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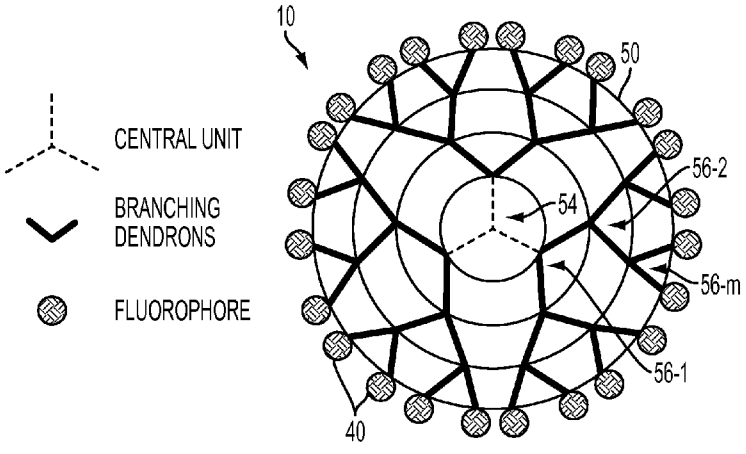

FIG. 2

(57) Abstract: Electrophoretic displays with an electrophoretic medium having charged fluorescent particles are disclosed. The charged fluorescent particles have a dendrimer core covalently bonded with fluorophores of various emissive wavelengths so that microparticles that emit a variety of different colored electromagnetic radiation 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.

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ELECTROPHORETIC DISPLAYS HAVING CHARGED FLUORESCENT DENDRIMER PARTICLES

BACKGROUND

[0001] Electrophoretic displays, such as those that may be used in e-reader devices or other display applications, are displays based on an electrophoresis phenomenon influencing charged color particles suspended in a dielectric solvent. The color particles may be of a size of about 1-2 microns in diameter, carrying a charge, and are able to migrate within the dielectric solvent under the influence of externally applied charges from adjacent electrode plates or conducting films. The color particles may provide at least one visible color in the display.

[0002] Electrophoretic displays have an electrophoretic fluid having at least one type of charged color particle dispersed in the dielectric solvent. The electrophoretic fluid may be pigmented with a color that is in contrast to the color particles, for example, white particles in a colorless or clear dielectric solvent. Upon application of a charge to the electrode plates, the color particles may be influenced to migrate towards or away from the electrode plates, by attraction to a plate of opposite charge, or repulsion 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 provided by the particles if the particles are attracted to that surface. Reversal of plate polarity may then cause the particles to migrate back to the opposite plate, thereby reversing the color.

[0003] Alternatively, an electrophoretic fluid may have two types of color particles of contrasting colors (for example, white and black) and carrying opposite charges, dispersed in a clear solvent. Upon application of a voltage difference between two electrode plates, the two types of color particles may move to opposite ends (top or bottom) in a display

cell. Thus, one or the other of the colors provided by the two types of color particles would be visible at the viewing side of the display cell.

[0004] The color-providing particles may be ionic or ionizable microparticles composed of white, black or otherwise colored molecules encapsulated by a polymer. The color-providing particles may be formed from a non-covalent bonding of a polymer matrix to the encapsulated colored molecules. The non-covalent bonding may be broken down by radiant energy, resulting in a loss of color over time and rendering the electrophoretic display no longer functioning as designed. In addition, molecules that have color because of dyes may not be exceptionally bright as these molecules simply reflect ambient light.

[0005] For electrophoretic displays, there remains a need for charged color-providing particles which have improved color-fastness and photostability, and which are able to provide brighter colors for the displays.

SUMMARY

[0006] Micro- and nano-particle based approaches to electrophoretic displays employing charged fluorescent dendrimers can provide improved color-fastness and photostability. As the fluorescent dendrimers can emit light, they may also provide brighter colors for the displays.

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

[0008] In an embodiment, a method of using an electrophoretic display includes providing an electrophoretic display to emit colored electromagnetic radiation from a surface

of the display. The display includes at least one first electrode layer and an array of microcapsules disposed adjacent to the at least one first electrode layer with a first side of the microcapsules adjacent to the at least one first electrode layer and a second side of the microcapsules away from the at least one first electrode layer. Each of the microcapsules includes an electrophoretic medium having at least one electrically charged particle disposed in a fluid and capable of moving through the fluid upon application of an electrical field to the fluid. The at least one charged particle includes a charged fluorescent dendrimer. The method further includes selectively applying an electric charge to the first electrode layer adjacent to selected microcapsules in the array to cause the at least one charged particle in the selected microcapsules to move away from the first electrode layer to the second side of the selected microcapsules, and irradiating the display with electromagnetic radiation capable of fluorescing the at least one charged particle to emit colored electromagnetic radiation from the second side of the selected microcapsules.

[0009] In an embodiment, an electrophoretic medium includes at least one electrically charged particle disposed in a fluid and capable of moving through the fluid upon application of an electrical field to the fluid. The at least one charged particle includes a charged fluorescent dendrimer.

[0010] In an embodiment, a kit for producing charged fluorescent dendrimers includes core dendrimers and charged fluorophores configured to covalently bond with the dendrimers to form the charged fluorescent dendrimers.

[0011] In an embodiment, a charged fluorescent particle for an electrophoretic display includes at least one charged fluorophore covalently bonded to a dendrimer core, wherein the charged fluorophore is a derivative of a charged fluorophore molecule comprising at least one reactive functional group, and the dendrimer core is a derivative of a dendrimer molecule comprising at least one surface reactive functional group. One of the

reactive functional groups and the surface reactive functional groups includes amine-reactive carbonyl groups, and the other one of the reactive functional groups and the surface reactive functional groups includes surface reactive amines.

[0012] In an embodiment, a method for producing charged fluorescent particles includes contacting charged fluorophores with dendrimers, wherein the fluorophores have at least one amine-reactive carbonyl group selected from the group comprising: aldehyde, ketone, carboxylic acid, ester, acyl halide, anhydride, and combinations thereof, and the dendrimers have at least one surface reactive amine. The surface reactive amines react with the at least one amine-reactive carbonyl group to covalently bond the dendrimers with the fluorophores to form the charged fluorescent particles.

BRIEF DESCRIPTION OF THE FIGURES

[0013] FIGS. 1A-1C are representative configurations of an electrophoretic display according to an embodiment.

[0014] FIG. 2 depicts a representative dendrimer according to an embodiment.

[0015] FIGS. 3A and 3B depict schematic functionalized dendrimer cores for producing fluorescent dendrimers according to an embodiment.

[0016] FIG. 4 depicts fluorescent dyes that may be used for fluorescent dendrimers according to embodiments.

[0017] FIG. 5 depicts a schematic illustration of a method for producing charged fluorescent dendrimers according to an embodiment.

[0018] FIG. 6 depicts a schematic illustration of a method for producing charged fluorescent dendrimers according to an embodiment.

DETAILED DESCRIPTION

[0019] Charged fluorescent dendrimers may be used as charged particles to provide visible colors in both flexible and non-flexible display technologies, and provide improved hue, brightness, and color intensity as compared to non-fluorescent pigments and dyes. In addition, the fluorescent dyes covalently bound to a dendrimer may provide improved color-fastness and photostability as compared to non-polymer bound pigments and dyes. Non-fluorescent pigments can simply reflect light at a particular wavelength or wavelengths, while fluorescent dendrimers may emit light at a particular wavelength or wavelengths, thereby providing brighter colors for displays such as electrophoretic displays. Electrophoretic displays incorporating such charged particles, for example as illustrated in FIGS. 1A-1C, 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.

[0020] Electrophoretic displays may include charged fluorescent particles **10**, depicted in FIGS. 1A-1C, for providing color to the display. The particles **10** may include fluorophores covalently bonded to a dendrimer core. The particles **10** may be nanoparticles, microparticles, nanospheres, or microspheres, may have a size from about 1 nanometer to about 20 nanometers, and will, for simplification, be generally referred to as microparticles herein. A fluorophore may be any molecular moiety which emits a visible color upon excitation with radiation of an appropriate wavelength.

[0021] At least one charged microparticle **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 that allows the microparticles to be suspended in the solvent, for movement within the solvent when an electric charge is applied to attract or repel

the microparticles. In an embodiment, the density of the solvent may be approximately the same as the density of the microparticles **10**. To allow for high particle mobility, the solvent or solvent mixture in the suspension fluid **12** in which the fluorescent particles are dispersed may have a low viscosity and a dielectric constant of about 2 to about 50. For example, the fluid may have a kinematic viscosity of about 0.2 centistokes to about 50 centistokes. Specific examples of kinematic viscosity include about 0.2, about 0.4, about 0.6, about 0.8, about 1, about 2, about 4 about 6, about 8, about 10, about 15, about 20, about 25, about 30, about 35, about 40, about 45, about 50, and any values or ranges between an of the listed values. In addition, the dielectric constant may be about 2 to about 50, about 2 to about 25, about 2 to about 20, or about 2 to about 15. Specific examples of dielectric constants include about 2, about 5, about 10, about 15, about 20, about 25, about 30, about 35, about 40, about 45, about 50, and ranges between any two of these values (including endpoints).

[0022] The solvent, or two or more solvents for the suspension fluid 12 may be selected such that the fluorescent microparticles are insoluble in the solvent, the long term chemical and structural stabilities of the fluorescent microparticles are maintained, and the solvent counteracts fluorescent quenching and aggregation of the fluorescent microparticles. 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, polydimethylsiloxane, poly(chlorotrifluoroethylene) polymer, or combinations of any two or more of these.

[0023] 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 alkylnaphthalene; 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(perfluoropropylene 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.

[0024] The microcapsules **14** may be formed of polymers and may be visually 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.

[0025] In an embodiment, the microcapsules **14** may be disposed adjacent to at least a first electrode layer **16** configured for applying a positive or negative charge adjacent to a side of the microcapsules. The first electrode layer **16** may be a conducting film, and

may be flexible to allow for flexible displays. The first electrode layer **16** may have a base substrate **13** supporting individual electrodes **15** corresponding to each microcapsule **14**

[0026] With a configuration as shown in FIG. 1A, wherein the microparticles **10** have a positive charge, an application of a positive charge to the first electrode layer **16** adjacent to a microcapsule **14** may repel the microparticles away from the electrode, while an application of a negative charge to the first electrode layer adjacent to a microcapsule may attract the microparticles to the electrode. In this manner, if the suspension fluid **12** 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 first 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 first electrode layer. On the other hand, the upper side of the microcapsules **14** will visually appear to have the color of the microparticles **10** (left-side microcapsule in FIG. 1A) when the microparticles are repelled away from the first electrode layer **16**.

[0027] In an alternative embodiment, instead of just one electrode layer **16**, the display may also have a second electrode layer **16A** (shown in dotted lines in FIGS. 1A and 1B) of appropriate conducting material, and spaced apart from, and opposite to the first electrode layer **16**. 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 second electrode layer **16A** towards the first electrode layer **16**. The microcapsules **14** may be sandwiched between the first electrode layer **16** and the second electrode layer **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 poly(styrene sulfonate) (PSS), poly(4,4-dioctylcyclopentadithiophene), and carbon

nanotubes. A voltage difference may be imposed across the microcapsules **14** wherein one electrode layer may apply a charge which is opposite to the charge of the other electrode 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**.

[0028] The colors produced at the surface of face **17** of such electrophoretic displays may be promoted and/or enhanced by direct sunlight, other external lighting sources, or back-lighting.

[0029] As an alternative, as depicted in FIG. 1B, the visible color in microcapsules **14** may be produced by providing two sets of oppositely charged microparticles **10** in each microcapsule **14**, wherein each set of microparticles **10** fluoresces a different color. For example, the positively charged particles may fluoresce red and the negatively charged particles may fluoresce yellow (or any other color combinations). Application of electric fields as shown, would attract the red-fluorescing (positive) particles to the negatively charged electrodes and the yellow fluorescing (negative) particles to the positively charged electrodes, and in the depiction of FIG. 1B, the upper surface in the left microcapsule would appear red, and the upper surface in the right microcapsule would appear yellow.

[0030] An electrophoretic display may be assembled as follows. A substrate having thin film transistor (TFT) elements may be coated with a photoresist layer by coating a resist material on the TFT glass substrate. Grooves arranged in an intended partition pattern may be formed in the photoresist layer by photolithography. The grooves may be supplied with a two-part curable silicone resin and the resin may be cured. Thereafter, the resulting photoresist layer may be exfoliated and removed from the substrate, whereby partitions formed of the silicone resin extending upward from the substrate may be formed. In an

embodiment, an electrophoretic dispersion may be filled directly into the corresponding spaces defined by the partitions (cell spaces) using an ink-jet device, or as discussed above, microcapsules may be filled with the microparticles dispersion and the microcapsules may be introduced onto the substrate layer. A glass substrate with an ITO layer on an entire surface thereof may be placed over the cell spaces, and the periphery portion of the paired substrates may be sealed with an epoxy resin to produce an electrophoretic display device. The terminal section of the resulting electrophoretic display device may be coupled with a power source through lines to activate the device.

[0031] The microparticles **10** that are used in electrophoretic displays may be chosen, or configured, based on the desired colors required for the display. While black and white colors would be used, for example, in e-book readers which display a replica of a white page with black type, alternative particles that fluoresce additional individual colors may also be used. To provide color combinations, the microcapsules **14** of an array of microcapsules may individually be filled with microparticles that fluoresce different colors in a repeating pattern so that by activating selected 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.

[0032] As an example, in an RYB system, individual microcapsules may be provided containing the individual microparticles that fluoresce 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 microparticles that fluoresce red, or alternatively, for yellow, a negative charge may be selectively applied to the microcapsules that fluoresce yellow. To produce orange,

however, a negative charge may be selectively applied to the microcapsules containing red-fluorescing particles and to the microcapsules containing yellow fluorescing particles, so that the red fluorescence and yellow fluorescence combine to produce an orange color. This could be applied to any combination of microcapsules to produce a variety of colors.

[0033] As mentioned above, and as represented in a simplified embodiment depicted FIG. 2, each microparticle **10** may be a charged particle including fluorophores **40** bonded to a dendrimer core **50**. The dendrimer core **50** may have a central 'starting' unit **54** as well as several generations of branching dendrons **56-1**, **56-2**, **56-m**. The charge of the microparticles **10** may be provided by the fluorophores **40**, the dendrimer molecules, or both, wherein anionic dendrimers or fluorophores may provide negatively charged particles, or cationic dendrimers or fluorophores may provide positively charged particles.

[0034] The fluorophore may be a derivative of a fluorophore molecule having at least one reactive functional group, and the dendrimer core may be a derivative of a dendrimer molecule having at least one surface reactive functional group. The fluorophore molecule and the dendrimer molecule may be selected or configured so that the at least one surface reactive functional groups of the dendrimer molecule may react with the at least one reactive functional group of the fluorophore molecule to covalently link the dendrimer molecule with the fluorophore molecule.

