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(54) Title: ELECTROPHORETIC INK INCLUDING PHOSPHORESCENT PIGMENT

(57) Abstract: According to an example, a resin, a carrier liquid, and a phosphorescent pigment may be mixed under high shear to form a paste. The paste may be diluted to form a slurry. In addition, an electrophoretic ink may be formed with the slurry and a charge director.



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ELECTROPHORETIC INK INCLUDING PHOSPHORESCENT PIGMENT

BACKGROUND

[0001] Ink compositions containing charged particles are used in a wide variety of applications such as toners in electrophotography printing, pigmented ink, electrophoretic displays as well as many other applications. Liquid electrophotographic printing is a specific type of electrophotographic printing where a liquid ink is employed in the process rather than a powder toner. A liquid electrophoretic ink composition is generally formed by grinding a carrier liquid, a resin, and a pigment to form an ink slurry. A charge adjuvant and a charge director may be mixed with the ink slurry after grinding. Ultimately, an electrophoretic ink is formed.

DETAILED DESCRIPTION

[0002] For simplicity and illustrative purposes, the present disclosure is described by referring mainly to an example thereof. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. It will be readily apparent however, that the present disclosure may be practiced without limitation to these specific details. In other instances, some methods and structures have not been described in detail so as not to unnecessarily obscure the present disclosure. As used herein, the terms “a” and “an” are intended to denote at least one of a particular element, the term “includes” means includes but not limited to, the term “including” means including but not limited to, and the term “based on” means based at least in part on.

[0003] Disclosed herein is a method for forming an electrophoretic ink, and particularly, a liquid electrophoretic ink. The liquid electrophoretic ink disclosed herein may be formed by mixing, under high shear, a resin, a

carrier liquid, and a phosphorescent pigment to form a paste. The paste may be diluted to form a slurry and a charge director may be added to the slurry to form the liquid electrophoretic ink. It will be noted that the method disclosed herein may vary from prior methods because the resin, carrier liquid, and phosphorescent pigment are not subjected to mechanical deformation, such as grinding. Through implementation of the disclosed method, in which the phosphorescent pigment does not undergo a mechanical deformation, the resultant liquid electrophoretic ink may exhibit an increased luminance as compared with phosphorescent pigments that have undergone mechanical deformation.

[0004] Generally, a carrier liquid may act as a dispersing medium for the other components in the liquid electrophoretic ink. The carrier liquid may have or be a hydrocarbon, silicone oil, vegetable oil, etc. The carrier liquid may include, but is not limited to, an insulating, non-polar, non-aqueous liquid that may be used as a medium for articles. In an aspect, the carrier liquid may be a low dielectric (< 2 dielectric constant) solvent.

[0005] The carrier liquid may include, but is not limited to, hydrocarbons. The hydrocarbon may include, but is not limited to, an aliphatic hydrocarbon, an isomerized aliphatic hydrocarbon, branched chain aliphatic hydrocarbons, aromatic hydrocarbons, and combinations thereof. Non-limiting examples of a carrier liquid may include aliphatic hydrocarbons, isoparaffinic compounds, paraffinic compounds, dearomatized hydrocarbon compounds, and the like. In particular, the carrier liquid can be chosen from Isopar-G™, Isopar-H™, Isopar-L™, Isopar-M™, Isopar-K™, Isopar-V™, Norpar 12™, Norpar 13™, Norpar 15™, Exxol D40™, Exxol D80™, Exxol D100™, Exxol D130™, and Exxol D140™ (each sold by EXXON CORPORATION); Teclen N-16™, Teclen N-20™, Teclen N-22™, Nisseki Naphthesol L™, Nisseki Naphthesol M™, Nisseki Naphthesol H™, #0 Solvent L™, #0 Solvent M™, #0 Solvent H™, Nisseki Isosol 300™, Nisseki Isosol 400™, AF-4™, AF-5™, AF-6™ and AF-7™ (each sold by NIPPON OIL CORPORATION); IP Solvent

1620™ and IP Solvent 2028™ (each sold by IDEMITSU PETROCHEMICAL CO., LTD.); Amsco OMS™ and Amsco 460™ (each sold by AMERICAN MINERAL SPIRITS CORP.); and Electron, Positron, New II, Purogen HF (100% synthetic terpenes) (sold by ECOLINK™).

