Electrophoretic displays with an electrophoretic medium having charged pigmented microparticles are disclosed. The microparticles are charged linking molecules polymerized with chromophores of various colors so that microparticles in a variety of colors may be produced. Methods for producing the microparticles and using the microparticles in an electrophoretic display are also disclosed. Such microparticles may be provided separately, or kits may be provided for producing the microparticles.
COLORED PIGMENT PARTICLES FOR ELECTROPHORETIC DISPLAYS

BACKGROUND

[0001] Electrophoretic displays, such as those that may be used in e-reader devices are displays based on the electrophoresis phenomenon influencing charged pigment particles suspended in a dielectric solvent. The pigment particles may be of a size of about 1-2 microns in diameter, carry a charge, and are able to migrate within the solvent under the influence of externally applied charges from adjacent electrode plates.

[0002] An electrophoretic fluid may have at least one type of charged pigment particles dispersed in the solvent or solvent mixture, and the electrophoretic fluid may be pigmented with a contrasting color to the color of the particles, for example, white particles in a colorless or clear solvent. Upon application of a charge to the electrode plates, the charged particles may be caused to migrate towards or away from the plates, by attraction to a plate of opposite charge, and repulsion away from a plate of similar charge. In this manner, the color showing at one surface may be either the color of the solvent if the particles are attracted away from that surface, or may be the color of the pigment particles if the particles are attracted to that surface. Reversal of plate polarity will cause the particles to migrate back to the opposite plate, thereby reversing the color.

[0003] Alternatively, an electrophoretic fluid may have two types of pigment particles of contrasting colors (for example, white and black) and carrying opposite charges, dispersed in a clear solvent or solvent mixture. Upon application of a voltage difference between the two electrode plates, the two types of pigment particles may move to opposite ends (top or bottom) in a display cell. Thus, one or the other of the colors of the two types of pigment particles would be visible at the viewing side of the display cell.

[0004] The pigment particles may be ionic or ionizable microparticles composed of a polymer encapsulating white, black or otherwise colored molecules. The particles may
be formed from a non-covalent bonding of polymer matrix to encapsulated dye molecules, and because of the non-covalent bonding may lose color over time, or may be broken down by radiant energy and no longer function as designed.

[0005] For electrophoretic displays, there remains a need for charged pigment particles which have improved color-fastness and photostability.

SUMMARY

[0006] Micro- and nano-particle based approaches to electrophoretic displays employing dye molecules that are covalently linked to the polymeric particle matrix display improved color-fastness and photostability.

[0007] In an embodiment, an electrophoretic display includes at least one first electrode layer and an electrophoretic medium disposed adjacent at least one first electrode layer. The electrophoretic medium includes at least one electrically charged particle disposed in a transparent fluid and capable of moving through the transparent fluid upon application of an electrical field to the transparent fluid. At least one charged particle includes an alternating copolymer of a chromophore and a charged linker molecule.

[0008] In an embodiment, an electrophoretic medium includes at least one electrically charged particle disposed in a transparent fluid and capable of moving through the transparent fluid upon application of an electrical field to the transparent fluid. At least one charged particle includes an alternating copolymer of a chromophore and a charged linker molecule.

[0009] In an embodiment, a charged pigment particle includes an alternating copolymer of a chromophore and a charged linker molecule.

[0010] In an embodiment, a method for producing charged pigment particles includes copolymerizing chromophores with charged linker molecules to form charged and colored microparticles.
In an embodiment, a kit for producing charged pigment particles includes chromophores and charged linker molecules for being copolymerized with the chromophores to form charged pigment particles.

In an embodiment, a method for using an electrophoretic display is disclosed. The display includes at least one first electrode layer and an array of microcapsules disposed adjacent at least one first electrode layer with a first side of the microcapsules adjacent the layer and a second side of the microcapsules away from the electrode layer. Each microcapsule includes an electrophoretic medium having at least one electrically charged particle disposed in a transparent fluid and capable of moving through the transparent fluid upon application of an electrical field to the transparent fluid. At least one charged particle includes an alternating copolymer of a chromophore and a charged linker molecule. The method includes selectively applying an electric charge to the electrode layer adjacent selected ones of the microcapsules to cause at least one charged particle in the selected microcapsules to move away from the electrode layer to provide a visual color corresponding to the chromophore at the second side of the selected microcapsules.

BRIEF DESCRIPTION OF THE FIGURES

FIGS. 1A and 1B are representative configurations of an electrophoretic display according to an embodiment.

FIG. 2 depicts an illustrative method of producing red-colored microparticles according to an embodiment.

FIGS. 3A and 3B show illustrative methods of producing blue-colored microparticles according to an embodiment.

FIGS. 4A and 4B show illustrative methods of producing yellow-colored microparticles according to an embodiment.
DETAILED DESCRIPTION

[0017] Charged polymeric pigmented particles, as discussed in more detail below, provide colors in both flexible, and non-flexible display technologies, and provide improved hue, brightness, color intensity, color-fastness and photostability compared to non-polymer-bound pigments and dyes. Electrophoretic displays incorporating such charged particles may be used in a variety of devices, such as cellular telephones, e-book readers, tablet computers, portable computers, smart cards, signs, watches, or shelf labels, to name a few examples.

[0018] In embodiments discussed below, colored pigment particles, such as those used in electrophoretic displays, may be polymers of at least one chromophore and at least one charged linker molecule. The polymer may be a polyamide or polyimide, wherein the polyamide or polyimide may include monomer units of an analog of a pigment molecule, or chromophore, and a linker molecule incorporating a cationic quaternary functionality. In certain other embodiments, the polymer may be a copolyimide or a copolyamide.

[0019] The pigment monomer units and charged linker molecule monomer units may be configured in accordance with a polymerization process so that the resulting charged pigmented polymer forms particles 10, as depicted in FIGS. 1A and IB. The particles 10 may be nanoparticles, microparticles, nanospheres, or microspheres, and will, for simplification, be generally referred to as microparticles herein. A pigment molecule, or chromophore, may be any molecular moiety which has a visible color, or which is capable of attaining a desired visible color upon polymerization with the linker molecule.

[0020] At least one charged particle 10 may be encapsulated along with a suspension fluid 12 within at least one microcapsule 14. Alternatively, a plurality of the microparticles 10 may be present in each microcapsule 14. The suspension fluid 12 may be a dielectric solvent having a density which is approximately the same as the density of the microparticles 10. The solvent or solvent mixture in the suspension fluid 12 in which the
pigment particles are dispersed may have a low viscosity and a dielectric constant in the range of about 2 to about 30, such as about 2 to about 15 for high particle mobility.

[0021] The solvent or solvents of suspension fluid 12 may be linear or branched hydrocarbon oil, halogenated hydrocarbon oil, silicone oil, water, decane epoxide, dodecane epoxide, cyclohexyl vinyl ether, naphthalene, tetrafluorodibromoethylene, tetrachloroethylene, trifluorochloroethylene, 1,2,4-trichlorobenzene, carbon tetrachloride, decane, dodecane, tetradecane, xylene, toluene, hexane, cyclohexane, benzene, an aliphatic hydrocarbon, naphtha, octamethyl cyclosiloxane, cyclic siloxanes, poly(methyl phenyl siloxane), hexamethyldisiloxane, polydimethyldisiloxane, poly(chlorotrifluoroethylene) polymer, or combinations of any two or more of these.

[0022] Some additional examples of suitable dielectric solvents may include hydrocarbons such as isopar, decahydronaphthalene (DECalIN), 5-ethylidene-2-norbornene, fatty oils, paraffin oil; silicon fluids; aromatic hydrocarbons such as phenylxylylethane, dodecylbenzene and alkynaphthalene; halogenated solvents such as perfluorodecalin, perfluorotoluene, perfluoroxylene, dichlorobenzotrifluoride, 3,4,5 -trichlorobenzotrifluoride, chloropentafluoro-benzene, dichlorononane, pentachlorobenzene; and perfluorinated solvents such as FC-43, FC-70 and FC-5060 from 3M Company, St. Paul Minn., low molecular weight halogen containing polymers such as poly(perfluoropropane oxide) from TCI America, Portland, Oregon, poly(chlorotrifluoro-ethylene) such as Halocarbon Oils from Halocarbon Product Corp., River Edge, N.J., perfluoropolyalkylether such as Galden from Ausimont or Krytox Oils and Greases K-Fluid Series from DuPont, Del., polydimethylsiloxane based silicone oil from Dow-Corning (DC-200). The solvent or solvent mixture may be visibly transparent, and, in addition, the solvent may be visibly colorless, or, alternatively, may be colored by a dye or pigment.
[0023] The microcapsules 14 may be formed of polymers and may be transparent for viewing of the contents therein. Additional types of micro-container units, or display cells, may be used in place of microcapsules 14. Micro-container units, or display cells, may include any type of separation units which may be individually filled with a display fluid. Some additional examples of such micro-container units may include, but are not limited to, micro-cups, micro-channels, other partition-typed display cells and equivalents thereof.

[0024] In an embodiment, the microcapsules 14 may be disposed adjacent at least a first electrode layer 16 configured for applying a positive or negative charge adjacent a side of the microcapsules. The electrode layer 16 may be a conducting film, and may be flexible to allow for flexible displays. The electrode layer 16 may have a base substrate 13 supporting individual electrodes 15 corresponding to each microcapsule 14.

[0025] With a configuration as shown in FIG. 1A, wherein the polymer microparticles 10 have a positive charge, an application of a positive charge to the electrode layer 16 adjacent a microcapsule 14 may repel the microspheres away from the electrode, while an application of a negative charge to the electrode layer adjacent a microcapsule may attract the microspheres to the electrode. In this manner, if the suspension fluid is of a first color, and the charged microparticles 10 are of a second color, the side of the microcapsules 14 (upper side in FIG. 1A) disposed away from the electrode layer 16 will appear to a viewer 20 to have the color of the suspension fluid (right-side microcapsule in FIG. 1A) when the microparticles are attracted to the electrode layer. On the other hand, the upper side of the microcapsules 14 will visually appear to have the color of the microparticles (left-side microcapsule in FIG. 1A) when the microparticles are repelled away from the electrode layer.

[0026] In an alternative embodiment, instead of just one electrode layer 16, the display may also have a second electrode layer 16A (shown in outline in FIGS. 1A and IB) of appropriate conducting material, and spaced apart from, and opposing the first layer. At
least one face 17 may be formed as a transparent conducting material which may also act as a substrate material for the individual electrodes 15A which may be disposed on an inner surface of the electrode layer 16A towards the microcapsules 14. The microcapsules 14 may be sandwiched between the electrode layers 16, 16A. Some examples of transparent conducting materials may include, but are not limited to, indium tin oxide (ITO) on polyester, aluminum zinc oxide (AZO), fluorine tin oxide (FTO), poly(3,4-ethylenedioxythiophene) (PEDOT), PEDOT with polystyrene sulfonate) (PSS), poly(4,4-dioctylcyclopentadithiophene), and carbon nanotubes. A voltage difference may be imposed across the microcapsules 14 wherein one layer may apply a charge which is opposite to the charge of the other layer. In this manner, one side of the arrangement may attract the microparticles 10 while the other side repels the microparticles 10 to better facilitate movement of the microparticles through the suspension fluid 12.

[0027] The colors appearing at the surface of face 17 of such electrophoretic displays may be enhanced or promoted by direct sunlight, other external lighting sources, or back-lighting.

[0028] As an alternative, as depicted in FIG. IB, the visible color in a microcapsules 14 may be produced by providing two sets of oppositely charged, and differently colored microparticles 10 in each microcapsule. For example, the positively charged particles may be black and the negatively charged particles may be white (or any other color combinations). Application of electric fields as shown, would attract the black particles to the negatively charged electrodes and the white particles to the positively charged electrodes, and in the depiction of FIG. IB, the upper surface in the left microcapsule would appear black, and the upper surface in the right microcapsule would appear white.

[0029] The pigmented microparticles 10 that are used in electrophoretic displays may be chosen, or configured, based on the desired colors required for the display. Black and
white colors may be used, for example, in e-book readers which display a replica of a white page with black type. Alternative, individual colors may also be used, or, to provide color combinations, the microcapsules 14 of an array of microcapsules may individually be filled with different colors in a repeating pattern so that by activating select ones of the microcapsules, individual colors, and color combinations may be achieved. Two common models for obtaining various colors and color combinations include the RYB or red-yellow-blue model which uses the named set of subtractive primary colors, or the RGB or red-green-blue model which uses the named set of additive primary colors.

[0030] As an example, in an RYB system, individual microcapsules may be provided containing the individual colored microparticles of red, yellow, or blue, and the microcapsules may be arranged in a repeating array of the three colors. When a red-color is desired to be displayed, a negative charge may be selectively applied to the microcapsules containing the red-colored microparticles, or alternatively, for yellow, a negative charge may be selectively applied to the microcapsules containing the yellow-colored microparticles. To produce orange, however, a negative charge may be selectively applied to the microcapsules containing red-colored particles and microcapsules containing yellow-colored particles, so that the red and yellow combine to produce an orange color. This could be applied to any combination of microcapsules to produce a variety of colors.

[0031] As mentioned briefly above, each microparticle 10 may be a charged particle having a polymer of chromophores and charged linker molecules. In an embodiment, the charged particles may be a polymer of chromophores and charged linker molecules. Alternatively, the charged particle may be an alternating copolymer (repeating units, such as ...A-B-A-B-A-B...) of chromophores and charged linker molecules so that the pigment molecule is covalently bound within the particle. As described in more detail below, by appropriate configuration of the reactants, that is, the chromophores and the charged linker
molecules, the microparticles 10 may be produced by a copolymerization reaction between the chromophores and charged linker molecules.

[0032] While not being limited to the following, the charged linker molecules may be molecular constituents which have at least one of: a quaternary ammonium constituent, a quaternary phosphonium constituent, a quaternary arsonium constituent, a quaternary stibonium constituent, and a ternary sulfonium constituent. In an embodiment wherein the charged linker molecule is selected from the above group, the resultant polymer will carry a positive charge (cation).

[0033] In an embodiment, the charged particle may be a copolyamide, wherein one of the pigment molecules and the charged linker molecule may be a component derived from a diamine moiety and the other of the pigment molecule and the charged linker molecule may be a component derived from a dicarboxyl moiety. With such molecular configurations, the diamine component and the dicarboxyl component may be polymerized by a condensation polymerization reaction. Some examples of dicarboxyls which may be used for copolymerization may include, but are not limited to, dicarboxylic acids, diacyl halides, dianhydrides, diesters, or any combination thereof.

[0034] The pigment molecule may be any diamine moiety or dicarboxyl moiety that has a visual color which remains after the copolymerization, or any diamine moiety or dicarboxyl moiety that attains a visual color upon copolymerization. Some examples of colors may include red, yellow, blue, green, black, white, etc., or variations or combinations thereof, such as cyan or magenta, orange, violet, pink, etc.

[0035] For producing red-colored charged particles for microparticles 10, a red-colored chromophore, or pigment molecule, may be copolymerized with a charged linker molecule. Alternatively, a pigment molecule may be used which is capable of attaining a red
color upon copolymerization with a charged linker molecule. In an embodiment, the pigment molecule may be a dianhydride moiety that is red-colored or capable of being red-colored, and the charged linker molecule may be a quaternary ammonium diamine moiety. Alternatively, the charged linker molecules may also be quaternary phosphonium, quaternary arsonium, quaternary stibonium, and ternary sulfonium cations.

[0036] One molecular entity which is capable of being used to produce red-colored pigment molecules is perylene. While perylene itself is brown in color, many derivatives of perylene are red in color. Some examples of perylene derivatives which are red in color, include, but are not limited to, (A) perylene-3,4,9,10-tetracarboxylic dianhydride (Pigment Red 224), (B) 2,9-Bis(4-ethoxyphenyl)anthra[2,1,9-def:6,5,10-d'e'f]diisoquinoline-1,3,8,10(2H,9H)-tetrone (Pigment Red 123), and (C) 2,9-Di(4-methoxyphenyl)-anthra2,1,9-def.6,5,10-d'e'fdiisoquinoline-1,3,8,10-tetrone (Pigment Red 190).

Pigment Red 123 (B) and Pigment Red 190 (C) are perylene diimides incorporating respectively, ethoxyphenyl or methoxyphenyl substituents, and are highly heat stable. Polycationic red pigment particles, in accordance with embodiments, may be produced based on the structures (B) and (C).
In an embodiment, red-colored cationic microparticles may be copolymers of a dianhydride moiety and at least one of: a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety. The dianhydride moiety may be perylene-3,4,9,10-tetracarboxylic dianhydride (A), analogs thereof, or derivatives thereof, or any combination of perylene-3,4,9, 10-tetracarboxylic dianhydride, its analogs and its derivatives.

In an additional embodiment, red-colored charged particles may be copolymers of a dianhydride moiety and a quaternary diamine moiety wherein the quaternary diamine moiety is a quaternary bis-alkoxy aniline (D), analogs thereof, or derivatives thereof, or any combination of the quaternary bis-alkoxy aniline (D), its analogs, and its derivatives.

\[
\text{(D)}
\]

where \(M\) is N or P, \(R_1\) and \(R_2\) are each independently \(\text{C}_i\) to \(\text{C}_{10}\) alkyl, and \(X_1\) and \(X_2\) are each independently \(\text{C}_2\) to \(\text{C}_{10}\) alkylene.