[0035] In an embodiment, one of the reactive functional groups and the surface reactive functional groups may be an amine-reactive carbonyl group, and the other one of the reactive functional groups and the surface reactive functional groups may be a surface reactive amine. In various embodiments, the amine-reactive carbonyl group may be an aldehyde, a ketone, a carboxylic acid, an ester, an acyl halide, an anhydride, or any combination thereof.

[0036] Dendrimer cores **50** having **m**-generations of branching dendrons may be synthesized by reiterative substitution reactions that build outwardly one generation upon another. The branching dendrons **56-1**, **56-2**, **56-m** may have the surface reactive functional groups as a part of the molecular structure of the dendrons, or alternatively, upon establishing the desired number of generations, a portion of the branching dendrons may be modified to include the surface reactive functional groups.

[0037] Similarly, fluorescent dyes may be chosen which already have the reactive functional groups as a part of the structure of the fluorophore molecules, or alternatively, fluorophore molecules may be modified to include the reactive functional groups.

[0038] FIGS. 3A and 3B depict non-limiting example of a dendrimer molecule represented in a 2-dimensional plane. A typical dendrimer may however be 3-dimensional and take on a spherical configuration. A central core may have a representative structure ($X\text{-}Y_n$) with each X bound to n units of Y, which as represented in FIGS. 3A and 3B corresponds to ($X\text{-}Y_3$) or each X binding to 3 units of Y. The dendrimer molecule may have a branching repeating structure of at least (m) generations of repeating units, which as represented in FIG. 3A corresponds to 3 generations. The repeating units may have a representative structure ($X\text{-}Y_{n-1}$) with each X bound to (n-1) units of Y, which as represented in FIG. 3A and 3B corresponds to ($X\text{-}Y_2$) with each X binding to 2 units of Y. The units Y in the m^{th} generation (3^{rd} generation in FIG. 3A, not represented in FIG.3B) of the repeating units may have at least one surface reactive functional groups (–s). For simplicity, additional generations of repeating units are not shown.

[0039] As represented in FIG. 3A, each Y may have 2 binding sites for an X, whereby the dendrimer growth branches at an X component that has 3 binding sites for a Y. As such, each generation has twice as many of each of the X and Y components as the previous generation (generation 1 has 3-X and 6-Y; generation 2 has 6-X and 12-Y;

generation 3 has 12-X and 24-Y; etc.) As an alternative as represented in FIG. 3B, each Y may have 3 binding sites for an X, whereby the dendrimer growth may then branch at both the X component and the Y component (generation 1 has 6-X and 12-Y; generation 2 has 24-X and 48-Y; generation 3 (not shown) would have 96-X and 192-Y; etc.). In various embodiments, the X and the Y components may each have two or more binding sites for the other of the X and Y components. If both X and Y have only two binding sites for the other of the X and Y, essentially linear growth would occur.

[0040] In an embodiment, the dendrimer molecules used for the electrophoretic particles **10** may have up to about 10 generations of repeating units. As examples, the dendrimer molecules may have 1 generation, 2 generations, 3 generations, 4 generations, 5 generations, 6 generations, 7 generations, 8 generations, 9 generations, or 10 generations. For larger sized particles additional generations may be added.

[0041] In embodiments as discussed below, the fluorophore may be a derivative of a fluorophore molecule having at least one amine-reactive carbonyl group, and the dendrimer core may be a derivative of a dendrimer molecule having at least one surface reactive amine. Two examples of dendrimer molecules having surface reactive amines, as represented schematically by FIGS. 3A and 3B, may be dendrimers wherein the X component is derived from1,3,5 triazine (cyanuric chloride or 2,4,6-trichloro-1,3,5-triazine, shown in FIG. 5 and discussed further herebelow). A dendrimer as in FIG. 3A may have a Y component that is derived from a component that has terminal diaminyl groups. While not limited to the following, some examples of terminal diaminyl groups include  and –NH-A-NH- wherein A is C_2 to C_{10} alkylene. Additional examples of diamine components may include aminomethylpiperidine, aminopiperidine, aminopyrrolidine, aminoalkylpiperidine, aminoalkylpyrrolidine. A dendrimer as in FIG. 3B may have a Y component that is derived from a triamine. While not limited to the following, some

examples of triamine components may include diaminodipropylamine and diaminodialkylamine,

[0042] While not limited to the following, some additional examples of chemical moieties from which the X component may be derived include diamines, such as ethylenediamine (shown in FIG. 6 and discussed further herebelow), and 1,4 diaminobenzene.

[0043] Amine-reactive fluorophores may include dyes having an activated N-hydroxysuccinimide (NHS) ester group as the amine reactive carbonyl group. Some examples of such dyes include the NHS esters of the photostable Alexa Fluor® fluorescent dyes (from Molecular Probes, Inc., Eugene, OR) as listed below in Table 1 with their corresponding emission colors, and the structures of which are correspondingly presented in FIG. 4. The amine-reactive fluorophores such as those listed in Table 1 below, may be excited with visible light to emit the various colored electromagnetic radiation or fluorescence.

TABLE 1

Fluorescent dye	Excitation (nm)	Emission (nm)	Emission color
(A) Alexa Fluor® 350 SE	346	442	Blue
(B) Alexa Fluor® 405 SE	402	421	Blue
(C) Alexa Fluor® 430 SE	434	539	Yellow-green
(D) Alexa Fluor® 488 SE	495	519	Green
(E) Alexa Fluor® 514 SE	518	540	Green
(F) Alexa Fluor® 532 SE	531	554	Yellow
(G) Alexa Fluor® 594 SE	590	617	Red
(H) Alexa Fluor® 610 SE	612	628	Red

[0044] As illustrated in the representative structures in FIG. 4, the Alexa Fluor® dyes carry a negative charge and therefore when covalently bound to a dendrimer may provide an anionic fluorescent dendrimer.

[0045] Additional examples of dyes that may also be usable include amine reactive anionic fluorescent dyes such as 5-carboxyfluorescein succinimidyl ester (excitation 492 nm, emission 518 nm, green), 6-carboxyfluorescein succinimidyl ester (excitation 492 nm, emission 515 nm, green), and Chromis 645 XT A – NHS ester (excitation 648 nm, emission 667 nm, green).

[0046] In an embodiment, charged fluorescent particles may be configured to emit blue-colored electromagnetic radiation. The charged fluorescent particles may have a core dendrimer with either one, or possibly both of the Alexa Fluor® dyes (A) and (B) covalently bonded to amine nitrogens of the dendrimer via a –(C=O)– of the dye molecules.

[0047] In an embodiment, charged fluorescent particles may be configured to emit yellow-green-colored electromagnetic radiation. The charged fluorescent particles may have a core dendrimer with the Alexa Fluor® dye (C) covalently bonded to amine nitrogens of the dendrimer via a –(C=O)– of the dye molecules.

[0048] In an embodiment, charged fluorescent particles may be configured to emit green-colored electromagnetic radiation. The charged fluorescent particles may have a core dendrimer with either one, or possibly both of the Alexa Fluor® dyes (D) and (E) covalently bonded to amine nitrogens of the dendrimer via a –(C=O)– of the dye molecules.

[0049] In an embodiment, charged fluorescent particles may be configured to emit yellow-colored electromagnetic radiation. The charged fluorescent particles may have a core dendrimer with the Alexa Fluor® dye (F) covalently bonded to amine nitrogens of the dendrimer via a –(C=O)– of the dye molecules.

[0050] In an embodiment, charged fluorescent particles may be configured to emit red-colored electromagnetic radiation. The charged fluorescent particles may have a core dendrimer with either one, or possibly both of the Alexa Fluor® dyes (G) and (H) covalently bonded to amine nitrogens of the dendrimer via a –(C=O)– of the dye molecules.

[0051] Charged fluorescent particles may be produced by contacting fluorophores with dendrimers, wherein the fluorophores comprise at least one amine-reactive carbonyl group selected from the group comprising: aldehyde, ketone, carboxylic acid, ester, acyl halide, anhydride, and combinations thereof, and the dendrimers include at least one surface reactive amine. By selecting or configuring the fluorophores and dendrimers with such reactive groups, the at least one surface reactive amines may react with the at least one amine-reactive carbonyl group to covalently bond the dendrimer molecules with the fluorophores.

[0052] As represented in FIGS. 5 and 6, and discussed in more detail further below, a dendrimer molecule may be formed by providing a core unit and adding a first generation of branched molecular units to the core unit. Additional generations of branched molecular units may be added to a previous generation of branched molecular units to produce an m^{th} generation dendrimer having m generations of the branched molecular units. When the dendrimer molecule is of a desired size, or has a specified number of generations, fluorophores may be covalently bonded to the m^{th} generation of molecular units to produce a charged fluorescent dendrimer.

[0053] In an embodiment as depicted in FIG. 5, the core molecule may be cyanuric chloride and the method may include producing a 0^{th} generation dendrimer by reacting the cyanuric chloride with a mono-protected diamine to replace chlorine moieties of the cyanuric chloride with the diamine, and deprotecting the diamine to produce the 0^{th} generation dendrimer.

[0054] Additional generations may then be added to the 0^{th} generation dendrimer by reacting the 0^{th} generation dendrimer with cyanuric chloride to bond the cyanuric chloride to each diamine. The cyanuric chloride bonded to the diamine may be reacted with additional mono-protected diamine to replace chlorine moieties of the cyanuric chloride. The diamine may be deprotected to produce an additional generation of the dendrimer. For each additional generation desired, the above steps may be repeated. The outermost, or m^{th} generation applied may have free-reactive amines available for reacting with the fluorophores, and the amine surface groups may be subsequently reacted with an amine reactive charged fluorophore to produce charged fluorescent dendrimer particles.

[0055] To produce a 0^{th} generation dendrimer, a first solution of mono-protected diamine, diisopropylethylamine, and a solvent may be cooled to less than about 5 °C. A second solution of cyanuric chloride in a solvent may be added dropwise to the first solution to produce a third solution, and the third solution may be heated to and maintained at at least about 50 °C for a period of time sufficient for reaction between the cyanuric chloride and the diamine to produce protected dendrimers in a first mixture. The mixture may be cooled to about room temperature and filtered to remove any undissolved/unreacted particulates. Protected dendrimer may be precipitated by treating the first mixture with diethyl ether, and the protected dendrimers may be filtered from solution. The protected dendrimer may be treated to deblock the dendrimer and produce the 0^{th} generation dendrimer.

[0056] The additional generations may then be added by making a fourth solution of the dendrimer, diisopropylethylamine, and a solvent, and cooling the fourth solution to about 5 °C. A solution of cyanuric chloride in a solvent may be added dropwise to the fourth solution to produce a fifth solution and the fifth solution may be stirred for a period of time sufficient for bonding of the cyanuric chloride to the dendrimer. This fifth solution may be mixed with a sixth solution of the mono-protected diamine, diisopropylethylamine and a

solvent to produce a seventh solution. The seventh solution may be heated to and maintained at least about 50 °C to react the cyanuric chloride to the additional mono-protected diamine to produce a next generation protected dendrimer in a second mixture. As was done above for the first mixture, the second mixture may then be cooled to about room temperature, filtered, and treated with diethyl ether to precipitate the next generation protected dendrimer. The next generation protected dendrimer may then be treated to deblock the dendrimer and produce the additional generation.

[0057] In an alternative embodiment, as depicted in FIG. 6, poly(amidoamine) (PAMAM) dendrimers may also be used for producing charged fluorescent dendrimers. PAMAM dendrimers may have a diamine core, such as ethylene diamine as shown or another diamine, and may be constructed by a reiterative reaction sequence beginning with treatment of the diamine core with methyl acrylate (**a**) followed by treatment with an additional diamine, that may again be ethylene diamine (**b**) as shown or another diamine. Additional generations may be formed by repeating treatments with methyl acrylate and the diamine. In the final generation, the amine surface groups may be subsequently reacted with an amine reactive charged fluorophore to produce charged fluorescent dendrimer particles. As an alternative to producing such dendrimers, generation 0 to generation 10 PAMAM dendrimers having amine surface groups are available from Dendritech (Midland, MI).

[0058] Charged fluorescent dendrimers, such as, for example, any of the embodiments as discussed above, may be produced and marketed in a final dendrimer form. Alternatively, the components for producing the charged fluorescent dendrimers could be sold in kit form to allow an end user to produce the dendrimers on site, for example, and possibly on an 'as-needed' basis. Such a kit may be for producing microparticles that emit only one color, and may include the fluorophores that emit the color, as well as the dendrimers to which the fluorophores will be bonded to form the charged fluorescent

dendrimers. As an alternative, instead of containing the completed dendrimer core to which the fluorophores will be attached, the kit may include the components needed for constructing the dendrimer core, thereby giving the end-user the ability to alter the size of the dendrimers on site. In an embodiment, a kit may be configured for producing a first batch of microparticles that emit one color as well as a second batch of microparticles that emit another color, or any combination of two or more batches of microparticles that emit particular colors.

[0059] Such a kit, for example, may include fluorophores with a reactive functional group and dendrimers with a surface reactive functional group, wherein the reactive functional groups of the fluorophores and the surface reactive functional group of the dendrimers are configured to react and covalently bond the fluorophores to the dendrimer. The fluorophores and dendrimers may be any of the components as previously discussed.

[0060] As a non-limiting example, for particles that emit blue color, the kit may include fluorophores A and/or B of FIG. 4, and dendrimers **9** in FIG. 5 with surface reactive amines.

[0061] As a non-limiting example, for particles that emit yellow-green color, the kit may include fluorophores C of FIG. 4, and dendrimers **9** in FIG. 5 with surface reactive amines.

[0062] As a non-limiting example, for particles that emit green color, the kit may include fluorophores D and/or E of FIG. 4, and dendrimers **9** in FIG. 5 with surface reactive amines.

[0063] As a non-limiting example, for particles that emit yellow color, the kit may include fluorophores F of FIG. 4, and dendrimers **9** in FIG. 5 with surface reactive amines.

[0064] As a non-limiting example, for particles that emit red color, the kit may include fluorophores G and/or H of FIG. 4, and dendrimers **9** in FIG. 5 with surface reactive amines.