[0006] The carrier liquid may be present in the liquid electrophoretic ink composition in an amount ranging from about 20% to about 99.5% by weight of the electrophoretic ink composition, and in some examples about 50% to about 90% by weight of the electrophoretic ink composition. In another example, the carrier liquid may be present in an amount ranging from about 60% to about 80% by weight of the electrophoretic ink composition.

[0007] The resin for use in the liquid electrophoretic ink composition may include a polymer. The resin may include, but is not limited to, a thermoplastic polymer. The polymer of the resin may be selected from ethylene acrylic acid copolymers; methacrylic acid copolymers; ethylene vinyl acetate copolymers; copolymers of ethylene (e.g. 80 wt. % to 99.9 wt. %), and alkyl (e.g. C₁ to C₅) ester of methacrylic or acrylic acid (e.g. 0.1 wt. % to 20 wt. %); copolymers of ethylene (e.g. 80 wt. % to 99.9 wt. %), acrylic or methacrylic acid (e.g. 0.1 wt. % to 20.0 wt. %) and alkyl (e.g. C₁ to C₅) ester of methacrylic or acrylic acid (e.g. 0.1 wt. % to 20 wt. %); polyethylene; polystyrene; isotactic polypropylene (crystalline); ethylene ethyl acrylate; polyesters; polyvinyl toluene; polyamides; styrene/butadiene copolymers; epoxy resins; acrylic resins (e.g. copolymer of acrylic or methacrylic acid and at least one alkyl ester of acrylic or methacrylic acid wherein alkyl is in some examples from 1 to about 20 carbon atoms, such as methyl methacrylate (e.g. 50 wt. % to 90 wt. %)/methacrylic acid (e.g. 0 wt. % to 20 wt. %)/ethylhexylacrylate (e.g. 10 wt. % to 50 wt. %)); ethylene-acrylate terpolymers: ethylene-acrylic esters-maleic anhydride (MAH) or glycidyl methacrylate (GMA) terpolymers; ethylene-acrylic acid ionomers and combinations thereof.

[0008] The resin may constitute about 5% to about 90%, in some examples about 5% to about 80%, by weight of the solids of the liquid electrophoretic ink composition. Additionally, the resin may constitute about 10% to about 60% by weight of the solids of the liquid electrophoretic ink composition. Moreover, the resin may constitute about 15% to about 40% by weight of the solids of the liquid electrophoretic ink composition.

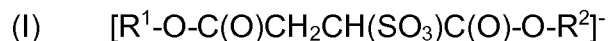
[0009] Non-limiting examples of the resin include the Nucrel family of toners (e.g. Nucrel 403TM, Nucrel 407TM, Nucrel 609HSTM, Nucrel 908HSTM, Nucrel 1202HCTM, Nucrel 30707TM, Nucrel 1214TM, Nucrel 903TM, Nucrel 3990TM, Nucrel 910TM, Nucrel 925TM, Nucrel 699TM, Nucrel 599TM, Nucrel 960TM, Nucrel RX 76TM, Nucrel 2806TM, Bynell 2002, Bynell 2014, and Bynell 2020 (sold by E. I. du PONT)), the Aclyn family of toners (e.g. Aclyn 201, Aclyn 246, Aclyn 285, and Aclyn 295), and the Lotader family of toners (e.g. Lotader 2210, Lotader, 3430, and Lotader 8200 (sold by Arkema)).

[0010] The resin may encapsulate the phosphorescent pigment during mixing to create an ink particle. The ink particle may have a final particle size from about 1 micron to about 10 microns. The resin encapsulated pigments may be formulated to provide a specific melting point. In one example, the melting point may be from about 30° C to about 150° C, and for example, from about 50° C. to about 100° C. Such melting points may allow for desired film formation during printing.

