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(54) DIGITAL ADVANCED LITHOGRAPHY IMAGING INKS WITH IMPROVED CURABLE PERFORMANCE, IMAGE ROBUSTNESS AND PROCESSES THEREOF

(57) An ink composition useful for digital offset printing applications includes a colorant and a high viscosity thickening agent. The ink comprises a radiation curable ink vehicle, a dispersant, a thermal stabilizer and a photoinitiator system comprising at least three photoinitiators for improving curing efficiency through multiple short UV light exposure in variable lithographic printing. A process for variable data lithographic printing includes applying a dampening fluid to an imaging member surface, forming a latent image by evaporating the dampening fluid from a selective locations on the imaging member surface to form hydrophobic non-image areas and hydrophilic image areas; developping the latent image by applying an ink composition to the hydrophilic image areas.

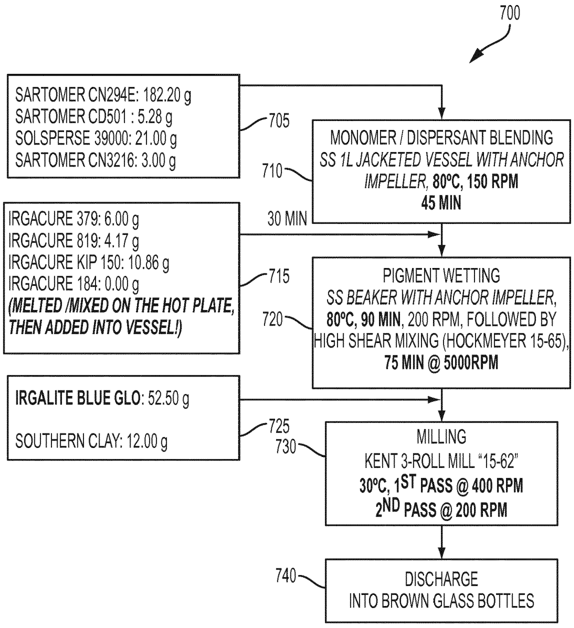

FIG. 7

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Description

BACKGROUND OF THE INVENTION

[0001] Disclosed herein are certain ink compositions which are compatible with dampening fluids and are useful for variable data lithographic printing. This disclosure also relates to methods of using such ink compositions, such as in variable lithographic printing applications.

[0002] Conventional lithographic printing techniques cannot accommodate true high-speed variable data printing processes in which images to be printed change from impression to impression, for example, as enabled by digital printing systems. The lithography process is often relied upon, however, because it provides very high quality printing due to the quality and color gamut of the inks used. Lithographic inks are also less expensive than other inks, toners, and many other types of printing or marking materials.

[0003] Ink-based digital printing uses a variable data lithography printing system, or digital offset printing system, or a digital advanced lithography imaging system. A "variable data lithography system" is a system that is configured for lithographic printing using lithographic inks and based on digital image data, which may be variable from one image to the next. "Variable data lithography printing," or "digital ink-based printing," or "digital offset printing," or digital advanced lithography imaging is lithographic printing of variable image data for producing images on a substrate that are changeable with each subsequent rendering of an image on the substrate in an image forming process.

[0004] For example, a digital offset printing process may include transferring radiation-curable ink onto a portion of a fluorosilicone-containing imaging member or printing plate that has been selectively coated with a dampening fluid layer according to variable image data. Regions of the dampening fluid are removed by exposure to a focused radiation source (e.g., a laser light source) to form pockets. A temporary pattern in the dampening fluid is thereby formed over the printing plate. Ink applied thereover is retained in the pockets formed by the removal of the dampening fluid. The inked surface is then brought into contact with a substrate and the ink transfers from the pockets in the dampening fluid layer to the substrate. The dampening fluid may then be removed, a new uniform layer of dampening fluid applied to the printing plate, and the process repeated. The ink is then transferred from the printing plate to a substrate such as paper, plastic, or metal on which an image is being printed and cured. The same portion of the imaging plate may be optionally cleaned depending on ink type and used to make a succeeding image that is different than the preceding image, based on the variable image data.

[0005] Digital offset printing inks differ from conventional inks because they must meet demanding rheological requirements imposed by the lithographic printing process while being compatible with system component materials and meeting the functional requirements of subsystem components, including wetting and transfer. Print process studies have demonstrated that higher viscosity is preferred for ink transfer in digital advanced lithography imaging blanket and yet even higher viscosity is needed to improve transfer to a print substrate. As a result, the earlier designs of digital advanced lithography imaging inks were found to have unacceptable curing performance for high speed printing applications (>1m/s), particularly at higher output densities (OD).

BRIEF SUMMARY OF THE INVENTION

[0006] According to aspects of the embodiments, the present disclosure relates to certain ink compositions which are compatible with dampening fluids and are useful for variable data lithographic printing. The ink composition includes a colorant and a high viscosity thickening agent. A process for variable data lithographic printing includes applying a dampening fluid to an imaging member surface; forming a latent image by evaporating the dampening fluid from selective locations on the imaging member surface to form hydrophobic non-image areas and hydrophilic image areas; developing the latent image by applying an ink composition comprising an ink component to the hydrophilic image areas, the ink is formulated to have improved curing performance and image robustness. This is achieved with use of a 4 photoinitiator system with each of the photoinitiator being used at very specific ratios to each other.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 illustrates a block diagram of a system that shows a related art ink-based digital printing system in which the ink compositions of the present disclosure may be used;

FIG. 2 illustrates the effect of curing speed on print robustness as measured by Double MEK Rub in accordance to an embodiment;

FIG. 3 illustrates the thickness of prints used for MEK Rub Test in accordance to an embodiment;

FIG. 4 illustrates the optimization summary and Double MEK Rub One-Pass Data for the Proposed digital advanced lithography imaging ink set in accordance to an embodiment;

FIG. 5 illustrates Double MEK Rub Data for the Proposed the digital advanced lithography imaging ink set compared to previous mainline design in accordance to an embodiment;

FIG. 6 is a plot of viscosity data for the proposed ink set in accordance to an embodiment; and

FIG. 7 illustrates a process flow diagram for making a three or more photoinitiator ink set for a digital advanced lithography imaging system in accordance to an embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0008] Exemplary embodiments are intended to cover all alternatives, modifications, and equivalents as may be included within the spirit and scope of the composition, apparatus and systems as described herein.