[0065] A kit may include any combination of, or all of the components for producing any combination of, or all of the red light-emitting microparticles, the blue light-emitting microparticles, green light-emitting microparticles, the yellow-green light-emitting microparticles, or the yellow light-emitting microparticles. In an additional embodiment, a kit may also be configured as a kit for producing an electrophoretic medium and may include a suitable solvent in addition to components for producing the microparticles, or alternatively the completed microparticles. The solvent may be a single-component solvent or solvent mixture selected from the solvent list as previously provided. In a further embodiment, a kit may also be configured as a kit for producing microcapsules filled with an electrophoretic medium. Such a kit may include components for producing the microparticles or the completed microparticles, a suitable solvent, and also micro-container components for containing the electrophoretic medium. The micro-container units may be microcapsules or other micro-container units selected from the examples as previously provided. In another embodiment, a kit may also be configured as a kit for producing an electrophoretic display. As such, the kit may include components for producing the microparticles or the completed microparticles, a suitable solvent, micro-container units, and electrode layers. The electrode layers may be selected from the examples as previously provided.

EXAMPLES

EXAMPLE 1: Production of Charged Fluorescent Dendrimers Capable of Emitting Red-Colored Light

[0066] As illustrated in FIG. 5, core dendrimers are synthesized by reiterative substitution reactions between cyanuric chloride **1** (a triazine derivative), and mono-Boc-protected diamine **2** or **3** followed by Boc-deprotection.

[0067] In a first iteration, a solution of the triazine **1** (about 1 equivalent) in a suitable solvent such as tetrahydrofuran (THF) is added drop-wise to an ice cold mixture of diamine **2** or **3** (about 3 equivalents), diisopropylethylamine (about 3 equivalents) and a suitable solvent such as THF. After about 1 hour, the mixture is heated slowly to about 70 °C and maintained at about 70 °C for about 6 hours. The mixture is cooled to room temperature, filtered to remove diisopropylethylamine hydrochloride and then treated with diethyl ether to precipitate the tris-Boc-protected triamino-triazine **4**. The tris-Boc-protected triamino-triazine **4** is filtered and treated with trifluoroacetic acid (TFA) in dichloroethane to deblock the Boc protective groups providing triamino-triazine **5**.

[0068] An additional generation is then added by starting with a drop-wise addition of a solution of triazine **1** (about 3 equivalents) in THF to an ice cold mixture of **5** (about 1 equivalent), diisopropylethylamine (about 3 equivalents) and THF. After stirring in an ice bath for about 1 hour, the mixture is treated with a mixture of diamine **2** or **3** (about 6 equivalents), diisopropylethylamine and THF and then heated slowly to about 70 °C and maintained at about 70 °C for about 6 hours. The mixture is cooled to room temperature, filtered, and treated with diethyl ether. The precipitate is treated with TFA and dichloroethane to provide hexamine **6**.

[0069] Additional generations may be added by repeating the above steps with appropriate proportions of reagents, until a desired number of generations are added. For example, component **7** is obtained from **6,** and component **8** is obtained from **7**.

[0070] In a final set of steps, the charged fluorescent dendrimers are synthesized by mixing dendrimer **8** and the carboxylic-reactive Alexa Fluor NHS ester (**G**) (about 1 equivalent per equivalent of free primary amino group present in **8**) in a dry polar aprotic solvent such as DMSO or N-methylpyrrolidinone (NMP). The mixture is stirred at room temperature or heated to about 60 °C overnight. The mixture is treated with a suitable solvent, such as toluene, to precipitate the dendrimer **9**. Anionic fluorescent dendrimer **9** that is capable of emitting red-colored light is filtered from solution and washed.

EXAMPLE 2: A Kit for Producing Charged Fluorescent Dendrimers

[0071] A kit is configured for producing colors for an RGB output device. The kit includes components for producing each of: dendrimers that emit red-colored light, dendrimers that emit green-colored light, and dendrimers that emit blue-colored light. For each of the three fluorescent dendrimers, the kit includes core dendrimers **8** as produced in Example 1. For the red-light emitting dendrimers, the kit includes Alexa Fluor® dye (E). For the green-light emitting dendrimers, the kit includes Alexa Fluor® dye (D). For the blue-light emitting dendrimers, the kit includes Alexa Fluor® dye (A).

EXAMPLE 3: An Electrophoretic Medium

[0072] An electrophoretic medium for use in electrophoretic displays includes any of the fluorescent dendrimers produced, for example, from the kit of Example 2, and according to the final steps in the procedure of Example 1. An electrophoretic medium having about 1 volume% to about 30 volume% charged dendrimers for producing a red color in an electrophoretic display is made by dispersing the red-fluorescing dendrimers of Example 1 in a hydrocarbon oil. Similarly, for any additional color desired, an electrophoretic medium having about 1 volume% to about 30 volume% charged dendrimers

for producing the desired color may be made by dispersing the appropriate fluorescing dendrimers in a hydrocarbon oil.

EXAMPLE 4: An Electrophoretic Display

[0073] Each individual electrophoretic medium of Example 3 is encapsulated within individual urea/melamine/formaldehyde microcapsules of about 50 micrometer diameter. The microcapsules are dispersed in a regular repeating pattern of colors, red-green-blue-red-green-blue, etc., on a conductive plates of indium tin oxide (ITO) on polyester, and the plate is connected to electrical circuitry that allows external signals to manipulate the electric charge at different precise points on the plate corresponding to individual microcapsules.

EXAMPLE 5: A Dual Layer Electrophoretic Display

[0074] Each individual electrophoretic medium of Example 3 is encapsulated within individual urea/melamine/formaldehyde microcapsules of about 50 micrometer diameter. The microcapsules are dispersed in a regular repeating pattern of colors, red-green-blue-red-green-blue, etc. between two parallel conductive plates of indium tin oxide (ITO) on polyester, spaced about 50 micrometers apart, and the plates are connected to electrical circuitry that allows external signals to manipulate the electric charge at different precise points on the plates corresponding to individual microcapsules.

EXAMPLE 6: Method of Using An Electrophoretic Display

[0075] An electrophoretic display as produced in Example 5 having red, green and blue fluorescing microcapsules will be provided as a color display in a cell-phone with the second electrode plate on top for viewing. An additional illuminating plate will be provided over the second electrode plate to expose the microcapsules to fluorescent light of a wavelength of about 350 nm to about 650 nm.

[0076] Since the microparticles are negatively charged, to activate the microcapsules a positive charge will be applied to the second plate adjacent the desired microcapsules to be activated, while a negative charge will be applied to the first plate. The microparticles in the activated microcapsules will then move towards the second plate to visibly fluoresce color at the second plate for viewing. To remove the colors from viewing, the charges will be reversed at the plates to withdraw the microparticles away from the second plate. As an example: to produce red in a portion of the display, individual microspheres containing red-fluorescing microparticles will be activated; to change the viewable color from red to green in that portion of the display, the red-fluorescing microspheres will be de-activated and the individual microspheres containing green-fluorescing microparticles will be activated; and to subsequently produce yellow in that same portion of the display, the microspheres containing the red-fluorescing microparticles will again be activated so that both red and green colors will be fluoresced to produce yellow.

[0077] 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.

[0078] 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.

[0079] 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.

[0080] 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.”

[0081] 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.

[0082] 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.

[0083] 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 of A, B, and 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, 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."

[0084] 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.

[0085] 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.

[0086] 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 to the at least one first electrode layer, wherein the electrophoretic medium comprises:

at least one electrically charged particle disposed in a fluid and capable of moving through the fluid upon application of an electrical field to the fluid, wherein the at least one charged particle comprises a charged fluorescent dendrimer configured for emitting a color different from a color of the fluid.

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

3. The electrophoretic display of claim 1, wherein the at least one charged particle has a cross-sectional dimension of about 1 nanometer to about 20 nanometers.

4. The electrophoretic display of claim 1, wherein the at least one charged particle is a nanoparticle having a cross-sectional dimension of about 2 nanometers to about 15 nanometers.

5. The electrophoretic display of claim 1, wherein the fluid is a transparent fluid.

6. The electrophoretic display of claim 1, wherein the at least one charged particle and the fluid have substantially matched densities.

7. The electrophoretic display of claim 6, wherein the fluid comprises at least one of: linear hydrocarbon oil, 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.

8. The electrophoretic display of claim 1, wherein the charged fluorescent dendrimer is an anionic fluorescent dendrimer.

9. The electrophoretic display of claim 8, wherein the anionic fluorescent dendrimer comprises anionic fluorophores covalently bonded to a dendrimer core.

10. The electrophoretic display of claim 1, wherein the charged fluorescent dendrimer comprises at least one charged fluorophore covalently bonded to a dendrimer core.

11. The electrophoretic display of claim 10, wherein:

the charged fluorophore is a derivative of a charged fluorophore molecule comprising at least one reactive functional group;

the dendrimer core is a derivative of a dendrimer molecule comprising at least one surface reactive functional group; and

the at least one surface reactive functional group of the dendrimer molecule is configured to react with the at least one reactive functional group of the charged fluorophore molecule to covalently link the dendrimer molecule with the charged fluorophore molecule.

12. The electrophoretic display of claim 11, wherein:

one of the reactive functional groups and the surface reactive functional groups, comprises amine-reactive carbonyl groups; and

the other one of the reactive functional groups and the surface reactive functional groups, comprises surface reactive amines.

13. The electrophoretic display of claim 10, wherein:

the charged fluorophore is a derivative of a charged fluorophore molecule comprising at least one amine-reactive carbonyl group; and

the dendrimer core is a derivative of a dendrimer molecule comprising at least one surface reactive amine.

14. The electrophoretic display of claim 13, wherein the dendrimer molecule comprises:

a central core comprising a first molecular species having at least two first reactive sites; and

at least a second molecular species covalently bonded at each of the at least two first reactive sites of the first molecular species to provide a 0th generation dendrimer, wherein each of the second molecular species comprises at least two additional reactive sites configured for attachment of one additional generation of the second molecular species to the 0th generation of the second molecular species.

15. The electrophoretic display of claim 14, wherein the dendrimer molecule comprises m generations of the second molecular species and the m^{th} generation comprises the surface reactive amines.

16. The electrophoretic display of claim 15, wherein:

the central core is a diamine with each amine of the diamine comprising two of the first reactive sites; and

each of the second molecular species is covalently bonded to a nitrogen of the amines at the first reactive sites, and comprises at least one additional free amine comprising the at least two additional reactive sites, wherein the at least one additional free amines in the mth generation comprises the surface reactive amines.

17. The electrophoretic display of claim 16, wherein:

the diamine is :N-A1-N:, wherein A1 is a substituted or non-substituted alkylene group, or a substituted or non-substituted arylene group; and

the second molecular species is -A2-CO-NH-A3-NX2, wherein X is hydrogen in the mth generation or a covalent bond in the 0th - (m-1)th generations, A2 is an alkylene group and A3 is a substituted or non-substituted alkylene group, or a substituted or non-substituted arylene group.

18. The electrophoretic display of claim 17, wherein A1, A2 and A3 are -CH2-CH2-.

19. The electrophoretic display of claim 13, wherein the dendrimer molecule has a central core of ($X\text{-}Y_n$) wherein X comprises a first molecular species having n substantially symmetrically disposed first functional groups, Y comprises a second molecular species having at least two second functional groups reactive with the first functional groups, n is the number of units of Y bonded to X, and the dendrimer molecule has a branching repeating structure of at least m generations of repeating units of ($X\text{-}Y_{n-1}$) wherein n-1 is the number of units of Y bonded to X, and the units Y in the m^{th} generation of the repeating units comprise the surface reactive amines.

20. The electrophoretic display of claim 19, wherein:

the dendrimer molecule is a 1 to 10 generation dendrimer;

X is 1,3,5-triazine; and

Y is a diaminyl terminated moiety.

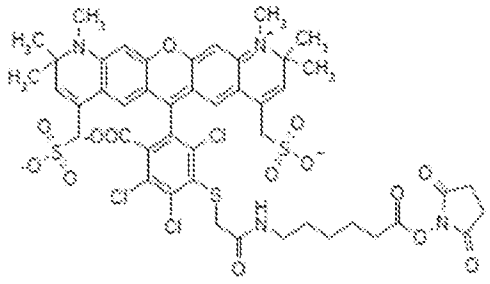
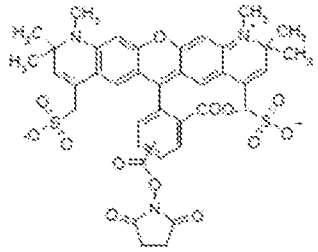
21. The electrophoretic display of claim 20, wherein Y is one of: aminomethylpiperidine, diaminodipropylamine, aminopiperidine, aminopyrrolidine, aminoalkylpiperidine, diaminodialkylamine, aminoalkylpyrrolidine,  , and -NH-A-NH, wherein A is C_2 to C_{10} alkylene.

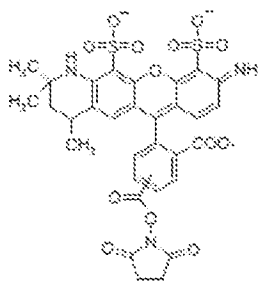
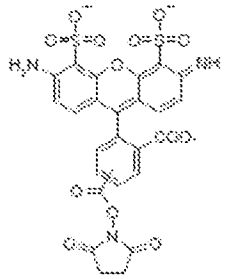
22. The electrophoretic display of claim 13, wherein the amine-reactive carbonyl group comprises at least one of: aldehyde, ketone, carboxylic acid, ester, acyl halide, and anhydride.

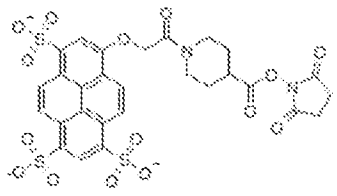
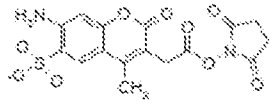
23. The electrophoretic display of claim 13, wherein the charged fluorophore molecule is selected from the group consisting of Alexa Fluor® 350 SE, Alexa Fluor® 405 SE, Alexa Fluor® 430 SE, Alexa Fluor® 488 SE, Alexa Fluor® 514 SE, Alexa Fluor® 532 SE, Alexa Fluor® 594 SE, Alexa Fluor® 610 SE, 5-carboxyfluorescein succinimidyl ester. 6-carboxyfluorescein succinimidyl ester, and Chromis 645 XT A – NHS ester.

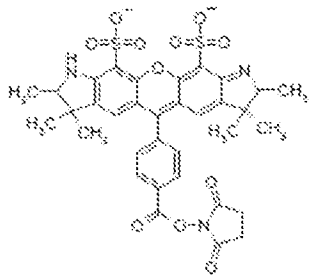
24. The electrophoretic display of claim 13, wherein the amine-reactive carbonyl group is N-hydroxysuccinimide ester.

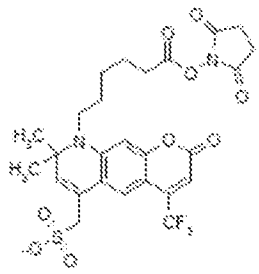
25. The electrophoretic display of claim 24, wherein the at least one charged nanoparticle is configured to emit red-colored electromagnetic radiation, and the charged fluorophore molecule

is at least one of  and  .