[0011] The liquid electrophoretic ink composition may include a pigment. Non-limiting examples of pigments include cyan pigments, magenta pigments, yellow pigments, white pigments, black pigments, phosphorescent pigments, electroluminescent pigments, photoluminescent pigments, and combinations thereof. According to an example, the pigment may be a phosphorescent pigment having strontium oxide aluminate phosphor particles. The phosphorescent pigment may have a general formula MAI_2O_4 in which M is at least one metal element selected from a group consisting of calcium, strontium and barium. The phosphorescent pigment may be

chosen from LUMINOVA® BGL-300FF (blue-green emitting), LUMINOVA® GLL-300FF (green emitting), and LUMINOVA® V-300M (violet emitting), GBU (yellowish green emitting), all of which are available from United Mineral and Chemical Corporation; UltraGreen V10(PDPG) (green emitting) available from Glow Inc.; and LUPL34/2 (turquoise emitting), LUPL24/2 (green emitting), LUPL09 (orange emitting), all of which are available from Luminochem.

[0012] A charge director imparts a charge to the liquid electrophoretic ink, which is identical to the charge of a photoconductive surface. The electrophoretic ink composition can include a charge director having a sulfosuccinate salt of the general formula MA_n , wherein M is a metal, n is the valence of M, and A is an ion of the general formula (I):



[0013] wherein each of R^1 and R^2 may be an alkyl group.

[0014] The charge director may be added in order to impart and/or maintain sufficient electrostatic charge on the ink particles.

[0015] The sulfosuccinate salt of the general formula MA_n may be an example of a micelle forming salt. The charge director may be substantially free or free of an acid of the general formula HA, where A is as described above. The charge director may include micelles of the sulfosuccinate salt enclosing at least some of the nanoparticles. The charge director may include at least some nanoparticles having a size of 200 nm or less, and/or in some examples 2 nm or more.

[0016] The charge director may further have a simple salt. Simple salts are salts that do not form micelles by themselves, although they may form a core for micelles with a micelle forming salt. The ions constructing the

simple salts are all hydrophilic. The simple salt may include a cation selected from the group consisting of Mg, Ca, Ba, NH₄, tert-butyl ammonium, Li⁺, and Al³⁺, or from any sub-group thereof. The simple salt may include an anion selected from the group consisting of SO₄²⁻, PO₄³⁻, NO₃⁻, HPO₄²⁻, CO₃²⁻, acetate, trifluoroacetate (TFA), Cl⁻, BF₄⁻, F⁻, ClO₄⁻, and TiO₃⁴⁻, or from any sub-group thereof. The simple salt may be selected from CaCO₃, Ba₂TiO₃, Al₂(SO₄), Al(NO₃)₃, Ca₃(PO₄)₂, BaSO₄, BaHPO₄, Ba₂(PO₄)₃, CaSO₄, (NH₄)₂CO₃, (NH₄)₂SO₄, NH₄OAc, Tert-butyl ammonium bromide, NH₄NO₃, LiTFA, Al₂(SO₄)₃, LiClO₄ and LiBF₄, or any sub-group thereof. The charge director may further include basic barium petronate (BBP).

[0017] In the formula [R¹-O-C(O)CH₂CH(SO₃⁻)C(O)-O-R²], for example each of R¹ and R² may be independently an aliphatic alkyl group, such as a C₆₋₂₅ alkyl. The aliphatic alkyl group may be linear or branched. The aliphatic alkyl group may have a linear chain of more than 6 carbon atoms. R¹ and R² may be the same or different. In some examples, at least one of R¹ and R² is C₁₃H₂₇. In some examples, M is Na, K, Cs, Ca, or Ba.

[0018] The charge director may further include one of, some of or all of (i) soya lecithin, (ii) a barium sulfonate salt, such as basic barium petronate (BPP), and (iii) an isopropyl amine sulfonate salt. Basic barium petronate is a barium sulfonate salt of a 21-26 hydrocarbon alkyl, and can be obtained, for example, from Chemtura. An example isopropyl amine sulphonate salt is dodecyl benzene sulfonic acid isopropyl amine, which is available from Croda.