[0009] A more complete understanding of the processes and apparatuses disclosed herein can be obtained by reference to the accompanying drawings. These figures are merely schematic representations based on convenience and the ease of demonstrating the existing art and/or the present development, and are, therefore, not intended to indicate relative size and dimensions of the assemblies or components thereof. In the drawing, like reference numerals are used throughout to designate similar or identical elements.

[0010] Example 1 includes an ink composition for variable data lithography printing comprising an ink vehicle and at least one colorant component suspended in solution in the ink composition; and the solution comprising two or more of at least one dispersant; a thermal stabilizer; and a photo initiator system comprising at least three or more photoinitiators being used at very specific ratios to each other; wherein the at least three or more photoinitiator improve curing efficiency through multiple short UV light exposure in variable lithography printing.

[0011] Example 2 includes Example 1 and the solution further comprising a rheology modifying agent.

[0012] Example 3 includes Example 2 and wherein the vehicle is a radiation-curable dilutable compound that comprises dilutable monomer compounds selected from the group of compounds comprising mono-, di-, and tri-functional dilutable acrylate monomers and oligomers.

[0013] Example 4 includes Example 3 and wherein the at least one colorant component comprises a pigment, the pigment component is in a proportion of at least 15% by weight.

[0014] Example 5 includes Example 3 and wherein the at least three or more photoinitiators are selected from one or more of: Irgacure 379, Esacure Kip 150, Irgacure 819, Irgacure 184, ADDITOL LX, ADDITOL DX, ADDITOL BDK, ADDITOL CPK, ADDITOL DMMTA, ADDITOL TPO.

[0015] Example 6 includes Example 5 and wherein the thickening agent component being in a range of 9% or less by weight in the solution and wherein the photo initiator system comprises at least four or more photoinitiators being used at very specific ratios to each other.

[0016] Example 7 includes Example 5 and the thickening agent component being in an amount of 1, 2, 8.81, or 9 percent by weight.

[0017] Example 8 includes Example 5 and the rheology modifying agent being in an amount of 2, 4, 8, or 9 percent by weight.

[0018] Example 9 includes Example 1 and wherein the at least three or more photoinitiators are selected from one or more of Irgacure and Esacure Kip.

[0019] Example 10 includes Example 9 and wherein the relative ratio of the at least three or more photoinitiators are 0.57:1:0.68:0.14 and total concentration is about 8.4 percent by weight.

[0020] Example 11 includes Example 10 and wherein the at least three or more photoinitiators are: Irgacure 379, Esacure Kip 150, Irgacure 819, and Irgacure 184.

[0021] Example 12 includes a process for variable lithographic printing, comprising applying a dampening fluid to an imaging member surface; forming a latent image by evaporating the dampening fluid from selective locations on the imaging member surface to form hydrophobic non-image areas and hydrophilic image areas; developing the latent image by applying an ink composition comprising an ink component to the hydrophilic image areas; and transferring the developed latent image to a receiving substrate; wherein the ink composition comprises an ink vehicle and at least one colorant component suspended in solution in the ink composition; and the solution comprising two or more of at least one dispersant; a thermal stabilizer; and a photo initiator system comprising at least three or more photoinitiators being used at very specific ratios to each other; wherein the at least three or more photoinitiator improve curing efficiency through multiple short UV light exposure in variable lithography printing.

[0022] Example 13 includes Example 12 and the solution further comprising a rheology modifying agent; wherein the rheology modifying agent being in an amount of 2, 4, 8, or 9 percent by weight.

[0023] The modifier "about" used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (for example, it includes at least the degree of error associated with the measurement of the particular quantity). When used with a specific value, it should also be considered as disclosing that value. For example, the term "about 2" also discloses the value "2" and the range "from about 2 to about 4" also discloses the range "from 2 to 4."

[0024] Although embodiments of the invention are not limited in this regard, the terms "plurality" and "a plurality" as used herein may include, for example, "multiple" or "two or more". The terms "plurality" or "a plurality" may be used throughout the specification to describe two or more components, devices, elements, units, parameters, or the like. For example, "a plurality of stations" may include two or more stations. The terms "first," "second," and the like, herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. The terms "a" and "an" herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

[0025] The term "printing device" or "printing system" as used herein refers to a digital copier or printer, scanner, image printing machine, digital production press, document processing system, image reproduction machine, bookmaking machine, facsimile machine, multi-function machine, or the like and can include several marking engines, feed mechanism, scanning assembly as well as other print media processing units, such as paper feeders, finishers, and the like. The printing system can handle sheets, webs, marking materials, and the like. A printing system can place marks on any surface, and the like and is any machine that reads marks on input sheets; or any combination of such machines.

[0026] The term "print media" generally refers to a usually flexible, sometimes curled, physical sheet of paper, substrate, plastic, or other suitable physical print media substrate for images, whether precut or web fed.

[0027] As shown in FIG. 1, the exemplary system 100 may include an imaging member 110. System 100 illustrates a system for variable lithography in which the ink compositions of the present disclosure may be used. The imaging member 110 in the embodiment shown in FIG. 1 is a drum, but this exemplary depiction should not be interpreted so as to exclude embodiments wherein the imaging member 110 includes a drum, plate or a belt, or another now known or later developed configuration. The reimageable surface may be formed of materials including, for example, a class of materials commonly referred to as silicones, including polydimethylsiloxane (PDMS), among others. For example, silicone, fluorosilicone, and/or VITON may be used. The reimageable surface may be formed of a relatively thin layer over a mounting layer, a thickness of the relatively thin layer being selected to balance printing or marking performance, durability and manufacturability.

[0028] The imaging member 110 is used to apply an ink image to an image receiving media substrate 114 at a transfer nip 112. The transfer nip 112 is formed by an impression roller 118, as part of an image transfer mechanism 160, exerting pressure in the direction of the imaging member 110. Image receiving medium substrate 114 should not be considered to be limited to any particular composition such as, for example, paper, plastic, or composite sheet film. The exemplary system 100 may be used for producing images on a wide variety of image receiving media substrates. There is wide latitude of marking (printing) materials that may be used, including marking materials with pigment loading greater than 10% by weight. This disclosure will use the term ink to refer to a broad range of printing or marking materials to include those which are commonly understood to be inks, pigments, and other materials which may be applied by the exemplary system 100 to produce an output image on the image receiving media substrate 114.

