments, e.g., drafts, checks, bonds, notes, certificates of deposit, stock certificates, etc.; government documents, e.g., currency, licenses, identification cards, benefit cards, visas, passports, official certificates, deeds etc.; consumer goods, e.g., software, compact discs ("CDs"), digital-video discs ("DVDs"), appliances, consumer electronics, sporting goods, cars, etc.; credit cards; and merchandise tags, labels and packaging.

[0023] The coating layer (2) applied over a surface of the substrate is formed from a treatment composition comprising:

(A) a polymer comprising carboxylic acid groups, pyrrolidone groups and alkoxysilane groups;

(B) an alkoxysilane comprising an amino functional group, an ammonium functional group, an epoxy functional group, or ethylenic unsaturation; and

(C) polyvinyl pyrrolidone. The components (A), (B), and (C) are different from each other.

[0024] The polymer (A) may be prepared from a mixture of vinyl monomers comprising: (i) a (meth)acrylic acid monomer, (ii) a (meth)acrylate functional alkoxysilane, and (iii) a pyrrolidone functional vinyl monomer. By "polymer" is meant a polymer including homopolymers and copolymers, and oligomers. Note that the term "(meth)acrylic" and like terms encompass both acrylic and methacrylic forms of a compound where they exist.

[0025] Examples of the (meth)acrylic acid monomer (i) include acrylic acid, methacrylic acid, or a combination thereof.

[0026] Non-limiting examples of the (meth)acrylate functional alkoxysilane (ii) include: ethylenically unsaturated alkoxysilanes and ethylenically unsaturated acyloxysilanes, more specific examples of which include acrylatoalkoxysilanes, such as gamma-acryloxypropyl trimethoxysilane and gamma-acryloxypropyl triethoxysilane, and methacrylatoalkoxysilanes, such as gamma-methacryloxypropyl trimethoxysilane, gamma-methacryloxypropyl triethoxysilane and gamma-methacryloxypropyl tris-(2-methoxyethoxy) silane; acetoxysilanes, including, for example, acrylato acetoxysilanes, methacrylato acetoxysilanes and ethylenically unsaturated acetoxysilanes, such as acrylatopropyl triacetoxysilane and methacrylatopropyl triacetoxysilane. 3-methacryloxypropyltrialkoxysilanes are used most often.

[0027] In certain circumstances, it may be desirable to utilize monomers which, upon addition polymerization, will result in an acrylic polymer in which the Si atoms of the resulting hydrolyzable silyl groups are separated by at least two atoms from the backbone of the polymer. One non-limiting commercial example

of a suitable (ii) silane-functional acrylic monomer includes SILQUEST A-174, available from Momentive Performance Materials (Waterford, N.Y.).

[0028] The pyrrolidone functional vinyl monomer (iii) typically comprises N-vinylpyrrolidone.

[0029] Other vinyl monomers may be present to prepare the polymer (A), and non-limiting examples may optionally include: methyl (meth)acrylate, ethyl (meth)acrylate, butyl (meth)acrylate, hydroxyethyl (meth)acrylate, hydroxybutyl (meth)acrylate, hydroxypropyl (meth)acrylate, styrene, acrylamide, alkyl substituted acrylamide, 2-ethylhexyl (meth)acrylate, isobornyl (meth)acrylate, cyclohexyl (meth)acrylate, lauryl (meth)acrylate, substituted styrenes, maleic anhydride, or combinations thereof.