26. The electrophoretic display of claim 24, wherein the at least one charged nanoparticle is configured to emit green-colored electromagnetic radiation, and the charged fluorophore molecule is at least one of  and  .

27. The electrophoretic display of claim 24, wherein the at least one charged nanoparticle is configured to emit blue-colored electromagnetic radiation, and the charged fluorophore molecule is at least one of  and  .

28. The electrophoretic display of claim 24, wherein the at least one charged nanoparticle is configured to emit yellow-colored electromagnetic radiation, and the charged fluorophore molecule comprises  .

29. The electrophoretic display of claim 24, wherein the at least one charged nanoparticle is configured to emit yellow-green-colored electromagnetic radiation, and the charged fluorophore molecule comprises  .

30. The electrophoretic display of claim 1, further comprising:

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

a second substrate spaced apart from and opposite to the at least one first electrode layer on the first substrate and defining a chamber between the first substrate and the second substrate;

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

at least one microcapsule received in the chamber and sandwiched between the first and second electrode layers, wherein the microcapsule contain the electrophoretic medium therein.

31. The electrophoretic display of claim 30, incorporated into one of a cellular telephone, a book reader, a tablet computer, a portable computer, a smart card, a sign, a watch, and a shelf label.

32. The electrophoretic display of claim 1, wherein the display is flexible or not flexible.

33. A method of using an electrophoretic display, the method comprising:

providing an electrophoretic display to emit colored electromagnetic radiation from a surface of the display, the display comprising at least one first electrode layer and an array of microcapsules disposed adjacent to the at least one first electrode layer with a first side of the microcapsules adjacent to the at least one first electrode layer and a second side of the microcapsules away from the at least one first electrode layer, wherein each of the microcapsules comprises an electrophoretic medium comprising at least one electrically charged particle disposed in a fluid and capable of moving through the fluid upon application of an electrical field to the fluid, wherein the at least one charged particle comprises a charged fluorescent dendrimer;

selectively applying an electric charge to the first electrode layer adjacent to selected microcapsules in the array to cause the at least one charged particle in the selected microcapsules to move away from the first electrode layer to the second side of the selected microcapsules; and

irradiating the display with electromagnetic radiation capable of fluorescing the at least one charged particle to emit colored electromagnetic radiation from the second side of the selected microcapsules.

34. The method of claim 33, wherein the display is a display 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 side of the microcapsules visible for viewing emitted colored electromagnetic radiation.

35. The method of claim 33, further comprising reversing or turning off the electric charge to the selected microcapsules to cause the at least one charged particle in the selected microcapsules to move towards the first electrode layer to terminate emission of the colored electromagnetic radiation from the second side of the selected microcapsules.

36. The method of claim 33, wherein the display is a multi-color display and the at least one charged particle in each microcapsule comprises one of: charged particles capable of fluorescing blue color, charged particles capable of fluorescing green color, charged particles capable of fluorescing red color, charged particles capable of fluorescing yellow color, and charged particles capable of fluorescing yellow-green color, and the method further comprises at least one of:

selectively applying the electric charge to the first electrode layer adjacent to selected microcapsules comprising charged particles capable of fluorescing blue color to cause the charged particles capable of fluorescing blue color in the selected microcapsules to move away from the first electrode layer to emit a blue colored electromagnetic radiation at the second side of the selected microcapsules;

selectively applying the electric charge to the first electrode layer adjacent to selected microcapsules comprising charged particles capable of fluorescing red color to cause the charged particles capable of fluorescing red color in the selected microcapsules to move away from the first electrode layer to emit a red colored electromagnetic radiation at the second side of the selected microcapsules;

selectively applying the electric charge to the electrode layer adjacent to selected microcapsules comprising charged particles capable of fluorescing green color to cause the charged particles capable of fluorescing green color in the selected microcapsules to move away from the first electrode layer to emit a green colored electromagnetic radiation at the second side of the selected microcapsules;

selectively applying the electric charge to the first electrode layer adjacent to selected microcapsules comprising charged particles capable of fluorescing yellow color to cause the charged particles capable of fluorescing yellow color in the selected microcapsules to move away from the first electrode layer to emit a yellow colored electromagnetic radiation at the second side of the selected microcapsules; and

selectively applying the electric charge to the first electrode layer adjacent to selected microcapsules comprising charged particles capable of fluorescing yellow-green color to cause the charged particles capable of fluorescing yellow-green color in the selected microcapsules to move away from the first electrode layer to emit a yellow-green colored electromagnetic radiation at the second side of the selected microcapsules.

37. The method of claim 36, wherein:

the microcapsules are arranged in repeating sets of microcapsules wherein each microcapsule comprises one of: the charged particles capable of fluorescing

blue color, the charged particles capable of fluorescing green color, the charged particles capable of fluorescing red color, the charged particles capable of fluorescing yellow color, and the charged particles capable of fluorescing yellow-green color; and

the method comprises selectively applying the electric charge to the first electrode layer adjacent to selected combinations of microcapsules to emit combinations of colored electromagnetic radiation at the second side of the microcapsules.

38. The method of claim 36, wherein:

the display further comprises a second electrode layer disposed adjacent to the second side of the microcapsules, and the method further comprises:

selectively applying an electric field between the first and second electrode layers for selected microcapsules to move the at least one charged particle in the selected microcapsules toward or away from the second side of the microcapsules to selectively emit and terminate emission of the colored electromagnetic radiation from the second side of the microcapsules.

39. The method of claim 33, wherein the at least one charged particle has a cross-sectional dimension of about 1 nanometer to about 20 nanometer.

40. The method of claim 33, wherein the at least one charged particle is a nanoparticle having a cross-sectional dimension of about 2 nanometers to about 15 nanometers.

41. The method of claim 33, wherein the fluid is a transparent fluid.

42. The method of claim 39, wherein the charged fluorescent dendrimer comprises at least one charged fluorophore covalently bonded to a dendrimer core.

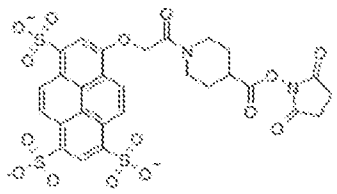
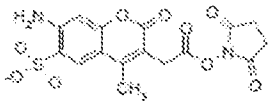
43. The method of claim 42, wherein:

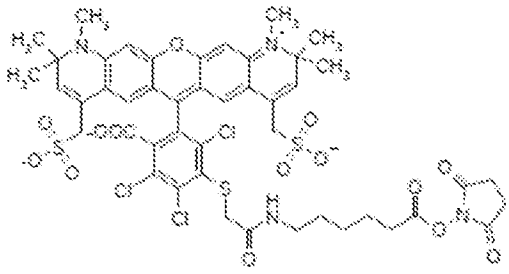
the charged fluorophore is a derivative of a charged fluorophore molecule comprising at least one amine-reactive carbonyl group; and

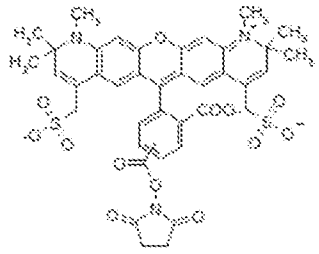
the dendrimer core is a derivative of a dendrimer molecule comprising at least one surface reactive amines.

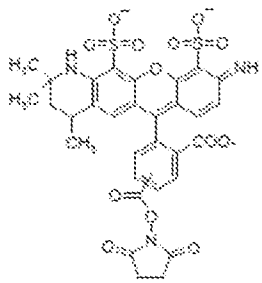
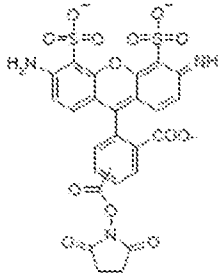
44. The method of claim 42, wherein the amine-reactive carbonyl group is N-hydroxysuccinimide ester.

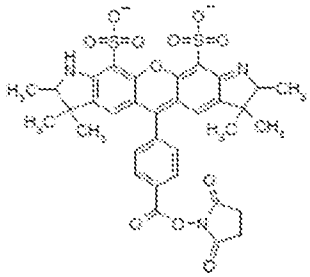
45. The method of claim 44, wherein:

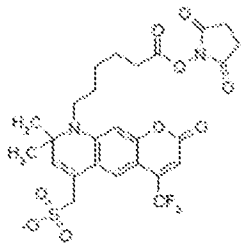
for the charged particles capable of fluorescing blue color, the charged fluorophore molecule is at least one of  and  ;

for the charged particles capable of fluorescing red color, the charged fluorophore molecule is at least one of  and


;

for the charged particles capable of fluorescing green color, the charged fluorophore molecule is at least one of  and  ;

for the charged particles capable of fluorescing yellow color, the charged fluorophore molecule is  ; and

for the charged particles capable of fluorescing yellow-green color, the charged fluorophore molecule is  .

46. An electrophoretic medium comprising at least one electrically charged particle disposed in a fluid and capable of moving through the fluid upon application of an electrical field to the fluid, wherein the at least one charged particle comprises a charged fluorescent dendrimer.

47. The electrophoretic medium of claim 46, wherein the at least one charged particle has a cross-sectional dimension of about 1 nanometer to about 20 nanometer.

48. The electrophoretic medium of claim 46, wherein the at least one charged particle is a nanoparticle having a cross-sectional dimension of about 2 nanometers to about 15 nanometers.

49. The electrophoretic medium of claim 46, wherein the at least one charged particle is an anionic fluorescent dendrimer comprising anionic fluorophores covalently bonded to a dendrimer core.

50. The electrophoretic medium of claim 46, wherein the at least one charged particle and the transparent fluid have substantially matched densities.

51. The electrophoretic medium of claim 50, wherein the fluid comprises a transparent fluid comprising at least one of: linear hydrocarbon oil, 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.

52. The electrophoretic medium of claim 46, wherein the charged fluorescent dendrimer comprises at least one charged fluorophore covalently bonded to a dendrimer core.

53. The electrophoretic medium of claim 52, wherein:

the charged fluorophore is a derivative of a charged fluorophore molecule comprising at least one reactive functional group;

the dendrimer core is a derivative of a dendrimer molecule comprising at least one surface reactive functional group; and

the at least one surface reactive functional group of the dendrimer molecule is configured to react with the at least one reactive functional group of the fluorophore molecule to covalently link the dendrimer molecule with the charged fluorophore molecule.

54. The electrophoretic medium of claim 53, wherein:

one of the reactive functional groups and the surface reactive functional groups,

comprises amine-reactive carbonyl groups; and

the other one of the reactive functional groups and the surface reactive functional groups, comprises surface reactive amines.

55. The electrophoretic medium of claim 52, wherein:

the charged fluorophore is a derivative of a charged fluorophore molecule comprising at least one amine-reactive carbonyl group; and

the dendrimer core is a derivative of a dendrimer molecule comprising surface reactive amine.

56. The electrophoretic medium of claim 55, wherein the charged fluorophore molecule is selected from the group consisting of Alexa Fluor® 350 SE, Alexa Fluor® 405 SE, Alexa Fluor® 430 SE, Alexa Fluor® 488 SE, Alexa Fluor® 514 SE, Alexa Fluor® 532

SE, Alexa Fluor® 594 SE, Alexa Fluor® 610 SE, 5-carboxyfluorescein succinimidyl ester. 6-carboxyfluorescein succinimidyl ester, and Chromis 645 XT A – NHS ester.

57. The electrophoretic medium of claim 55, wherein the dendrimer molecule has a central core of ($X-Y_n$) wherein X comprises a first molecular species having n substantially symmetrically disposed first functional groups, Y comprises a second molecular species having at least two second functional groups reactive with the first functional groups, n is the number of units of Y bonded to X, and the dendrimer molecule has a branching repeating structure of at least m generations of repeating units of ($X-Y_{n-1}$) wherein n-1 is the number of units of Y bonded to X, and the units Y in the m^{th} generation of the repeating units comprise the surface reactive amines.

58. The electrophoretic medium of claim 57, wherein:

the dendrimer molecule is a 1 to 10 generation dendrimer;

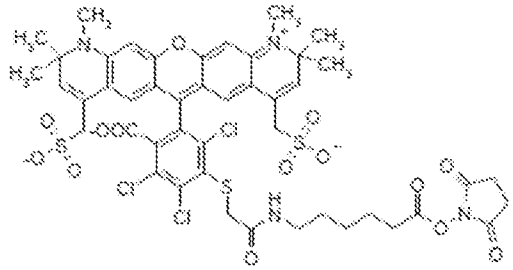
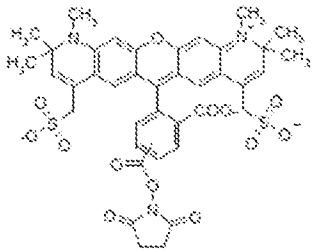
X is 1,3,5-triazine; and

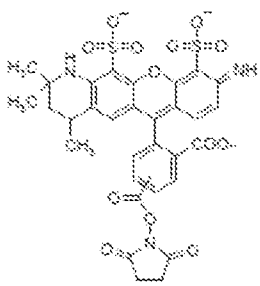
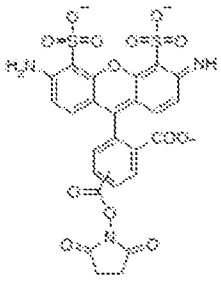
Y is a diaminyl terminated moiety.

59. The electrophoretic medium of claim 58, wherein Y is one of: aminomethylpiperidine, diaminodipropylamine, aminopiperidine, aminopyrrolidine, aminoalkylpiperidine, diaminodialkylamine, aminoalkylpyrrolidine,  , and -NH-A-NH, wherein A is C_2 to C_{10} alkylene.

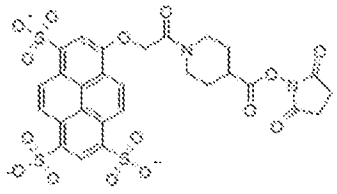
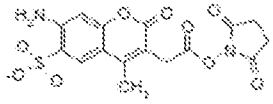
60. The electrophoretic medium of claim 55, wherein the amine-reactive carbonyl group comprises at least one of: aldehyde, ketone, carboxylic acid, ester, acyl halide, and anhydride.

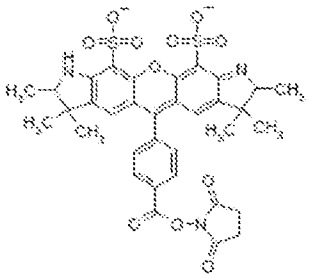
61. The electrophoretic medium of claim 55, wherein the amine-reactive carbonyl group is N-hydroxysuccinimide ester.

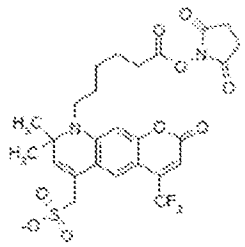
62. The electrophoretic medium of claim 61, wherein the at least one charged particle is configured to emit red-colored electromagnetic radiation and the charged fluorophore molecule is at least one of  and  .