In an embodiment, the red-colored charged particles may be a copolymer (E)

\[
\text{(E)}
\]

where \(M\) is N or P, \(R_1\) and \(R_2\) are each independently \(\text{C}_1\) to \(\text{C}_{10}\) alkyl, and \(x_1\) and \(X_2\) are each independently \(\text{C}_2\) to \(\text{C}_{10}\) alkylene.

As represented in FIG. 2, the red-colored copolymer (E) may be produced by a polycondensation of perylene-3,4,9, 10-tetracarboxylic dianhydride (A) and a quaternary bis-alkoxy aniline (D). The quaternary bis-alkoxy aniline (D) may be produced from a dinitroaryl amine component (F). The dinitroaryl amine component (F) may be alkylated by
treatment with an alkyl iodide in acetonitrile to produces a quaternary salt. The nitro groups may be reduced by treatment of the quaternary salt with hydrogen gas and palladium on carbon in methanol to provide the quaternary bis-alkoxyaniline (D). Polycondensation may be performed by heating a mixture of the perylene dianhydride (A) and the dianiline (D) in a suitable solvent for a period of time, and at a temperature sufficient for polymerization to occur. In an embodiment, the mixture may be heated to about 150 °C to about 200 °C for about 1 to about 2 days to produce the polyimide (E). Some examples of solvents which may be used include, but are not limited to, butanol, quinolone, toluene, xylene, or propionic acid. If a non-acidic solvent is used, the polymerization reaction may be promoted by addition of a base such as triethylamine or pyridine.

[0041] Other commercially available dianhydrides or diamines may be substituted for a portion of the dianhydride (A) or diamine (D), respectively, and may be polymerized into the polymer in the polycondensation reaction to alter the physicochemical properties of the resulting polyimides (E) and provide variations in the particle and optical properties as may be desired depending on the usage. Some examples of substitute dianhydrides may include, but are not limited to, pyromellitic dianhydride, bismaleimide, biphenyl tetracarboxylic dianhydride and benzophenone tetracarboxylic dianhydride. Dicarboxylic acids such as adipic acid may be used in place of dianhydrides. Some examples of substitute diamines may include simple diamines, such as, ethylenediamine, 1,3-diaminopropane or 1,2-diaminopropane 1,4-diaminobutane, and 1,6-diaminohexane.

[0042] For producing blue-colored charged particles for microparticles 10, a blue-colored chromophore, or pigment molecule, may be polymerized with a charged linker molecule. Alternatively, a pigment molecule may be used which is capable of attaining a
blue color upon polymerization with a charged linker molecule. The polymerization may be a condensation polymerization to copolymerize chromophores and charged linker molecules.

[0043] In an embodiment of blue-colored cationic microparticles, the pigment molecule may be a blue-colored dicarbonyl moiety and the charged linker molecule may be a quaternary diamine moiety. In an alternative embodiment, the pigment molecule may be a blue-colored diamine moiety and the charged linker molecule may be a quaternary dicarbonyl moiety. As mentioned above, the charged linker molecules may be quaternary ammonium, quaternary phosphonium, quaternary arsonium, quaternary stibonium, and ternary sulfonium cations. In an embodiment, the charged linker molecule may be at least one of a quaternary ammonium substituent and a quaternary phosphonium substituent. The dicarbonyl moiety may be at least one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, or a combination thereof.

[0044] One molecular entity which is capable of being used to produce blue-colored pigment molecules is anthraquinone (G), wherein R is an alkyl. Two examples of blue pigment molecules based on structural component (G) include Solvent Blue 35 (Oil Blue 35, Sudan Blue II) wherein R is n-butyl, or Solvent Blue 14 (Oil Blue N) wherein R is n-pentyl. Distal modifications of the side-chain alkyl groups R may negligibly affect the anthraquinone chromophore.

[0045] In one embodiment, the blue-colored chromophore may be a component derived from a dicarbonyl moiety and the charged linker molecule may be a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety. The dicarbonyl moiety may be at least one of: component
analogs thereof, and derivatives thereof, wherein each R₁ may be the same or different ones of C₁ to C₁₀ alkylene and X is one of -OH or -O-succinimide. At least one of the quaternary diamine moieties may be at least one of:

component (I)

where M is N or P, each R is the same or different ones of C₁ to C₁₀ alkyl, and each R₂ is the same or different ones of C₂ to C₁₀ alkylene.

In an embodiment, the particles may be blue-colored cationic copolymers (J) having the structure:

where M is N or P, each R is the same or different ones of C₁ to C₁₀ alkyl, each R₁ is the same or different ones of C₁ to C₁₀ alkylene, and each R₂ is the same or different ones of C₂ to C₁₀ alkylene.

In an embodiment, the chromophore may be a component derived from a diamine moiety and the charged linker molecule may be a component derived from at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety. The diamine moiety may be at least one of: component (K)
κ', analogs thereof, and derivatives thereof, where each $R_i$ is the same or different ones of $C_i$ to $C_{10}$ alkylene. At least one of the quaternary dicarbonyl moieties may be at least one of: component (L), analogs thereof, and derivatives thereof, where $M$ is $N$ or $P$, each $R$ is the same or different ones of $C_i$ to $C_{10}$ alkyl, and each $R_2$ is the same or different ones of $C_2$ to $C_{10}$ alkylene, and $Y$ is one of -OH or -O-succinimide.

[0048] In an embodiment, the particles may be blue-colored cationic copolymers (M) having the structure:

where $M$ is $N$ or $P$, each $R$ is the same or a different $C_i$ to $C_{10}$ alkyl, each $R_1$ is the same or a different $C_i$ to $C_{10}$ alkylene, and each $R_2$ is the same or a different $C_2$ to $C_{10}$ alkylene.

[0049] FIGS. 3A and 3B, show a representative method for producing the blue-colored copolymers (J) and (M) by polycondensation. Anthraquinone monomers (H) and (K) may be synthesized from their respective blue anthraquinones. Respective co-monomers for producing the copolymers (J) and (M) may be quaternary dicarboxylates (L) and quaternary diamines (I). A diacid (L) wherein $Y$ is -OH, may be produced by synthesizing a
diester of the quaternary component represented by (L), and subjecting the diester to an ester hydrolysis in a mixture of aqueous hydroxide and methanol.

[0050] The production of polyamides from di-carboxylic acid and diamine monomers typically employs polycondensation at high reaction temperatures (-200 °C). However, to reduce or avoid possible degradation of the anthraquinone moiety at the high temperatures, a lower temperature may be used by first converting carboxylic acids to succinimide esters. For anthraquinone monomers (H) wherein X is -OH, and diacids (L) wherein Y is -OH, the acids may first be converted to bis-N-hydroxysuccinimide (NHS) esters wherein the X and the Y are -O-succinimide. Bis-NHS-esters may be synthesized from di-carboxylates (X and Y are -OH) upon treatment of the di-carboxylates with a carbodiimide such as dicyclohexylcarbodiimide and N-hydroxysuccinimide in a dry inert solvent such as dioxane. Filtration of the dicyclohexyl urea byproduct, addition of a dry non-polar solvent such as toluene or heptane to the filtrate, and filtration of the precipitate will yield the respective bis-NHS-esters (X and Y are -O-succinimide).

[0051] The succinimide esters of (H) and (L) may then be used as the di-carboxylate monomer components in polycondensation with diamines (I) and (K), respectively, at lower temperatures that may be less than about 100 °C. Lower temperature polycondensation reactions may be conducted by placing a mixture of either the succinimide esters of (H) and the diamine (I) or alternatively, a mixture of the succinimide esters of (L) and the diamine (K) in a dry polar aprotic solvent such as dimethyl sulfoxide (DMSO) or N-methylpyrrolidinone (NMP). The mixture may be stirred at room temperature (about 20 °C), or possibly heated to about 60 °C, and allowed to polymerize for about 24 to about 48 hours. Treatment with ice cold water followed by filtration of the precipitate will yield blue polycationic anthraquinone pigments (J) and (M), respectively.
To optimize the physicochemical and optical properties of the polycationic pigment particles produced, at least a portion of the NHS-esters of the diacids may be replaced with NHS-esters of simple dicarboxylic acids such as adipic acid, and/or at least a portion of the diamines may be replaced with simple diamines such as 1,6-diaminohexane in the above-discussed polycondensation reaction.

For producing yellow-colored charged particles for microparticles 10, a yellow-colored pigment molecule, or chromophore, may be polymerized with a charged linker molecule. Alternatively, a pigment molecule may be used which is capable of attaining a yellow color upon polymerization with a charged linker molecule. The polymerization may be a condensation polymerization to copolymerize chromophores and charged linker molecules.

In an embodiment for yellow-colored cationic microparticles, the pigment molecule may be a yellow-colored dicarbonyl moiety and the charged linker molecule may be a quaternary diamine moiety. In an alternative embodiment, the pigment molecule may be a yellow-colored diamine moiety and the charged linker molecule may be a quaternary dicarbonyl moiety. As mentioned above, the charged linker molecules may be quaternary ammonium, quaternary phosphonium, quaternary arsonium, quaternary stibonium, and ternary sulfonium cations. In an embodiment, the charged linker molecule may be at least one of a quaternary ammonium substituent and a quaternary phosphonium substituent. The dicarbonyl moiety may be one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, or a combination thereof.

Arylides are a large class of azo pigments that include many yellow components having high tinctorial strength with utility as printer inks. This group includes
molecular component (N) wherein R is H (Pigment Yellow 1), or alkyl.

[0056] In one embodiment of yellow-colored microparticles, the chromophore may be a component derived from a dicarbonyl moiety and the charged linker molecule may be a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety. The dicarbonyl moiety may be at least one of:

![Chemical structure](image)

wherein, analogs thereof, and derivatives thereof, where R₁ and R₂ are one of -H and -succinimide, and X and Q are independently Cᵢ to C₁₀ alkylene. At least one of the quaternary diamine moiety may be at least one of:

![Chemical structure](image)

where M is N or P, each R is the same or a different one of Cᵢ to C₁₀ alkyl, and each A is the same or a different one of Cᵢ to C₁₀ alkylene.

[0057] In an embodiment, the particles may be yellow-colored cationic copolymers having the structure:

![Chemical structure](image)

where M is N or P, each R is the same or a different one of Cᵢ to C₁₀ alkyl, and A, X and Q are independently Cᵢ to C₁₀ alkylene.
[0058] Yellow-colored copolymers (Q) may be produced by a method as represented in FIG. 4A. An amino-nitro-phenyl carboxylic acid (U) with Y = N₃, such as amino-nitro-phenylacetic acid with X = C₃, may be treated with aqueous nitrous acid to yield a diazonium salt wherein Y = N₂⁺. An acetoacetamide (V) may be synthesized from an amino phenyl carboxylic acid by treatment with diketene in a suitable solvent such as water. For example, an acetoacetamide wherein Q = CH₂CH₂, may be synthesized from 3-(4-aminophenyl)propionic acid. An ice cold mixture of the acetoacetamide (V) and water may be treated with diazonium component (U) and maintained at about pH 5 by dropwise addition of about 40% aqueous sodium hydroxide and stirring for about 3-4 hours. The solid may be filtered, washed with water and dried under reduced pressure to provide the yellow dicarboxy azo-arylide pigment (O) wherein R₁ and R₂ are H.

[0059] The production of polyamides from di-carboxylic acid and diamine monomers typically is done by polycondensation at high reaction temperatures (about 200 °C). To avoid possible degradation of the azo-arylide monomer during polycondensation, the dicarboxylic acid (O) wherein R₁ and R₂ are H may be converted into a diester wherein R₁ and R₂ are N-hydroxysuccinimide (NHS). The bis-NHS ester may be synthesized from the dicarboxylic acid upon treatment of the dicarboxylic acid with N-hydroxysuccinimide and a carbodiimide such as dicyclohexylcarbodiimide in a dry inert solvent such as dioxane, filtration of the dicyclohexyl urea byproduct, addition of a dry non-polar solvent such as toluene or heptane to the filtrate, and filtration of the precipitate. The use of the bis-N-hydroxysuccinimide (NHS) ester as the di-carboxylate monomer components allows for lower temperature polycondensation reactions (less than about 100 °C) with the diamines.

[0060] A mixture of diamine (P) and dicarboxylate (O) in a dry polar aprotic solvent, such as DMSO or N-methylpyrrolidinone (NMP), may be stirred for about 24 to about 48 hours at room temperature (which may be about 20 °C) or alternatively heated at
about 60 °C. Treatment with ice cold water followed by filtration of the precipitate yields the
yellow polycationic azo-arylide pigment (Q).

[0061] To optimize the physicochemical and optical properties of the polycationic
pigment particles produced, at least a portion of the NHS-esters of the diacids may be
replaced with NHS-esters of simple dicarboxylic acids such as adipic acid, and/or at least a
portion of the diamines may be replaced with simple diamines such as 1,6-diaminohexane in
the above-discussed polycondensation reaction.

[0062] For alternative embodiments for yellow microparticles, the chromophore
may be a component derived from a yellow-colored diamine moiety and the charged linker
molecule may be a component derived from at least one of a quaternary ammonium
dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety. The diamine moiety
may be at least one of: component (R)

\[
\begin{align*}
R_3 - H - X - \text{N} - \text{N} &\text{O} \quad \text{N} - \text{N} - Q - N - R_4 \\
\text{HO} - \text{CH}_3 - &
\end{align*}
\]

(R), analogs thereof, and derivatives thereof, where \( R_3 \) is - H or Fmoc, \( R_4 \) is - H or boc and X and Q are independently C\text{\textsubscript{i}} to C\text{\textsubscript{o}} alkylene. The quaternary dicarbonyl moiety may be at least one of: component (S)

\[
\begin{align*}
\text{N} - \text{O} - A &\text{M}^+ - A - \text{O} - \text{N} - \\
&
\end{align*}
\]

(S), analogs thereof, and derivatives thereof, where \( M \) is \( N \) or \( P \), each \( R \) is the same or a different C\text{\textsubscript{i}} to C\text{\textsubscript{o}} alkyl and each \( A \) is the same or a different C\text{\textsubscript{i}} to C\text{\textsubscript{o}} alkylene.

[0063] In an embodiment, the particles may be yellow-colored cationic
copolymers (T) having the structure
Comparable methods to those described above for microparticles (Q) may be applied to production of yellow-colored microparticles (T). As shown in FIG. 4B, amines (W) and (X), protected by either a Boc group (tert-butylxycarbonyl), or Fmoc group (fluorenylmethyloxycarbonyl), may be combined to form the yellow pigment component (R). An amino nitro aniline (such as 4-(2-aminoethyl)-2-nitroaniline) may be Fmoc-protected to provide the component (W) wherein Y = NH$_2$. This component may then be converted without deblocking of the Fmoc protecting group, by aqueous nitrous acid mediated synthesis, to a diazonium salt wherein Y = N$_2$$^+$. A Boc-protected acetoacetamide (X) may be synthesized from a 4-(2-aminoalkyl)aniline (such as 4-(2-aminoethyl)aniline) by mono-Boc-protection followed by treatment with diketene in a suitable solvent, such as water. An ice cold mixture of the acetoacetamide (X) and water may be treated with diazonium component (W) and maintained at about pH 5 by dropwise addition of about 40% aqueous sodium hydroxide and stirring for about 3-4 hours. The solid may be filtered, washed with water and dried under reduced pressure to provide the pigment molecules (R) where R$_3$ and R$_4$ are both still protected by Fmoc and boc respectively. The pigment molecules (R) may be Boc-deprotected with trifluoroacetic acid and then Fmoc-deprotected with piperidine to produce yellow diamino azo-arylide (R) wherein R$_3$ and R$_4$ are both H.

Quaternary di-NHS-ester (S) may be synthesized from a quaternary dicarboxylate ester after ester hydrolysis using a mixture of aqueous hydroxide and methanol. A mixture of diamine (R) and dicarboxylate (S) in a dry polar aprotic solvent, such as DMSO

, where M is N or P, each R is the same or a different Ci to Cio alkyl, each A is the same or a different Ci to Cio alkylene, and X and Q are independently Ci to Cio alkylene.
or N-methylpyrrolidinone (NMP), may be stirred for about 24 to about 48 hours at room temperature (which may be about 20 °C) or alternatively heated at about 60 °C. Treatment with ice cold water followed by filtration of the precipitate yields the yellow polycationic azo-arylide pigment (T).

[0066] Charged pigment particles, such as, for example, any of the embodiments as discussed above, may be produced and marketed in a final polymeric form, or alternatively, the components for producing the particles could be sold in kit form to allow an end user to produce the particles on site, for example, and possibly on an 'as-needed' basis. Such a kit may be for producing one color of microparticle and may include the needed chromophores for producing a certain color, as well as the charged linker molecules for being copolymerized with the chromophores to form the charged pigment particles. Alternatively, such a kit may be for producing microparticles of one color as well as microparticles of another color, or any combinations of colored microparticles.

[0067] Such a kit may, for example, have chromophores which are of a diamine moiety and charged linking molecules which are of a dicarboxyl moiety, or alternatively, chromophores which are of a dicarboxyl moiety and charged linking molecules which are of a diamine moiety. For either the chromophores, or the charged linking molecules, the dicarboxyl moiety may be at least one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, a dialdehyde, a diketone or a combination thereof. The charged linking molecule may be cations selected from the group consisting of quaternary ammonium, quaternary phosphonium, quaternary arsonium, quaternary stibonium, and ternary sulfonium cations.

[0068] For red-colored particles, the kit may include dianhydride moieties of at least one of component (A), analogs thereof, and derivatives thereof, and quaternary diamine
moieties of at least one of component (D), analogs thereof, and derivatives thereof, where M is N or P, R is C₁ to C₁₀ alkyl, and X is C₂ to C₁₀ alkylene.