[0019] In some examples, the charge director may constitute about 0.001% to 20%, for example from about 0.01 % to 20% by weight, as an additional example from about 0.01 to 10% by weight, and as a further example from about 0.01 % to 1% by weight of the solids of an electrophoretic ink composition. The charge director may constitute about 0.001 % to 0.15 % by weight of the solids of the electrophoretic ink composition, for example 0.001

% to 0.15 %, as a further example 0.001 % to 0.02 % by weight of the solids of an electrophoretic ink composition, for example 0.1 % to 2 % by weight of the solids of the electrophoretic ink composition, for example 0.2 % to 1.5 % by weight of the solids of the electrophoretic ink composition in an example 0.1 % to 1 % by weight of the solids of the electrophoretic ink composition, for example 0.2 % to 0.8 % by weight of the solids of the electrophoretic ink composition. The charge director can be present in an amount of at least 1 mg of charge director per gram of solids of the electrophoretic ink composition (which will be abbreviated to mg/g), for example at least 2 mg/g, in a further example at least 3 mg/g, in another example at least 4 mg/g, for example at least 5 mg/g. The moderate acid can be present in the amounts stated above, and the charge director can be present in an amount of from 1 mg to 50 mg of charge director per gram of solids of the electrostatic ink composition (which will be abbreviated to mg/g), for example from 1 mg/g to 25 mg/g, as a further example from 1 mg/g to 20 mg/g, for example from 1 mg/g to 15 mg/g, as an additional example from 1 mg/g to 10 mg/g, for example from 3 mg/g to 20 mg/g, as a further example from 3 mg/g to 15 mg/g, and for example from 5 mg/g to 10 mg/g.

[0020] The electrophoretic ink composition may include a charge adjuvant. A charge adjuvant may promote charging of the particles when a charge director is present. The method as described here may involve adding a charge adjuvant at any stage. The charge adjuvant may include, but is not limited to, barium petronate, calcium petronate, Co salts of naphthenic acid, Ca salts of naphthenic acid, Cu salts of naphthenic acid, Mn salts of naphthenic acid, Ni salts of naphthenic acid, Zn salts of naphthenic acid, Fe salts of naphthenic acid, Ba salts of stearic acid, Co salts of stearic acid, Pb salts of stearic acid, Zn salts of stearic acid, Al salts of stearic acid, Zn salts of stearic acid, Cu salts of stearic acid, Pb salts of stearic acid, Fe salts of stearic acid, metal carboxylates (e.g., Al tristearate, Al octanoate, Li heptanoate, Fe stearate, Fe distearate, Ba stearate, Cr stearate, Mg

octanoate, Ca stearate, Fe naphthenate, Zn naphthenate, Mn heptanoate, Zn heptanoate, Ba octanoate, Al octanoate, Co octanoate, Mn octanoate, and Zn octanoate), Co lineolates, Mn lineolates, Pb lineolates, Zn lineolates, Ca oleates, Co oleates, Zn palmitate, Ca resinsates, Co resinsates, Mn resinsates, Pb resinsates, Zn resinsates, AB diblock copolymers of 2-ethylhexyl methacrylate-co- methacrylic acid calcium and ammonium salts, copolymers of an alkyl acrylamidoglycolate alkyl ether (e.g., methyl acrylamidoglycolate methyl ether- co-vinyl acetate), and hydroxy bis(3,5-di-tert-butyl salicylic) aluminate monohydrate. In an example, the charge adjuvant may be or may include aluminum di- or tristearate. The charge adjuvant may be present in an amount of about 0.1 to 5 % by weight, for example about 0.1 to 1 % by weight, in some examples about 0.3 to 0.8 % by weight of the solids of the electrophoretic ink composition, in some examples about 1 wt % to 3 wt% of the solids of the electrophoretic ink composition, in some examples about 1.5 wt % to 2.5 wt% of the solids of the electrophoretic ink composition.

[0021] In some examples, the electrophoretic ink composition may include, e.g. as a charge adjuvant, a salt of multivalent cation and a fatty acid anion. The salt of multivalent cation and a fatty acid anion can act as a charge adjuvant. The multivalent cation may, in some examples, be a divalent or a trivalent cation. In some examples, the multivalent cation may be selected from Group 2, transition metals and Group 3 and Group 4 in the Periodic Table. In some examples, the multivalent cation may include a metal selected from Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Al and Pb. In some examples, the multivalent cation is Al^{3+} . The fatty acid anion may be selected from a saturated or unsaturated fatty acid anion. The fatty acid anion may be selected from a C_8 to C_{26} fatty acid anion, in some examples a C_{14} to C_{22} fatty acid anion, in some examples a C_{16} to C_{20} fatty acid anion, in some examples a C_{17} , C_{18} or C_{19} fatty acid anion. In some examples, the fatty acid anion may be selected from a caprylic acid anion, capric acid

anion, lauric acid anion, myristic acid anion, palmitic acid anion, stearic acid anion, arachidic acid anion, behenic acid anion and cerotic acid anion.