[0029] The imaging member 110 including the imaging member 110 being comprised of a reimageable surface layer formed over a structural mounting layer that may be, for example, a cylindrical core, or one or more structural layers over a cylindrical core.

[0030] The exemplary system 100 includes a dampening fluid system 120 generally comprising a series of rollers, which may be considered as dampening rollers or a dampening unit, for uniformly wetting the reimageable surface of the imaging member 110 with dampening fluid. A purpose of the dampening fluid system 120 is to deliver a layer of dampening fluid, generally having a uniform and controlled thickness, to the reimageable surface of the imaging member 110. As indicated above, it is known that a dampening fluid such as fountain solution may comprise mainly water optionally with small amounts of isopropyl alcohol or ethanol added to reduce surface tension as well as to lower evaporation energy necessary to support subsequent laser patterning, as will be described in greater detail below. Small amounts of certain surfactants may be added to the fountain solution as well. Alternatively, other suitable dampening fluids may be used to enhance the performance of ink based digital lithography systems. Exemplary dampening fluids include water, NOVEC® 7600 (1,1,1,2,3,3-Hexafluoro-4-(1,1,2,3,3,3-hexafluoropropoxy)pentane and has CAS#870778-34-0.), and D4 (octamethylcyclotetrasiloxane).

[0031] Once the dampening fluid is metered onto the reimageable surface of the imaging member 110, a thickness of the dampening fluid may be measured using a sensor 125 that may provide feedback to control the metering of the dampening fluid onto the reimageable surface of the imaging member 110 by the dampening fluid system 120.

[0032] After a precise and uniform amount of dampening fluid is provided by the dampening fluid system 120 on the reimageable surface of the imaging member 110, and optical patterning subsystem 130 may be used to selectively form a latent image in the uniform dampening fluid layer by image-wise patterning the dampening fluid layer using, for example, laser energy. Typically, the dampening fluid will not absorb the optical energy (IR or visible) efficiently. The reimageable surface of the imaging member 110 should ideally absorb most of the laser energy (visible or invisible such as IR) emitted from the optical patterning subsystem 130 close to the surface to minimize energy wasted in heating the dampening fluid and to minimize lateral spreading of heat in order to maintain a high spatial resolution capability. Alternatively, an appropriate radiation sensitive component may be added to the dampening fluid to aid in the absorption of the incident radiant laser energy. While the optical patterning subsystem 130 is described above as being a laser emitter, it should be understood that a variety of different systems may be used to deliver the optical energy to pattern the dampening fluid.

[0033] The mechanics at work in the patterning process undertaken by the optical patterning subsystem 130 of the exemplary system 100 are known to those in the art. Briefly, the application of optical patterning energy from the optical patterning subsystem 130 results in selective removal of portions of the layer of dampening fluid.

[0034] Following patterning of the dampening fluid layer by the optical patterning subsystem 130, the patterned layer over the reimageable surface of the imaging member 110 is presented to an inker subsystem 140. The inker subsystem 140 is used to apply a uniform layer of ink over the layer of dampening fluid and the reimageable surface layer of the imaging member 110. The inker unit 140 further comprises heated ink baths whose temperatures are regulated by temperature control module. The inker subsystem 140 may use an anilox roller to meter an offset lithographic ink onto one or more ink forming rollers that are in contact with the reimageable surface layer of the imaging member 110. Separately, the inker subsystem 140 may include other traditional elements such as a series of metering rollers to provide a precise feed rate of ink to the reimageable surface. The inker subsystem 140 may deposit the ink to the pockets representing the imaged portions of the reimageable surface, while ink on the unformatted portions of the dampening fluid will not adhere to those portions.

[0035] The cohesiveness and viscosity of the ink residing in the reimageable layer of the imaging member 110 may be modified by a number of mechanisms. One such mechanism may involve the use of a rheology (complex viscoelastic modulus) control subsystem 150. The rheology control system 150 may form a partial crosslinking core of the ink on the reimageable surface to, for example, increase ink cohesive strength relative to the reimageable surface layer. Curing mechanisms may include optical or photo curing, heat curing, drying, or various forms of chemical curing. Cooling may be used to modify rheology as well via multiple physical cooling mechanisms, as well as via chemical cooling.

[0036] The ink is then transferred from the reimageable surface of the imaging member 110 to a substrate of image receiving medium 114 using a transfer subsystem 160. The transfer occurs as the substrate 114 is passed through a nip 112 between the imaging member 110 and an impression roller 118 such that the ink within the voids of the reimageable surface of the imaging member 110 is brought into physical contact with the substrate 114. With the adhesion of the ink having been modified by the rheology control system 150, modified adhesion of the ink causes the ink to adhere to the substrate 114 and to separate from the reimageable surface of the imaging member 110. Careful control of the temperature and pressure conditions at the transfer nip 112 may allow transfer efficiencies for the ink from the reimageable surface of the imaging member 110 to the substrate 114 to exceed 95%. While it is possible that some dampening fluid may also wet substrate 114, the volume of such a dampening fluid will be minimal, and will rapidly evaporate or be absorbed by the substrate 114.

[0037] In certain offset lithographic systems, it should be recognized that an offset roller, not shown in FIG. 1, may first receive the ink image pattern and then transfer the ink image pattern to a substrate according to a known indirect transfer method. Following the transfer of the majority of the ink to the substrate 114, any residual ink and/or residual dampening fluid must be removed from the reimageable surface of the imaging member 110, preferably without scraping or wearing that surface. An air knife may be employed to remove residual dampening fluid. It is anticipated, however, that some amount of ink residue may remain. Removal of such remaining ink residue may be accomplished through use of some form of cleaning subsystem 170. The cleaning subsystem 170 comprises at least a first cleaning member such as a sticky or tacky member in physical contact with the reimageable surface of the imaging member 110, the sticky or tacky member removing residual ink and any remaining small amounts of surfactant compounds from the dampening fluid of the reimageable surface of the imaging member 110. The sticky or tacky member may then be brought into contact with a smooth roller to which residual ink may be transferred from the sticky or tacky member, the ink being subsequently stripped from the smooth roller by, for example, and a doctor blade.