[0030] The mixture of vinyl monomers used to prepare the polymer (A) may comprise at least 1, or at least 2, or at least 5 percent by weight, and at most 20, or at most 10 percent by weight (meth)acrylic acid monomer (i). For example, the mixture of vinyl monomers used to prepare the polymer (A) may comprise 1 to 20 percent by weight, or 1 to 10 percent by weight, or 2 to 20 percent by weight, or 2 to 10 percent by weight, or 5 to 20 percent by weight or 5 to 10 percent by weight (meth)acrylic acid monomer (i). The mixture of vinyl monomers used to prepare the polymer (A) may comprise at least 10, or at least 20, or at least 40, or at least 45 and at most 80, or at most 70, or at most 60, or at most 55 percent by weight (meth)acrylate functional alkoxysilane (ii). For example, the mixture of vinyl monomers used to prepare the polymer (A) may comprise 10 to 80 percent by weight, or 10 to 70 percent by weight, or 10 to 60 percent by weight, or 10 to 55 percent by weight, or 20 to 80 percent by weight, or 20 to 70 percent by weight, or 20 to 60 percent by weight, or 20 to 55 percent by weight, or 40 to 80 percent by weight, or 40 to 70 percent by weight, or 40 to 60 percent by weight, or 40 to 55 percent by weight, or 45 to 80 percent by weight, or 45 to 70 percent by weight, or 45 to 60 percent by weight, or 45 to 55 percent by weight (meth)acrylate functional alkoxysilane (ii). The mixture of vinyl monomers used to prepare the polymer (A) may comprise at least 1, or at least 5 percent by weight, and at most 60, or at most 40, or at

most 30, or at most 25, or at most 15 percent by weight pyrrolidone functional vinyl monomer (iii). For example, the mixture of vinyl monomers used to prepare the polymer (A) may comprise 1 to 60 percent by weight, or 1 to 40 percent by weight, or 1 to 30 percent by weight, or 1 to 25 percent by weight, or 1 to 15 percent by weight, or 5 to 60 percent by weight, or 5 to 40 percent by weight, or 5 to 30 percent by weight, or 5 to 25 percent by weight, or 5 to 15 percent by weight pyrrolidone functional vinyl monomer (iii). The percent by weight is based on the total weight of monomers used to prepare the polymer (A).

[0031] An exemplary mixture of vinyl monomers comprises 1 to 20 percent by weight (meth)acrylic acid, 10 to 70 percent by weight (meth)acrylate functional alkoxysilane, and 1 to 30 percent by weight pyrrolidone functional vinyl monomer, based on the total weight of monomers used to prepare the polymer (A).

[0032] The polymer (A) may be made by addition polymerization of different unsaturated polymerizable materials, including the three mentioned above. The result of such a polymerization is a polymer that comprises hydrolyzable alkoxysilane functional groups.

[0033] The polymer (A) may have a weight average molecular weight (Mw in Da) of at least 10,000, or at least 12,000, and at most 35,000, such as at most 30,000, or at most 25,000, or at most20,000, or at most 16,000, or at most 15,000. For example, the Mw may range from 10,000 to 35,000, or 10,000 to 30,000, or 10,000 to 25,000, or 10,000 to 20,000, or 10,000 to 16,000, or 10,000 to 15,000, or 12,000 to 35,000, or 12,000 to 30,000, or 12,000 to 25,000, or 12,000 to 20,000, or 12,000 to 16,000, or 12,000 to 15,000. As used herein, Mw is measured by gel permeation chromatography of the solvent-borne resin (prior to dispersion in water) using a Waters 2695 separation module with a Waters 2414 differential refractometer (RI detector); tetrahydrofuran (THF) was used as the eluent at a flow rate of 1 ml/min, and two PL gel Mixed-C (300x7.5 mm) columns were used for separation; Mw of polymeric samples can be measured by gel permeation chromatography relative to linear polystyrene standards of 1000 – 1.3M Da.

[0034] The treatment composition used to form the coating layer (2) further comprises (B) an alkoxysilane (e. g., methoxysilane and/or ethoxysilane) comprising an amino functional group, an ammonium functional group, an epoxy functional group, or ethylenic unsaturation. Examples of suitable alkoxysilanes include 3-methacryloxypropyltrialkoxysilane, 3-glycidoxypropyltrialkoxysilane such as 3-glycidoxypropyltrimethoxysilane and 3-glycidoxypropyltriethoxysilane, dimethyloctadecyl[3-(trialkoxysilyl)propyl]ammonium chloride, 3-aminopropyltrialkoxysilane, N(beta-aminoethyl) gamma-aminopropyltrialkoxy-silane, and/or 3-[2-(2-aminoethylamino)ethylamino]propyl-trialkoxysilane.

[0035] The treatment composition used to form the coating layer (2) further comprises (C) polyvinyl pyrrolidone. The polyvinyl pyrrolidone can have any suitable molecular weight; for example, suitable commercial sources may typically have a reported average molecular weight of 8000 to 3,000,000 Da.