[0022] The charge adjuvant, which may, for example, be or include a salt of multivalent cation and a fatty acid anion, may be present in an amount of 0.1 wt% to 5 wt% of the solids of the electrophoretic ink composition, in some examples in an amount of 0.1 wt% to 2 wt% of the solids of the electrophoretic ink composition, in some examples in an amount of 0.1 wt% to 2 wt% of the solids of the electrostatic ink composition, in some examples in an amount of 0.3 wt% to 1.5 wt% of the solids of the electrophoretic ink composition, in some examples about 0.5 wt% to 1.2 wt% of the solids of the electrophoretic ink composition, in some examples about 0.8 wt% to 1 wt% of the solids of the electrophoretic ink composition, in some examples about 1 wt % to 3 wt% of the solids of the electrophoretic ink composition, in some examples about 1.5 wt % to 2.5 wt% of the solids of the electrophoretic ink composition.

[0023] The resin, carrier liquid, and phosphorescent pigment may be mixed in a continuous mixer to form a paste. This may involve subjecting the mixture to a high shear process to reduce the size of at least some of the particles within the mixture. The high shear process may involve, for example, agitation of the mixture. The high shear process may involve stirring the mixture, for example at a high speed. The speed of rotation may depend on several factors, such as the high shear machine, the volume of the material in the machine, and the viscosity of the material. For example, the rotation may range from about 200 rpm to about 30000 rpm, for example from about 1000 rpm to about 12000 rpm, and as a further example from about 3000 rpm to about 1000 rpm.

[0024] The paste can be diluted to form a slurry having from about 15% to about 70% non-volatile solids, for example from about 35-50%, and as a further example from about 40% non-volatile solids.

[0025] The slurry can be further diluted to have from about 2% to about 25% non-volatile solids, for example from about 7% to about 15% non-volatile solids, and as a further example about 10% non-volatile solids.

[0026] The temperature for the method for forming the electrophoretic ink may vary over time. The temperature may be carried out at a temperature ranging from about 25° C to about 140° C, for example from about 30° C to about 120° C, and as a further example from about 60° C to about 85° C.

[0027] According to an example, the use of the mixer does not mechanically deform the phosphorescent pigment like, for example, a grinder. The disclosed method is free from grinding the phosphorescent pigment, the resin, and the carrier liquid. As a result, the formed liquid electrophoretic ink may exhibit an increased luminance as compared to an electrophoretic ink that underwent mechanical deformation. Additionally, the electrophoretic ink may have a particle conductivity that is less than an ink prepared by grinding. The particle conductivity may range from about 10 pmho/cm to about 400 pmho/cm, for example about 20 pmho/cm to about 200 pmho/cm, and as a further example from about 25 pmho/cm to about 50 pmho/cm.

[0028] The temperature may decrease over time as the liquid electrophoretic ink is formed. A cooling rate of the liquid electrophoretic ink may range from about 0.001° C/minute to about 0.5° C/minute, for example from about 0.01° C/minute to about 0.1° C/minute; and as a further example from about 0.03° C/minute to about 0.08 ° C/minute.

[0029] The following examples illustrate examples of the disclosure that are presently best known. However, it is to be understood that the following are only examples or illustrative of the application of the principles of the present disclosure. Numerous modifications and alternative compositions, methods, and systems may be devised by those skilled in the art without departing from the spirit and scope of the present disclosure. The claims are intended to cover such modifications and arrangements. Thus, while the present disclosure has been described above with particularity, the following

examples provide further details in connection with what are presently deemed to be the most practical and preferred examples of the disclosure.

[0030] Examples

[0031] Example 1

[0032] A resin (NUCREL® 599, a 500 melt index ethylene-methacrylic acid co-polymer from DuPont, Wilmington, DE) was inserted at 40% non-volatile substances to the Ross high shear mixer at a temperature ranging from about 120° C to about 150° C at 50 rpm for 90 minutes. The rotation of the mixer was increased to 70 rpm for 120 minutes. The temperature was lowered to room temperature and the rotation was lowered to 50 rpm after 30 minutes. The resulting product was a paste.