[0069] For yellow-colored particles, the kit may include at least one of Option 1 and Option 2. For Option 1, the kit may include dicarbonyl moieties of at least one of component (O), analogs thereof, and derivatives thereof, where R₁ and R₂ are one of -H and -succinimide, and X and Q are C₁ to C₁₀ alkylene; and quaternary diamine moieties of at least one of component (P), analogs thereof, and derivatives thereof, where M is N or P, R is C₁ to C₁₀ alkyl, and A is C₁ to C₁₀ alkylene. For Option 2, the kit may include diamine moieties of at least one of component (R), analogs thereof, and derivatives thereof, wherein R₃ and R₄ are -H, and X and Q are C₁ to C₁₀ alkylene; and quaternary dicarbonyl moieties of at least one of component (S), analogs thereof, and derivatives thereof, where M is N or P, R is C₁ to C₁₀ alkyl and A is C₁ to C₁₀ alkylene.

[0070] For blue-colored particles, the kit may include at least one of Option 1 and Option 2. For Option 1, the kit may include dicarbonyl moieties of at least one of component (H), analogs thereof, and derivatives thereof, where R₁ is C₁ to C₁₀ alkylene and X is one of -OH or -O-succinimide; and quaternary diamine moieties of at least one of component (I), analogs thereof, and derivatives thereof, where M is N or P, R is C₁ to C₁₀ alkyl, and R₂ is C₂ to C₁₀ alkylene. For Option 2, the kit may include diamine moieties of at least one of component (K), analogs thereof, and derivatives thereof, where R₁ is C₁ to C₁₀ alkylene; and quaternary dicarbonyl moieties of at least one of component (L), analogs thereof, and derivatives thereof, where M is N or P, R is C₁ to C₁₀ alkyl, and R₂ is C₂ to C₁₀ alkylene, and Y is one of -OH or -O-succinimide.

[0071] In alternative embodiments, the kit may include any combination of, or all of the components for producing any combination of, or all of the red-colored microparticles, the blue-colored microparticles, or the yellow-colored microparticles.
EXAMPLES

EXAMPLE 1: Red-Colored Charged Microparticles

[0072] Red-colored copolymer (E) is produced by a polycondensation of perylene-3,4,9,10-tetracarboxylic dianhydride (A) and quaternary ammonium salt (D) wherein \( M = N \), \( X_1 \) and \( X_2 = CH_2CH_2 \) and \( R_1 \) and \( R_2 = CH_2 \) (synthesized according to the method described in Telepova, ND, Ginzburg, OF. (1969) Synthesis and some properties of methylbis(2-aryloxyethyl)amines. Zh Org Khim 5, 1429-1432).

[0073] A mixture of the perylene dianhydride (A) and an N,N-dimethylbis(2-(4-aminophenoxy)ethyl)ammonium salt (D) in about a 1:1 molar ratio in toluene is stirred while heating at 200 °C for 48 hours to produce red-colored cationic polyimide (E) wherein \( M = N \), \( X_1 \) and \( X_2 = CH_2CH_2 \) and \( R_1 \) and \( R_2 = CH_2 \). The microparticles (E) are filtered from the mixture and washed with toluene.

EXAMPLE 2: Blue-Colored Charged Microparticles

[0074] Blue-colored copolymer (J) is produced by a polycondensation of an anthraquinone dicarboxylic acid derivative (H) wherein \( R_1 \) is \( CH_2CH_2 \) and \( X \) is \(-O-\)succinimide, and a quaternary ammonium diamine (I) wherein \( M = N \), \( R \) is \( CH_2CH_2 \) and \( R_2 \) is \( CH_2CH_2 \) (synthesized according to the method described in Zhao, Y, et al. (2009) Synthesis, cytotoxicity and cucurbituril binding of triamine linked dinuclear platinum complexes. Dalton Trans 5190-5198).

[0075] A mixture of dicarboxylic acid (H) wherein \( X \) is OH (synthesized according to the method described in Stapleton, IW. (1978) Dyestuffs containing isothiouranium groups. Brit Pat GB1508238) (1 equivalent), N-hydroxysuccinimide (2.1 equivalents), dicyclohexylcarbodiimide (2.1 equivalents) and dry dioxane is stirred at about 20 °C for 24 hours. The dicyclohexylurea byproduct is removed by filtration, and dry toluene
is added to the filtrate. The solid bis-NHS ester \( (H) \) wherein \( X = -\text{O-succinimide} \) is filtered from solution.

[0076] A mixture of bis-NHS ester \( (H) \) and the diamine \( (I) \) at about a 1:1 molar ratio in dry DMSO is stirred at 60 °C, for 24 hours. The mixture is stirred while treating with ice cold water to precipitate blue polycationic anthraquinone microparticles \( (J) \) wherein \( R \) is \( C\%4, \ R_1 \) and \( R_2 \) is \( \text{CH}_2\text{CH}_2 \), and \( M \) is \( N \). The microparticles are filtered from solution and washed with ice cold water.

EXAMPLE 3: Second Configuration of Blue-Colored Charged Microparticles

[0077] Blue-colored copolymer \( (M) \) is produced by a polycondensation of an anthraquinone diamine \( (K) \) wherein \( R_1 \) is \( \text{CH}_2\text{CH}_2\text{CH}_2 \) (synthesized according to the method described in Barasch, D, et al. (1999) Novel anthraquinone derivatives with redox-active functional groups capable of producing free radicals by metabolism: are free radicals essential for cytotoxicity? Eur J Med Chem 34, 597-615) and a quaternary ammonium dicarboxylate \( (L) \) wherein \( Y = -\text{O-succinimide} \), \( M \) is \( N \), \( R \) is \( C\%4 \), and \( R_2 \) is \( \text{CH}_2\text{CH}_2 \).

[0078] Diethyl ester \( (L) \) wherein \( Y = \text{CH}_2\text{CH}_3 \) (synthesized according to the method described in Craig, LE, Tarbell, DS. (1949) Curariform activity and chemical structure. IV. Synthesis in the piperidine series. J Amer Chem Soc 71, 465-467) is stirred with a solution of 10% aqueous sodium hydroxide and methanol for 1 hour and then adjusted to pH 3 by addition of 10% hydrochloric acid. Solvent evaporation yields dicarboxylic acid \( (L) \) wherein \( Y \) is \( \text{OH} \).

[0079] A mixture of dicarboxylic acid \( (L) \) (1 equivalent), \( N\)-hydroxysuccinimide (2.1 equivalents), dicyclohexylcarbodiimide (2.1 equivalents) and dry dioxane is stirred at 20 °C for 24 hours. The dicyclohexylurea byproduct is removed by filtration and dry toluene is added to the filtrate. The solid bis-NHS ester \( (L) \) wherein \( Y = -\text{O-succinimide} \), is filtered from solution.
A mixture of bis-NBS ester of (L) and diamine (K) at about a 1:1 molar ratio in dry DMSO is stirred at 60 °C for 24 hours. The mixture is stirred while treating with ice cold water to precipitate blue polycationic anthraquinone microparticles (M) wherein R is C34, R1 and R2 are CH2CH2, and M is N. The microparticles are filtered from solution and washed with ice cold water.

EXAMPLE 4: Yellow-Colored Charged Microparticles

Yellow-colored copolymer (Q) is produced by a polycondensation of a bis-NHS ester azo-arylide pigment (O) wherein R1 and R2 are -succinimide, and X and Q are CH2CH2 and a quaternary ammonium diamine (P) wherein M is N, R is C34 and A is CH2CH2 (P is identical to I above).

3-(4-Aminophenyl)propionic acid (synthesized according to the method described in Smith, CR, et al. Triazolopyridazine protein kinase modulators. US Pat Appl 2010/0120739) (1 equivalent) is dissolved in a minimum volume of 5% aqueous sodium hydroxide (pH 8-10) and cooled in an ice bath. Diketene (3 equivalents) is added and the mixture is stirred for 1 hour. Evaporation of the solvent yields acetoacetamide (V) wherein R2 is H, and Q is CH2CH2.

A mixture of 2-(4-amino-3-nitrophenyl)acetic acid (1 equivalent) and 4% hydrochloric acid is cooled in an ice bath, treated with aqueous sodium nitrite solution (1.2 equivalents), and stirred for 1 hour. Unreacted nitrous acid is quenched by addition of sulfamic acid to yield an acidic aqueous solution of diazonium salt (U) wherein X is CH2CH2, Y is N2+, and R1 is H that is used directly in the following step.

An ice cold mixture of water and acetoacetamide (V) wherein R2 is H, and Q is CH2CH2 (1 equivalent) is added slowly to the ice cold acidic aqueous solution of diazonium salt (U) wherein X is CH2CH2, Y is N2+, and R1 is H (1 equivalent). The mixture is adjusted to pH about 5 by dropwise addition of 40% aqueous sodium hydroxide solution.
and then stirred for 3 hours. The solid is filtered, washed with water and dried under reduced
pressure to provide the yellow dicarboxylic acid azo-arylide pigment (O) wherein \( R_1 \) and \( R_2 \)
are H, and X and Q are \( \text{CH}_2\text{CH}_2 \).

[0085] A mixture of dicarboxylic acid (O) wherein \( R_1 \) and \( R_2 \) are H (1 equivalent), N-hydroxysuccinimide (2.1 equivalents), dicyclohexylcarbodiimide (2.1 equivalents) and dry dioxane is stirred at 20 °C for 24 hours. The dicyclohexylurea byproduct is removed by filtration and dry toluene is added to the filtrate. The solid bis-NHS ester (O) wherein \( R_1 \) and \( R_2 = \text{succinimide} \), is filtered from solution.

[0086] A mixture of diamine (P) and bis-NHS ester (O) at about a 1:1 molar ratio in dry DMSO is stirred at 60 °C for 24 hours. The mixture is treated with ice cold water to precipitate yellow polycationic azo-arylide pigment microparticles (Q) wherein M is N, R is \( \text{CH}_3 \), and A, X and Q are \( \text{CH}_2\text{CH}_2 \). The microparticles are filtered from solution and washed with ice cold water.

EXAMPLE 5: A Second Configuration of Yellow-Colored Charged Microparticles

[0087] Yellow-colored copolymer (T) is produced by a polycondensation of diamino-azo-arylide pigment (R) wherein \( R_3 \) is H, and X and Q are \( \text{CH}_2\text{CH}_2 \) and a quaternary ammonium bis-NHS ester (S) wherein M is N, R is \( \text{CH}_3 \) and A is \( \text{CH}_2\text{CH}_2 \) (S is identical to L wherein Y is \(-\text{O-succinimide above})

[0088] Di-t-butyldicarbonate (1 equivalent) is added dropwise to a stirred mixture of 4-(2-aminoethyl)aniline (1 equivalent), 4% aqueous sodium hydroxide (1.1 equivalent), and tetrahydrofuran. After stirring for 16 hours, the mixture is extracted with ethyl acetate. The extract is dried over sodium sulfate and concentrated to yield 4-(2-(t-butoxycarbonyl)aminoethyl)aniline.

[0089] To a solution of 4-(2-(t-butoxycarbonyl)aminoethyl)aniline (1 equivalent) in tetrahydrofuran and water is added 5% aqueous sodium hydroxide dropwise to maintain
pH 8-10 and cooled in an ice bath. Diketene (3 equivalents) is added and the mixture is stirred for 1 hour. Evaporation of the solvent yields Boc-protected acetoacetamide (X) wherein Q is CH₂CH₂.

[0090] A mixture of 4-(2-aminoethyl)-2-nitroaniline (synthesized according to the method described in Buchstaller, H-P, et al. (2011) Design and synthesis of isoquinolines and benzimidazoles as RAF kinase inhibitors. Bioorg Med Chem Lett 21, 2264-2269) (1 equivalent), N-(9-fluorenylmethoxycarbonyloxy)succinimide (1 equivalent), 10% aqueous sodium carbonate solution, and 1,2-dimethoxyethane is stirred for 16 hours. The solid is filtered, the filtrate is evaporated and the residue is dissolved in ethyl acetate. The solution is washed with water and concentrated to yield Fmoc-protected nitroaniline (W) wherein X is CH₂CH₂ and Y is NH₂.

[0091] To an ice cold solution of Fmoc-protected nitroaniline (W) (1 equivalent) and HBF₄ (1.5 equivalent) in water is added sodium nitrite (1 equivalent) and stirred for 30 minutes yielding an aqueous solution of Fmoc-protected diazonium salt (W) wherein X is CH₂CH₂ and Y is N₂⁺ that is used directly in the next step.

[0092] An ice cold mixture of water and Boc-protected acetoacetamide (X) wherein Q is CH₂CH₂ (1 equivalent) is added slowly to the ice cold aqueous solution of Fmoc-protected diazonium salt (W) wherein X is CH₂CH₂ and Y is N₂⁺ (1 equivalent). The mixture is adjusted to pH 5 and then stirred for 3 hours. The solid is filtered, washed with water and dried under reduced pressure to provide the yellow Boc- and Fmoc-protected azo-arylide pigment (R) wherein R₃ is Fmoc, R₄ is Boc and X and Q are CH₂CH₂.

[0093] A mixture of the Boc- and Fmoc-protected azo-arylide pigment (R) and 50% trifluoroacetic acid in dichloromethane is stirred for 30 minutes. Evaporation of solvents yields Fmoc-protected azo-arylide pigment (R) wherein R₃ is Fmoc, R₄ is H, and X and Q are CH₂CH₂.
[0094] A mixture of Fmoc-protected azo-arylide pigment (R), 1,8-diazobicycloundec-7-ene (0.03 equivalent), 1-octanethiol (10 equivalents) and tetrahydrofuran is stirred for 4 hours. After solvent evaporation diamino azo-arylide pigment (R) wherein both R₃ and R₄ are H, and X and Q are CH₂CH₂ is purified by trituration with diethyl ether.

[0095] A mixture of diamine (R) and bis-NHS ester (S) at about a 1:1 molar ratio in dry DMSO is stirred at 60 °C for 24 hours. The mixture is treated with ice cold water to precipitate yellow polycationic azo-arylide pigment microparticles (T) wherein M is N, R is CH₃, and A, X and Q are CH₂CH₂. The microparticles are filtered from solution and washed with ice cold water.

EXAMPLE 6: A Kit for Producing Charged Pigmented Microparticles

[0096] A kit is configured for producing each of red-colored microparticles, blue-colored microparticles, and yellow-colored microparticles.

[0097] For the red-colored microparticles, the kit will include: component (A); and component (D), where M is N, R is C₂₄, and X is C₂ alkylenes.

[0098] For the yellow-colored microparticles, the kit will include: component (O), where R₁ and R₂ are -succinimide, and X and Q are C₂ alkylenes; and component (P), where M is N, R is CH₃, and A is C₂ alkylenes.

[0099] For the blue-colored microparticles, the kit will include: component (H), where R₁ is C₂ alkylenes, and X is -O-succinimide; and component (I), where M is N, R is CH₃, and R₂ is C₂ alkylene.

EXAMPLE 7: An Electrophoretic Medium

[00100] An electrophoretic medium for use in electrophoretic displays may include any of the microparticles of Examples 1-5. An electrophoretic medium having about 1 to 30
volume % charged particles for producing a blue color in an electrophoretic display is made
by dispersing the blue-colored particles (J) of Example 2 in a hydrocarbon oil.

EXAMPLE 8: An Electrophoretic Display

[00101] The electrophoretic medium of Example 7 is encapsulated within
individual urea/melamine/formaldehyde microcapsules of about 50 micrometer diameter.
The microcapsules is dispersed between two parallel conductive plates, spaced about 50
micrometers apart, and the plates is connected to electrical circuitry that allows external
signals to manipulate the electric charge at different precise points on the plates.

[00102] This disclosure is not limited to the particular systems, devices and
methods described, as these may vary. The terminology used in the description is for the
purpose of describing the particular versions or embodiments only, and is not intended to
limit the scope.

[00103] In the above detailed description, reference is made to the accompanying
drawings, which form a part hereof. In the drawings, similar symbols typically identify
similar components, unless context dictates otherwise. The illustrative embodiments
described in the detailed description, drawings, and claims are not meant to be limiting.
Other embodiments may be used, and other changes may be made, without departing from
the spirit or scope of the subject matter presented herein. It will be readily understood that
the aspects of the present disclosure, as generally described herein, and illustrated in the
Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of
different configurations, all of which are explicitly contemplated herein.

[00104] The present disclosure is not to be limited in terms of the particular
embodiments described in this application, which are intended as illustrations of various
aspects. Many modifications and variations can be made without departing from its spirit and
scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, components, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[00105] As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" or "comprises" or "comprise" means "including, but not limited to."

[00106] While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups.

[00107] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.
It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one
of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[00109] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[00110] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.
Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.
CLAIMS

What Is Claimed Is:

1. An electrophoretic display comprising:
   at least one first electrode layer; and
   an electrophoretic medium disposed adjacent at least one first electrode layer,
   wherein the electrophoretic medium comprises:
   at least one electrically charged particle disposed in a transparent fluid
   and capable of moving through the transparent fluid upon application of an
   electrical field to the transparent fluid, wherein at least one charged particle
   comprises an alternating copolymer of a chromophore and a charged linker
   molecule.

2. The electrophoretic display of claim 1, further comprising at least one
   microcapsule having the transparent fluid and at least one charged particle retained therein.

