Abstract: According to an example, 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 electrophotographic ink may be formed with the slurry and a charge director.
RESIN-FREE LIQUID ELECTROPHOTOGRAPHIC INK

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 electrophotographic 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 electrophotographic 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] A liquid electrophoretic ink may be formed by grinding a carrier liquid and a phosphorescent pigment to form a paste. The paste may be diluted to form
a slurry. A charge director may be added to the ink slurry to form the liquid electrophotographic ink. It will be noted that the method disclosed herein may vary from prior methods because the ink is free of resin and therefore allows for 100% pigment loading. Through implementation of the disclosed method, the resultant liquid electrophotographic ink may exhibit an increased luminance.

[0004] Generally, a carrier liquid may act as a dispersing medium for the other components in the liquid electrophotographic 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 electrophotographic ink composition in an amount ranging from about 20% to about 99.5% by weight of the electrophotographic ink composition, and in some examples about 50% to about 90% by weight of the electrophotographic 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 electrophotographic ink composition.

[0007] The liquid electrophotographic 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. The pigment may be a phosphorescent pigment having strontium oxide aluminate phosphor particles. The phosphorescent pigment may have a general formula $\text{MAI}_2\text{O}_4$ 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 from Hungary, Budapest.

[0008] The phosphorescent pigment can have a small particle size so that the phosphorescent pigment is not destroyed or degraded during grinding. The small particle size of the phosphorescent pigment can make the particle less sensitive to mechanical wearing. The particle size of the phosphorescent pigment can range from about 0.05 microns to about 1000 microns, for example from about 0.007 microns to about 100 microns, and as a further example from about 0.01 microns to about 5 microns.
The liquid electrophotographic ink composition may have up to about 50% pigment loading, for example 100% pigment loading. The liquid electrophotographic ink composition may be free from resin.

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 MAn, wherein M is a metal, n is the valence of M, and A is an ion of the general formula (I):

$$[\text{I}] \quad \left[R^1\text{-}0\text{-}C\left(\text{CH}_2\text{SO}_3\right)\text{-}0\text{-}R^2\right]^-$$

wherein each of $R^1$ and $R^2$ may be an alkyl group.

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

The sulfosuccinate salt of the general formula MAn 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.

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 Al+3, or from any sub-group thereof. The simple salt may include an anion selected from the group
consisting of $\text{SO}_4^{2-}$, $\text{PO}_3^{-}$, $\text{NO}_3^{-}$, $\text{HPO}_4^{2-}$, $\text{CO}_3^{2-}$, acetate, trifluoroacetate (TFA), $\text{Cl}^-$, $\text{BF}_4^-$, $\text{F}^-$, $\text{ClO}_4^-$, and $\text{TiO}_3^{4-}$, or from any sub-group thereof. The simple salt may be selected from $\text{CaCO}_3$, $\text{Ba}_2\text{TiO}_3$, $\text{Al}_2(\text{SO}_4)_3$, $\text{Al}(\text{NO}_3)_3$, $\text{Ca}_2(\text{PO}_4)_2$, $\text{BaSO}_4$, $\text{BaHPO}_4$, $\text{Ba}_2(\text{PO}_4)_3$, $\text{CaSO}_4$, $(\text{NH}_4)_2\text{CO}_3$, $(\text{NH}_4)_2\text{SO}_4$, $\text{NH}_4\text{OAc}$, tert-butyl ammonium bromide, $\text{NH}_4\text{NO}_3$, $\text{LiTFA}$, $\text{Al}_2(\text{SO}_4)_3$, $\text{LiClO}_4$ and $\text{LiBF}_4$, or any sub-group thereof.

The charge director may further include basic barium petronate (BPP).

In the formula $[\text{R}^1\text{O}-\text{C(O)}\text{CH}_2\text{CH(\text{SO}_3')C(O)}\text{-O-R}^2]$, for example each of $\text{R}^1$ and $\text{R}^2$ may be independently an aliphatic alkyl group, such as a $\text{C}_{25}$ 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. $\text{R}^1$ and $\text{R}^2$ may be the same or different. In some examples, at least one of $\text{R}^1$ and $\text{R}^2$ is $\text{Cl}_3\text{H}_{27}$. In some examples, $\text{M}$ is Na, K, Cs, Ca, or Ba.

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.

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.

[0018] 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 napthenate, Zn napthenate, Mn heptanoate, Zn heptanoate, Ba octanoate, Al octanoate, Co octanoate, Mn octanoate, and Zn octanoate), Co linoleates, Mn linoleates, Pb linoleates, Zn linoleates, Ca oleates, Co oleates, Zn palmirate, Ca resinates, Co resinates, Mn resinates, Pb resinates, Zn resinates, 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.