[0038] Other mechanisms by which cleaning of the reimageable surface of the imaging member 110 may be facilitated. Regardless of the cleaning mechanism, however, cleaning of the residual ink and dampening fluid from the reimageable surface of the imaging member 110 is essential to preventing ghosting in the proposed system. Once cleaned, the reimageable surface of the imaging member 110 is again presented to the dampening fluid system 120 by which a fresh layer of dampening fluid is supplied to the reimageable surface of the imaging member 110, and the process is repeated.

[0039] As discussed above, digital offset ink must possess physical and chemical properties that are specific to ink-based digital printing systems. The ink must be compatible with materials that it comes in contact with, including the imaging plate and dampening fluid, and printable substrates such as paper, metal, or plastic. The ink must also meet all functional requirements of the subsystems including wetting and transfer properties defined by subsystem architecture and material sets.

[0040] Inks formulated for ink-based digital printing, or digital offset inks, are different in many ways from other inks developed for printing applications, including pigmented solvents, UV gel inks, and other inks. For example, digital offset inks contain much higher pigment and therefore have higher viscosity at room temperature than other inks, which can make ink delivery by way of an anilox roll or inkjet system difficult. Digital offset inks must meet certain wetting and release property requirements imposed by the imaging member used for ink-based digital printing processes, while being compatible with non-aqueous dampening fluid options. Digital offset ink should not cause the imaging member surface to swell. Water-dilutable and water-diluted inks in accordance with embodiments include digital offset acrylate inks meeting such requirements.

[0041] Digital offset inks in accordance with water-dilutable ink embodiments advantageously have a much lower solubility in dampening fluid such as D4 than related art inks. Also, digital offset inks of embodiments do not tend to swell a silicone-containing imaging member surface layer used in ink-based digital printing systems such as that shown in FIG. 1, which may be a silicone, fluorosilicone, or VITON-containing imaging plate or blanket.

[0042] The ink must be compatible with materials it is in contact with, including printing plate 110, fountain solution applied by dampening fluid system 120, and other cured or non-cured inks. It must also meet all functional requirements of the sub-systems, including wetting and transfer properties. Transfer of the imaged inks is challenging, as the ink must at once wet the blanket material homogeneously (plate 110), and transfer from the blanket to the substrate (112, 114, and 118). Transfer of the image layer must be very efficient, at least as high as 90%, as the cleaning sub-station can only eliminate small amounts of residual ink. Any ink remaining on the blanket after cleaning would result in an unacceptable ghost image appearing in subsequent prints. Not surprisingly, ink rheology plays a key role in the transfer characteristics of an ink.

[0043] The disclosed ink formulation covers the composition of an ink set targeting the extension of the color gamut of a colored printing ink set useful in digital lithography printing. The ink compositions described are new compositions for digital advanced lithography imaging ink which are formulated to have specified materials properties enabling transfer, release, and the desired print properties in digital lithographic imaging print process.

[0044] The inks described herein may include the following components: (a) radiation-curable water-dilutable monomer compounds, including mono-, di-, and tri-functional water-dilutable acrylate monomers, oligomers; (b) dispersants; (c) pigments; (d) clays or additives; (e) initiators; (f) additional curable compounds including monomers, oligomers, including oligomers from Sartomer USA, LLC or Cytec Industries, Inc., prepolymers, polymers; (g) additives including surfactants, free-radical scavengers, and the like; (h) thermal stabilizers.

[0045] The water-diluted curable components may include any water-dilutable acrylate or methacrylate monomer compound(s) suitable for use as a phase change ink carrier or ink vehicle that may be water dilutable, with an addition of water being available to adjust and/or enhance background performance for use in the variable digital data lithographic printing architecture. In embodiments, the water-diluted curable component is a water-dilutable functional acrylate monomer, a methacrylate monomer, a multifunctional acrylate monomer, a multifunctional methacrylate monomer, or a mixture or combination thereof. Exemplary acrylates may include acrylate monomers or polymers such as polyester acrylates Sartomer CN294E, Sartomer CD-501, Sartomer CN9014, Sartomer CN2282 and Sartomer CN2256. In embodiments, a mixture of the components is water-dilutable.

[0046] Examples of curable monomers and diluting acrylates which can be used in the ink compositions as vehicles may include Trimethylolpropane triacrylate; SR-492, SR-501, SR-444, SR-454, SR-499, SR-502, SR-9035 and SR-415 from Sartomer; EBECRYL 853 and EBECRYL 5500 from Allnex. Trimethylolpropane triacrylate has a refractive index of 1.474, a specific gravity of 1.06 g/cm^3, an APHA Color of less than 300 and a viscosity range of 80 to 120 cps at 25°C. Sartomer SR-492 is a three mole propoxylated trimethylolpropane triacrylate and has a refractive index of 1.459, a specific gravity of 1.05 g/cm^3, a Tg of -15°C, an APHA Color of 30 and a viscosity of 90 cps at 25°C. Sartomer SR-501 is a six mole propoxylated trimethylolpropane triacrylate and has a refractive index of 1.4567, a specific gravity of 1.048 g/cm^3, a Tg of -2°C, an APHA Color of 90 and a viscosity of 125 cps at 25°C. Sartomer SR-444 is a pentaerythritol triacrylate and has a refractive index of 1.4801, a specific gravity of 1.162 g/cm^3, a Tg of 103°C, an APHA Color of 50 and a viscosity of 520 cps at 25°C. Sartomer SR-454 is a three mole ethoxylated trimethylolpropane triacrylate and has a refractive index of 1.4689, a specific gravity of 1.103 g/cm^3, a Tg of 120°C, an APHA Color of 55 and a viscosity of 60 cps at 25°C. Sartomer SR-499 is a six mole ethoxylated trimethylolpropane triacrylate and has a refractive index of 1.4691, a specific gravity of 1.106 g/cm^3, a Tg of -8°C, an APHA Color of 50 and a viscosity of 85 cps at 25°C. Sartomer SR-502 is a nine mole ethoxylated trimethylolpropane triacrylate and has a refractive index of 1.4691, a specific gravity of 1.11 g/cm^3, a Tg of -19°C, an APHA Color of 140 and a viscosity of 130 cps at 25°C. Sartomer SR-9035 is a fifteen mole ethoxylated trimethylolpropane triacrylate and has a refractive index of 1.4695, a specific gravity of 1.113 g/cm^3, a Tg of -32°C, an APHA Color of 60 and a viscosity of 168 cps at 25°C. Sartomer SR-415 is a twenty mole ethoxylated trimethylolpropane triacrylate and has a refractive index of 1.4699, a specific gravity of 1.115 g/cm^3, a Tg of -40°C, an APHA Color of 55 and a viscosity of 225 cps at 25°C. EBECRYL 853 is a low viscosity polyester triacrylate and has a specific gravity of 1.10 g/cm^3, an APHA Color of 200 and a viscosity of 80 cps at 25°C. EBECRYL 5500 is a low viscosity glycerol derivative triacrylate and has a specific gravity of 1.07 g/cm^3, an APHA Color of 62 and a viscosity of 130 cps at 25°C. Other triacrylate, monoacrylate, diacrylate, tetraacrylate and higher functional acrylate monomers, diluting acrylates, and various combinations thereof, can also be used in the ink compositions as vehicles.