63. The electrophoretic medium of claim 61, wherein the at least one charged particle is configured to emit green-colored electromagnetic radiation and the charged fluorophore molecule is at least one of  and  .

64. The electrophoretic medium of claim 61, wherein the at least one charged particle is configured to emit blue-colored electromagnetic radiation and the charged

fluorophore molecule is at least one of  and  .

65. The electrophoretic medium of claim 61, wherein the at least one charged particle is configured to emit yellow-colored electromagnetic radiation and the charged fluorophore molecule comprises  .

66. The electrophoretic medium of claim 61, wherein the at least one charged particle is configured to emit yellow-green-colored electromagnetic radiation and the charged fluorophore molecule comprises  .

67. A kit for producing charged fluorescent dendrimers, the kit comprising:

core dendrimers; and

charged fluorophores configured to covalently bond with the dendrimers to form the charged fluorescent dendrimers.

68. The kit of claim 67, wherein:

the core dendrimers comprise at least one surface reactive functional group;

the fluorophores comprise at least one reactive functional group; and

the at least one surface reactive functional group of the dendrimers is configured to react with the at least one reactive functional group of the fluorophores to covalently link the fluorophores with the core dendrimers.

69. The electrophoretic display of claim 68, wherein the core dendrimers comprise:

a central core comprising a first molecular species having at least two first reactive sites; and

at least a second molecular species covalently bonded at each of the at least two first reactive sites of the first molecular species to provide a 0th generation dendrimer, wherein each of the second molecular species comprises at least two additional reactive sites configured for attachment of one additional generation of the second molecular species to the 0^{th} generation of the second molecular species.

70. The electrophoretic display of claim 69, wherein the dendrimer molecule comprises m generations of the second molecular species and the m^{th} generation comprises the surface reactive functional group.

71. The electrophoretic display of claim 70, wherein:

the central core is a diamine with each amine of the diamine comprising two of the first reactive sites; and

each of the second molecular species is covalently bonded to a nitrogen of the amines at the first reactive sites, and comprises at least one additional free amine

comprising the at least two additional reactive sites, wherein the at least one additional free amines in the m^{th} generation comprises the surface reactive functional group.

72. The electrophoretic display of claim 71, wherein:

the diamine is :N-A1-N:, wherein A1 is a substituted or non-substituted alkylene group, or a substituted or non-substituted arylene group; and

the second molecular species is -A2-CO-NH-A3-NX_2, wherein X is hydrogen in the m^{th} generation or a covalent bond in the 0^{th} - $(m-1)^{th}$ generations, A2 is an alkylene group and A3 is a substituted or non-substituted alkylene group, or a substituted or non-substituted arylene group.

73. The electrophoretic display of claim 72, wherein A1, A2 and A3 are -CH2-CH2-.

74. The kit of claim 68, wherein:

one of the reactive functional groups and the surface reactive functional groups, comprises amine-reactive carbonyl groups; and

the other of the reactive functional groups and the surface reactive functional groups, comprises surface reactive amines.

75. The kit of claim 67, wherein:

the fluorophores comprise at least one amine-reactive carbonyl group; and

the core dendrimers comprises at least one surface reactive amine.

76. The kit of claim 67, wherein the fluorophores are selected from the group consisting of Alexa Fluor® 350 SE, Alexa Fluor® 405 SE, Alexa Fluor® 430 SE, Alexa

Fluor® 488 SE, Alexa Fluor® 514 SE, Alexa Fluor® 532 SE, Alexa Fluor® 594 SE, Alexa Fluor® 610 SE, 5-carboxyfluorescein succinimidyl ester. 6-carboxyfluorescein succinimidyl ester, and Chromis 645 XT A – NHS ester.

77. The kit of claim 75, wherein the core dendrimers have a central core of $(X\text{-}Y_n)$ wherein X comprises a first molecular species having n substantially symmetrically disposed first functional groups, Y comprises a second molecular species having at least two second functional groups reactive with the first functional groups, n is the number of units of Y bonded to X, and the dendrimer molecule has a branching repeating structure of at least m generations of repeating units of $(X\text{-}Y_{n-1})$ wherein n-1 is the number of units of Y bonded to X, and the units Y in the m^{th} generation of the repeating units comprise the surface reactive amines.

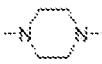
78. The kit of claim 77, wherein:

the core dendrimers are 1 to 10 generation dendrimers;

X is 1,3,5-triazine; and

Y is a diaminyl terminated moiety.

79. The kit of claim 78, wherein Y is one of: aminomethylpiperidine, diaminodipropylamine, aminopiperidine, aminopyrrolidine, aminoalkylpiperidine,

diaminodialkylamine, aminoalkylpyrrolidine,  , and -NH-A-NH, wherein A is C_2 to C_{10} alkylene.

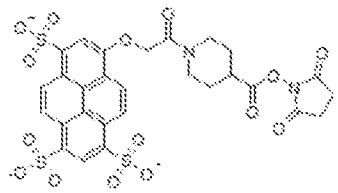
80. The kit of claim 75, wherein the amine-reactive carbonyl group comprises at least one of: aldehydes, ketones, carboxylic acids, esters, acyl halides, and anhydrides.

81. The kit of claim 75, wherein the amine-reactive carbonyl group is N-hydroxysuccinimide ester.

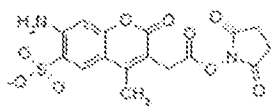
82. The kit of claim 81, wherein:

the kit is configured to produce charged fluorescent dendrimers capable of emitting blue-colored light upon excitation with electromagnetic radiation; and

the fluorophores comprise at least one of:



capable of emitting about 421 nm electromagnetic radiation upon excitation with electromagnetic radiation of about 402 nm; and

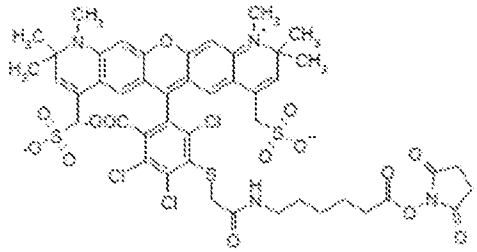


capable of emitting about 442 nm electromagnetic radiation upon excitation with electromagnetic radiation of about 346 nm.

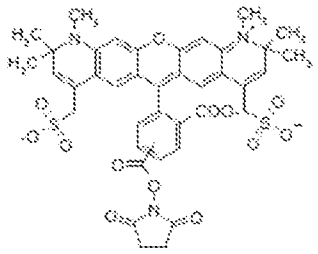
83. The kit of claim 81, wherein:

the kit is configured to produce charged fluorescent dendrimers capable of emitting red-colored light upon excitation with electromagnetic radiation; and

the fluorophores comprise at least one of:



capable of emitting about 628 nm electromagnetic radiation upon excitation with electromagnetic radiation of about 612 nm; and

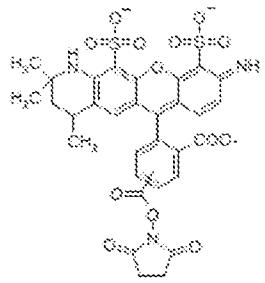


capable of emitting about 617 nm electromagnetic radiation upon excitation with electromagnetic radiation of about 590 nm.

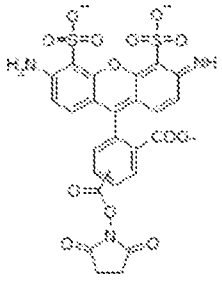
84. The kit of claim 81, wherein:

the kit is configured to produce charged fluorescent dendrimers capable of emitting green-colored light upon excitation with electromagnetic radiation; and

the fluorophores comprise at least one of:

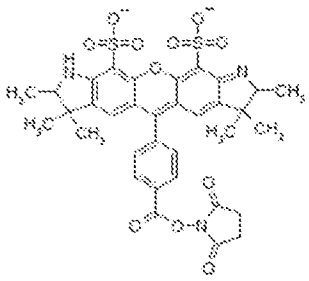


capable of emitting about 540 nm electromagnetic radiation upon excitation with electromagnetic radiation of about 518 nm; and

 capable of emitting about 519 nm electromagnetic radiation upon excitation with electromagnetic radiation of about 495 nm.

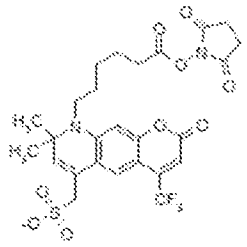
85. The kit of claim 81, wherein:

the kit is configured to produce charged fluorescent dendrimers capable of emitting yellow-colored light upon excitation with electromagnetic radiation; and

the fluorophores comprise  capable of emitting about 554 nm electromagnetic radiation upon excitation with electromagnetic radiation of about 531 nm.

86. The kit of claim 81, wherein:

the kit is configured to produce charged fluorescent dendrimers capable of emitting yellow-green-colored light upon excitation with electromagnetic radiation; and

the fluorophores comprise  capable of emitting about 539 nm electromagnetic radiation upon excitation with electromagnetic radiation of about 434 nm.

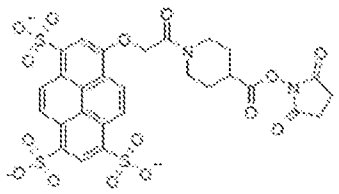
87. The kit of claim 81, wherein:

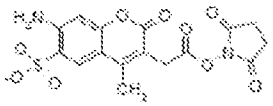
the kit is configured to produce any selected combination of two or more of: charged fluorescent dendrimers capable of emitting blue-colored light, charged fluorescent dendrimers capable of emitting green-colored light, charged fluorescent dendrimers capable of emitting yellow-colored light, charged fluorescent dendrimers capable of emitting yellow-green-colored light, and charged fluorescent dendrimers capable of emitting red-colored light;

the core dendrimers have a central core of $(X\text{-}Y_n)$ wherein n is the number of units of Y bonded to X, and the dendrimer molecule has a branching repeating structure of at least m generations of repeating units of $(X\text{-}Y_{n-1})$ wherein n-1 is the number of units of Y bonded to X, and the units Y in the m^{th} generation of the repeating units comprise the surface reactive amines, wherein the dendrimer molecule is a 1 to 10 generation dendrimer, X is 1,3,5-triazine, and Y is a diaminyl terminated moiety; and

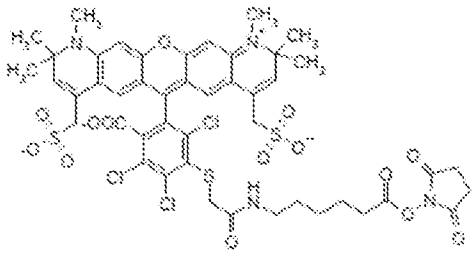
for the selected combination, the fluorophores comprise corresponding ones of:

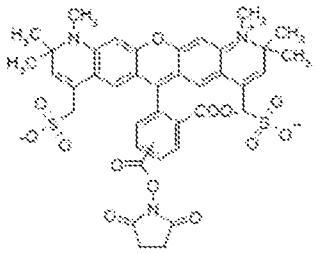
for the charged fluorescent dendrimers capable of emitting blue-colored light

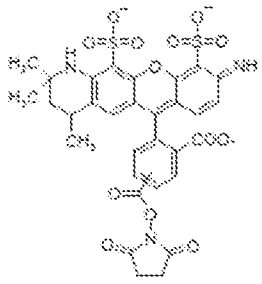
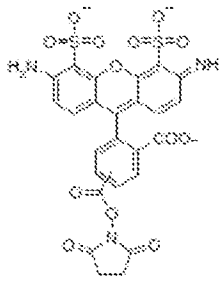
the fluorophores comprise at least one of:  and

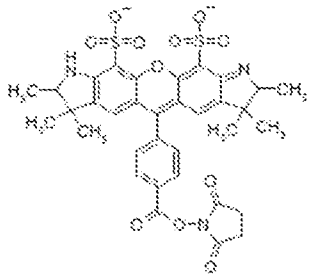
 ;

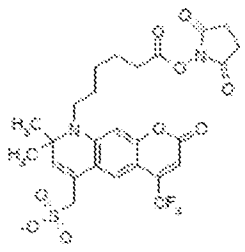
for the charged fluorescent dendrimers capable of emitting red-colored light

the fluorophores comprise at least one of:  and

 ;

for the charged fluorescent dendrimers capable of emitting green-colored light the fluorophores comprise at least one of:  and  ;

for the charged fluorescent dendrimers capable of emitting yellow-colored light the fluorophores comprise  ; and

for the charged fluorescent dendrimers capable of emitting yellow-green-colored light the fluorophores comprise  .

88. The kit of claim 87, wherein the kit comprises a kit for producing an electrophoretic medium and the kit additionally comprises a transparent fluid configured for suspension of the charged fluorescent dendrimers therein.

89. The kit of claim 88, 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.

90. The kit of claim 88, wherein the kit comprises a kit for producing microcapsules of electrophoretic medium, and the kit additionally comprises at least one polymer for encapsulating the electrophoretic medium.

91. The kit of claim 90, wherein the kit comprises a kit for producing an electrophoretic display and the kit additionally comprises first and second electrode layers for sandwiching the microcapsules therebetween.

92. A charged fluorescent particle for an electrophoretic display, the charged fluorescent particle comprising at least one charged fluorophore covalently bonded to a dendrimer core, wherein:

the charged fluorophore is a derivative of a charged fluorophore molecule comprising at least one reactive functional group;

the dendrimer core is a derivative of a dendrimer molecule comprising at least one surface reactive functional group;

one of the reactive functional groups and the surface reactive functional groups

comprises amine-reactive carbonyl groups; and

the other one of the reactive functional groups and the surface reactive functional groups

comprises surface reactive amines.

93. The charged fluorescent particle of claim 92, wherein:

the charged fluorophore is a derivative of a charged fluorophore molecule comprising at least one amine-reactive carbonyl group; and

the dendrimer core is a derivative of a dendrimer molecule comprising at least one surface reactive amine.

94. The charged fluorescent particle of claim 93, wherein the charged fluorophore molecule is selected from the group consisting of Alexa Fluor® 350 SE, Alexa Fluor® 405 SE, Alexa Fluor® 430 SE, Alexa Fluor® 488 SE, Alexa Fluor® 514 SE, Alexa Fluor® 532 SE, Alexa Fluor® 594 SE, Alexa Fluor® 610 SE, 5-carboxyfluorescein succinimidyl ester. 6-carboxyfluorescein succinimidyl ester, and Chromis 645 XT A – NHS ester.