[0036] The treatment composition used to form the coating layer (2) may further comprise (D) a tetraalkoxysilane, such as tetramethoxysilane and/or tetraethoxysilane.

[0037] The polymer (A) is typically present in the treatment composition in an amount of at least 0.03 percent by weight, or at least 0.05 percent by weight, or at least 0.06 percent by weight, and at most 89.9 percent by weight, or at most 75 percent by weight, or at most 60 percent by weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C). For example, the polymer (A) may be present in the treatment composition in an amount of 0.03 to 89.9 percent by weight, or 0.03 to 75 percent by weight, or 0.03 to 60 percent by weight, or 0.05 to 89.9 percent by weight, or 0.05 to 75 percent by weight, or 0.05 to 60 percent by weight, or 0.06 to 89.9 percent by weight, or 0.06 to 75 percent by weight, or 0.06 to 60 percent by weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C). The alkoxysilane (B) is typically present in the treatment composition in an amount of at least 0.1 percent by weight, or at least 0.3 percent by weight, or at least 0.5 percent by weight, and at most 50 percent by

weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C). For example, the alkoxysilane (B) may be present in the treatment composition in an amount of 0.1 to 50 percent by weight, or 0.3 to 50 percent by weight, or 0.5 to 50 percent by weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C). The polyvinyl pyrrolidone (C) is typically present in the treatment composition in an amount of at least 10 percent by weight, or at least 35 percent by weight, or at least 40 percent by weight, and at most 99.5 percent by weight, or at most 99 percent by weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C). For example, the polyvinyl pyrrolidone (C) may be present in the treatment composition in an amount of 10 to 99.5 percent by weight, or 10 to 99 percent by weight, or 35 to 99.5 percent by weight, or 35 to 99 percent by weight, or 40 to 99.5 percent by weight, or 40 to 99 percent by weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C).

[0038] When the tetraalkoxysilane (D) is present in the treatment composition, it is typically present in an amount of 0.1 to 15 percent by weight, or 0.1 to 10 percent by weight, or 0.1 to 5 percent by weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C).

[0039] The treatment composition often additionally comprises a solvent. Suitable solvents typically have hydroxyl functional (i. e., alcohol) and/or ether functional groups. Examples include glycol ethers such as propylene glycol methyl ether, propylene glycol methyl ether acetate, dipropylene glycol monomethyl ether, and/or diethylene glycol monobutyl ether. Lower alkyl alcohols (e. g., having less than six carbon atoms) such as methanol, ethanol, n-propanol, isopropanol, n-butanol, and the like, are also suitable.

[0040] The treatment composition can optionally include a variety of further ingredients and/or additives depending on the particular application such as the intended application of a final coated article. For example, the composition may contain an ingredient that exhibits a light influencing property such as a colorant. Other optional ingredients include rheology control agents,

surfactants, initiators, catalysts, cure-inhibiting agents, reducing agents, acids, bases, preservatives, free radical donors, free radical scavengers and thermal stabilizers, which adjuvant materials are known to those skilled in the art. Catalysts may include those known to promote condensation of Si-O-Si bonds, such as protic acids or Lewis acids. In certain examples, the treatment composition contains less than 40 percent by weight silica particles, based on the total weight of solids in the treatment composition. Solids, which may be in a liquid or solid state at ambient temperature, include any compounds remaining in a sample of the composition, initially weighing 1 gram, that has been subjected to 110°C for one hour.

[0041] In the preparation of the coated optical article, the coating layer (2) is applied as a topmost (outermost) layer over a surface of the substrate (1). The coating layer (2) may be applied directly to the substrate (1) with no intervening layers. Alternatively, the coating layer (2) may be applied indirectly over a surface of the substrate on top of an intervening layer, wherein the intervening layer comprises a primer layer (e. g., an adhesion/tie layer or a cushion coat layer), a tinted layer, a photochromic layer and/or a hardcoat layer interposed between the substrate and the coating layer.

[0042] For example, an intervening layer on the surface of the substrate may comprise a hardcoat layer, which in turn comprises a siloxane. Examples of commercially available hardcoat layers include the HI-GARD series of products, available from PPG.