[0033] 150g of the phosphorescent pigments (Green emitting, LumiNova BGL-300FF from United Mineral & Chemical Corp) were grinded with the paste at a ratio of 1:1 (pigment:paste) by weight for 4 hours in the presence of 1% VCA (aluminum stearate as a charge adjuvant, available from Sigma Aldrich) in a ceramic attritor, without any prior treatment. The grinding conditions were: 58° C, 250 rpm and the overall material in the attritor was 1500g (lower than the usual amount of 1700g). An electrophoretic ink was produced.

[0034] Example 2

[0035] A resin (NUCREL® 599, a 500 melt index ethylene-methacrylic acid co-polymer from DuPont, Wilmington, DE) and ISOPAR® L (an isoparaffinic hydrocarbon available from Exxon Corporation) were loaded to a 2 Liter jacketed glass reactor which was equipped with a mechanical stirrer and mixer. 141.5 g NUCREL® 599 and 510 g ISOPAR L were mixed at a speed of 250 rpm and at a temperature of 120° C for one hour. The melted mixture was then cooled down to 80° C under constant mixing and at a cooling rate

of 0.5° C/minute. After, 50 wt. % (to total resin mass) of the pigment LUMINOVA® BGL-300FF (manufactured by Nemoto & Company, Tokyo and available from United Mineral and Chemical Corporation, Lyndhurst, NJ) (141.5 g) was added slowly under constant mixing. A high shear mixer (Polytron PT 10-35 GT from Kinematica) was then operated at 300 rpm. The temperature was then reduced to 65° C at a rate of 2.5° C /minute under constant mixing. At 65° C, the melted mixture turned into a white-greenish ink paste. The ink paste was cooled down to 30° C at 0.5° C/minute and discharged.

[0036] The ink produced in the above method was diluted with ISOPAR® L to a 10% non-volatile substances ink mixture. High shear mixing was performed at 1000 rpm for 15 minutes to disperse the ink particles and form a slurry in room temperature. From the obtained slurry, a 5% non-volatile substances working dispersion was prepared by dilution with ISOPAR® L and then the natural charge directors (including one of, some of or all of (i) soya lecithin, (ii) a barium sulfonate salt, such as basic barium petronate (BPP), and (iii) an isopropyl amine sulfonate salt) (5.5 mg/1g ISOPAR) were added to the diluted work dispersion to form an electrophoretic ink.

[0037] Example 3

[0038] The electrophoretic ink from Example 1 and the electrophoretic ink from Example 2 were tested to determine the luminescent values according to German standard DIN67510 using spec. Xenon lamp : L2175 150W type available from HAMAMATSU; Excitation: Xenon lamp 1000lux activation for 5 minutes.

[0039] The results of the testing is found in Table 1 below,

Table 1. Luminescent Values for Electrophoretic Inks

Time (minute)	Afterglow luminance (mcd/m ²)	
	Example 1	Example 2
2	17.7	19.8
5	7.3	8.2
10	3.7	4.1
20	1.7	1.9
30	1	1.2
60	0.4	0.5

[0040] As may be seen from the data in Table 1, the electrophoretic ink prepared from Example 2 exhibited an increased luminescent value as compared to the ink prepared from Example 1. Additionally, the electrophoretic ink prepared from Example 2 was able to sustain the increased luminescent value over the same period of time as compared to the ink prepared from Example 1.

[0041] Example 4

[0042] For each of the electrophoretic inks of Example 1 and 2, 100 mg/g solids of a natural charge director as used in Example 2 were added. The resulting compositions were mixed in a shaker to yield an initial low field conductivity of 80 pS (as measured in a Q/m test cell). The inks were then allowed to sit for a charging period (12 hours) during which charges accumulated on ink particles and were stabilized. The inks were subsequently diluted with ISOPAR-L® to a non-volatile substance concentrate of about 5% w/w. Particle conductivity (PC) of the diluted sample inks was then evaluated in Q/m test cells. The particle's conductivity is expressed in pS (1 pS/cm=1 pmho/cm). The results are illustrated in TABLE 2 below.