[0047] One or more components in a mixture may be non-water dilutable, if the ink is water dilutable, and the reactive component are themselves miscible. In the same way that water may be added, in some embodiments, co-reactive monomers may be added to control polarity of the ink. Specific examples of water-dilutable curable components include, but are not limited to, the functional water soluble aromatic urethane acrylate compound (available from CYTEC as EBECRYL 2003), the di-functional compound polyethylene glycol diacrylate (available from CYTEC as EBECRYL 11), and the tri-functional compound polyether triacrylate (available from CYTEC as EBECRYL 12). The monomer or oligomer can be present in any suitable amount. In embodiments, the monomer or oligomer, or combination thereof is added in an amount of from about 10 to about 85%, or from about 30 to about 80%, or from about 50 to about 70%, by weight based on the total weight of the curable ink composition. Curable oligomers which can be used in the ink compositions as vehicles may include Sartomer CN294E; CN2256; CN2282; CN9014 and CN309. Sartomer CN294E is a tetrafunctional acrylated polyester oligomer. CN294E is a clear liquid having a specific gravity of 0.93 and a viscosity of 4,000 cps at 60°C. Sartomer CN2256 is a difunctional polyester acrylate oligomer and has a refractive index of 1.5062, a Tg of -22°C, a tensile strength of 675 psi, and a viscosity of 11,000 cps at 60°C. Sartomer CN2282 is tetrafunctional acrylated polyester and is a clear liquid having a specific gravity of 1.15 and a viscosity of 2,500 cps at 60°C. Sartomer CN9014 is a difunctional acrylated urethane and is a non-clear liquid having a specific gravity of 0.93 and a viscosity of 19,000 cps at 60°C. Sartomer CN309 is an oligomer containing an acrylate ester that derives from an aliphatic hydrophobic backbone, or in other words is an aliphatic acrylate ester. CN309 is a clear liquid having a specific gravity of 0.92, a density of 7.68 pounds/gallon, a surface tension of 26.3 dynes/cm, a viscosity of 150 cps at 25°C, and a viscosity of 40 cps at 60°C.

[0048] Examples of curable oligomers which can be used in the ink compositions as vehicles may include CN294E, CN2256, CN2282, CN9014 and CN309 from Sartomer; EBECRYL 8405, EBECRYL 8411, EBECRYL 8413, EBECRYL 8465, EBECRYL 8701, EBECRYL 9260, EBECRYL 546, EBECRYL 657, EBECRYL 809, and the like from Allnex. EBECRYL 8405 is a tetrafunctional urethane acrylate diluted as 80 weight percent (wt%) by weight in 1,6-Hexanediol diacrylate (HDDA). EBECRYL 8405 is a clear liquid having a Gardner Color of 2 and a viscosity of 4,000 cps at 60°C. EBECRYL 8411 is a difunctional urethane acrylate diluted as 80 wt% by weight in isobornylacrylate (IBOA). EBECRYL 8411 is a clear liquid having a viscosity range of 3,400 to 9,500 cps at 65°C. EBECRYL 8413 is a difunctional urethane acrylate diluted as 67 wt% by weight in IBOA. EBECRYL 8413 is a clear liquid having a viscosity of 35,000 cps at 60°C. EBECRYL 8465 is a trifunctional urethane acrylate. EBECRYL 8465 is a clear liquid having a Gardner Color of 2 and a viscosity of 21,000 cps at 60°C. EBECRYL 8701 is a trifunctional urethane acrylate. EBECRYL 8701 is a clear liquid having a Gardner Color of 2 and a viscosity of 4,500 cps at 60°C. EBECRYL 9260 is a trifunctional urethane acrylate. EBECRYL 9260 is a clear liquid having a Gardner Color of 2 and a viscosity of 4,000 cps at 60°C. EBECRYL 546 is a trifunctional polyester acrylate. EBECRYL 546 is a clear liquid having a Gardner Color of 1.5 and a viscosity of 350,000 cps at 25°C. EBECRYL 657 is a tetrafunctional polyester acrylate. EBECRYL 657 is a clear liquid having a Gardner Color of 4 and a viscosity of 125,000 cps at 25°C. EBECRYL 809 is a trifunctional polyester acrylate. EBECRYL 809 is a clear liquid having a Gardner Color of 3 and a viscosity of 1,300 cps at 60°C.