[0043] The compositions that form the coating layer (2) and any intervening layers may each be applied to the substrate (1) by one or more of a number of methods such as spray coating, dip coating (immersion), spin coating, slot die coating, or flow coating onto a surface thereof. Spraying is used most often, such as ultrasonic spray application, precision spray application, and air atomized spray application. The coating compositions may be kept at ambient temperature immediately prior to application. By “ambient” conditions is meant the condition of surroundings without adjustment of the temperature, humidity or pressure. For example, a composition that cures at ambient temperature

undergoes a thermosetting reaction without the aid of heat or other energy, for example, without baking in an oven, use of forced air, or the like. Usually, ambient temperature ranges from 60 to 90 °F (15.6 to 32.2 °C), such as a typical room temperature, 72°F (22.2°C). Again, at least one surface of the substrate is coated; if the substrate has two opposing surfaces, either one or both surfaces may be coated.

[0044] After application of the coating layer(s), the coated substrate is then subjected to conditions for a time sufficient to effect cure of the layers and form a coated optical article, wherein the coating layer (2) comprises a crosslinked network of siloxane linkages. The term "cure", "cured" or similar terms, as used in connection with a cured or curable composition, e.g., a "cured composition" of some specific description, means that at least a portion of any polymerizable and/or crosslinkable components that form the curable composition is polymerized and/or crosslinked. Additionally, curing of a composition refers to subjecting said composition to curing conditions such as those listed above, leading to the reaction of the reactive functional groups of the composition. The term "at least partially cured" means subjecting the composition to curing conditions, wherein reaction of at least a portion of the reactive groups of the composition occurs. The compositions can also be subjected to curing conditions such that a substantially complete cure is attained and wherein further curing results in no significant further improvement in physical properties, such as hardness. For example, the coated substrate may be heated to a temperature of at least 120°C for at least 0.5 hours, to promote the continued polymerization of the composition. In particular examples, the coated substrate may be heated to a temperature of 120°C for at least 3 hours, or the coated substrate may be heated to a temperature of at least 150°C for at least 1 hour, or the coated substrate may be heated to a temperature of at least 450°C for at least 0.5 hour.

[0045] The coating layer (2) typically demonstrates a dry film thickness of 150 nm to 4000 nm. When the treatment composition further includes the tetraalkoxysilane (D), the dry film thickness may be as high as 5000 nm. Dry

film thickness may be measured using an ELCOMETER 415 Paint Thickness Gauge, available from Elcometer Inspection Equipment.

[0046] The resultant coated optical articles are hydrophilic, demonstrating anti-fogging properties. The coating layer (2) typically demonstrates an initial water contact angle less than 50°, or less than 30°, or less than 25°. By "contact angle" is meant static contact angle, which may be measured via a sessile drop measurement technique using an optical goniometer/tensiometer such as a VGA Optima Water Contact Angle Analyzer from AST Products, Billerica, MA. A droplet of deionized water with 1 μl in volume is placed on the outer surface of a sample of the coated optical article and an image of the droplet is recorded. The static contact angle is then defined by fitting the Young-Laplace equation around the droplet using image analysis software. Thus, the present disclosure also provides a method of providing an optical article with anti-fogging properties, the method comprising applying a coating layer as a topmost layer over a surface of an optical substrate, wherein the coating layer is formed from a treatment composition comprising:

(A) a polymer comprising carboxylic acid groups, pyrrolidone groups and alkoxysilane groups;

(B) an alkoxysilane comprising an amino functional group, an ammonium functional group, an epoxy functional group, or ethylenic unsaturation; and

(C) polyvinyl pyrrolidone. The optical substrate and each of the components of the treatment composition may independently comprise any of those described above.

[0047] The present disclosure further provides the use of any of the treatment compositions disclosed above to provide an optical article with anti-fogging properties, comprising: applying a coating layer as a topmost layer over a surface of an optical substrate, wherein the coating layer is formed from any of the treatment compositions disclosed above.