3. The electrophoretic display of claim 1, wherein the charged linker molecule
   comprises cations selected from a group comprising quaternary ammonium, quaternary
   phosphonium, quaternary arsonium, quaternary stibonium, and ternary sulfonium cations.

4. The electrophoretic display of claim 1, wherein at least one charged particle
   consists essentially of the alternating copolymer of the chromophore and the charged linker
   molecule.

5. The electrophoretic display of claim 1, wherein:
   at least one charged particle is a copolyamide; and
one of the chromophore and the charged linker molecule comprises a component derived from a diamine moiety and the other of the chromophore and the charged linker molecule comprises a component derived from a dicarbonyl moiety.

6. The electrophoretic display of claim 5, wherein the charged linker molecule comprises at least one of a quaternary ammonium substituent and a quaternary phosphonium substituent.

7. The electrophoretic display of claim 5, wherein the dicarbonyl moiety is one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, or a combination thereof.

8. The electrophoretic display of claim 5, wherein:

   the charged linker molecule comprises at least one of a quaternary ammonium substituent and a quaternary phosphonium substituent;
   the dicarbonyl moiety is one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester or a combination thereof; and
   the chromophore is red colored.

9. The electrophoretic display of claim 5, wherein:

   the charged linker molecule comprises at least one of a quaternary ammonium substituent and a quaternary phosphonium substituent;
   the dicarbonyl moiety is one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, or a combination thereof; and
   the chromophore is blue colored.

10. The electrophoretic display of claim 5, wherein:
the charged linker molecule comprises at least one of a quaternary ammonium substituent and a quaternary phosphonium substituent;

the dicarbonyl moiety is one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, or a combination thereof; and

the chromophore is yellow colored.

11. The electrophoretic display of claim 5, wherein:

the charged linker molecule comprises at least one of a quaternary ammonium substituent and a quaternary phosphonium substituent;

the dicarbonyl moiety is one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, or a combination thereof; and

the chromophore is green colored.

12. The electrophoretic display of claim 1, wherein the chromophore is red colored.

13. The electrophoretic display of claim 12, wherein:

the chromophore comprises a component derived from a dianhydride moiety;

and

the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

14. The electrophoretic display of claim 13, wherein the dianhydride moiety comprises at least one of:
15. The electrophoretic display of claim 14, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

\[
\begin{align*}
\text{H}_2\text{N}-\text{O}-\text{X}\text{M}^+\text{X}^-\text{O}-\text{NH}_2 \\
\end{align*}
\]

, analogs thereof, and derivatives thereof,

where \(M\) is \(N\) or \(P\), each \(R\) is individually a \(C_1\) to \(C_{10}\) alkyl, and each \(X\) is individually a \(C_2\) to \(C_{10}\) alkyne.

16. The electrophoretic display of claim 1, wherein the particle is a red colored cationic microparticle having the structure:

\[
\begin{align*}
\text{O} & \quad \text{N} & \quad \text{O} \\
\end{align*}
\]

, where \(M\) is \(N\) or \(P\), each \(R\) is individually a \(C_1\) to \(C_{10}\) alkyl, and each \(X\) is individually a \(C_2\) to \(C_{10}\) alkyne.

17. The electrophoretic display of claim 1, wherein the chromophore is yellow colored.

18. The electrophoretic display of claim 17, wherein the chromophore comprises a component derived from a dicarbonyl moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.
19. The electrophoretic display of claim 18, wherein the dicarbonyl moiety comprises at least one of:

![Chemical Structure Image]

, analogs thereof, and derivatives thereof, where R₁ and R₂ are one of -H and -succinimide, and X and Q are each individually a C₁₀ alkylene.

20. The electrophoretic display of claim 18, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

![Chemical Structure Image]

, analogs thereof, and derivatives thereof, where M is N or P, each R is individually a C₁₀ alkyl, and each A is individually a C₁₀ alkylene.

21. The electrophoretic display of claim 1, wherein the particle is a yellow colored cationic microparticle having the structure

![Chemical Structure Image]

, where M is N or P, each R is individually a C₁₀ alkyl, and each A, X and Q are individually a C₁₀ alkylene.
22. The electrophoretic display of claim 17, wherein the chromophore comprises a component derived from a yellow colored diamine moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety.

23. The electrophoretic display of claim 22, wherein the diamine moiety comprises at least one of:

\[ R_1 - N \cdot X - \text{aryl} - O - \text{aryl} - Q - N \cdot R_4 \]

, analogs thereof, and derivatives thereof, where \( R_3 \) and \( R_4 \) are \(-H\), and \( X \) and \( Q \) are each individually a \( \text{C}_i \) to \( \text{C}_{10} \) alkylene.

24. The electrophoretic display of claim 22, wherein at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:

\[ \text{M} \cdot \text{A} - \text{O} - \text{A} - \text{O} - \text{M} \]

, analogs thereof, and derivatives thereof, where \( M \) is \( N \) or \( P \), each \( R \) is individually a \( \text{C}_i \) to \( \text{C}_{10} \) alkyl, and each \( A \) is individually a \( \text{C}_i \) to \( \text{C}_{10} \) alkylene.

25. The electrophoretic display of claim 1, wherein the particle is a yellow colored cationic microparticle having the structure:
R is individually a C\textsubscript{i} to C\textsubscript{i0} alkyl, and each A, X and Q are individually C\textsubscript{i} to C\textsubscript{i0} alkylene.

26. The electrophoretic display of claim 1, wherein the chromophore is blue colored.

27. The electrophoretic display of claim 26, wherein the chromophore comprises a component derived from a dicarbonyl moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

28. The electrophoretic display of claim 27, wherein the dicarbonyl moiety comprises at least one of:

\[
\begin{align*}
\text{R} & \text{1} - \text{N} - \text{N} - \text{R}1 - \text{X}
\end{align*}
\]

, analogs thereof, and derivatives thereof, where each R\textsubscript{1} is individually a C\textsubscript{i} to C\textsubscript{i0} alkylene and each X is one of -OH or -O-succinimide.

29. The electrophoretic display of claim 27, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:
where $M$ is N or P, each $R$ is individually a C$_i$ to C$_{10}$ alkyl, and each $R_2$ is individually a C$_2$ to C$_{10}$ alkylene.

30. The electrophoretic display of claim 1, wherein the particle is a blue colored cationic microparticle having the structure:

![Chemical Structure]

, where $M$ is N or P, each $R$ is individually a C$_i$ to C$_{10}$ alkyl, each $R_1$ is individually a C$_i$ to C$_{10}$ alkylene, and each $R_2$ is individually a C$_2$ to C$_{10}$ alkylene.

31. The electrophoretic display of claim 26, wherein the chromophore comprises a component derived from a diamine moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety.

32. The electrophoretic display of claim 31, wherein the diamine moiety comprises at least one of:
33. The electrophoretic display of claim 31, wherein at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:

\[ \text{analogs thereof, and derivatives thereof, where each } R_i \text{ is individually a } C_1 \text{ to } C_{10} \text{ alkylene.} \]

34. The electrophoretic display of claim 1, wherein the particle is a blue colored cationic microparticle having the structure:

\[ \text{, where } M \text{ is } N \text{ or } P, \text{ each } R \text{ is individually a } C_1 \text{ to } C_{10} \text{ alkyl, each } R_2 \text{ is individually a } C_2 \text{ to } C_{10} \text{ alkylene, and each } Y \text{ is one of } -OH \text{ or } -O\text{-succinimide.} \]

35. The electrophoretic display of claim 1, wherein the transparent fluid comprises at least one of: linear or branched hydrocarbon oil, halogenated hydrocarbon oil, silicone oil,
water, decane epoxide, dodecane epoxide, cyclohexyl vinyl ether, naphthalene, tetrafluorodibromoethylene, tetrachloroethylene, trifluorochloroethylene, 1,2,4-trichlorobenzene, carbon tetrachloride, decane, dodecane, tetradecane, xylene, toluene, hexane, cyclohexane, benzene, an aliphatic hydrocarbon, naphtha, octamethyl cyclosiloxane, cyclic siloxanes, poly(methyl phenyl siloxane), hexamethyldisiloxane, polydimethylsiloxane, and poly(chlorotrifluoroethylene) polymer.

36. The electrophoretic display of claim 1, wherein at least one electrically charged particle comprises a plurality of the electrically charged particles and the display further comprises:

   a first substrate with at least one first electrode layer disposed on the first substrate;

   a second substrate spaced apart from and opposing the first electrode layer on the first substrate and defining a space between the first substrate and the second substrate;

   a second electrode layer disposed on an inner surface of the second substrate towards the first electrode layer; and

   a plurality of microcapsules received in the chamber and sandwiched between the first and second electrode layers, wherein the microcapsules contain the electrophoretic medium therein.

37. The electrophoretic display of claim 36, incorporated into one of a cellular telephone, an e-book reader, a tablet computer, a portable computer, a smart card, a sign, a watch or a shelf label.
38. The electrophoretic display of claim 1, wherein the display is flexible or non-flexible.

39. An electrophoretic medium comprising at least one electrically charged particle disposed in a transparent fluid and capable of moving through the transparent fluid upon application of an electrical field to the transparent fluid, wherein at least one charged particle comprises an alternating copolymer of a chromophore and a charged linker molecule.

40. The electrophoretic medium of claim 39, wherein at least one charged particle consists essentially of the alternating copolymer of the chromophore and the charged linker molecule.

41. The electrophoretic medium of claim 39, wherein:

   at least one charged particle is a copolyamide; and

   one of the chromophore and the charged linker molecule comprises a component derived from a diamine moiety and the other of the chromophore and the charged linker molecule comprises a component derived from a dicarboxyl moiety.

42. The electrophoretic medium of claim 41, wherein the dicarboxyl moiety is one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester or a combination thereof.

43. The electrophoretic medium of claim 39, wherein the chromophore is red colored.

44. The electrophoretic medium of claim 43, wherein the chromophore comprises a component derived from a dianhydride moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.
45. The electrophoretic medium of claim 44, wherein the dianhydride moiety comprises at least one of:

\[ \text{structure image} \]
, analogs thereof, and derivatives thereof.

46. The electrophoretic medium of claim 44, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

\[ \text{structure image} \]
, analogs thereof, and derivatives thereof,

wherein M is N or P, each R is individually a \( C_i \) to \( C_{10} \) alkyl, and each X is individually a \( C_2 \) to \( C_{10} \) alkylene.

47. The electrophoretic medium of claim 39, wherein the particle is a red colored cationic microparticle having the structure:

\[ \text{structure image} \]
, where M is N or P, each R is individually a \( C_i \) to \( C_{10} \) alkyl, and each X is individually a \( C_2 \) to \( C_{10} \) alkylene.

48. The electrophoretic medium of claim 39, wherein the chromophore is yellow colored.

49. The electrophoretic medium of claim 48, wherein the chromophore comprises a component derived from a dicarbonyl moiety and the charged linker molecule comprises a
component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

50. The electrophoretic medium of claim 49, wherein the dicarbonyl moiety comprises at least one of:

\[
R_1\text{OOC-}X\text{-N}^\text{N}-\text{Q}^\text{COOR_2}
\]

, analogs thereof, and derivatives thereof, and \( \frac{3}{2} \) and \( R_2 \) are one of -H and -succinimide, and X and Q are individually a Ci to Cio alkylene.

51. The electrophoretic medium of claim 49, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

\[
\text{R-}\text{H}_2\text{N-}_{_{\text{A}}}\text{M}^\text{A-}_{\text{N}}\text{H}_2\text{R}
\]

, analogs thereof, and derivatives thereof, and M is N or P, each R is individually a Ci to Cio alkyl, and each A is individually a Ci to Cio alkylene.

52. The electrophoretic medium of claim 39, wherein the particle is a yellow colored cationic microparticle having the structure
R is individually a C_i to C_i alkyl, and each A, X and Q are individually a C_i to C_i alkylene.

53. The electrophoretic medium of claim 48, wherein the chromophore comprises
a component derived from a diamine moiety and the charged linker molecule comprises a
component derived from at least one of a quaternary ammonium dicarbonyl moiety and a
quaternary phosphonium dicarbonyl moiety.

54. The electrophoretic medium of claim 53, wherein the diamine moiety
comprises at least one of:

\[ \text{derivatives thereof, and analogs thereof, wherein } R_3 \text{ and } R_4 \text{ are } -H, \text{ and } X \text{ and } Q \text{ are individually a C}_i \text{ to C}_i \text{ alkylene.} \]

55. The electrophoretic medium of claim 53, wherein at least one of the
quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety
comprises at least one of:

\[ \text{derivatives thereof, and analogs thereof, where } M \text{ is } N \text{ or } P, \text{ each } R \text{ is individually a C}_i \text{ to C}_i \text{ alkyl and each } A \text{ is individually a C}_i \text{ to C}_i \text{ alkylene.} \]
56. The electrophoretic medium of claim 39, wherein the particle is a yellow colored cationic microparticle having the structure:

\[ \text{Structure Image} \]

, where \( M \) is \( \text{N or P} \), each \( R \) is individually a \( \text{C}_i \) to \( \text{C}_{10} \) alkyl, and each \( A \), \( X \) and \( Q \) are individually a \( \text{C}_i \) to \( \text{C}_{10} \) alkylene.

57. The electrophoretic medium of claim 39, wherein the chromophore is blue colored.

58. The electrophoretic medium of claim 57, wherein the chromophore comprises a component derived from a dicarbonyl moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

59. The electrophoretic medium of claim 58, wherein the dicarbonyl moiety comprises at least one of:

\[ \text{Structure Image} \]

, analogs thereof, and derivatives thereof, where each \( R_1 \) is individually a \( \text{C}_i \) to \( \text{C}_{10} \) alkylene and each \( X \) is one of -OH or -O-succinimide.
60. The electrophoretic medium of claim 58, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

\[
\begin{align*}
\text{R} & \quad \text{R}_2 \\
\text{H}_2 \text{N} - \text{R} \quad & \quad \text{R}_1 \\
\end{align*}
\]

, analogs thereof, and derivatives thereof, where M is N or P, each R is individually a C\text{1} to C\text{10} alkyl, and each R\text{2} is individually a C\text{2} to C\text{10} alkyne.

61. The electrophoretic medium of claim 39, wherein the particle is a blue colored cationic microparticle having the structure:

\[
\begin{align*}
\text{R} & \quad \text{R}_2 \\
& \quad \text{R}_1 \\
\end{align*}
\]

, where M is N or P, each R is individually a C\text{1} to C\text{10} alkyl, each R\text{1} is individually a C\text{1} to C\text{10} alkyne, and each R\text{2} is individually a C\text{2} to C\text{10} alkyne.

62. The electrophoretic medium of claim 57, wherein the chromophore comprises a component derived from a diamine moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety.

63. The electrophoretic medium of claim 62, wherein the diamine moiety comprises at least one of:
analogs thereof, and derivatives thereof, where each $R_i$ is individually a $C_i$ to $C_{10}$ alkylene.

64. The electrophoretic medium of claim 62, wherein at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:

$$\text{Y} \quad \text{R}_1 \quad \text{M} \quad \text{R}_2 \quad \text{O} \quad \text{Y}$$

, analogs thereof, and derivatives thereof, where $M$ is N or P, each $R$ is individually a $C_i$ to $C_{10}$ alkyl, and each $R_2$ is individually a $C_2$ to $C_{10}$ alkylene, and each $Y$ is one of -OH or -O-succinimide.

65. The electrophoretic medium of claim 39, wherein the particle is a blue colored cationic microparticle having the structure:

$$\text{H} \quad \text{N} \quad \text{R}_1 \quad \text{N} \quad \text{R}_1 \quad \text{NH}_2$$

, where $M$ is N or P, each $R$ is individually a $C_i$ to $C_{10}$ alkyl, each $R_1$ is individually a $C_i$ to $C_{10}$ alkylene, and each $R_2$ is individually a $C_2$ to $C_{10}$ alkylene.

66. The electrophoretic medium of claim 39, wherein the transparent fluid comprises at least one of: linear or branched hydrocarbon oil, halogenated hydrocarbon oil,
silicone oil, water, decane epoxide, dodecane epoxide, cyclohexyl vinyl ether, naphthalene, tetrafluorodibromoethylene, tetrachloroethylene, trifluorochloroethylene, 1,2,4-trichlorobenzene, carbon tetrachloride, decane, dodecane, tetradecane, xylene, toluene, hexane, cyclohexane, benzene, an aliphatic hydrocarbon, naphtha, octamethyl cyclosiloxane, cyclic siloxanes, poly(methyl phenyl siloxane), hexamethyldisiloxane, polydimethylsiloxane, and poly(chlorotrifluoroethylene) polymer.

67. A charged pigment particle comprising an alternating copolymer of a chromophore and a charged linker molecule.

68. The charged pigment particle of claim 67, wherein the charged linker molecule comprises cations selected from the group consisting of quaternary ammonium, quaternary phosphonium, quaternary arsonium, quaternary stibonium, and ternary sulfonium cations.

69. The charged pigment particle of claim 67, wherein the particle consists essentially of an alternating copolymer of the chromophore and the charged linker molecule.

70. The charged pigment particle of claim 67, wherein the particle is a copolyamide, and one of the chromophore and the charged linker molecule comprises a component derived from a diamine moiety, and the other of the chromophore and the charged linker molecule comprises a component derived from a dicarbonyl moiety.

71. The charged pigment particle of claim 70, wherein the dicarbonyl moiety is one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, a dialdehyde, a diketone or a combination thereof.