95. The charged fluorescent particle of claim 93, wherein the dendrimer molecule has a central core of $(X\text{-}Y_n)$ wherein X comprises a first molecular species having n substantially symmetrically disposed first functional groups, Y comprises a second molecular species having at least two second functional groups reactive with the first functional groups, n is the number of units bonded to X, and the dendrimer molecule has a branching repeating structure of m generations of repeating units of $(X\text{-}Y_{n-1})$ wherein n-1 is the number of units of Y bonded to X, and the units Y in the m^{th} generation of the repeating units comprise the surface reactive amines.

96. The charged fluorescent particle of claim 95, wherein:

the dendrimer molecule is a 1 to 10 generation dendrimer;

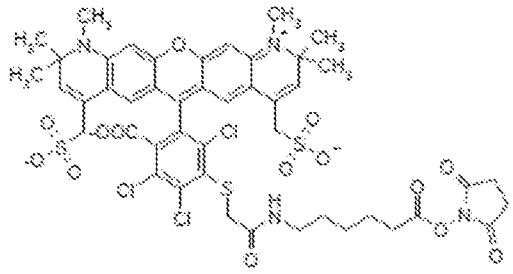
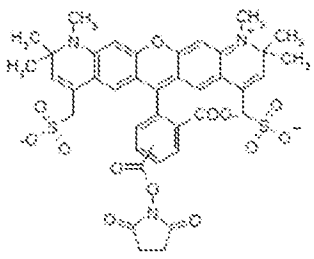
X is 1,3,5-triazine; and

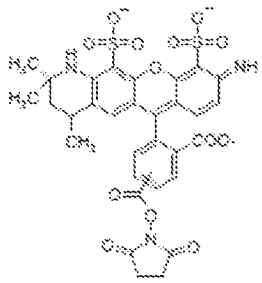
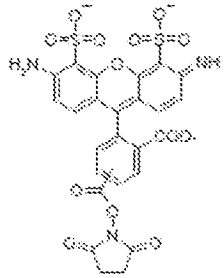
Y is a diaminyl terminated moiety.

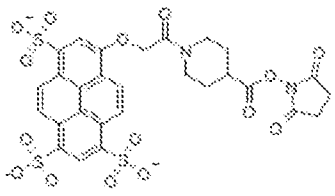
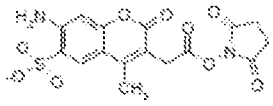
97. The charged fluorescent particle of claim 95, wherein Y is one of: aminomethylpiperidine, diaminodipropylamine, aminopiperidine, aminopyrrolidine, aminoalkylpiperidine, diaminodialkylamine, aminoalkylpyrrolidine,  , and -NH-A-NH, wherein A is C_2 to C_{10} alkylene.

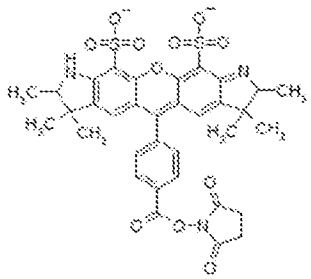
98. The charged fluorescent particle of claim 93, wherein the amine-reactive carbonyl group includes: aldehydes, ketones, carboxylic acids, esters, acyl halides, and anhydrides.

99. The charged fluorescent particle of claim 93, wherein the amine-reactive carbonyl group is N-hydroxysuccinimide ester.

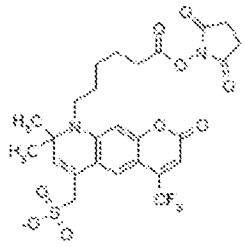
100. The charged fluorescent particle of claim 92, wherein the charged fluorescent particle is configured to emit red-colored electromagnetic radiation and the charged fluorophore molecule is at least one of  and  .

101. The charged fluorescent particle of claim 92, wherein the at least one charged particle is configured to emit green-colored electromagnetic radiation and the charged fluorophore molecule is at least one of  and  .

102. The charged fluorescent particle of claim 92, wherein the at least one charged particle is configured to emit blue-colored electromagnetic radiation and the charged fluorophore molecule is at least one of  and  .

103. The charged fluorescent particle of claim 92, wherein the at least one charged particle is configured to emit yellow-colored electromagnetic radiation and the charged fluorophore molecule comprises  .

104. The charged fluorescent particle of claim 92, wherein the at least one charged particle is configured to emit yellow-green-colored electromagnetic radiation and the charged

fluorophore molecule comprises  .

105. A method for producing charged fluorescent particles, the method comprising:

contacting charged fluorophores with dendrimers, wherein:

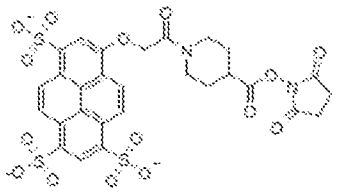
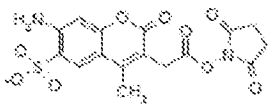
the fluorophores comprise at least one amine-reactive carbonyl group selected from the group comprising: aldehyde, ketone, carboxylic acid, ester, acyl halide, anhydride, and combinations thereof, and

the dendrimers comprise at least one surface reactive amine, and

wherein the at least one surface reactive amine reacts with the at least one amine-reactive carbonyl group to covalently bond the dendrimers with the fluorophores to form the charged fluorescent particles.

106. The method of claim 105, wherein:

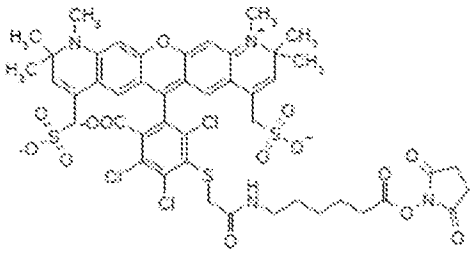
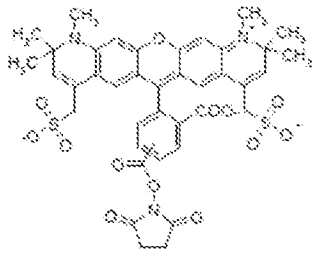
the charged fluorescent particles are capable of emitting blue-colored electromagnetic radiation; and

the fluorophores comprise at least one of:  and  .

107. The method of claim 105, wherein:

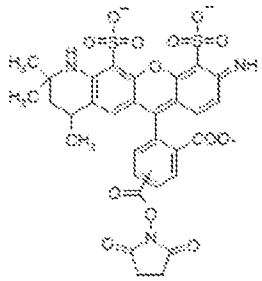
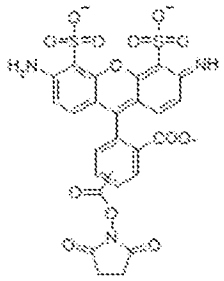
the charged fluorescent particles are capable of emitting red-colored electromagnetic radiation; and

the fluorophores comprise at least one of:

 and  .

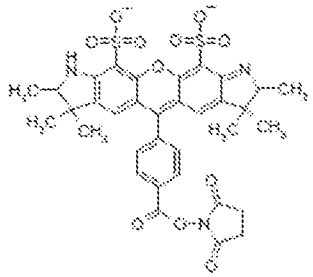
108. The method of claim 105, wherein:

the charged fluorescent particles are capable of emitting green-colored electromagnetic radiation; and

the fluorophores comprise at least one of:  and  .

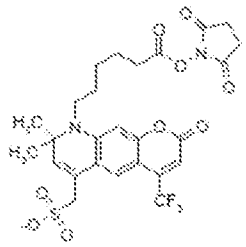
109. The method of claim 105, wherein:

the charged fluorescent particles are capable of emitting yellow-colored electromagnetic radiation; and

the fluorophores comprise  .

110. The method of claim 105, wherein:

the charged fluorescent particles are capable of emitting yellow-green colored electromagnetic radiation; and

the fluorophores comprise  .

111. The method of claim 105, further comprising:

forming the dendrimers, wherein forming the dendrimers comprises:

providing a core molecule;

adding a 0^{th} generation of molecular units to the core molecule; and

successively adding additional generations of molecular units to a previous generation of molecular units to produce an m^{th} generation dendrimer having m generations of the molecular units; and

wherein contacting the charged fluorophores with the dendrimers comprises covalently bonding the fluorophores to the m^{th} generation of molecular units.

112. The method of claim 111, wherein the fluorophores are selected from the group consisting of Alexa Fluor® 350 SE, Alexa Fluor® 405 SE, Alexa Fluor® 430 SE, Alexa Fluor® 488 SE, Alexa Fluor® 514 SE, Alexa Fluor® 532 SE, Alexa Fluor® 594 SE,

Alexa Fluor® 610 SE, 5-carboxyfluorescein succinimidyl ester. 6-carboxyfluorescein succinimidyl ester, and Chromis 645 XT A – NHS ester.

113. The method of claim 111, wherein the core molecule comprises cyanuric chloride and the method further comprises:

producing the 0^{th} generation dendrimer by:

reacting the cyanuric chloride with a mono-protected diamine to replace chlorine moieties of the cyanuric chloride with the diamine; and

deprotecting the diamine to produce the 0^{th} generation dendrimer.

114. The method of claim 113, further comprising producing an additional generation of the dendrimer by:

A) reacting the 0^{th} generation dendrimer with cyanuric chloride to bond the cyanuric chloride to each diamine;

B) reacting the cyanuric chloride bonded to the diamine with additional mono-protected diamine to replace chlorine moieties of the cyanuric chloride bonded to the diamine; and

C) deprotecting the diamine to produce the additional generation of the dendrimer; and

D) repeating step A, step B and step C (m-1) additional times to produce the (m^{th}) generation dendrimer comprising free-reactive amines in the (m^{th}) generation.

115. The method of claim 114, wherein producing the 0^{th} generation dendrimer additionally comprises:

cooling a first solution of the mono-protected diamine, diisopropylethylamine, and a solvent to less than about 5 °C;

drop-wise addition of a second solution of cyanuric chloride in a solvent to the first solution after cooling to produce a third solution;

heating and maintaining the third solution to at least about 50 °C for a period of time sufficient for reaction between the cyanuric chloride and the diamine to produce a protected dendrimer in a first mixture;

cooling the first mixture to about room temperature;

filtering the first mixture;

treating the first mixture with diethyl ether to precipitate the protected dendrimer; and

treating the protected dendrimer to deblock the dendrimer and produce the 0^{th} generation dendrimer.

116. The method of claim 114, wherein step A additionally comprises:

cooling a fourth solution of the dendrimer, diisopropylethylamine, and a solvent to about 5 °C;

dropwise addition of a fifth solution of cyanuric chloride in a solvent to the fourth solution after cooling; and

stirring for a period of time sufficient for bonding of the cyanuric chloride to the dendrimer to produce a fifth solution.

117. The method of claim 116, wherein step B additionally comprises:

mixing the fifth solution of step A with a sixth solution of the mono-protected diamine, diisopropylethylamine and a solvent to produce a seventh solution;

heating and maintaining the seventh solution to at least about 50 °C for reacting the cyanuric chloride bonded to the additional mono-protected diamine to produce a next generation protected dendrimer in a second mixture;

cooling the second mixture to about room temperature;

filtering the second mixture; and

treating the second mixture with diethyl ether to precipitate the next generation protected dendrimer.

118. The method of claim 117, wherein step C additionally comprises treating the next generation protected dendrimer of Step B to deblock the dendrimer and produce the additional generation.

119. The method of claim 111, wherein:

the core molecule comprises a first diamine;

adding the 0^{th} generation of molecular units comprises:

A) contacting the first diamine with methyl acrylate to covalently bond the methyl acrylate with an amine nitrogen of the first diamines to produce a methyl acrylate substituted diamine; and

B) contacting the methyl acrylate substituted diamine with a second diamine to produce an amidoamine as the 0^{th} generation of molecular units; and

successively adding additional generations of molecular units comprises repeating the steps of A and B for each generation.

120. The method of claim 119, wherein the first and the second diamines are the same or different ones of the group consisting of: aminomethylpiperidine, diaminodipropylamine, aminopiperidine, aminopyrrolidine, aminoalkylpiperidine,

diaminodialkylamine, aminoalkylpyrrolidine,  , and –NH-A-NH- wherein A is a substituted or unsubstituted alkylene, or a substituted or unsubstituted arylene.