[0048] The following examples are intended to illustrate various aspects of the coated articles disclosed herein, and should not be construed as limiting the disclosure in any way. It is understood that the coated optical articles described

in this specification are not necessarily limited to the examples described in this section. Components that are mentioned elsewhere in the specification as suitable alternative materials for use in the coated optical articles, but which are not demonstrated in the working Examples below, are expected to provide results comparable to their demonstrated counterparts. Unless otherwise indicated, all parts are by weight.

EXAMPLES

Part 1. Preparation of Polymers (A):

[0049] For each of Examples 1 to 3, see Table 1, a reaction flask was equipped with a stirrer, thermocouple, nitrogen inlet and a condenser. Charge A was then added and stirred with heat to reflux temperature (75°C-80°C) under nitrogen atmosphere. To the refluxing ethanol, charge B and charge C were simultaneously added over three hours. The reaction mixture was held at reflux condition for one hour. Charge D was then added over a period of 30 minutes. Molecular weight by GPC was determined at this stage. The clear solution was then cooled to 50°C, and poured into Charge E with strong agitation over period of fifteen minutes. The dispersion was stirred for 30 minutes and then filtered through a 100-micron mesh filter bag.

Table 1.

Component	Parts by weight		
	Example 1	Example 2	Example 3
Charge A			
Ethanol	29.68	46.14	46.14
Charge B			
Ethanol	7.83	8.72	8.72
Methyl Methacrylate	15.17	3.87	9.68
Butyl Acrylate	0.04		
Hydroxyethyl Methacrylate	0.04		
Acrylic Acid	2.84	1.94	1.94
Methacryloxypropyl trimethoxysilane	16.11	9.68	3.87
N-Vinyl pyrrolidone	3.79	3.87	3.87

Charge C			
2,2'-Azobis(2-methylbutyronitrile)	1.61	0.81	0.81
Ethanol	20.11	11.46	11.46
RINSE			
Ethanol		6.25	6.25
Charge D			
AZOBIS 2,2'-(2-METHYLBUTYRONITRILE)	0.40	0.20	0.20
Ethanol	2.37	7.06	7.06
Charge E			
Water	289.28	289.28	289.28
Ethanol	14.03	14.03	14.03
Aerosol® OT-75[1]	0.82	0.82	0.82
N,N-Dimethylethanamine	6.99	6.99	6.99
Weight percent solid (theory)	10%	6%	6%
GPC Average Mw (g/mol)[2]	13500	12700	12500

[1] An anionic surfactant available from Solvay.

[2] Measured prior to dispersion into Charge E.

Part 2. Preparation of coating formulations.

[0050] Coating formulations were prepared by adding the components as described in Table 2 and Table 3, and stirring at ambient temperature for at least one hour prior to use.

Table 2. Examples according to the disclosure

Component	Ex 4	Ex 5	Ex 6	Ex 7	Ex 8	Ex 9	Ex 10	Ex 11
Polyvinylpyrrolidone K90[3]	9.9	8.9	9.9	9.1	9.9	5.1	9.9	4.9
[3-(2-Aminoethylamino)propyl] trimethoxysilane	0.1	0.2						
3-[2-(2-Aminoethylamino)ethylamino] propyltrimethoxysilane			0.1					

(3-Aminopropyl)triethoxysilane				0.1	0.1	4.9	0.1	0.1
Polymer dispersion of Example 1	0.1	9.0	0.1	7.7				
Polymer dispersion of Example 2					0.1	0.1		
Polymer dispersion of Example 3							0.1	49.5
Deionized water	89.9	81.9	89.9	83.1	89.9	89.9	89.9	45.5

[3]A Polyvinylpyrrolidone with a reported average molecular weight of 360,000 g/mol

Table 3. Comparative Examples

Component	Parts by weight					
	CE-12	CE-13	CE-14	CE-15	CE-16	CE-17
Polyvinylpyrrolidone K90	10	-	-	-	9.94	9
(3-Aminopropyl)triethoxysilane	-	10	-	-	0.06	-
Polymer dispersion of Example 1	-	-	100	-	-	91
HI-GARD® HC 1080S[4]	-	-	-	100	-	-
Deionized Water	90	90	-	-	90	-

[4] A commercial optical hard coat available from PPG

Part 3. Preparation and testing of coated samples:

[0051] Polycarbonate lenses were first prepared by pretreating with oxygen plasma. Each coating formulation of Examples 4 through 11 and Comparative Examples CE-12 through CE-17 were then applied by spin coating (1100rpm for 13sec) and cured at 120°C for 2hrs, resulting in a coating thickness of 0.5-1 micron. All lenses were allowed to sit at room temperature for 2 hours prior to testing.