72. The charged pigment particle of claim 67, wherein the particle is a microparticle.
73. The charged pigment particle of claim 67, wherein the chromophore is red colored.

74. The charged pigment particle of claim 73, wherein the chromophore comprises a component derived from a dianhydride moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

75. The charged pigment particle of claim 74, wherein the dianhydride moiety comprises at least one of:

![Dianhydride Moiety](image)

, analogs thereof, and derivatives thereof.

76. The charged pigment particle of claim 74, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

![Quaternary Diamine Moiety](image)

, analogs thereof, and derivatives thereof,

wherein M is N or P, each R is individually a C\textsubscript{i} to C\textsubscript{o} alkyl, and each X is individually a C\textsubscript{2} to C\textsubscript{o}alkylene.

77. The charged pigment particle of claim 74, further comprising at least one of:

a component derived from an additional dianhydride moiety different from the dianhydride moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from the dianhydride moiety, and
a component derived from an additional diamine moiety different from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety,

to alter at least one of physicochemical properties and optical properties of the particle.

78. The charged pigment particle of claim 77, wherein the dianhydride moiety comprises , the additional dianhydride moiety comprises pyromellitic dianhydride, at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises , where each X is individually a C2 to C10 alkylene, and the additional diamine moiety comprises a simple diamine.

79. The charged pigment particle of claim 67, wherein the particle is a red colored cationic microparticle having the structure:

, where M is N or P, each R is individually a C1 to C10 alkyl, and each X is individually a C2 to C10 alkylene.

80. The charged pigment particle of claim 67, wherein the particle is a red colored cationic microparticle having the structure:
where each $X_i$ is individually a $C_2 \text{to} C_{10}$alkylene.

81. The charged pigment particle of claim 67, wherein the chromophore is blue colored.

82. The charged pigment particle of claim 81, wherein the chromophore comprises a component derived from a dicarbonyl moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

83. The charged pigment particle of claim 82, wherein the dicarbonyl moiety comprises at least one of:

84. The charged pigment particle of claim 82, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:
analogs thereof, and derivatives thereof, where \( M \) is \( N \) or \( P \), each \( R_i \) is individually a \( C_i \) to \( C_{10} \) alkyl, and each \( R_2 \) is individually a \( C_2 \) to \( C_{10} \)alkylene.

85. The charged pigment particle of claim 82, further comprising at least one of:

- a component derived from an additional dicarbonyl moiety different from the dicarbonyl moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from the dicarbonyl moiety, and

- an additional diamine moiety different from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety,

  to alter at least one of physicochemical properties and optical properties of the particle.

86. The charged pigment particle of claim 85, wherein the dicarbonyl moiety comprises \( \end{align*} \)

where \( \text{X} \) is one of \(-\text{OH}\) or \(-\text{O-succinimide}\), the additional dicarbonyl moiety comprises an \( \text{N-hydroxysuccinimide ester of a simple acid}\), at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium
diamine moiety comprises , and the additional diamine moiety comprises a simple diamine.

87. The charged pigment particle of claim 86, wherein the simple acid is adipic acid and the simple diamine is 1,6-diaminohexane.

88. The charged pigment particle of claim 67, wherein the particle is a blue colored cationic microparticle having the structure:

89. The charged pigment particle of claim 67, wherein the particle is a blue colored cationic microparticle having the structure:

90. The charged pigment particle of claim 81, wherein the chromophore comprises a component derived from a diamine moiety and the charged linker molecule
comprises a component derived from at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety.

91. The charged pigment particle of claim 90, wherein the diamine moiety comprises at least one of:

```
\[
\begin{array}{c}
\text{H}_2\text{N} \quad \text{R}_1 \quad \text{NH} \quad \text{N} \quad \text{R}_1 \quad \text{NH}_2 \\
\end{array}
\]
```

, analogs thereof, and derivatives thereof, where each \( R_1 \) is individually a C1 to C10 alkylene.

92. The charged pigment particle of claim 90, wherein at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:

```
\[
\begin{array}{c}
\text{Y} \quad \text{R}_2 \quad \text{M}^+ \quad \text{R}_2 \quad \text{Y} \\
\end{array}
\]
```

, analogs thereof, and derivatives thereof, where \( M \) is N or P, each \( R \) is individually a C1 to C10 alkyl, each \( R_2 \) is individually a C2 to C10 alkylene, and each \( Y \) is one of -OH or -O-succinimide.

93. The charged pigment particle of claim 90, further comprising at least one of:

a component derived from an additional diamine moiety different from the diamine moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from the diamine moiety, and
a component derived from an additional dicarbonyl moiety different from at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety, to alter at least one of physicochemical properties and optical properties of the particle.

94. The charged pigment particle of claim 93, wherein the diamine moiety comprises

\[
\text{[Chemical Structure]}
\]

, the additional diamine moiety comprises a simple diamine, at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises \( \text{[Chemical Structure]} \), wherein each \( Y \) is one of -OH or -O-succinimide, and the additional dicarbonyl moiety comprises an N-hydroxsuccinimide ester of a simple acid.

95. The charged pigment particle of claim 94, wherein the simple acid is adipic acid and the simple diamine is 1,6-diaminohexane.

96. The charged pigment particle of claim 67, wherein the particle is a blue colored cationic microparticle having the structure:
where \( M \) is \( N \) or \( P \), each \( R \) is individually a \( C_1 \) to \( C_{10} \) alkyl, each \( R_1 \) is individually a \( C_1 \) to \( C_{10} \) alkylen,
and each \( R_2 \) is individually a \( C_2 \) to \( C_{10} \) alkylen.

97. The charged pigment particle of claim 67, wherein the particle is a blue colored cationic microparticle having the structure:

98. The charged pigment particle of claim 67, wherein the chromophore is yellow colored.

99. The charged pigment particle of claim 98, wherein the chromophore comprises a component derived from a dicarbonyl moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

100. The charged pigment particle of claim 99, wherein the dicarbonyl moiety comprises at least one of:
analogs thereof, and derivatives thereof, and $R_1$ and $R_2$ are one of $-H$ and $-\text{succinimide}$, and $X$ and $Q$ are individually a C$_i$ to C$_{io}$ alkylene.

101. The charged pigment particle of claim 99, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

$$
\begin{align*}
R & = H, N-\text{fl}-A-\text{NH}_2 \\
H, N-\text{fl} & \rightarrow A-\text{NH}_2 \\
R
\end{align*}
$$

, analogs thereof, and derivatives thereof, and $M$ is N or P, each $R$ is individually a C$_i$ to C$_{io}$ alkyl, and each $A$ is individually a C$_i$ to C$_{io}$ alkylene.

102. The charged pigment particle of claim 99, further comprising at least one of:

a component derived from an additional dicarboxyl moiety different from the dicarboxyl moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from the dicarboxyl moiety, and

a component derived from an additional diamine moiety different from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety,

to alter at least one of physicochemical properties and optical properties of the particle.
103. The charged pigment particle of claim 102, wherein the dicarbonyl moiety comprises
where $R_1$ and $R_2$ are one of -H and -succinimide, and $X$ and $Q$ are individually a C$i$ to C$_{10}$ alkylene, the additional dicarbonyl moiety comprises an N-hydroxysuccinimide ester of a simple acid, at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises

$$H_2N{-}A{-}N{-}A{-}NH_2$$

wherein each A is individually a C$_1$ to C$_{10}$ alkylene, and the additional diamine moiety comprises a simple diamine.

104. The charged pigment particle of claim 103, wherein the simple acid is adipic acid and the simple diamine is 1,6-diaminohexane.

105. The charged pigment particle of claim 67, wherein the particle is a yellow colored cationic microparticle having the structure

$$\text{structure}$$

, where $M$ is N or P, each $R$ is individually a C$i$ to C$_{10}$ alkyl, and each $A$, $X$ and $Q$ are individually a C$i$ to C$_{10}$ alkylene.

106. The charged pigment particle of claim 67, wherein the particle is a yellow colored cationic microparticle having the structure
107. The charged pigment particle of claim 98, wherein the chromophore comprises a component derived from a yellow colored diamine moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety.

108. The charged pigment particle of claim 107, wherein the diamine moiety comprises at least one of:

109. The charged pigment particle of claim 107, wherein at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:

110. The charged pigment particle of claim 107, further comprising at least one of:
a component derived from an additional dicarbonyl moiety different from the
dicarbonyl moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from the dicarbonyl moiety, and

a component derived from an additional diamine moiety different from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety and polymerized into the polymer as a substitute for at least a portion of the component derived from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety,
to alter at least one of physicochemical properties and optical properties of the particle.

111. The charged pigment particle of claim 110, wherein the diamine moiety

\[
\begin{array}{c}
R_3 - N^+ - X - N - H - N^+ - Q - N^+ - R_4 \\
\end{array}
\]

comprises , where \( R_3 \) and \( R_4 \) are -H, and X and Q are individually a C\(_1\) to C\(_{10}\) alkylene, the additional diamine moiety comprises a simple diamine, at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium

dicarbonyl moiety comprises

\[
\begin{array}{c}
\end{array}
\]

, wherein each \( A \) is individually a C\(_1\) to C\(_{10}\) alkylene, and the additional dicarbonyl moiety comprises an N-hydroxysuccinimide ester of a simple acid.

112. The charged pigment particle of claim 111, wherein the simple acid is adipic acid and the simple diamine is 1,6-diaminohexane.
113. The charged pigment particle of claim 67, wherein the particle is a yellow colored cationic microparticle having the structure:

\[ \text{structure image} \]

where \( M \) is N or P, each \( R \) is individually a Ci to Cio alkyl, and each A, X and Q are individually a Ci to Cio alkenylene.

114. The charged pigment particle of claim 67, wherein the particle is a yellow colored cationic microparticle having the structure:

\[ \text{structure image} \]

where each A, X and Q are individually a Ci to Cio alkenylene.

115. A method for producing charged pigment particles, the method comprising copolymerizing chromophores with charged linker molecules to form charged and colored microparticles.

116. The method of claim 115, wherein the charged linker molecules comprise at least one of a quaternary ammonium constituent and a quaternary phosphonium constituent, and the method comprises copolymerizing chromophores and charged linker molecules to form a copolymer of alternating chromophores and components comprising at least one of the quaternary ammonium constituent and the quaternary phosphonium constituent.

117. The method of claim 115, wherein one of: the chromophores and the charged linker molecules comprise a component derived from a diamine moiety, and the other of: the
chromophores and the charged linker molecules comprise a component derived from a dicarbonyl moiety, and the copolymerizing comprises a polycondensation of the diamine moiety with the dicarbonyl moiety to form one of copolyamides or copolyimides.

118. The method of claim 115, wherein the chromophore comprises a component derived from a dianhydride moiety, the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety, and the copolymerizing comprises a condensation of the dianhydride moiety and at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety to form red colored cationic microparticles.

119. The method of claim 118, wherein the dianhydride moiety comprises at least one of:

\[
\begin{align*}
\text{, analogs thereof, and derivatives thereof.}
\end{align*}
\]

120. The method of claim 118, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

\[
\begin{align*}
\text{, analogs thereof, and derivatives thereof,}
\end{align*}
\]

where \( M \) is N or P, each \( R \) is individually a C\(_i\) to C\(_o\) alkyl, and each \( X \) is individually a C\(_2\) to C\(_o\) alkylene.

121. The method of claim 118, further comprising substituting at least one of:

an additional dianhydride moiety different from the dianhydride moiety for at least a portion of the dianhydride moiety, and
an additional diamine moiety different from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety for at least a portion of at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety,

to alter at least one of physicochemical properties and optical properties of the particle.

122. The method of claim 121, wherein the dianhydride moiety comprises

\[
\begin{align*}
\text{H}_2\text{N} & - \text{O} - \text{X}_i \text{N} & - \text{O} - \text{C}_2 \text{H}_4 \text{O} - \text{N} & - \text{NH}_2 \\
\text{CH}_3 & & \\
\end{align*}
\]

, the additional dianhydride moiety comprises pyromellitic dianhydride,
at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine

moiety comprises

\[
\begin{align*}
\text{H}_2\text{N} & - \text{O} - \text{X}_i \text{N} & - \text{O} - \text{C}_2 \text{H}_4 \text{O} - \text{N} & - \text{NH}_2 \\
\text{CH}_3 & & \\
\end{align*}
\]

, where each \(X\) is individually a \(C_2\) to \(C_{10}\) alkylene, and the additional diamine moiety comprises a simple diamine.

123. The method of claim 115, wherein the chromophores comprise components

\[
\begin{align*}
\text{H}_2\text{N} & - \text{O} - \text{X}_i \text{M} & - \text{O} - \text{R} \\
\text{R} & & \\
\end{align*}
\]

derived from dianhydrides of the structure , the charged linker molecules comprise components derived from diamines of the structure

\[
\begin{align*}
\text{H}_2\text{N} & - \text{O} - \text{X}_i \text{M} & - \text{O} - \text{R} \\
\text{R} & & \\
\end{align*}
\]

, where \(M\) is \(N\) or \(P\), each \(R\) is individually a \(C_1\) to \(C_{10}\) alkyl, and each \(X\) is individually a \(C_2\) to \(C_{10}\) alkylene, and the copolymerizing comprises a polycondensation of the dianhydrides and the diamines to produce red colored cationic
microparticles of the structure

where

M is N or P, each R is individually a C\textsubscript{i} to C\textsubscript{io} alkyl, and each X is individually a C\textsubscript{2} to C\textsubscript{10} alkyne.

124. The method of claim 115, wherein the chromophores comprise components derived from dianhydrides of the structure , the charged linker molecules comprise components derived from diamines of the structure , where each X is individually a C\textsubscript{2} to C\textsubscript{io} alkyne, and the copolymerizing comprises a polycondensation of the dianhydrides and diamines to produce red colored cationic microparticles of the structure

, where each X is individually a C\textsubscript{2} to C\textsubscript{io} alkyne.

125. The method of claim 124, further comprising forming the diamines by a method comprising the steps of:

methyllating a dinitro aryl amine compound having the structure

, wherein each X is individually a C\textsubscript{2} to C\textsubscript{io} alkyne, to produce a quaternary ammonium salt; and

reducing the nitro groups to amine groups to form the diamines.

126. The method of claim 125, wherein:
the methylating comprises treatment with methyl iodide in acetonitrile;
the reducing comprises treatment with hydrogen gas and palladium on carbon in the presence of methanol; and
the polycondensation comprises heating a mixtures of the dianhydrides and the diamines in a solvent for a period of time and a temperature sufficient for polymerization.

127. The method of claim 126, wherein:

the solvent comprises at least one of: butanol, quinolone, toluene, xylene, or propionic acid;
the temperature is about 150 °C to about 200 °C; and
the period of time is about 1 to about 2 days.

128. The method of claim 115, wherein the chromophore comprises a component derived from a dicarbonyl moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety, and the copolymerizing comprises a condensation of the dicarbonyl moiety and at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety to form blue colored cationic microparticles.

129. The method of claim 128, wherein the dicarbonyl moiety comprises at least one of:
130. The method of claim 128, wherein at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

\[
\begin{align*}
\text{H}_2\text{N} & \quad \text{R}_2^- \\
& \quad \text{M}^+ - \text{NR}_2^- \quad \text{NH}_2
\end{align*}
\]

, analogs thereof, and derivatives thereof, where each \( R_1 \) is individually \( \text{C}_i \) to \( \text{C}_{10} \) alkylene and each \( X \) is one of -OH or -O-succinimide.

131. The method of claim 128, further comprising substituting at least one of:

- an additional dicarbonyl moiety different from the dicarbonyl moiety for at least a portion of the dicarbonyl moiety, and
- an additional diamine moiety different from at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety for at least a portion of at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety,

to alter at least one of physicochemical properties and optical properties of the particle.
132. The method of claim 131, wherein the dicarbonyl moiety comprises

where each X is one of -OH or -O-succinimide, the additional dicarbonyl moiety comprises an N-hydroxysuccinimide ester of a simple acid, at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises, and the additional diamine moiety comprises a simple diamine.

133. The method of claim 132, wherein the simple acid is adipic acid and the simple diamine is 1,6-diaminohexane.

134. The method of claim 115, wherein the chromophore comprises components

derived from dicarboxyls of the structure , where each R₁ is individually a Cᵢ to Cᵦ alkylene and each X is one of -OH or -O-succinimide, the charged linker molecules comprise components derived from diamines of the structure

H₂N—R₁—and

, where M is N or P, each R is individually a Cᵢ to Cᵦ alkyl, and each R₂ is individually a C₂ to Cᵦ alkylene, and the copolymerizing comprises a
polycondensation of the dicarbonyls and the diamines to produce blue colored cationic microparticles of the structure

\[
\begin{align*}
\text{M}_i & \text{N}_r, \quad \text{each } R_i \text{ is individually a } C_1 \text{ to } C_{10} \text{ alkyl, each } R_j \text{ is individually a } C_1 \text{ to } C_{10} \text{ alkyene, and each } R_2 \text{ is individually a } C_2 \text{ to } C_{10} \text{ alkyene.}
\end{align*}
\]

135. The method of claim 115, wherein the chromophore comprises components derived from dicarbonyls of the structure, where each \( X \) is one of -OH or -O-succinimide, the charged linker molecules comprise components derived from diamines of the structure, and the copolymerizing comprises a polycondensation of the dicarbonyls and the diamines to produce blue colored cationic microparticles of the structure.
136. The method of claim 135, further comprising converting the dicarbonyls of structure wherein each $X_i$ is -OH, to diesters wherein each $X$ is O-succinimide, by treatment of the dicarbonyls with a carbodiimide and a carboxylic acid in a dry inert solvent, filtering urea byproduct from a filtrate, adding a dry non-polar solvent to the filtrate to precipitate the diester, and filtration of the diester from the solvent.