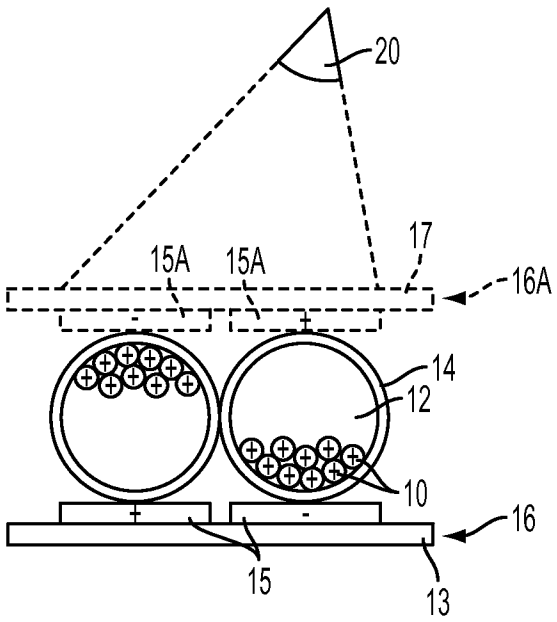

20
17
15A
15A
16A
14
12
10
16
15
13

FIG. 1A

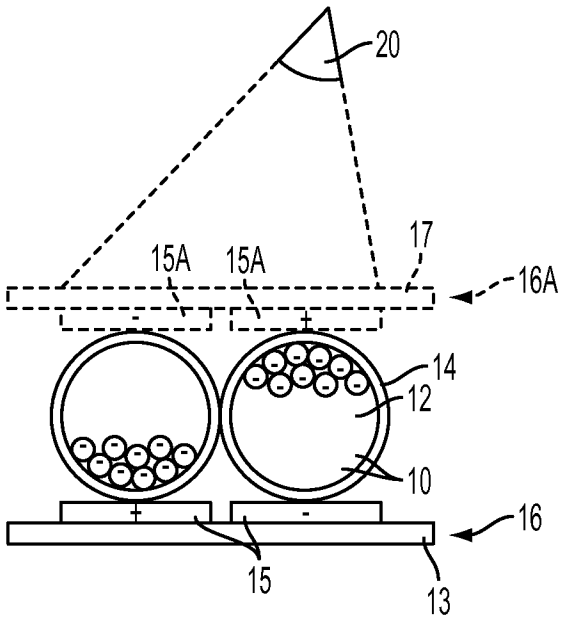

20
17
15A
15A
16A
14
12
10
16
15
13

FIG. 1B

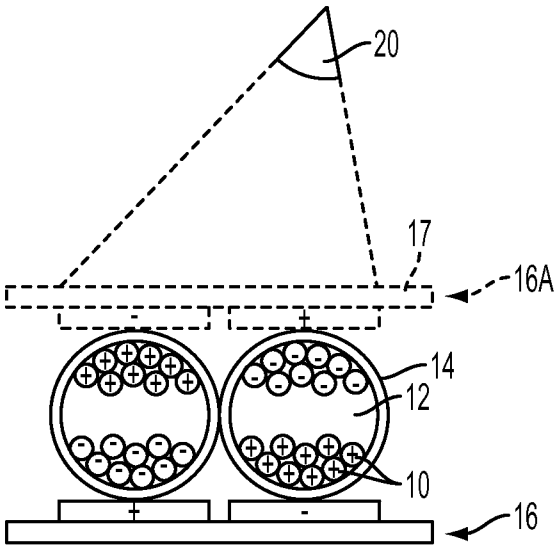

20
17
16A
14
12
10
16

FIG. 1C

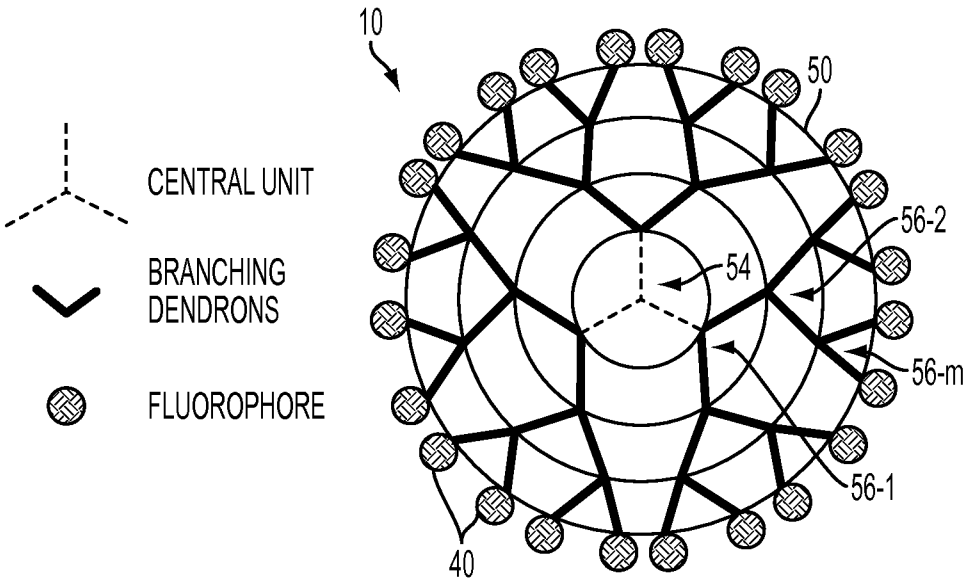

CENTRAL UNIT
BRANCHING DENDRONS
FLUOROPHORE
10
50
56-2
54
56-m
56-1
40

FIG. 2

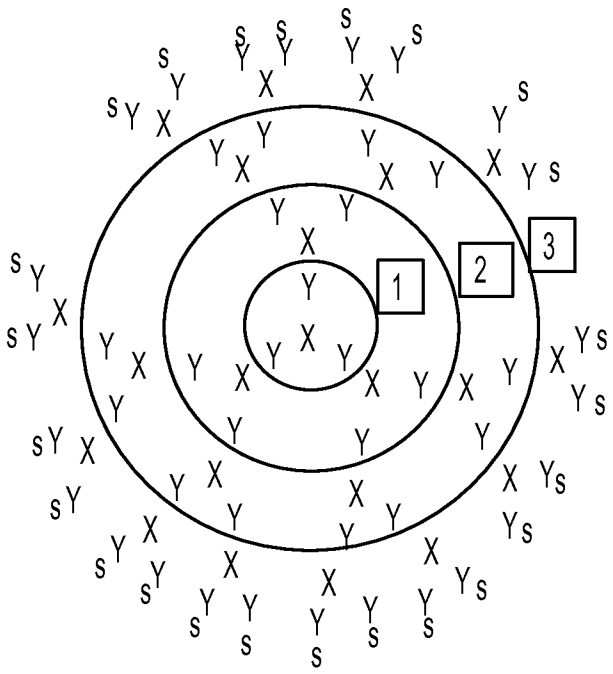


FIG. 3A

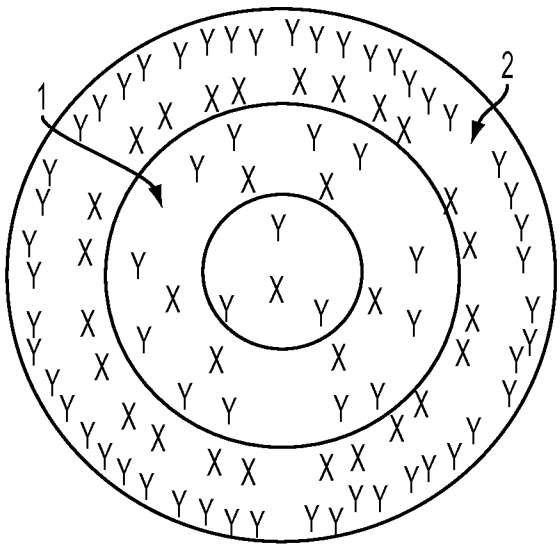


FIG. 3B

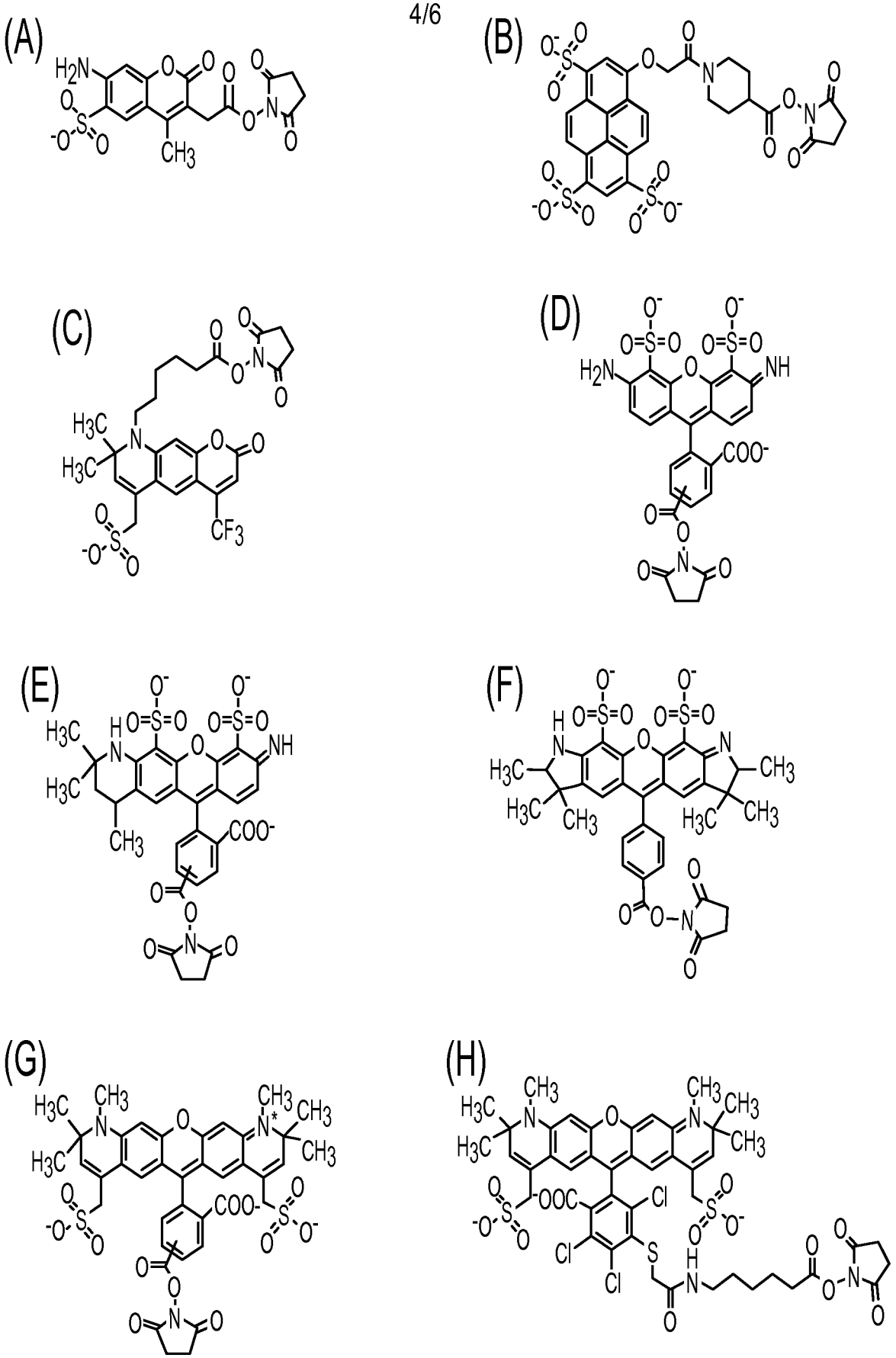


FIG. 4

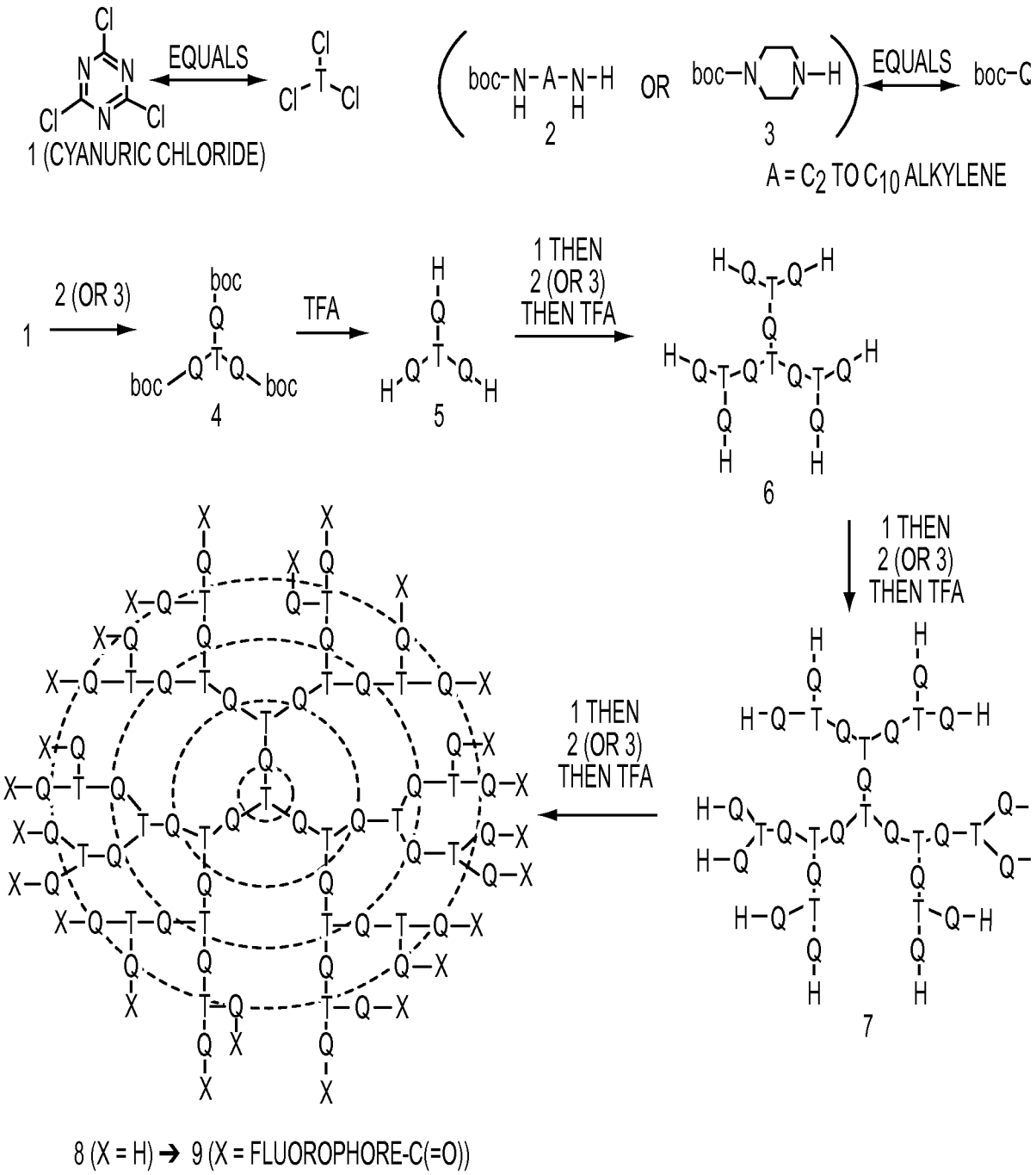

EQUALS
1 (CYANURIC CHLORIDE)
OR
EQUALS
A = C2 TO C10 ALKYLENE
2 (OR 3)
TFA
1 THEN
2 (OR 3)
THEN TFA
1 THEN
2 (OR 3)
THEN TFA
1 THEN
2 (OR 3)
THEN TFA
8 (X = H) → 9 (X = FLUOROPHORE-C(=O))