[0049] The dispersant components may include any suitable or desired dispersant including, but not limited to AB-diblock copolymers of high molecular weight such as EFKA® 4340 available from BASF SE, and DISPERBYK ® 2100 available from Byk-Chemie GmbH, or a mixture thereof. In a specific embodiment, the dispersant mixture comprises a cyclohexane dimethanol diacrylate (such as CD406® available from Sartomer USA, LLC) and at least one additional component, such as EFKA® 4340 is a high molecular weight dispersing agent having an AB-diblock copolymer structure available from BASF SE. In an exemplary embodiment, the dispersant is a polymeric dispersant, such as SOLSPERSE® 39000, commercially available from The Lubrizol Corporation. The dispersant may be added in an amount within the range of from about 20% to about 100% by weight, based on the weight of the composition. Dispersant may be added in an amount that is determined based on the amount of pigment used.

[0050] The disclosed curable ink composition also includes a colorant or pigment component, which may be any desired or effective colorant may be employed, including pigments, mixtures of pigments, mixtures of pigments and dyes, and the like, provided that the colorant may be dissolved or dispersed in the at least one monomer and at least one dispersant. In specific embodiments, the colorant is a pigment. Examples of suitable pigments include PALIOGEN Violet 5100 (BASF); PALIOGEN Violet 5890 (BASF); HELIOGEN Green L8730 (BASF); LITHOL Scarlet D3700 (BASF); SUNFAST. Blue 15:4 (Sun Chemical); Hostaperm Blue B2G-D (Clariant); Permanent Red P-F7RK; HOSTAPERM Violet BL (Clariant); LITHOL Scarlet 4440 (BASF); Bon Red C (Dominion Color Company); ORACET Pink RF (Ciba); PALIOGEN Red 3871 K (BASF); SUNFAST Blue 15:3 (Sun Chemical); PALIOGEN Red 3340 (BASF); SUNFAST Carbazole Violet 23 (Sun Chemical); LITHOL Fast Scarlet L4300 (BASF); SUNBRITE Yellow 17 (Sun Chemical); HELIOGEN Blue L6900, L7020 (BASF); SUNBRITE Yellow 74 (Sun Chemical); SPECTRA PAC C Orange 16 (Sun Chemical); HELIOGEN Blue K6902, K6910 (BASF); SUNFAST® Magenta 122 (Sun Chemical); HELIOGEN Blue D6840, D7080 (BASF); Sudan Blue OS (BASF); NEOPEN Blue FF4012 (BASF); PV Fast Blue B2GO1 (Clariant); IRGALITE Blue BCA (Ciba); PALIOGEN Blue 6470 (BASF); Sudan Orange G (Aldrich), Sudan Orange 220 (BASF); PALIOGEN Orange 3040 (BASF); PALIOGEN Yellow 152, 1560 (BASF); LITHOL Fast Yellow 0991 K (BASF); PALIOTOL Yellow 1840 (BASF); NOVOPERM Yellow FGL (Clariant); Lumogen Yellow D0790 (BASF); Suco-Yellow L1250 (BASF); Suco-Yellow D1355 (BASF); Suco Fast Yellow D1355, D1351 (BASF); HOSTAPERM Pink E 02 (Clariant); Hansa Brilliant Yellow 5GX03 (Clariant); Permanent Yellow GRL 02 (Clariant); Permanent Rubine L6B 05 (Clariant); FANAL Pink D4830 (BASF); CINQUASIA Magenta

(DuPont); PALIOGEN Black L0084 (BASF); Pigment Black K801 (BASF); and carbon blacks such as REGAL 330® (Cabot), Carbon Black 5250, Carbon Black 5750 (Columbia Chemical), and the like, as well as mixtures thereof.

[0051] The disclosed curable ink composition also includes a thermal stabilizer, an exemplary thermal stabilizer is Sartomer CN3216, which is an acrylate stabilizing additive having a specific gravity of 1.113 at 25°C and a viscosity of 1,100 cps at 25°C. Another exemplary thermal stabilizer is IRGASTAB UV 10, available from Ciba Specialty Chemicals, which acts as a radical scavenger. Both aforementioned radical scavengers, among others, promote in-can stability of the ink as it is stored at room temperature over time and prevent partial thermal curing of UV curable components while they are being processed at elevated temperatures with a pigment and other components to form a radiation curable ink.

[0052] The disclosed curable ink composition also includes a mixture of clay and CN2256 to achieve optimum rheological or image transfer characteristics.

[0053] In an exemplary embodiment, a digital offset ink composition may include a cyan pigment, BASF HELIOGEN Blue D 7088, originally available as IRGALITE Blue GLO from Ciba. The amount of colorant or pigment added to the ink composition may be within the range of from about 10% to about 30% by weight of the composition, or from about 19% to about 25%, or from about 20% or more, up to about 30%, based on the total weight of the ink composition.

[0054] In some embodiments, the acrylate ink compositions may include rheology modifiers. Exemplary rheology modifiers may be modified or unmodified inorganic compounds including organoclays, attapulgite clays and bentonite clays, including tetraallkyl ammonium bentonites as well as treated and untreated synthetic silicas. Suitable organoclays include from Southern Clay Products CLAYTONE HA and CLAYTONE HY. Suitable examples of tetraallkyl ammonium bentonites include from Celeritas Chemicals CELCHEM 31743-09, CELCHEM 31744-09, and CELCHEM 31745-09. Other exemplary rheology modifiers include organic compounds such as EFKA® 1900 and EFKA® 1920, both modified hydrogenated castor oils from BASF. The colorant may be added together with a clay component. In an embodiment, the clay is CLAYTONE® HY from Southern Clay Products. In an embodiment the clay component may be replaced with a silica, e.g.: AEROSIL 200 available from Degussa Canada, Ltd, and is added in an amount within the range of from about 1% to about 5% by weight, or from about 1.4% to about 3.5% by weight, or from about 1.8% to 2.0% by weight, based on the total weight of the composition.