137. The method of claim 136, wherein:

- the carbodiimide is dicyclohexylcarbodiimide;
- the dry inert solvent is dioxane; and
- the dry non-polar solvent is at least one of toluene or heptane.

138. The method of claim 135, wherein the copolymerizing comprises:

- mixing the diester with the diamine in a dry polar aprotic solvent;
- stirring for a period of time sufficient for copolymerization to occur;
- treating with cold water to precipitate blue colored polycationic anthraquinone polymer; and
- filtering the precipitate from solution.

139. The method of claim 138, wherein:

- the dry polar aprotic solvent comprises at least one of dimethyl sulfoxide or N-methylpyrrolidinone; and
- the stirring comprises stirring for about 24 hours at a temperature between about 20 °C to about 60 °C.
140. The method of claim 115, wherein the chromophore comprises a component derived from a diamine moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety, and the copolymerization comprises a condensation of the diamine moiety and at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety to form blue colored cationic microparticles.

141. The method of claim 140, wherein the diamine moiety comprises at least one of:

\[
\begin{align*}
\text{H}_2\text{N} & \text{--R}1 \text{--N} \text{--R}1 \text{--NH}_2 \\
\text{O} & \text{=\ =\ =O}
\end{align*}
\]

, analogs thereof, and derivatives thereof, where each \( R_1 \) is individually a \( \text{C}_1 \) to \( \text{C}_{10} \) alkylene.

142. The method of claim 140, wherein at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:

\[
\begin{align*}
\text{R} & \text{--M}^{+} \text{--R}2 \text{--Y} \\
\text{O} & \text{=\ =\ =O}
\end{align*}
\]

, analogs thereof, and derivatives thereof, where \( M \) is \( \text{N} \) or \( \text{P} \), each \( R \) is individually a \( \text{C}_1 \) to \( \text{C}_{10} \) alkyl, and each \( R_2 \) is individually a \( \text{C}_2 \) to \( \text{C}_{10} \) alkylene, and each \( Y \) is one of \( \text{-OH} \) or \( \text{-O-succinimide} \).
143. The method of claim 140, further comprising substituting at least one of:

an additional diamine moiety different from the diamine moiety for at least a portion of the diamine moiety, and

an additional dicarbonyl moiety different from at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety for at least a portion of at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety,

to alter at least one of: physicochemical properties and optical properties of the particle.

144. The method of claim 143, wherein the diamine moiety comprises

![Chemical Structure]

the additional diamine moiety comprises a simple diamine, at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises

![Chemical Structure]

wherein each Y is one of -OH or -O-succinimide, and the additional dicarbonyl moiety comprises an N-hydroxysuccinimide ester of a simple acid.

145. The method of claim 144, wherein the simple acid is adipic acid and the simple diamine is 1,6-diaminohexane.
146. The method of claim 115, wherein the chromophores comprise components
derived from diamines of the structure , where each $R_1$ is $C_i$ to $C_{10}$ alkylene, the charged linker molecules comprise components derived from
dicarboxyls of the structure , where $M$ is $N$ or $P$, each $R$ is
individually a $C_i$ to $C_{10}$ alkyl, and each $R_2$ is individually a $C_2$ to $C_{10}$ alkylene, and each $Y$ is
one of -OH or -O-succinimide, and the copolymerizing comprises a polycondensation of the
diamines and the dicarboxyls to produce blue colored cationic microparticles of the structure
, where $M$ is $N$ or $P$, each $R$ is
individually a $C_i$ to $C_{10}$ alkyl, each $R_1$ is individually a $C_i$ to $C_{10}$ alkylene, and each $R_2$ is
individually a $C_2$ to $C_{10}$ alkylene.

147. The method of claim 115, wherein the chromophores comprise components
derived from diamines of the structure , the charged linker
molecules comprise components derived from dicarboxyls of the structure
, wherein each $Y_i$ is one of -OH or -O-succinimide, and the copolymerizing comprises a polycondensation to produce blue colored cationic microparticles of the structure

148. The method of claim 147, further comprising converting the dicarbonyls of structure

, wherein each $Y$ is -OH, to diesters having each $Y$ as O-succinimide, by treatment with a carbodiimide and a carboxylic acid in a dry inert solvent, filtering urea byproduct from a filtrate, adding a dry non-polar solvent to the filtrate to precipitate the diester, and filtration of the diester from the solvent.

149. The method of claim 148, wherein:

- the carbodiimide is dicyclohexylcarbodiimide;
- the dry inert solvent is dioxane; and
- the dry non-polar solvent is at least one of toluene or heptane.

150. The method of claim 147, wherein the copolymerizing comprises:

- mixing the diester with the diamine in a dry polar aprotic solvent;
- stirring for a period of time sufficient for copolymerization to occur;
- treating with cold water to precipitate blue colored polycationic anthraquinone polymer; and
- filtering the precipitate from solution.
151. The method of claim 150, wherein:

the dry polar aprotic solvent comprises at least one of dimethyl sulfoxide or N-methylpyrrolidinone; and

the stirring comprises stirring for about 24 hours at a temperature between about 20 °C to about 60 °C.

152. The method of claim 115, wherein the chromophore comprises a component derived from a diamine moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety, and the copolymerization comprises a condensation of the diamine moiety and at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety to form yellow colored cationic microparticles.

153. The method of claim 152, wherein the diamine moiety comprises at least one of:

\[ \text{structure image} \]

, analogs thereof, and derivatives thereof, and \( R_3 \) and \( R_4 \) are -H, and X and Q are individually a C1 to C10 alkylene.

154. The method of claim 152, wherein at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:
M is N or P, each R is individually a C_i to C_{io} alkyl and each A is individually a C_i to C_{io} alkylene.

155. The method of claim 152, further comprising substituting at least one of:

- an additional diamine moiety different from the diamine moiety for at least a portion of the diamine moiety, and
- an additional dicarbonyl moiety different from at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety for at least a portion of at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety,

   to alter at least one of: physicochemical properties and optical properties of the particle.

156. The method of claim 155, wherein the dicarbonyl moiety comprises

\[
\text{where } R_1 \text{ and } R_2 \text{ are one of } -H \text{ and } -\text{succinimide,}
\]

and X and Q are individually a C_i to C_{io} alkylene, the additional dicarbonyl moiety comprises an N-hydroxysuccinimide ester of a simple acid, at least one of the quaternary ammonium diamine
moiety and the quaternary phosphonium diamine moiety comprises wherein each A is individually a C\textsubscript{i} to C\textsubscript{10} alkyene, and the additional diamine moiety comprises a simple diamine.

157. The method of claim 156, wherein the simple acid is adipic acid and the simple diamine is 1,6-diaminohexane.

158. The method of claim 115, wherein the chromophores comprise components derived from diamines of the structure

\[
\begin{align*}
R_3 & = N - X - \text{ } & N - A - N - A - NH_2 \\
\text{NO}_2 & & \text{H} \\
\text{HO} & & \text{CH}_3 \\
\end{align*}
\]

wherein R\textsubscript{3} and R\textsubscript{4} are -H, and X and Q are individually a C\textsubscript{i} to C\textsubscript{10} alkyene, the charged linker molecules comprise components derived from dicarboxyls of the structure

\[
\begin{align*}
\text{O} & \text{O} & \text{A} & \text{M} & \text{A} & \text{O} & \text{O} \\
\text{O} & & \text{A} & & \text{M} & & \text{A} \\
\end{align*}
\]

wherein M is N or P, each R is individually a C\textsubscript{i} to C\textsubscript{10} alkyl, and each A is individually a C\textsubscript{i} to C\textsubscript{10} alkyene, and the copolymerizing comprises a polycondensation of the diamines and dicarboxyls to produce yellow colored cationic microparticles of the structure

\[
\begin{align*}
\text{NO}_2 & \text{O} & \text{N} & \text{O} & \text{N} & \text{A} & \text{M} & \text{A} - \text{A} - \text{A} - \ldots - \text{CH}_3 \\
\text{HO} & & \text{N} & & \text{O} & & \text{A} & & \text{M} & & \text{A} - \text{A} - \text{A} - \ldots - \text{OH} \\
\end{align*}
\]

wherein M is N or P, each R is individually a C\textsubscript{i} to C\textsubscript{10} alkyl, and each A, X and Q are individually a C\textsubscript{i} to C\textsubscript{10} alkyene.

159. The method of claim 115, wherein the chromophores comprise components
derived from diamines of the structure \[ R_3 - \text{N} - \text{X} - \text{N} - R_4 \]
and \( R_4 \) are \(-H\), and \( X \) and \( Q \) are individually a \( \text{Ci to Cio} \) alkylene, the charged linker molecules comprise components derived from dicarboxyls of the structure

\[
\text{N} - \text{O} - \text{A} - \text{N} - \text{A} - \text{O} - \text{N} - \text{O}
\]
wherein each \( A \) is individually a \( \text{Ci to Cio} \) alkylene, and the copolymerizing comprises a polycondensation of the diamines and dicarboxyls to produce yellow colored cationic microparticles of the structure

\[
\text{N} - \text{O} - \text{A} - \text{N} - \text{A} - \text{O} - \text{N} - \text{O}
\]
where each \( A, X \) and \( Q \) are individually a \( \text{Ci to Cio} \) alkylene.

160. The method of claim 159, wherein the copolymerizing comprises:

- mixing the dicarboxyls with the diamines in a dry polar aprotic solvent;
- stirring for a period of time sufficient for copolymerization to occur;
- treating with cold water to precipitate blue colored polycationic anthraquinone polymer; and
- filtering the precipitate from solution.

161. The method of claim 160, wherein:

- the dry polar aprotic solvent comprises at least one of dimethyl sulfoxide or \( N \)-methylpyrrolidinone; and
- the stirring comprises stirring for about 24 hours at a temperature between about 20 °C to about 60 °C.
162. The method of claim 161, further comprising producing the diamines by a method comprising the steps of:

mono-protecting the methylamino nitrogen of 4-(2-aminoethyl)aniline with tert-butyloxy carbonyl, and treating the mono-butyloxy carbonyl-protected aniline with diketene to produce tert-butyloxy carbonyl-protected acetoacetamide

\[ \text{Structural formula} \]

fluorenylethoxycarbonyl protecting 4-(2-aminoethyl)-2-nitroaniline to produce a compound of structure

\[ \text{Structural formula} \]

and subsequently treating the protected amino nitro aniline with aqueous nitrous acid to yield a diazonium compound

\[ \text{Structural formula} \]

treating a cold mixture of the acetoacetamide with the diazonium compound;

maintaining the mixture at about pH 5 by drop wise addition of about 40% sodium hydroxide for about 3 to about 4 hours;

filtering, washing and drying the filtrate; and

treating the filtrate with trifluoroacetic acid to remove the tert-butyloxy carbonyl protective groups.

163. The method of claim 115, wherein the chromophores comprise a component derived from a dicarbonyl moiety and the charged linker molecule comprises a component derived from at least one of a quaternary ammonium diamine moiety and a quaternary
phosphonium diamine moiety, and the copolymerization comprises a condensation of the
dicarbonyl moiety and at least one of the quaternary ammonium diamine moiety and the
quaternary phosphonium diamine moiety to form yellow colored cationic microparticles.

164. The method of claim 163, wherein the dicarbonyl moiety comprises at least one of:

\[ \text{HOC} = \text{C} = \text{X}, \text{alanogs thereof, and derivatives thereof, and } \frac{3}{4} \text{ and } R_2 \text{ are one of } \text{H and } \text{-succinimide, and } X \text{ and } Q \text{ are individually a C}_i \text{ to } C_{10} \text{ alkylene.} \]

165. The method of claim 163, wherein at least one of the quaternary ammonium
diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of

\[ \text{R} \]
\[ \text{H}_2\text{N} \cdot \text{A} \cdot \text{M} \cdot \text{A} \cdot \text{NH}_2 \]

, analogs thereof, and derivatives thereof, where \( M \) is N or P, each \( R \) is individually a C\(_i\) to C\(_{10}\) alkyl, and each A is individually a C\(_i\) to C\(_{10}\) alkylene.

166. The method of claim 163, further comprising substituting at least one of:

an additional diamine moiety different from the diamine moiety for at least a portion of the diamine moiety, and

an additional dicarbonyl moiety different from at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety for at least a portion of at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety,
to alter at least one of physicochemical properties and optical properties of the particle.

167. The method of claim 166, the diamine moiety comprises

\[
\begin{align*}
R_3 &- N \cdot X \cdot \text{H}_2O \cdot CH_3 \cdot Q \cdot N \cdot R_4 \\
\end{align*}
\]

, where \( R_3 \) and \( R_4 \) are -H, and \( X \) and \( Q \) are individually a \( C_i \) to \( C_{10} \) alkylene, the additional diamine moiety comprises a simple diamine, at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises

\[
\text{\begin{smallmatrix}
\text{O} & - \text{A} \cdot \text{N} & \text{H}_2 \cdot \text{O} & - \text{A} \cdot \text{O} & - \text{N} \\
\text{CH}_3 & & & & \\
\end{smallmatrix}}
\]

, wherein each \( A \) is individually a \( C_i \) to \( C_{10} \) alkylene, and the additional dicarbonyl moiety comprises an N-hydroxysuccinimide ester of a simple acid.

168. The method of claim 167, wherein the simple acid is adipic acid and the simple diamine is 1,6-diaminohexane.

169. The method of claim 115, wherein the chromophores comprise components

\[
\begin{align*}
R_1, \text{OCC} &- X \cdot \text{H}_2O \cdot CH_3 \cdot Q \cdot \text{O} - \text{COOR}_2 \\
\end{align*}
\]

derived from dicarboxyls of the structure

\[
\begin{align*}
\text{\begin{smallmatrix}
\text{N} & - \text{A} & \text{N} & - \text{H}_2O & - \text{A} & \text{N} & - \text{H}_2 \\
\text{CH}_3 & & & & & & \\
\end{smallmatrix}}
\]

, wherein \( R_1 \) and \( R_2 \) are one of -H and -succinimide, and \( X \) and \( Q \) are individually a \( C_i \) to \( C_{10} \) alkylene, the charged linker molecules comprise components derived from diaminates of the structure

\[
\begin{align*}
\text{\begin{smallmatrix}
\text{R} & - \text{N} & - \text{M} & - \text{N} & - \text{R} \\
\end{smallmatrix}}
\]

, wherein \( M \) is N or P, each \( R \) is individually a \( C_i \) to \( C_{10} \) alkyl, and each \( A \) is individually a \( C_i \) to \( C_{10} \) alkylene, and the copolymerizing comprises a polycondensation

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of the diamine and the dicarboxyl to produce yellow colored cationic microparticles of the

\[
\text{H} - \text{N} - \text{A} - \text{M} - \text{A} - \text{N} - \text{X} - \text{O} - \text{N} - \text{H} - \text{O} - \text{OH}
\]

structure, where \( M \) is \( N \) or \( P \), each \( R \) is individually a \( C_i \) to \( C_{io} \) alkyl, and each \( A, X \) and \( Q \) are individually a \( C_i \) to \( C_{io} \) alkylenes.

170. The method of claim 115, wherein the chromophores comprise components derived from dicarboxyls of the structure

\[
\text{R}_1,\text{OOC} - \text{X} - \text{N} - \text{N} - \text{N} - \text{C} - \text{O} - \text{COOR}_2
\]

, wherein \( R_1 \) and \( R_2 \) are one of -H and -succinimide, and \( X \) and \( Q \) are individually a \( C_i \) to \( C_{io} \) alkylenes, the charged linker molecules comprise components derived from diamines of the structure

\[
\text{H}_2\text{N} - \text{A} - \text{N} - \text{A} - \text{NH}_2
\]

, wherein each \( A \) is individually a \( C_i \) to \( C_{io} \) alkylenes, and the copolymerizing comprises a polycondensation of the diamine and the dicarboxyl to produce yellow colored cationic microparticles of the structure

\[
\text{H} - \text{N} - \text{A} - \text{N} - \text{A} - \text{N} - \text{X} - \text{O} - \text{N} - \text{H} - \text{O} - \text{OH}
\]

, where each \( A, X \) and \( Q \) are individually a \( C_i \) to \( C_{io} \) alkylenes.

171. The method of claim 170, further comprising converting the dicarboxyls of the structure

\[
\text{R}_1,\text{OOC} - \text{X} - \text{N} - \text{N} - \text{N} - \text{C} - \text{O} - \text{COOR}_2
\]

, wherein \( R_1 \) and \( R_2 \) are -H, to diesters having the \( R_1 \) and \( R_2 \) as -succinimide, by treatment with a carbodiimide and \( N \)-hydroxysuccinimide in a dry inert solvent, filtering urea byproduct from a filtrate, adding a
dry non-polar solvent to the filtrate to precipitate the diester, and filtration of the diester from the solvent.

172. The method of claim 171, wherein:

the carbodiimide is dicyclohexylcarbodiimide;
the dry inert solvent is dioxane; and
the dry non-polar solvent is at least one of toluene or heptane.

173. The method of claim 170, wherein the copolymerizing comprises:

mixing the diester with the diamine in a dry polar aprotic solvent;
stirring for a period of time sufficient for copolymerization to occur;
treating with water to precipitate yellow colored polycationic azo-arylide polymer; and
filtering the precipitate from solution.