[0019] 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 Al3+. The fatty acid anion may be selected from a saturated or unsaturated fatty acid anion. The fatty acid anion may be selected from a C8 to C26 fatty acid anion, in some examples a C14 to C22 fatty acid anion, in some examples a C16 to C20 fatty acid anion, in some examples a C17, C18 or C19 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.

[0020] 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.
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] The electrophotographic ink may have a particle conductivity ranging 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.

[0022] The electrophotographic ink compositions disclosed herein may be prepared by grinding a carrier liquid and a phosphorescent pigment to form an ink slurry; mixing a charge director with the ink slurry; and ultimately forming the ink. In an example, a carrier liquid and a phosphorescent pigment may be loaded into a ball mill, such as a ceramic attritor, and ground for a period of time, such as from about 2.5 hours to about 25 hours, for example from about 3 hours to about 20 hours, and as a further example from about 5 hours to about 15 hours.

[0023] A temperature for the method for forming the electrophotographic ink may vary over time. The temperature may be carried out at a temperature ranging from about 10° 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.

[0024] The rotation of the grinder may range from about 100 rpm to about 300 rpm. The temperature is reduced over a period of time to provide at various cooling rates until the particles have a desired size distribution. The composition may be allowed to cool to room temperature and a charge director may be added and mixed. The composition may be allowed to sit or rest for a period of time so that the charge director may charge the particles.

[0025] In some examples, the resultant ink composition may have a concentration of non-volatile substances ranging from about 2 to about 45 wt.% and may be diluted with additional carrier liquid as may be needed for storage or printing. In some examples, the ink composition may have a weight percentage of
non-volatile substances that ranges from about 1% to about 45%, and as a further example from about 5% to about 25%.

[0026] The electrophotographic ink can be used to form an image. A method can include printing an image so that an electrophotographic ink layer can be accumulated on a blanket. The accumulated ink layers can be transferred to a substrate, such as paper, as a ready image. The ink particles in the electrophotographic ink can be conductive and reactive to an applied electric field, even though no resin is present in the ink. Transparent ink layers can be printed on either side of the substrate to form a printed image. The transparent ink layers can have a resin and an additive, but no pigments.

[0027] The printed image can have a layered structure having two transparent, adhesive ink layers located on either side of a liquid electrophotographic ink layer. The transparent, adhesive layers can act as a primer layer and a protective varnish by allowing for binding of the resinless electrophotographic ink and by enabling transfer from the blanket to the substrate.

[0028] The internal layer of liquid electrophotographic ink can provide the resultant printed image luminance properties.

[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
Example 1

The pigment (LumiNova® BGL-300FF from United Mineral and Chemical Corporation) was ground with ISOPAR® L (isoparaffinic hydrocarbon from Exxon Mobil Corporation) for 2 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: 40° C, 250 rpm and the overall material in the attritor was 1500 g (lower than the usual 1700 g). A slurry was formed.

From the formed slurry a 5% non-volatile substance working dispersion was prepared. A natural charge director (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) was added to the diluted working dispersion.

Example 2

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.

150g of the phosphorescent pigment (Green emitting, LumiNova BGL-300FF from United Mineral & Chemical Corp) were grinded with the paste at a ratio of 1:1 (pigmentpaste) 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 electrophotographic ink was produced.
The electrophotographic ink from Example 1 and the electrophotographic ink from Example 2 were tested to determine the luminescent values according to German DIN67510 using spec. Xenon lamp: L2175 150W type available from HAMAMATSU; Excitation: Xenon lamp 1000lux activation for 5 minutes.

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

Table 1. Luminance Values for Electrophotographic Inks

<table>
<thead>
<tr>
<th>Time (minute)</th>
<th>Afterglow luminance (mcd/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Example 1 – 100% pigment loading with 4 layers</td>
</tr>
<tr>
<td>2</td>
<td>39.9</td>
</tr>
<tr>
<td>5</td>
<td>16.3</td>
</tr>
<tr>
<td>10</td>
<td>7.6</td>
</tr>
<tr>
<td>20</td>
<td>3.6</td>
</tr>
<tr>
<td>30</td>
<td>2.2</td>
</tr>
<tr>
<td>60</td>
<td>0.9</td>
</tr>
</tbody>
</table>

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

**Example 4**

**Example 5**  
prepared from Example 2. Additionally, the electrophotographic ink prepared from Example 1 was able to sustain the increased luminescent value over the same period of time as compared to the ink prepared from Example 2.