Test Method descriptions:

Fog Formation Test

[0052] The coated articles were placed on top of a 125ml beaker filled with 60ml of deionized water maintained at 55 °C for 60 seconds, after which the lens was removed and examined visually for any fog. Samples rated as “good” showed

no fog formation. Samples rated as "marginal" showed fog formation around the edges of the lenses and samples with a "poor" rating showed uniform fog formation over the entire testing area. Only lenses exhibiting no fog formation ("good" rating) were considered acceptable.

Bayer Abrasion

[0053] The resulting coated substrates were tested for surface abrasion resistance with a Bayer Abrasion Tester from COLTS Laboratories. The resistance of the coated substrate to abrasion was quantified by measuring the haze of the test sample after abrasion and comparing that value to that measured on a control sample, i.e, an uncoated, untreated plano polycarbonate lens. Measurements were made on multiple pairs of test sample/controls, e.g., 5 pairs, to ensure statistically significant results. The samples and controls to be tested were cleaned with mild soapy water, rinsed with water and then dried with air. The percent haze of the test sample and control was measured using an UltraScan Pro spectrophotometer (HunterLab). The test sample and control were mounted on the Bayer Abrader and the abrasion medium, REFR AZ 12Grit purchased from Saint Gobain, was placed in the pan of the Abrader. The Abrader was operated for 4 minutes at a rate of 150 cycles per minute for a total of 600 cycles. After abrasion, both the test samples and controls were cleaned with mild soapy water, rinsed and dried with air. The haze of the test samples and controls were again measured using the UltraScan Pro spectrophotometer The Haze Gain was calculated from the difference in haze before and after abrading. The reported Bayer Ratio was calculated by dividing the measured haze of the control by that of the test sample, i.e., Bayer Ratio = Haze Gain (control)/Haze Gain (test sample). A Bayer ratio of greater than 1.3 is considered good. A value of between 1.0 to 1.3 is considered acceptable, and any ratio less than 1.0 is considered poor.

Adhesion Testing

[0054] The coated optical articles of the Examples were tested for coating adhesion using TEST Method B – CROSS-CUT TAPE TEST as described in ASTM D3359-17. using Scotch 600 tape (3M). Three tape pulls were

performed in the same crosscut area before rating the coating adhesion performance, which is reported in Tables 4 and 5. The coating loss was determined by a combination of xenon arc lamp and microscope inspection. The ratings are qualitative rather than quantitative, but a rating of "0B" generally corresponds to 100% coating loss, "5B" generally corresponds to 0% coating loss, and ratings of 4B and 5B are considered passing.

Haze/%Transmittance

[0055] The coated optical articles described above were also evaluated for haze, measured at 550 nanometers, and percent transmittance by a Hunter UltraScan PRO (Hunter Associates Laboratory, Inc.) according to the operating instructions using D65 illuminant. Passing is considered <0.5% haze and >80% transmittance.

[0056] The results for each of the Examples 4 through 11 are shown below in Table 4. The results for the Comparative Examples CE-13 through CE-17 are shown in Table 5. As evidence by the results in Tables 4 and 5, the absence of any of the components of the disclosure results in failure of at least one measured parameter. In addition, the examples of the disclosure provide fog formation performance much improved over that of a commercial hard coat (CE-15), while maintaining acceptable hardness.

Table 4.

	Ex 4	Ex 5	Ex 6	Ex 7	Ex 8	Ex 9	Ex 10	Ex 11
Fog formation	Good	Good	Good	Good	Good	Good	Good	Good
Bayer Ratio	1.57	1.56	1.55	1.55	1.71	1.54	1.62	1.35
Adhesion	5B	5B	4B	4B	5B	5B	5B	5B
Haze/%Transmittance	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 5.