174. The method of claim 173, wherein:

the dry polar aprotic solvent comprises at least one of dimethyl sulfoxide or N-methylpyrrolidinone; and
the stirring comprises stirring for about 24 hours at a temperature between about 20 °C to about 60 °C.

175. The method of claim 170, further comprising producing the dicarbonyls by a method comprising:
treating amino-nitro-phenyl carboxylic acid with aqueous nitrous acid to yield a diazonium compound, wherein X is Ci to Cio alkylene, and Y is N₂⁺;

treating 3-(4-aminophenyl)propionic acid with diketene in water to produce an acetoacetamide, where Q is Ci to Cio alkylene;

treating an ice cold mixture of the acetoacetamide with the diazonium compound;

maintaining the mixture at about pH 5 by drop wise addition of about 40% sodium hydroxide for about 3 to about 4 hours; and

filtering, washing and drying the filtrate.

176. A kit for producing charged pigment particles, the kit comprising:

chromophores; and

charged linker molecules for being copolymerized with the chromophores to form charged pigment particles.

177. The kit of claim 176, wherein one of the chromophores and the charged linker molecules comprises a diamine moiety, and the other of the chromophores and the charged linker molecules comprises a dicarbonyl moiety.

178. The kit of claim 177, wherein the dicarbonyl moiety comprises at least one of a dicarboxylic acid, a diacyl halide, a dianhydride, a diester, a dialdehyde, a diketone or a combination thereof.
179. The kit of claim 177, wherein the charged linker molecule comprises cations selected from the group consisting of quaternary ammonium, quaternary phosphonium, quaternary arsonium, quaternary stibonium, and ternary sulfonium cations.

180. The kit of claim 176, wherein the kit comprises a kit for producing charged, red colored pigment particles, and the chromophores comprise a dianhydride moiety and the charged linker molecules comprise at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

181. The kit of claim 180, wherein:

the dianhydride moiety comprises at least one of:

\[
\text{\begin{tikzpicture}
  \draw (-0.5,0) -- (0.5,0) -- (0.5,0.5) -- (-0.5,0.5) -- cycle;
  \draw (-0.5,0) -- (0.5,-0.5) -- (0.5,0.5) -- (-0.5,-0.5) -- cycle;
  \draw (-0.5,0) -- (0.5,-0.5);
  \draw (-0.5,0.5) -- (0.5,-0.5);
  \draw (-0.5,-0.5) -- (0.5,0);
  \draw (-0.5,0.5) -- (0.5,0);
  \draw (-0.5,0) -- (0.5,0.5);
end{tikzpicture}}
\]

, analogs thereof, and derivatives thereof; and

at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

\[
\text{\begin{tikzpicture}
  \draw (-0.5,0) -- (0.5,0) -- (0.5,0.5) -- (-0.5,0.5) -- cycle;
  \draw (-0.5,0) -- (0.5,-0.5) -- (0.5,0.5) -- (-0.5,-0.5) -- cycle;
  \draw (-0.5,0) -- (0.5,-0.5);
  \draw (-0.5,0.5) -- (0.5,-0.5);
  \draw (-0.5,-0.5) -- (0.5,0);
  \draw (-0.5,0.5) -- (0.5,0);
  \draw (-0.5,0) -- (0.5,0.5);
end{tikzpicture}}
\]

, analogs thereof, and derivatives thereof,

where \( M \) is N or P, each \( R \) is individually a \( C_1 \) to \( C_{10} \) alkyl, and each \( X \) is individually a \( C_2 \) to \( C_{10} \) alkylene.

182. The kit of claim 176, wherein the kit comprises a kit for producing charged, yellow colored pigment particles, and the chromophores comprise a yellow colored dicarbonyl moiety and the charged linker molecule comprises at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

183. The kit of claim 182, wherein:
the yellow colored dicarbonyl moiety comprises at least one of:

\[
\begin{align*}
R_2\text{OCOC-X} & \quad \text{N} \quad \text{N} \quad \text{Q} \quad \text{COOR}_2 \\
\text{HO-CH}_3 &
\end{align*}
\]

, analogs thereof, and derivatives thereof, and \( R_1 \) and \( R_2 \) are one of -H and -succinimide, and \( X \) and \( Q \) are individually a \( C_i \) to \( C_{io} \) alkylene; and

the quaternary ammonium diamine moiety comprises at least one of:

\[
\begin{align*}
R & \\
K_N & \quad -A \quad -M \quad -A \quad -\text{NH}_2 \\
R &
\end{align*}
\]

, analogs thereof, and derivatives thereof, where \( M \) is \( N \) or \( P \), each \( R \) is individually a \( C_i \) to \( C_{io} \) alkyl, and each \( A \) is individually a \( C_i \) to \( C_{io} \) alkylene.

184. The kit of claim 176, wherein the kit comprises a kit for producing charged, yellow colored pigment particles, and the chromophores comprise a yellow colored diamine moiety and the charged linker molecule comprises at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety.

185. The kit of claim 184, wherein:

the yellow colored diamine moiety comprises:

\[
\begin{align*}
R \quad - \quad \text{N} \quad - \quad \text{X} \quad - \quad \text{N} \quad - \quad \text{Q} \quad - \quad \text{NH}_2 \\
\text{HO-CH}_3 &
\end{align*}
\]

, analogs thereof, and derivatives thereof, where \( R_3 \) and \( R_4 \) are -H, and \( X \) and \( Q \) are individually a \( C_i \) to \( C_{io} \) alkylene; and

at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:
186. The kit of claim 176, wherein the kit comprises a kit for producing charged, blue colored pigment particles, and the chromophores comprise a blue colored dicarbonyl moiety and the charged linker molecule comprises at least one of a quaternary ammonium diamine moiety and a quaternary phosphonium diamine moiety.

187. The kit of claim 186, wherein:

the blue colored dicarbonyl moiety comprises at least one of:

, analogs thereof, and derivatives thereof, where each \( R_1 \) is individually a C\( _i \) to C\( _{io} \) alkyl and each \( X \) is one of -OH or -O-succinimide; and

at least one of the quaternary ammonium diamine moiety and the quaternary phosphonium diamine moiety comprises at least one of:

, analogs thereof, and derivatives thereof, where
M is N or P, each R is individually a C\( _i \) to C\( _{io} \) alkyl, and each \( R_2 \) is individually a C\( _2 \) to C\( _{io} \) alkylene.
188. The kit of claim 176, wherein the kit comprises a kit for producing charged, blue colored pigment particles, and the chromophores comprise a blue colored diamine moiety and the charged linker molecule comprises at least one of a quaternary ammonium dicarbonyl moiety and a quaternary phosphonium dicarbonyl moiety.

189. The kit of claim 188, wherein:

the blue colored diamine moiety comprises at least one of:

\[
\begin{align*}
\text{H}_2\text{N} &\text{-R}_1\text{-N} \text{-H} \\
\text{N} &\text{-R}_1\text{-NH}_2
\end{align*}
\]

, analogs thereof, and derivatives thereof, where each \( \text{R}_1 \) is individually a \( \text{C}_1 \) to \( \text{C}_\text{io} \) alkylene; and

at least one of the quaternary ammonium dicarbonyl moiety and the quaternary phosphonium dicarbonyl moiety comprises at least one of:

\[
\begin{align*}
\text{Y} &\text{-R}_2\text{-M} \text{-R}_2\text{-Y} \\
\text{R}_1 &\text{-Y}
\end{align*}
\]

, analogs thereof, and derivatives thereof, where \( \text{M} \) is \( \text{N} \) or \( \text{P} \), each \( \text{R} \) is individually a \( \text{C}_1 \) to \( \text{C}_\text{io} \) alkyl, each \( \text{R}_2 \) is individually a \( \text{C}_2 \) to \( \text{C}_\text{io} \) alkyene, and each \( \text{Y} \) is one of \( \text{-OH} \) or \( \text{-O-succinimide} \).

190. The kit of claim 176, wherein the kit comprises a kit for producing charged red-colored pigment particles, charged blue-colored pigment particles, and charged yellow-colored pigment particles, and the kit comprises:
chromophores capable of producing a visual red color and first charged linker molecules for producing the charged red-colored pigment particles, wherein the chromophores and the first charged linker molecules comprise a pairing of:

at least one first dianhydride moiety and at least one of: at least one first quaternary ammonium diamine moiety and at least one first quaternary phosphonium moiety;

blue colored chromophores and second charged linker molecules for producing the charged blue-colored pigment particles, wherein the blue colored chromophores and second charged linker molecules comprise at least one of the pairings:

at least one blue colored dicarbonyl moiety and at least one of: at least one second quaternary ammonium diamine moiety and at least one second quaternary phosphonium diamine moiety, and

at least one blue colored diamine moiety and at least one of: at least one second quaternary ammonium dicarbonyl moiety and at least one second quaternary phosphonium dicarbonyl moiety; and

yellow colored chromophores and third charged linker molecules for producing the charged yellow-colored pigment particles, wherein the yellow colored chromophores and third charged linker molecules comprise at least one of the pairings:

at least one yellow colored dicarbonyl moiety and at least one of: at least one third quaternary ammonium diamine moiety and at least one third quaternary phosphonium moiety, and
at least one yellow colored diamine moiety and at least one of: at least one third quaternary ammonium dicarbonyl moiety and at least one third quaternary phosphonium dicarbonyl moiety.

191. The kit of claim 190, wherein:

the first dianhydride moiety comprises at least one of:

\[
\begin{align*}
\text{H}_2\text{N} & \text{-} \text{O} \text{-} \text{X} \text{-} \text{M} \text{-} \text{C} \text{-} \text{NH}_1 \\
\end{align*}
\]

, analogs thereof, and derivatives thereof;

at least one of: at least one first quaternary ammonium diamine moiety and at least one first quaternary phosphonium moiety comprises at least one of:

\[
\begin{align*}
\text{R} & \text{-} \text{N} \text{-} \text{O} \text{-} \text{X} \text{-} \text{R} \\
\end{align*}
\]

, analogs thereof, and derivatives thereof, where \( M \) is \( N \) or \( P \), each \( R \) is individually a \( C_1 \) to \( C_6 \) alkyl, and each \( X \) is individually a \( C_2 \) to \( C_6 \) alkylene;

the blue colored dicarbonyl moiety comprises at least one of:

\[
\begin{align*}
\text{X} & \text{-} \text{R} \text{1} \text{-} \text{N} \text{-} \text{H} \text{1} \text{-} \text{R} \text{1} \text{-} \text{X} \\
\end{align*}
\]

, analogs thereof, and derivatives thereof, where each \( R_1 \) is individually a \( C_1 \) to \( C_6 \) alkylene and each \( X \) is one of \(-\text{OH}\) or \(-\text{O-succinimide}\);

at least one second quaternary ammonium diamine moiety and at least one second quaternary phosphonium diamine moiety comprises at least one of:
H₂N—R₂= 

, analogs thereof, and derivatives thereof,

where M is N or P, each R is individually a Cᵢ to Cᵢ₀ alkyl, and each R₂ is individually a C₂ to Cᵢ₀alkylene;

the blue colored diamine moiety comprises at least one of:

, analogs thereof, and derivatives thereof, where each R₁ is individually a Cᵢ to Cᵢ₀alkylene; and

at least one second quaternary ammonium dicarbonyl moiety and at least one second quaternary phosphonium dicarbonyl moiety comprises at least one of:

, analogs thereof, and derivatives thereof, where M is N or P, each R is individually a Cᵢ to Cᵢ₀ alkyl, each R₂ is individually a C₂ to Cᵢ₀alkylene, and each Y is one of -OH or -O-succinimide;

the yellow colored dicarbonyl moiety comprises at least one of:

, analogs thereof, and derivatives thereof, and R₁ and R₂ are one of -H and -succinimide, and X and Q are individually a Cᵢ to Cᵢ₀ alkylene; and
at least one third quaternary ammonium diamine moiety and at least one third quaternary phosphonium moiety comprises at least one of:

\[ R \quad H_2N\text{-}A\text{-}M\text{-}A\text{-}NH_2 \quad R \]

, analogs thereof, and derivatives thereof, where M is N or P, each R is individually a C\(_1\) to C\(_\text{io}\) alkyl, and each A is individually a C\(_i\) to C\(_\text{io}\) alkylene;

the yellow colored diamine moiety comprises:

\[ R_3 \quad H \quad N \quad X \quad \text{NO}_2 \quad \text{N} \quad \text{N} \quad \text{N} \quad \text{N} \quad \text{CH}_3 \quad \text{H} \quad Q \quad N \quad R_4 \]

, analogs thereof, and derivatives thereof, where \( R_3 \) and \( R_4 \) are -H, and X and Q are individually a C\(_1\) to C\(_\text{io}\) alkylene; and

at least one third quaternary ammonium dicarbonyl moiety and at least one third quaternary phosphonium dicarbonyl moiety comprises at least one of:

\[ \text{N} \text{-} \text{O} \text{-} \text{O} \text{-} \text{M} \text{-} \text{A} \text{-} \text{O} \text{-} \text{N} \text{-} \text{O} \text{-} \text{O} \text{-} \text{A} \text{-} \text{M} \text{-} \text{A} \text{-} \text{O} \text{-} \text{N} \text{-} \text{O} \text{-} \text{O} \]

, analogs thereof, and derivatives thereof, where M is N or P, each R is individually a C\(_i\) to C\(_\text{io}\) alkyl and each A is individually a C\(_i\) to C\(_\text{io}\) alkylene.

192. The kit of claim 190, wherein:

the first dianhydride moiety comprises at least one of:

\[ \text{O} \text{-} \text{O} \text{-} \text{O} \text{-} \text{N} \text{-} \text{O} \text{-} \text{O} \text{-} \text{O} \text{-} \text{N} \text{-} \text{O} \text{-} \text{O} \text{-} \text{N} \text{-} \text{O} \text{-} \text{O} \text{-} \text{N} \text{-} \text{O} \text{-} \text{O} \text{-} \text{N} \text{-} \text{O} \text{-} \text{O} \text{-} \text{N} \text{-} \text{O} \text{-} \text{O} \]

, analogs thereof, and derivatives thereof;
at least one first quaternary ammonium diamine moiety comprises at least one of:

\[
\begin{align*}
\text{H}_2\text{N}^-\text{H}_2\text{N}^- &\text{X}^-\text{X}^-\text{N}^-\text{O}^-\text{O}^-\text{Ni}^-\text{H}_2 \\
&\text{analogs thereof, and derivatives thereof, and each X is individually a C}_2\text{ to C}_9\text{alkylene;} \\
\text{the blue colored dicarbonyl moiety comprises at least one of:}
\end{align*}
\]

\[
\begin{align*}
\text{X}^-\text{O}^- &\text{O}^-\text{X}^-\text{N}^-\text{N}^-\text{O}^-\text{O}^-\text{Ni}^-\text{H}_2 \\
&\text{analogs thereof, and derivatives thereof, and each X is one of -OH or -O-succinimide;} \\
\text{at least one second quaternary ammonium diamine moiety comprises at least one of:}
\end{align*}
\]

\[
\begin{align*}
\text{H}_2\text{N}^- &\text{H}_2\text{N}^-\text{N}^-\text{O}^-\text{O}^-\text{Ni}^-\text{H}_2 \\
&\text{analogs thereof, and derivatives thereof;}
\end{align*}
\]

\[
\begin{align*}
\text{the blue colored diamine moiety comprises at least one of:}
\end{align*}
\]

\[
\begin{align*}
\text{H}_2\text{N}^- &\text{H}_2\text{N}^-\text{O}^-\text{O}^-\text{Ni}^-\text{H}_2 \\
&\text{analogs thereof, and derivatives thereof; and}
\end{align*}
\]

\[
\begin{align*}
\text{at least one second quaternary ammonium dicarbonyl moiety comprises at least one of:}
\end{align*}
\]

\[
\begin{align*}
\text{Y}^- &\text{N}^-\text{O}^-\text{O}^-\text{Y}^-\text{Ni}^-\text{H}_2 \\
&\text{analogs thereof, and derivatives thereof, and each Y is one of -OH or -O-succinimide;} \\
\text{the yellow colored dicarbonyl moiety comprises at least one of:}
\end{align*}
\]
analogs thereof, and derivatives thereof, and $R_1$ and $R_2$ are one of $-H$ and $\text{succinimide}$, and $X$ and $Q$ are individually a $C_1\text{ to } C_6$ alkylene; and

at least one third quaternary ammonium diamine moiety and at least one third quaternary phosphonium moiety comprises at least one of:

$$\text{CH}_3$$

$$\text{H}_2\text{N-}A\text{-}N\text{-}A\text{-}\text{NH}_2$$

$$\text{CH}_3$$

, analogs thereof, and derivatives thereof, and each $A$ is individually a $C_1\text{ to } C_6$ alkylene;

the yellow colored diamine moiety comprises:

$$R_3 - N\text{-}X - N\text{-}N\text{-}Q\text{-}N\text{-}R_4$$

$H$

, analogs thereof, and derivatives thereof, where $R_3$ and $R_4$ are $-H$, and $X$ and $Q$ are individually a $C_1\text{ to } C_6$ alkylene; and

at least one third quaternary ammonium dicarbonyl moiety comprises at least one of:

$$\text{A}$$

, analogs thereof, and derivatives thereof, and each $A$ is individually a $C_1\text{ to } C_6$ alkylene.