[0055] Digital offset ink compositions of embodiments include initiator systems, which may include a photoinitiator that initiates polymerization of curable components of the ink, including the curable monomer. In an embodiment, the initiator is an ultraviolet radiation-activated photoinitiator. Exemplary photoinitiators include IRGACURE 379, IRGACURE 184 and IRGACURE 819, both available from Ciba Specialty Chemicals. IRGACURE 379 is 2-dimethylamino-2-(4-methylbenzyl)-1-(4-morpholino-4-yl-phenyl)-butan-1-one, with a molecular weight of 380.5. IRGACURE 184 is 1-hydroxy-cyclohexyl-phenyl-ketone, having a molecular weight of 204.3. IRGACURE 819 is bis(2,4,6-trimethylbenzoyl)-phenylphosphine oxide, having a molecular weight of 418.5. Another exemplary photoinitiator is Esacure KIP 150, available from Lamberti Technologies, which is an oligomeric alpha hydroxyketone, oligo[2-hydroxy-2-methyl-1-[4-(1-methylvinyl)phenyl]propanone]. The photoinitiator(s) may be present in an amount of from 0 to about 10 wt % of the ink composition, including from about 5 to about 8 wt %. In some embodiments, the (meth)acrylate ink compositions may include photoinitiators. Photoinitiators may be liquid- or solid-based or combinations thereof. In general, the photoinitiator may comprise 1-hydroxy-cyclohexyl-phenyl-ketone, bis(2,4,6-trimethylbenzoyl)-phenylphosphineoxide, Oligo[2-hydroxy-2-methyl-1-[4-(1-methylvinyl)phenyl]propanone], 2-Dimethylamino-2-(4-methyl-benzyl)-1-(4-morpholin-4-yl-phenyl)-butan-1-one, Diphenyl(2,4,6-trimethylbenzoyl)phosphate oxide, and 2-methyl-1[4-methylthio]phenyl]-2-morpholinopropane-lone, or a mixture or combination thereof. Suitable photoinitiators include those from classes of dialkoxy-acetopheonones, dialkoxy-alkyl-pheonones, amino-alkyl-pheonones, and acyl-phosphine oxides. Other suitable photoinitiators are from classes of benzophenones and thioxanthones, which require activation from suitable amine synergists. Exemplary photoinitiators include ADDITOL LX, ADDITOL DX, ADDITOL BDK, ADDITOL CPK, ADDITOL DMMTA, ADDITOL TPO from Allnex, Esacure 1001M from IRGACURE 127, IRGACURE 184, IRGACURE 379, IRGACURE 819 and IRGACURE 2959 from BASF. Exemplary amine synergists that are used with Type II photoinitiators include SPEEDCURE PDA, SPEEDCURE EDB from Lambson, Diethylaminoethyl Methacrylate, Ethyl-4-dimethylamino benzoate, 2-Ethylhexyl 4-dimethylamino benzoate from Esstech, Inc. In some embodiment, the (meth)acrylate ink composition may include low odor photoinitiators, such as, ESACURE KIP 150 available from Lamberti S.p.A.

[0056] Suitable equipment and processes to effect a high quality dispersion of the pigment, filler materials, thixotropes and the like, such as to result in colors with high degrees of saturation, include 3-roll mills, high viscosity blenders, kneaders, high shear mixers, acoustic mixers, planetary mixers, extruders and other equipment that can adequately disperse pigments in high viscosity media, to be used alone or in combination.

[0057] Ink formulations based on the above-mentioned water-dilutable ink material components were formed. These inks were prepared by process familiar to those in the art. An exemplary formulation is disclosed in Table 1.

Table 1: Digital advanced lithography imaging high viscosity ink set with improved curing and robustness

DALI High Viscosity Ink Set With Improved Curing and Robustness					
Components		**K-70**	**C-186**	**M-52**	**Y-19**
Type	**Used**	**%**	**%**	**%**	**%**
Pigment		Mogul E Carbon	Irgalite Blue GLO	Permanent Rubine Red L5B01	Permanent Yellow GMX
		16.25	17.50	15.00	17.50
Dispersant		Solsperse J200	Solsperse 39000	Solsperse J180	Solsperse 32000
		2.40	7.00	6.00	4.80
Vehicle	CN294E	62.87	59.36	54.93	51.52
	CN2256	2.00	1.00	8.81	9.00
	CD-501		1.76	3.88	5.80
Stabilizer	CN3216	0.10	1.00	1.00	1.00
	Irgacure 379	2.00	2.00	2.00	2.00
Photoinitiators	Irgacure 819	2.40	2.40	2.40	2.40
	Esacure Kip 150	3.50	3.50	3.50	3.50
	Irgacure 184	0.48	0.48	0.48	0.48
Additives	Claytone HY	8.00	4.00	2.00	2.00
Total Amount	%	100.00	100.00	100.00	100.00

[0058] Key features of the formulated ink of Table 1 are: 1) Use of a 4 photoinitiator system to maximize light absorption if a mercury lamp is used and enable UV LED has required; 2) Unexpected increase in curing efficiency when using multi-passes of short exposure, favoring higher speed capability at constant image robustness. It is expected that even better performance can be enabled with even shorter exposure times; 3) Enables efficient curing for inks of viscosity of about 150 Pa·s (pascal-second) at 35°C or higher; 4) Ink set where all 4 inks have MEK Double Rub of 50 or above after cumulative light exposure time of 1.5 seconds; 5) Use of 4 photoinitiators facilitates the design of inks that have the same photoinitiator package and as required same curing performance as measured with MEK Double Rub method. All inks contain UV curable components for the digital advanced lithography imaging architecture and pigments are compatible in the required UV curable components. The inks are in the viscosity range of 1 - 2.5 $\times 10^5$ cps (100 rad/s), and the tack range of 25-35 g·m (60 s) at 35°C. The previous three formulations are only examples of functioning inks and could be mixed in various combinations and with other pigments.

[0059] The formulation of the resulting inks is shown in Table 1. Table 2 compares the old design to the new proposed design. Table 2 also includes the recommended ranges for the photoinitiator selected for conventional offset inks, two of the photoinitiators used in digital advanced lithography imaging, the Irgacure 819 and 184, are outside of the recommended amounts.