	CE-12	CE-13	CE-14	CE-15	CE-16	CE-17
Fog formation	Good	Marginal	Marginal	Poor	Good	Good
Bayer Ratio	0.21	1.84	0.17	>4	1.18	0.40
Adhesion	0B	5B	5B	5B	5B	5B
Haze/%Transmittance	Pass	Pass	Pass	Pass	Pass	Pass

[0057] 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 thereof may be made without departing from the scope of the disclosure as defined in the appended claims.

WHAT IS CLAIMED IS:

1. A coated optical article comprising:

(1) an optical substrate; and

(2) a coating layer applied as a topmost layer over a surface of the substrate, wherein the coating layer is formed from a treatment composition comprising:

(A) a polymer comprising carboxylic acid groups, pyrrolidone groups and alkoxysilane groups;

(B) an alkoxysilane comprising an amino functional group, an ammonium functional group, an epoxy functional group, or ethylenic unsaturation; and

(C) polyvinyl pyrrolidone.

2. The coated optical article of claim 1, wherein the substrate (1) comprises glass, polymethylmethacrylate, polycarbonate, polyethylene terephthalate (PET), polyurethane, polyurea-urethane, polythiourethane, polyamide, episulfide, cellulose triacetate (TAC), cyclic olefin polymer (COP), cyclic olefin copolymer (COC) and/or poly (allyl diglycol carbonate).

3. The coated optical article of claim 1 or claim 2, wherein the substrate has two opposing surfaces.

4. The coated optical article of claim 3, wherein the coating layer (2) is applied over one surface of the substrate.

5. The coated optical article of claim 3 or 4, wherein the coating layer (2) is applied over both opposing surfaces of the substrate.

6. The coated optical article of any of claims 1 to 5, wherein the polymer (A) is prepared from a mixture of vinyl monomers comprising: (i) a

(meth)acrylic acid monomer, (ii) a (meth)acrylate functional alkoxysilane, and (iii) a pyrrolidone functional vinyl monomer.

7. The coated optical article of claim 6, wherein the polymer (A) is prepared from a mixture comprising 1 to 20 percent by weight (meth)acrylic acid, 10 to 70 percent by weight (meth)acrylate functional alkoxysilane, and 1 to 30 percent by weight pyrrolidone functional vinyl monomer, based on the total weight of monomers used to prepare the polymer (A).

8. The coated optical article of claim 6 or 7, wherein the (meth)acrylate functional alkoxysilane comprises 3-methacryloxypropyltrialkoxysilane.

9. The coated optical article of any of claims 6 to 8, wherein the pyrrolidone functional vinyl monomer comprises N-vinylpyrrolidone.

10. The coated optical article of any of claims 1 to 9, wherein the polymer (A) has a weight average molecular weight of 10,000 to 35,000, or 10,000 to 30,000, or 10,000 to 25,000, or 10,000 to 20,000, or 10,000 to 16,000, or 10,000 to 15,000, or 12,000 to 35,000, or 12,000 to 30,000, or 12,000 to 25,000, or 12,000 to 20,000, or 12,000 to 16,000, or 12,000 to 15,000Da, measured by GPC using polystyrene calibration standards.

11. The coated optical article of any of claims 1 to 10, wherein the alkoxysilane (B) comprises 3-methacryloxypropyltrialkoxysilane, 3-glycidoxypropyltrialkoxysilane, dimethyloctadecyl[3-(trialkoxysilyl)propyl]ammonium chloride, 3-aminopropyltrialkoxysilane, N(beta-aminoethyl) gamma-aminopropyltrialkoxy-silane, 3-(2-aminoethylamino)propyltrialkoxysilane and/or 3-[2-(2-aminoethylamino)ethylamino]propyl-trialkoxysilane.

12. The coated optical article of claim 11 wherein the alkoxysilane (B) comprises 3-glycidoxypropyltrimethoxysilane and/or 3-glycidoxypropyltriethoxysilane.