193. A method for using an electrophoretic display comprising at least one first electrode layer and an array of microcapsules disposed adjacent at least one first electrode layer with a first side of the microcapsules adjacent the layer and a second side of the
microcapsules away from the electrode layer, wherein each microcapsule comprises an
electrophoretic medium comprising at least one electrically charged particle disposed in a
transparent fluid and capable of moving through the transparent fluid upon application of an
electrical field to the transparent fluid, wherein at least one charged particle comprises an
alternating copolymer of a chromophore and a charged linker molecule, and the method
comprises:

selectively applying an electric charge to the electrode layer adjacent selected
ones of the microcapsules to cause at least one charged particle in the selected
microcapsules to move away from the electrode layer to provide a visual color
Corresponding to the chromophore at the second side of the selected microcapsules.

194. The method of claim 193, further comprising incorporating the display into
one of a cellular telephone, a book reader, a tablet computer, a portable computer, a smart
card, a sign, a watch or a shelf label with the second sides of the microcapsules visible for
viewing the visual color.

195. The method of claim 193, further comprising reversing or turning off the
electric charge to the selected ones of the microcapsules to cause at least one charged particle
in the selected microcapsules to move towards the electrode layer to remove the visual color
corresponding to the chromophore from the second side of the selected microcapsules.

196. The method of claim 193, wherein the display is a multi-color display and at
least one charged particle in each microcapsule comprises: at least one red-colored charged
particle comprising a red-colored chromophore, at least one blue-colored charged particle
comprising a blue-colored chromophore or at least one yellow colored charged particle
comprising a yellow-colored chromophore, and the method further comprises at least one of:
selectively applying an electric charge to the electrode layer adjacent selected ones of the microcapsules comprising at least one red-colored charged particle to cause at least one red-colored charged particle in the selected microcapsules to move away from the electrode layer to provide a visual red color corresponding to the chromophore at the second side of the selected microcapsules;

selectively applying an electric charge to the electrode layer adjacent selected ones of the microcapsules comprising at least one blue-colored charged particle to cause at least one blue-colored charged particle in the selected microcapsules to move away from the electrode layer to provide a visual blue color corresponding to the chromophore at the second side of the selected microcapsules; and

selectively applying an electric charge to the electrode layer adjacent selected ones of the microcapsules comprising at least one yellow-colored charged particle to cause at least one yellow-colored charged particle in the selected microcapsules to move away from the electrode layer to provide a visual yellow color corresponding to the chromophore at the second side of the selected microcapsules.

197. The method of claim 196, wherein the microcapsules are arranged in repeating sets of three, with one of the three comprising at least one red-colored charged particles, one of the three comprising at least one blue-colored charged particles, and one of the three comprising at least one yellow colored charged particles, and the method comprises selectively applying an electric charge to the electrode layer adjacent selected ones of the microcapsules for combinations of selected ones of the microcapsules to produce combinations of colors at the second side of the microcapsules.
198. The method of claim 196, wherein the display further comprises a second electrode layer disposed adjacent the second sides of the microcapsules, and the method further comprises:

selectively applying an appropriate electric field between the first and second electrode layers for selected ones of the microcapsules to move at least one charged particle in the selected microcapsules toward or away from the second side of the microcapsules to selectively produce and remove the visual color from the second side of the microcapsules.

199. The method of claim 196, wherein:

at least one red-colored charged particle comprises red colored chromophores copolymerized with first charged linker molecules, wherein the red colored chromophores and the first charged linker molecules comprise a pairing of:

a component derived from a first dianhydride moiety and a component derived from at least one of: a first quaternary ammonium diamine moiety and a first quaternary phosphonium diamine moiety;

at least one blue-colored charged particle comprises blue colored chromophores copolymerized with second charged linker molecules, wherein the blue colored chromophores and second charged linker molecules comprise at least one pairing of:

a component derived from a blue colored dicarbonyl moiety and a component derived from at least one of: a second quaternary ammonium diamine moiety and a second quaternary phosphonium diamine moiety, and

a component derived from a blue colored diamine moiety and a component derived from at least one of: a second quaternary ammonium...
dicarbonyl moiety and a second quaternary phosphonium dicarbonyl moiety; and

at least one yellow-colored charged particle comprises yellow colored chromophores copolymerized with third charged linker molecules, wherein the yellow colored chromophores and third charged linker molecules comprise at least one pairing of:

a component derived from a yellow colored dicarbonyl moiety and a component derived from at least one of: a third quaternary ammonium diamine moiety and a third quaternary phosphonium diamine moiety, and

a component derived from a yellow colored diamine moiety and a component derived from at least one of: a third quaternary ammonium dicarbonyl moiety and a third quaternary phosphonium dicarbonyl moiety.

200. The method of claim 199, wherein:

the first dianhydride moiety comprises at least one of:

\[ \text{structure 1} \]

\[ \text{structure 2} \]

analog thereof, and derivatives thereof; and

at least one of the first quaternary ammonium diamine moiety and the first quaternary phosphonium moiety comprises at least one of:

\[ \text{structure 3} \]

\[ \text{structure 4} \]

analog thereof, and derivatives thereof, where \( M \) is \( N \) or \( P \), each \( R \) is individually a \( C_1 \) to \( C_{10} \) alkyl, and each \( X \) is individually a \( C_2 \) to \( C_{10} \) alkylene;

the blue colored dicarbonyl moiety comprises at least one of:
analogs thereof, and derivatives thereof, where each $R_1$ is individually a C$_i$ to C$_o$ alkylene and each $X$ is one of -OH or -O-succinimide; and

at least one of the second quaternary ammonium diamine moiety and the second quaternary phosphonium diamine moiety comprises at least one of:

![Diagram]

, analogs thereof, and derivatives thereof, where $M$ is N or P, each $R$ is individually a C$_i$ to C$_o$ alkyl, and each $R_2$ is individually a C$_2$ to C$_o$ alkylene;

the blue colored diamine moiety comprises at least one of:

![Diagram]

, analogs thereof, and derivatives thereof, where each $R_1$ is individually a C$_i$ to C$_o$ alkylene; and

at least one of the second quaternary ammonium dicarbonyl moiety and the second quaternary phosphonium dicarbonyl moiety comprises at least one of:
where M is N or P, each R is individually a C\textsubscript{i} to C\textsubscript{i0} alkyl, each R\textsubscript{2} is individually a C\textsubscript{2} to C\textsubscript{i0} alkylene, and each Y is one of -OH or -O-succinimide;

the yellow colored dicarbonyl moiety comprises at least one of:

\[
\begin{array}{c}
\text{R}_1\text{N}^\alpha\text{N}^\beta\text{N}^\gamma\text{N}^\delta\text{N}^\epsilon\text{N}^\zeta\text{N}^\iota\text{N}^\kappa\text{N}^\lambda\text{N}^\mu\text{N}^\nu\text{N}^\xi\text{N}^\rho\text{N}^\sigma\text{N}^\tau\text{N}^\upsilon\text{N}^\phi\text{N}^\chi\text{N}^\psi\text{N}^\omega\text{N}^\alpha\text{N}^\beta\text{N}^\gamma\text{N}^\delta\text{N}^\epsilon\text{N}^\zeta\text{N}^\iota\text{N}^\kappa\text{N}^\lambda\text{N}^\mu\text{N}^\nu\text{N}^\xi\text{N}^\rho\text{N}^\sigma\text{N}^\tau\text{N}^\upsilon\text{N}^\phi\text{N}^\chi\text{N}^\psi\text{N}^\omega\text{N}^\alpha\text{N}^\beta\text{N}^\gamma\text{N}^\delta\text{N}^\epsilon\text{N}^\zeta\text{N}^\iota\text{N}^\kappa\text{N}^\lambda\text{N}^\mu\text{N}^\nu\text{N}^\xi\text{N}^\rho\text{N}^\sigma\text{N}^\tau\text{N}^\upsilon\text{N}^\phi\text{N}^\chi\text{N}^\psi\text{N}^\omega
\end{array}
\]

, analogs thereof, and derivatives thereof, and R\textsubscript{1} and R\textsubscript{2} are one of -H and -sucninimide, and X and Q are individually a C\textsubscript{i} to C\textsubscript{i0} alkylene; and

at least one of the third quaternary ammonium diamine moiety and the third quaternary phosphonium moiety comprises at least one of:

\[
\begin{array}{c}
\text{R}_1\text{N}^\alpha\text{N}^\beta\text{N}^\gamma\text{N}^\delta\text{N}^\epsilon\text{N}^\zeta\text{N}^\iota\text{N}^\kappa\text{N}^\lambda\text{N}^\mu\text{N}^\nu\text{N}^\xi\text{N}^\rho\text{N}^\sigma\text{N}^\tau\text{N}^\upsilon\text{N}^\phi\text{N}^\chi\text{N}^\psi\text{N}^\omega\text{N}^\alpha\text{N}^\beta\text{N}^\gamma\text{N}^\delta\text{N}^\epsilon\text{N}^\zeta\text{N}^\iota\text{N}^\kappa\text{N}^\lambda\text{N}^\mu\text{N}^\nu\text{N}^\xi\text{N}^\rho\text{N}^\sigma\text{N}^\tau\text{N}^\upsilon\text{N}^\phi\text{N}^\chi\text{N}^\psi\text{N}^\omega
\end{array}
\]

, analogs thereof, and derivatives thereof, where M is N or P, each R is individually a C\textsubscript{i} to C\textsubscript{i0} alkyl, and each A is individually a C\textsubscript{i} to C\textsubscript{i0} alkylene;

the yellow colored diamine moiety comprises at least one of:

\[
\begin{array}{c}
\text{R}_1\text{N}^\alpha\text{N}^\beta\text{N}^\gamma\text{N}^\delta\text{N}^\epsilon\text{N}^\zeta\text{N}^\iota\text{N}^\kappa\text{N}^\lambda\text{N}^\mu\text{N}^\nu\text{N}^\xi\text{N}^\rho\text{N}^\sigma\text{N}^\tau\text{N}^\upsilon\text{N}^\phi\text{N}^\chi\text{N}^\psi\text{N}^\omega\text{N}^\alpha\text{N}^\beta\text{N}^\gamma\text{N}^\delta\text{N}^\epsilon\text{N}^\zeta\text{N}^\iota\text{N}^\kappa\text{N}^\lambda\text{N}^\mu\text{N}^\nu\text{N}^\xi\text{N}^\rho\text{N}^\sigma\text{N}^\tau\text{N}^\upsilon\text{N}^\phi\text{N}^\chi\text{N}^\psi\text{N}^\omega
\end{array}
\]

, analogs thereof, and derivatives thereof, where R\textsubscript{3} and R\textsubscript{4} are -H, and X and Q are individually a C\textsubscript{i} to C\textsubscript{i0} alkylene; and

at least one of the third quaternary ammonium dicarbonyl moiety and at least one third quaternary phosphonium dicarbonyl moiety comprises at least one of:
analogs thereof, and derivatives thereof, where $M$ is $N$ or $P$, each $R$ is individually a $C_i$ to $C_{10}$ alkyl and each $A$ is individually a $C_i$ to $C_{10}$ alkylene.
FIG. 2
FIG. 4A

R₁ and R₂ are H or NHS
X and Q are independently C₁ to C₁₀ alkylene
Y is NH₂ or N₂⁺
R are same or different C₁ to C₁₀ alkyl
M is N or P
A are same or different C₁ to C₁₀ alkylene
FIG. 4B
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G02B 26/00 (2013.01)
USPC - 359/295

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)
IPC(8) - G02B 26/00 (2013.01)
USPC - 359/295

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) - G02B 26/00; G03G 17/04 (2013.01)
USPC - 359/295; 296; 430/32

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, GoogleScholar, Dialog

electrophoretic display, electrode, medium, microcapsule, Charge, transparent fluid, charged particle (copolyamide) chromophore
dicarbonyl (dicarboxylic acid, a diacyl halide, a dihydride, a diester, dihydride, quaternary ammonium diamine, etc.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>WO2011/075720A1 (CLAPP et al.) 23 June 2011 (23.06.2011) Figs. 4A-4B, para[0019], para[0023], para[0037]-para[0038], para[0049]-para[0052], para[0059], para[0063]), para[0065]-para[0067], para[0094], para[0118], para[0120], para[0122], para[0123], para[0126]</td>
<td>1-2, 4, 17, 26, 35-36, 38-40, 48, 57, 66-67, 69, 72, 81 and 98</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier application or patent but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  "O" document referring to an oral disclosure, use, exhibition or other means
  "P" document published prior to the international filing date but later than the priority date claimed
  "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
  "&" document member of the same patent family

Date of the actual completion of the international search
1 July 2013 (01.07.2013)

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-3201

Date of mailing of the international search report
11 JUL 2013

Authorized officer: Lee W. Young
PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774
### Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. **Claims Nos.**: because they relate to subject matter not required to be searched by this Authority, namely:

2. **Claims Nos.**: because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. **Claims Nos.**: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

**SEE SUPPLEMENTAL SHEET**

1. **As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.**

2. **As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.**

3. **As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:**

4. **No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:**

**Claims 1-114**

### Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

No protest accompanied the payment of additional search fees.

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Form: PCT/ISA/210 (continuation of first sheet (2)) (July 2009)
<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
</table>
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-114, drawn to an electrophoretic display comprising: at least one first electrode layer; and an electrophoretic medium disposed adjacent at least one first electrode layer, wherein the electrophoretic medium comprises: at least one electrically charged particle disposed in a transparent fluid and capable of moving through the transparent fluid upon application of an electrical field to the transparent fluid, wherein at least one charged particle comprises an alternating copolymer of a chromophore and a charged linker molecule.

Group II: Claims 115-192, drawn to a method and kit for producing charged pigment particles, the method comprising copolymerizing chromophores with charged linker molecules to form charged and colored microparticles.

Group III: Claims 193-200, drawn to a method for using an electrophoretic display comprising at least one first electrode layer and an array of microparticles disposed adjacent at least one first electrode layer with a first side of the microparticles adjacent the layer and a second side of the microparticles away from the electrode layer, wherein each microparticle comprises an electrophoretic medium comprising at least one electrically charged particle disposed in a transparent fluid and capable of moving through the transparent fluid upon application of an electrical field to the transparent fluid, wherein at least one charged particle comprises an alternating copolymer of a chromophore and a charged linker molecule, and the method comprises: selectively applying an electric charge to the electrode layer adjacent selected ones of the microparticles to cause at least one charged particle in the selected microparticles to move away from the electrode layer to provide a visual color corresponding to the chromophore at the second side of the selected microparticles.

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

SPECIAL TECHNICAL FEATURES
Group II includes the special technical features of a method for producing charged pigment particles, the method comprising copolymerizing chromophores with charged linker molecules to form charged and colored microparticles, not required by Group I.

Group III includes the special technical feature of a method for using an electrophoretic display comprising at least one first electrode layer and an array of microparticles disposed adjacent at least one first electrode layer with a first side of the microparticles adjacent the layer and a second side of the microparticles away from the electrode layer, wherein each microparticle comprises an electrophoretic medium and selectively applying an electric charge to the electrode layer adjacent selected ones of the microparticles to cause at least one charged particle in the selected microparticles to move away from the electrode layer to provide a visual color corresponding to the chromophore at the second side of the selected microparticles, not required by Group I and II.

COMMON TECHNICAL FEATURES
Groups I and III share the common technical feature of an electrophoretic display comprising: at least one first electrode layer; and an electrophoretic medium disposed adjacent at least one first electrode layer, wherein the electrophoretic medium comprises: at least one electrically charged particle disposed in a transparent fluid and capable of moving through the transparent fluid upon application of an electrical field to the transparent fluid, wherein at least one charged particle comprises an alternating copolymer of a chromophore and a charged linker molecule.

Groups I-III share the common technical feature of chromophores copolymerized with charged linker molecules to form charged and colored microparticles.

However, these shared technical features do not represent a contribution over the prior art, as obvious over WO 2011/075720 A1 to Clapp et al. (hereinafter "Clapp").

Clapp teaches an electrophoretic display (para [0010], [0012], [0026]) comprising: at least one first electrode layer (Fig. 4A-Fig. 4B, para [0013], [0126], electrodes 18, 20); and an electrophoretic medium (para [0012], [0017], [0026]) disposed adjacent at least one first electrode layer, wherein the electrophoretic medium comprises: at least one electrically charged particle (para [0065], [0126], charged particle 52) disposed in a transparent fluid (para [0120]) and capable of moving through the transparent fluid upon application of an electrical field to the transparent fluid (Fig. 4A-Fig. 4B, para [0126]), wherein at least one charged particle comprises an alternating copolymer (para [0027], [0034]-[0035]-alternating copolymers of QX and XY) of a chromophore (para [0011]) and a charged linker molecule (para [0037]-[0038], [0044]) and Q(X-Y+), m is 1; and para[0049]-[0052], X+ and Y+ are cationic ammonium groups and the formula is shown in compounds which teaches an alternating of the charged particle and the chromophore of para[0043]; Q is an anthraquinone chromophore) and further wherein the chromophore (para [0011]) and charged linker molecule are copolymerized (para[0017], [0126]. Clapp does not specifically mention that the electrodes are layers, but teaches electrode 18 and 20 (para [0013], [0126], Fig 4A and 4A). Therefore, it would have been obvious to a person having ordinary skill in the art to provide first layer and second layer of electrodes, because to improve color-fastness and photo-stability.

As the shared technical features were known or would have been obvious to one of ordinary skill in the art at the time of the invention, these cannot be considered special technical features that would otherwise unify the groups.

Therefore, Groups I-III lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.