**[0040]** Example 4

**[0041]** For each of the electrophotographic inks of Examples 1 and 2, 100 mg/g solids of a natural charge director as used in Example 2 was 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 2% 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>
<thead>
<tr>
<th></th>
<th>Particle conductivity (working dispersion of 5 wt. %)</th>
<th>Particle conductivity range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example 1 – 100% pigment loading</td>
<td>33</td>
<td>25-50</td>
</tr>
<tr>
<td>Example 2 – 50 % pigment loading</td>
<td>174</td>
<td>150-300</td>
</tr>
</tbody>
</table>

**[0042]** As may be seen from the data in Table 2, the ink from Example 1 exhibited a decreased particle conductivity as compared to the ink from Example 2.

**[0043]** Example 5
An image was printed on an Indigo oneshot press so that the ink (from Example 1) layers were accumulated on a blanket and then transferred to the paper as a ready image. The ink particles were conductive and reacted according to the electric field that was forced upon them, although the ink was free of resin.

The printed image has a "sandwich" structure of two adhesive resin layers that acted as a primer layer and a protective varnish. The liquid electrophotographic resin-free ink layer gave the image its glow properties and was between the two resin layers.

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 liquid electrophotographic ink comprising:
   a carrier liquid; and
   a phosphorescent pigment;
   wherein the liquid electrophotographic ink is free from resin.

2. The ink of claim 1, wherein the liquid electrophotographic ink exhibits an increased luminance as compared to an electrophotographic ink having resin.

3. The ink of claim 1, wherein the liquid electrophotographic ink has greater than about 50% non-volatile solids.

4. The ink of claim 1, wherein the liquid electrophotographic ink has 100% non-volatile solids.

5. The ink of claim 1, wherein the liquid electrophotographic ink has a particle conductivity ranging from about 10 to about 400 pmho/cm.

6. The ink of claim 1, wherein the carrier liquid is a low dielectric solvent.

7. The ink of claim 1, wherein the phosphorescent pigment has a particle size ranging from about 0.05 micron to about 100 micron.

8. The ink of claim 1, wherein the phosphorescent pigment is less sensitive to mechanical wearing.

9. The ink of claim 1, further comprising a charge director.
10. The ink of claim 9, wherein the charge director includes at least one of (i) soya lecithin, (ii) a barium sulfonate salt, such as basic barium petronate (BPP), and (iii) an isopropyl amine sulfonate salt.

11. A method comprising:
   grinding a phosphorescent pigment and a carrier liquid to form a slurry;
   and
   diluting the slurry to form a liquid electrophotographic ink;
   wherein the liquid electrophotographic ink is free from resin.

12. The method of claim 11, wherein grinding the phosphorescent pigment and the carrier liquid further comprises grinding the phosphorescent pigment and the carrier liquid in a ceramic attritor.

13. The method of claim 11, wherein grinding the phosphorescent pigment and the carrier liquid further comprises grinding the phosphorescent pigment and the carrier liquid at a temperature ranging from about 10°C to about 140°C.

14. The method of claim 11, wherein grinding the phosphorescent pigment and the carrier liquid further comprises grinding the phosphorescent pigment for a period of time ranging from about 2.5 hours to about 25 hours.

15. A method comprising:
   forming accumulated electrophotographic ink layers on a blanket, wherein the electrophotographic ink comprises a phosphorescent pigment and a carrier liquid;
   transferring the accumulated electrophotographic ink layers to a substrate; and
printing transparent ink layers on either side of the substrate to form an image.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. G03G9/12 G03G9/125 G03G9/135

ADD.

According to International Patent Classification (IPC) and national classification (NAC)

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

G03G C09D

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**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<tr>
<td>X</td>
<td>US 2002/119294 AI (MONKARSH JASON [US] ET AL) 29 August 2002 (2002-08-29) paragraphs [0023], [0028], [0029]; claims 1, 13, 16, 17</td>
<td>1-8, 15</td>
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<td>X</td>
<td>US 2008/148837 AI (AUSLANDER JUDITH D [US] ET AL) 26 June 2008 (2008-06-26) paragraphs [0035], [0036], [0037], [0039]; claim 1</td>
<td>1-8, 15</td>
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<td>X</td>
<td>Wo 01/96908 A2 (JESSEN WESLEY CORP [US]; NOVARTIS AG [CH]; TUCKER ROBERT C [US]) 20 December 2001 (2001-12-20) page 5, paragraphs 2, 3 page 6, paragraph 4 page 8 claims 1, 17</td>
<td>1-10, 15</td>
</tr>
</tbody>
</table>

[X] 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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  - **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

**Date of the actual completion of the international search**

11 November 2016

**Date of mailing of the international search report**

21/11/2016

**Name and mailing address of the ISA**

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Fax: (+31-70) 340-3016

**Authorized officer**

Vogt, Carol a
<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
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<td>X</td>
<td>Wo 2004/057426 Al (Arjo Wiggins Fine Papers Ltd [GB]; Saunders Richard David [GB]; Sincla) 8 July 2004 (2004-07-08) page 8; claim 1; example 1</td>
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