FIG. 5

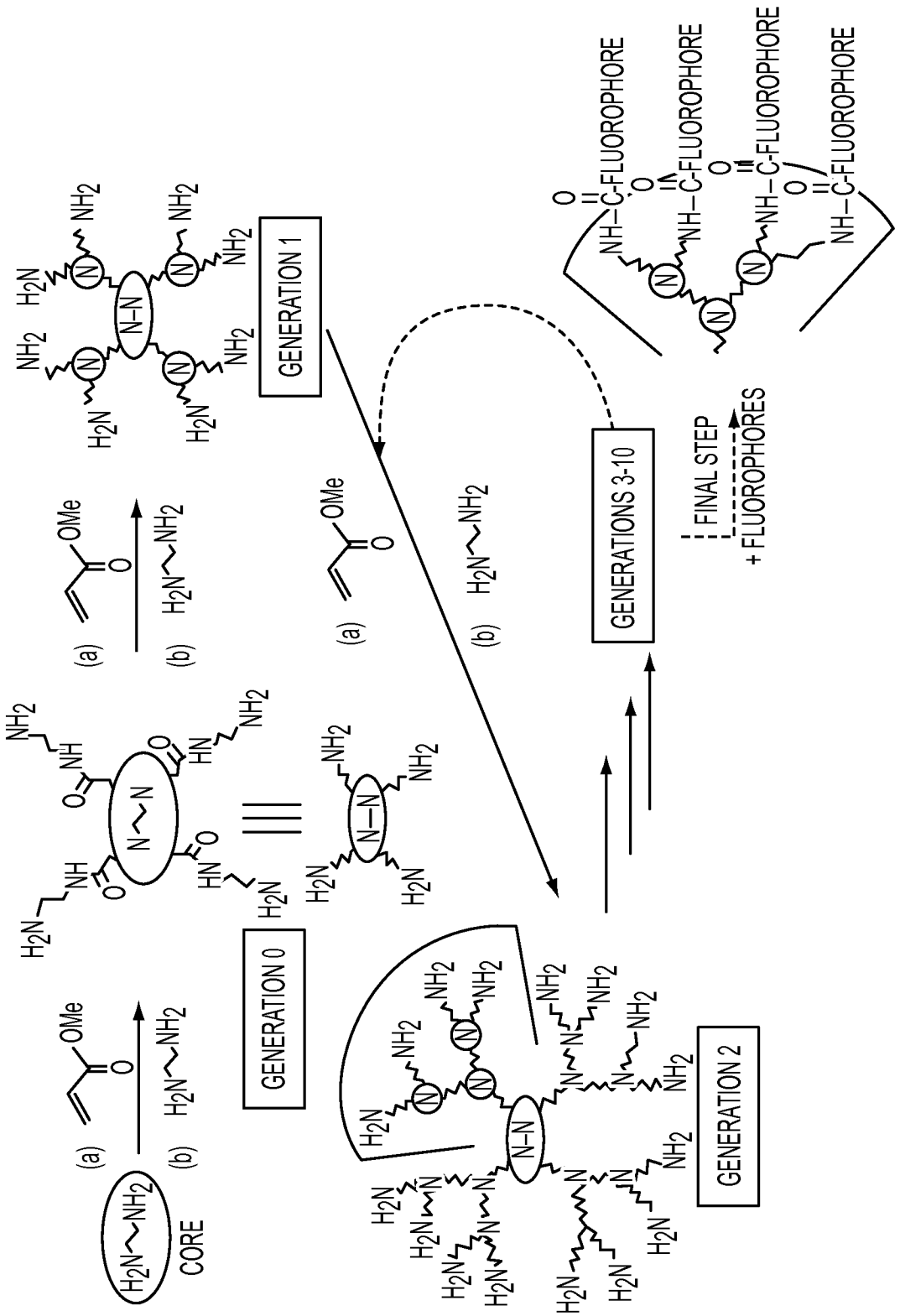

CORE
(a)
(b)
GENERATION 0
GENERATION 1
GENERATION 2
GENERATIONS 3-10
FINAL STEP
+ FLUOROPHORES
NH—C-FLUOROPHORE

FIG. 6

Box No. II 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).

Box No. III 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 Box-----

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.:
1-17, 23, 46-56 (in part), 92-94, and 98

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.

INTERNATIONAL SEARCH REPORT

International application No.: PCT/US 13/47903

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G02F 1/00; C08K 5/00 (2014.01)
USPC - 359/321,254;106/493,499
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)
USPC-359/321

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC-359/321,254;106/493,499
IPC(8)-G02F 1/00; C08K 5/00 (2014.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase (PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD), FreePatentsOnline (US Pat, PgPub, EPO, JPO, WIPO, NPL), GoogleScholar (PL, NPL); search terms: electrophoretic displays charged fluorescent dendrimer particles Alexa Fluor 350 SE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/0000813 A1 (Pullen et al.) 6 January 2005 (06.01.2005) Abstract, para [0016]-[0017], [0022] -[0038]	1-17, 23, 46-56
Y	US 2010/0002414 A1 (Meir et al.) 7 January 2010 (07.01.2010) Abstract, para [0016], [0059], [0076]-[0077], [0101], [0103]	1-17, 23, 46-56, 92-94, 98
Y	Beaudette et al., Chemoselective Ligation in the Functionalization of Polysaccharide-based Particles, J Am Chem Soc. 131(30): 10360-10361, 5 August 2009 (5.08.2009) pg 1, pg 6, Scheme 1	12-17, 23, 54-56, 92-94, 98
Y	WO 2012/072218 A1 (Greinert et al.) 7 June 2012 (07.06.2012) abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2002/0028347 A1 (Marrocco et al.) 7 March 2002 (07.03.2002) abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2009/225397 A1 (Amundson et al.) 10 September 2009 (10.09.2009) para [0056]- [0059]	1-17, 23, 46-56, 92-94, 98
Y	US 2008/0299859 A1 (Paolini et al.) 4 December 2008 (04.12.2008) abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2011/032596 A1 (Danner et al.) 10 February 2011 (10.02.2011) abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2008/0174853 A1 (Danner et al.) 24 July 2008 (24.07.2008) abstract	1-17, 23, 46-56, 92-94, 98

☒ 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	Date of mailing of the international search report
28 January 2014 (28.01.2014)	10 FEB 2014
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	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/0035941 A1 (Albert et al.) 17 February 2005 (17.02.2005) abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2004/0075634 A1 (Gates) 22 April 2004 (22.04.2004) abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2003/0011560 A1 (Albert et al.) 16 January 2003 (16.01.2003) abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2008/0264791 A1 (Paolini et al.) 30 October 2008 (30.10.2008) abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2006/023296 A1 (Whitesides et al.) 02 February 2006 (02.02.2006) Abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2009/0027762 A1 (Comiskey et al.) 29 January 2009 (29.01.2009) Abstract	1-17, 23, 46-56, 92-94, 98
Y	US 5,716,508 A (Starr) 10 February 1998 (10.02.1998) Abstract, col 2, ln 45-58; col 7, ln 50 to col 8, ln 8	1-17, 23, 46-56, 92-94, 98
Y	US 2011/0273906 A1 (Nichol et al.) 10 November 2011 (10.11.2011) Abstract, para [0132]-[0135], [0152], [0199], [0368]	1-17, 23, 46-56, 92-94, 98
Y	US 2010/0317045 A1 (Desai et al.) 16 December 2010 (16.12.2010) Abstract	1-17, 23, 46-56, 92-94, 98
Y	US 2009/0124534 A1 (Reineke) 14 May 2009 (14.05.2009) entire document	1-17, 23, 46-56, 92-94, 98
Y	US 2005/0017943 A1 (Weisbuch et al.) 27 January 2005 (27.01.2005) col 2, ln 1-50	1-17, 23, 46-56, 92-94, 98
A	Life Technologies, Alexa Fluor, 350 Protein Labeling Kit (A10170) and Alexa Fluor Dyes Spanning the Visible and Infrared Spectrum Section 1.3, Commercial Internet Sales Brochure, available at:http://www.lifetechnologies.com/us/en/home/references/molecular-probes-the-handbook/fluorophores-and-their-amine-reactive-derivatives/alexa-fluor-dyes-spanning-the-visible-and-infrared-spectrum.html (accessed on 28 January 2014) 23 August 2004 (23.08.2004) pg 1, Fig 1	1-17, 23, 46-56, 92-94, 98 1-17, 23, 46-56, 92-94, 98

Box III
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 1-32, 46-66, and 92-104 directed to an electrophoretic display and charged fluorescent dendrimers. Group I+ will be searched to the extent that it reads on the chemical structure N-Al-N:, wherein Al is a substituted or non-substituted alkylene group; -A2-CO-NH-A3-NX2, wherein X is hydrogen in the mth generation or a covalent bond in the 0th - (m-l)th generations, A2 is an alkylene group and A3 is a substituted or non-substituted alkylene group (claim 17), and Alexa Fluor- 350 SE (the first fluorophore in claim 23), without fee. It is believed that claims 1-17, 23, 46-56 (in part), 92-94, and 98 read on this first named invention. Applicants must indicate, if applicable, the claims which read on the first named invention if different than what was indicated above for this group. Failure to clearly identify how any paid additional invention fees are to be applied to the "+" group(s) will result in only the first claimed invention to be searched/examined. An exemplary election would be: N-Al-N:, wherein Al is a substituted or non-substituted arylene group; -A2-CO-NH -A3-NX2, wherein X is hydrogen in the mth generation or a covalent bond in the 0th - (m-l)th generations, A2 is an alkylene group and A3 is a substituted or non-substituted arylene group (claim 17) and Alexa Fluor- 350 SE (the first fluorophore in claim 23): Claims 1-17, 23, 46-56 (in part), 92-94, and 98.

Group II: Claims 33-45 directed to a method of using an electrophoretic display.

Group III+: Claims 67-91 and 105-120 directed to a kit and method for producing charged fluorescent dendrimers. An exemplary election would be: the chemical structure N-Al-N:, wherein Al is a substituted or non-substituted alkylene group; -A2-CO-NH-A3-NX2, wherein X is hydrogen in the mth generation or a covalent bond in the 0th - (m-l)th generations, A2 is an alkylene group and A3 is a substituted or non-substituted alkylene group (claim 72) and Alexa Fluor-350 SE (the first fluorophore in claim 112): 67-76 (in part), 80, 105, and 111-112.

The inventions listed as Groups I+, II, and 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 technical features for the following reasons:
Special Technical Features

The special technical feature of each invention of Groups I+ is its specific structure, which is not required by any other invention of Group I+.

Group II includes the special technical feature of a method of using an electrophoretic display, which is not required by any other group.

The special technical feature of each invention of Groups III+ is its specific structure, which is not required by any other invention of Group III+. In addition, Group III+ includes the special technical feature of a kit and method for producing charged fluorescent particles, which is not required by any other group.

The inventions of Group I+, Group II and the inventions of Group III+ share the technical feature of (claim 1) an electrophoretic display comprising: at least one first electrode layer; and an electrophoretic medium disposed adjacent to the at least one first electrode layer, wherein the electrophoretic medium comprises: at least one electrically charged particle disposed in a fluid and capable of moving through the fluid upon application of an electrical field to the fluid, wherein the at least one charged particle comprises a charged fluorescent dendrimer configured for emitting a color different from a color of the fluid. However, this shared technical feature does not represent a contribution over prior art as obvious over US 2005/0000813 A1 to Pullen et al. (hereafter 'Pullen') in view of US 2010/0002414 A1 to Meir et al. (hereafter 'Meir').

Pullen teaches an electrophoretic display comprising at least one first electrode layer (para [0027], [0099]-carbon black layer); and an electrophoretic medium disposed adjacent to the at least one first electrode layer (para [0027]; claim 25), wherein the electrophoretic medium comprises at least one electrically charged particle disposed in a fluid and capable of moving through the fluid upon application of an electrical field to the fluid (para [0027]-droplets, [0020]-charged carbon black, titania, pigment particles, [0039], [0040]-copper chromite black), wherein the at least one charged particle comprises a charged polymer ([0024]- the polymer may be bonded to the particle. The residue of the functionalization agent may comprise charged or chargeable groups.) configured for emitting a color different from a color of the fluid (para [0016],[0017], electrophoretic medium comprises white titania and carbon black particles in a hydrocarbon suspending fluid; See also, applicant's specification at para [0003]- Alternatively, an electrophoretic fluid may have two types of color particles of contrasting colors (for example, white and black) and carrying opposite charges, dispersed in a clear solvent.), wherein the polymer is formed by a method comprising polymerizing vinyl monomers (para [0023]- The at least one electrically charged particle may be coated with silica and/or have a polymer chemically bonded to, or cross-linked around? the polymer may be formed by radical polymerization from acrylate, methacrylate, styryl, or other vinyl monomers or mixtures thereof; [0082]- N-isopropylacrylamide or acrylonitrile), but does not teach fluorescent dendrimers. However, Meir further teaches an electrophoretic display device (para [0016]; [0059]) wherein at least one particle (para [0029]) comprises a polymer (para [0029]; [0101]; [0103]) having at least one fluorescent dendrimers (para [0076]-[0077]). It would have been obvious to one of skill in the art to combine the teachings of these references and incorporate fluorescent dendrimer of Meir in to the electrophoretic display having the polymer as taught by Pullen in order to provide efficient fluorescence property to the device because dendrimer are polymeric material currently used as fluorescent in OLEDs. Further Dendrimer has definite polymeric structure with definite physical properties due to the fact that core moiety of a dendrimer, which consists of a series of chemical shells built on the core moiety, and therefore unique light emitting properties (Meir, para [0077])

In addition to the above, inventions of Group III+ share the feature of a kit. However, this shared technical feature does not represent a contribution over prior art as being anticipated by US 5,716,508 A (Starr). Starr teaches electrophoresis system wherein fluorophore is either itself charged or coupled to a species that imparts a charge on an otherwise uncharged fluorophore (col 2, ln 52-58; col 7, ln 50-55), and is configured for emitting a color different from a color of the fluid (col 2, ln 45-47, Fluorophore assisted carbohydrate electrophoresis permits the electrophoretic separation of a complex mixture of carbohydrates into distinct bands on a gel.), and kits containing fluorophores, fluorophore-labelled substrates, and instructions thereof (col 7, ln 50 to col 8, ln 8). Further, US 2011/0273906 A1 (Nichol et al.) discloses an electrophoretic display (Abstract, para [0132]) comprising a film (abstract, para [0199]), polymer (para [0134]-[0135], [0199]), fluorophores (para [0152]), particles (para [0199]), and kits thereof (para [0368]).

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Inventions of Group III+ share the feature of a method of making charged fluorescent particles comprising contacting charged fluorophores with dendrimers, wherein: the fluorophores comprise at least one amine-reactive carbonyl group. However, this shared technical feature does not represent a contribution over prior art as obvious over Pullen in view of Meir.
Pullen discloses as discussed above an electrophoretic display, wherein the charged fluorescent particles are formed by a method of producing comprising contacting fluorescent particles (para [0023]- The at least one electrically charged particle may ? have a polymer chemically bonded to, or cross-linked around?. It is generally preferred that the polymer be chemically bonded to the at least one particle.) and vinyl monomers having amine-reactive carbonyl group (para [0023]- the polymer may be formed by radical polymerization from acrylate, methacrylate, styryl, or other vinyl monomers or mixtures thereof; [0082]- N-isopropylacrylamide), but does not teach specificaly fluorescent dendrimers. However, Meir further teaches an electrophoretic display device (para [0016]; [0059]) wherein at least one charged particle (para [0029]) comprises a polymer (para [0029]; [0101]; [0103]) having at least one fluorescent dendrimers (para [0076]-[0077]). It would have been obvious to one of skill in the art to combine the teachings of these references and incorporate fluorescent dendrimer of Meir in the method of producing electrophoretic display having the polymer as taught by Pullen in order to provide efficient fluorescence property to the device because dendrimer are polymeric material currently used as fluorescent in OLEDs. Further Dendrimer has definite polymeric structure with definite physical properties due to the fact that core moiety of a dendrimer, which consists of a series of chemical shells built on the core moiety, and therefore unique light emitting properties (Meir, para [0077]).

Consequently, Groups I+, II and III+ do not share the same or corresponding technical feature.

Therefore, Inventions of Groups I+, II and III+ lack unity under PCT Rule 13.