Table 2. Particle Conductivity for Electrophoretic Inks

	Particle conductivity (working dispersion of 3 wt.%)	Particle conductivity (working dispersion of 5 wt. %)	Particle conductivity Range (pmho/cm)
Example 1	262.0	323	150-300
Example 2	35	36	25-50

[0043] As may be seen from the data in Table 2, the ink from Example 2 exhibited a decreased particle conductivity as compared to the ink from Example 1.

[0044] Although described specifically throughout the entirety of the instant disclosure, representative examples of the present disclosure have utility over a wide range of applications, and the above discussion is not intended and should not be construed to be limiting, but is offered as an illustrative discussion of aspects of the disclosure. What has been described and illustrated herein is an example of the disclosure along with some of its variations. The terms, descriptions and figures used herein are set forth by way of illustration only and are not meant as limitations. Many variations are possible within the spirit and scope of the disclosure, which is intended to be defined by the following claims -- and their equivalents -- in which all terms are meant in their broadest reasonable sense unless otherwise indicated.

What is Claimed Is:

1. A method comprising:
mixing, under high shear, a resin, a carrier liquid, and a phosphorescent pigment to form a paste;
diluting the paste to form a slurry; and
forming an electrophoretic ink with the slurry and a charge director.
2. The method of claim 1, wherein the carrier liquid is a low dielectric solvent.
3. The method of claim 1, wherein the resin is selected from the group consisting of ethylene acrylic acid copolymers; methacrylic acid copolymers; ethylene vinyl acetate copolymers; copolymers of ethylene and alkyl ester of methacrylic or acrylic acid; copolymers of ethylene acrylic or methacrylic acid and alkyl ester of methacrylic or acrylic acid; copolymers of acrylic or methacrylic acid and at least one alkyl ester of acrylic or methacrylic acid; ethylene-acrylate terpolymers; ethylene-acrylic esters-maleic anhydride or glycidyl methacrylate terpolymers; ethylene-acrylic acid ionomers; and combinations thereof.
4. The method of claim 1, wherein the slurry has from about 15% to about 70% non-volatile solids.
5. The method of claim 1, wherein the slurry is further to diluted to have from about 2% to about 25% non-volatile solids to form the electrophoretic ink.
6. The method of claim 1, wherein a temperature for the method ranges from about 25° C to about 140° C.

7. The method of claim 1, wherein mixing, under high shear, comprises a rotation that ranges from about 200 rpm to about 30000 rpm.
8. The method of claim 1, a cooling rate for the method ranges from about 0.001° C/minute to about 0.5° C/minute.
9. The method of claim 1, wherein the phosphorescent pigment does not undergo a mechanical deformation.
10. The method of claim 1, wherein the electrophoretic ink exhibits an increased luminance as compared to an electrophoretic ink that underwent mechanical deformation.
11. The method of claim 1, wherein the electrophoretic ink has a particle conductivity ranging from about 10 to about 400 pmho/cm.
12. The method of claim 1, wherein the method is free from grinding the phosphorescent pigment.
13. A liquid electrophoretic ink comprising:
a carrier liquid; and
particles comprising a resin and a phosphorescent pigment,
wherein the electrophoretic ink has a particle conductivity ranging from about 10 pmho/cm to about 400 pmho/cm.
14. The ink of claim 13, wherein the electrophoretic ink has an increased luminance as compared to an electrophoretic ink that underwent mechanical deformation.
15. The ink of claim 13, further comprising a charge director.

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/054976

A. CLASSIFICATION OF SUBJECT MATTER

INV. G03G9/08 G03G9/09 G03G9/12
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G03G

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/013522 A1 (HEWLETT PACKARD DEVELOPMENT CO [US]; GAL VICTOR [IL]; SCHEFFER DAN [IL]) 31 January 2008 (2008-01-31) examples 5-7 claims 1-22	13-15
A	----- examples 5-7 claims 1-22	1-12
X	WO 2011/003442 A1 (HEWLETT PACKARD INDIGO BV [NL]; GRINWALD YARON [IL]; BEN-AVRAHAM PERET) 13 January 2011 (2011-01-13) example 1 page 8, line 9 - line 12	1-15
X	----- EP 0 410 800 A2 (XEROX CORP [US]) 30 January 1991 (1991-01-30) examples I-III column 7, line 28 - line 43 column 9, line 16 - line 29 -----	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* 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

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"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

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"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

23 August 2016

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/054976

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