13. The coated optical article of any of claims 1 to 12, wherein the polymer (A) is present in the treatment composition in an amount of 0.03 to 89.9 percent by weight, or 0.03 to 75 percent by weight, or 0.03 to 60 percent by weight, or 0.05 to 89.9 percent by weight, or 0.05 to 75 percent by weight, or 0.05 to 60 percent by weight, or 0.06 to 89.9 percent by weight, or 0.06 to 75 percent by weight, or 0.06 to 60 percent by weight; the alkoxysilane (B) is present in the treatment composition in an amount of 0.1 to 50 percent by weight, or 0.3 to 50 percent by weight, or 0.5 to 50 percent by weight, and the polyvinyl pyrrolidone (C) is present in the treatment composition in an amount of 10 to 99.5 percent by weight, or 10 to 99 percent by weight, or 35 to 99.5 percent by weight, or 35 to 99 percent by weight, or 40 to 99.5 percent by weight, or 40 to 99 percent by weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C).

14. The coated optical article of any of claims 1 to 13, wherein the treatment composition further comprises (D) a tetraalkoxysilane.

15. The coated optical article of claim 14, wherein the tetraalkoxysilane (D) is present in the treatment composition in an amount of 0.1 to 15 percent by weight, or 0.1 to 10 percent by weight, or 0.1 to 5 percent by weight, based on the total weight of the polymer (A), the polysiloxane (B), and the polyvinyl pyrrolidone (C).

16. The coated optical article of claim 11, wherein the tetraalkoxysilane (D) comprises tetramethoxysilane and/or tetraethoxysilane.

17. The coated optical article of any of claims 1 to 16, wherein the coating layer is applied indirectly over a surface of the substrate on top of an intervening layer, and wherein the intervening layer comprises a primer layer, a tinted layer, a photochromic layer and/or a hardcoat layer interposed between the substrate and the coating layer.

18. The coated optical article of claim 17, wherein the intervening layer on the surface of the substrate comprises a hardcoat layer, which in turn comprises a siloxane.

19. The coated optical article of any of claims 1 to 18, wherein the coating layer (2) demonstrates an initial water contact angle of less than 50°, or less than 30°, or less than 25°, measured via a sessile drop measurement technique using an optical goniometer/tensiometer.

20. The coated optical article of any of claims 1 to 19, wherein the coating layer (2) demonstrates a dry film thickness of 150 nm to 4000 nm.

21. The coated optical article of any of claims 1 to 20, wherein said coated optical article comprises a display element, window, mirror, active or passive liquid crystal cell element, magnifying lens, ophthalmic lens, contact lens, sun lens, fashion lens, sport mask, face shield, visor, goggle, vehicular headlight, vehicular taillight, vehicular signal light, vehicular window, and/or vehicular windshield.

22. The coated optical article of any of claims 1 to 21, wherein the coating layer (2) comprises a crosslinked network of siloxane linkages.

23. A method of providing an optical article with anti-fogging properties, the method comprising: applying a coating layer as a topmost layer

over a surface of an optical substrate, wherein the coating layer is formed from a treatment composition comprising:

(A) a polymer comprising carboxylic acid groups, pyrrolidone groups and alkoxysilane groups;

(B) an alkoxysilane comprising an amino functional group, an ammonium functional group, an epoxy functional group, or ethylenic unsaturation; and

(C) polyvinyl pyrrolidone.

24. Use of a treatment composition to provide an optical article with anti-fogging properties, comprising: applying a coating layer as a topmost layer over a surface of an optical substrate, wherein the coating layer is formed from the treatment composition, wherein the treatment composition comprises:

(A) a polymer comprising carboxylic acid groups, pyrrolidone groups and alkoxysilane groups;

(B) an alkoxysilane comprising an amino functional group, an ammonium functional group, an epoxy functional group, or ethylenic unsaturation; and

(C) polyvinyl pyrrolidone.

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
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ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B C08F C08L C08K

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005 298237 A (NIPPON SHEET GLASS CO LTD) 27 October 2005 (2005-10-27) claim 1 paragraph [0072] - paragraph [0073]; example 6	1-24
A	US 2007/155852 A1 (RATHORE OSMAN [US]) 5 July 2007 (2007-07-05) paragraph [0084] - paragraph [0085]	1-24
A	JP 2001 233638 A (CENTRAL GLASS CO LTD) 28 August 2001 (2001-08-28) claim 4	1-24
A	JP 2017 149057 A (AIST) 31 August 2017 (2017-08-31) claim 1	1-24

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

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

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Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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