Table 2: Comparative photoinitiator packages for Control and New Design vs Recommended Range

Photoinitiator Type	Recommended Range from Literature Data	Melting Point, °C	Pre-Optimization Photoinitiator Package	Post-Optimization Photoinitiator Package	Comments	Wavelength; max and limit
			Concentration, wt% in ink	Concentration, wt% in ink		
Irgacure 379	2-4%	82-87%	2	2	Excellent Solubility compared to 369	320 nm up to 425
Irgacure 819	0.5-1%	127-133	1.39	2.4		300 nm up to 440
Esacure Kip 150	2-4%; 0.5-5%	Viscous Liquid	3.62	3.5		260 nm up to 380
Irgacure 184	1-3% for thick film and 2-4% for 5-20 microns 1-2% in combination with 819	45-49		0.48		240,280, up to 380
Total Amount (g)			7.01	8.38		

[0060] FIG. 2 illustrates the effect of curing speed on print robustness as measured by Double MEK Rub in accordance to an embodiment. The samples were cured through multiple exposures in a Fusion UV Light Hammer 6 and 2 different speeds, 1 m/s and 0.168 m/s. The photoinitiator composition with the highest MEK double rub value after 1 pass at 1 m/s and the highest cure rate (highest maximum cure after multi-passes) was selected for the cyan ink. This optimum was then used for K, M and Y inks. The actual UV exposure times were calculated and the curing properties at 1 m/s and 0.168 m/s were compared. A significant difference in Double MEK Rub response was found as shown in FIG. 2. The target MEK Rub resistance was achieved in less than 1.5 seconds with multi-passes at high speed while it takes more than 3 seconds of light exposure to achieve same MEK rub when slow curing speed is used. In addition, the high speed curing data were for all practical purpose increasing linearly with time while this was not the case for the slow speed curing data. It is believed that if the cumulative exposure time can be obtained by a higher number of equivalent passes (N) or higher speed passes, e.g.: 2 m/s then one would see a further increase in the curing efficiency.

[0061] FIG. 3 illustrates the thickness of prints used for MEK Rub Test in accordance to an embodiment. FIG. 3 illustrates the comparative curing performance of all inks (K, C, M, Y) that were printed on a XRCC Mimico Test Fixture at targeted OD and respective thicknesses.

[0062] FIG. 4 illustrates the optimization summary and Double MEK Rub One-Pass Data for the proposed digital advanced lithography imaging ink set in accordance to an embodiment. FIG. 4 illustrates the comparative MEK Double Rub data for the control inks (pre-optimization) and the ink set of Table 1 (post-optimization with 4 photo initiators) after the first pass and FIG. 5 shows the comparative MEK Double Rub data after multi-pass at 1m/s. Note that all 4 digital advanced lithography imaging inks show significant improvement in MEK rub resistance even after a single pass.

[0063] FIG. 5 illustrates the Double MEK Rub Data for the proposed digital advanced lithography imaging ink set as compared to previous mainline design in accordance to an embodiment. The key impact of the use of a three photoinitiator system, as shown in FIG. 4 and 5, is that significant improvement in robustness for short exposure times seen for all colors (K > 100%) and that the new compositions or inks can take full advantage of multi-curing stations or multi-pass printing process where each color is applied individually or sequentially. While three (3) photoinitiators are required; the use of four (4) photoinitiators can be used to facilitate the design of inks that have the same photoinitiator package and as may be required the same curing performance as measured with MEK Double Rub method.

[0064] Each of the inks were applied to a digital advanced lithography imaging composite fluorosilicone blanket and completely transferred from the surface onto a paper substrate, in contrast to a traditional offset process where the ink layer is split between blanket and substrate. The inks were transferred onto XEROX Digital Color Elite Gloss (DCEG) paper at a nominal optical density such that the L* brightness of the transferred images are in a range suitable for each color after having been cured using a Fusion UV Lighthammer L6 curing station equipped with D bulb and such that the applied energy doses for UW, UVA, UVB, and UVC bands are 640, 1401, 420 and 37 mJ/cm^2, respectively. The print sample was passed under the UV lamp at a speed of 197 feet/min.

[0065] MEK Rub Testing (Robustness): A soft applicator dipped in methylethyl ketone (MEK) solvent at room temperature is spread evenly across (about 2 cm) each of the images on DCEG paper using constant pressure with fresh MEK being re-applied onto the applicator after every 5 double MEK rubs. The value reported is the number of MEK double rubs required before the paper substrate becomes visible.

[0066] Ink Preparation for MEK Rub Testing: The method described here was used to prepare all inks listed in the column of Table 3 below. Examples 1 & 2 (EX1 & EX2) were then compared to comparative examples (CEX1 ... CEX6).

[0067] Based on a 300 g total scale of preparation of ink, the first set of ink base components (including the dispersant, monomer, oligomer and thermal stabilizer) were added in a 1 L stainless steel vessel. The vessel was placed on a heating mantle, available from IKA® equipped with a thermocouple and stirrer apparatus also available from IKA® and with an anchor impeller. The components in the vessel were stirred at about 200 RPM for about 30 minutes at about 80°C. Then the second set of ink base components, the photoinitiators, was added slowly with stirring at about 80°C which continued for about another hour. With the vehicle base components solubilized, the given quantity of colored pigment was added to the system and the stirring rate increased to about 400 RPM, taking care to avoid introducing entrained air into the system. The pigmented mixture was allowed to stir for about 30 minutes at about 400 RPM at which point the clay was added slowly to the pigmented mixture and then stirred another 15 minutes at about 400 RPM. The vessel containing the mixed components was transferred to a high speed shearing mill available from the Hockmeyer Equipment Corporation equipped with a 40 mm diameter high shear Cowles blade and the ink was stirred at about 5,000 RPM for about an hour. The thoroughly mixed component mixture was then qualitatively transferred to a 3-roll mill apparatus manufactured by Kent Machine Works where the material composite paste was passed through the 3-roll mill first at an input apron roll speed of 400 RPM for the first pass and then at an input apron roll speed of 200 RPM for the second pass.

Table 3: MEK Rub Testing Ink Compositions

	EX1	EX2		CEX1	CEX2	CEX3	CEX4	CEX5	CEX6
BASF H7088	17.50	17.50		17.50	17.50	17.50	17.50	17.50	17.50
Southern Clay Claytone HY	4	4		4	4	4	4	4	4
Solsperse 39000	7.00	7.00		7.00	7.00	7.00	7.00	7.00	7.00
Sartomer SR501	1.76	1.76		1.76	1.76	1.76	1.76	1.76	1.76
Sartomer CN294E	59.36	58.81		61.49	60.74	58.49	59.91	57.74	59.05
Sartomer CN2256	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00
Sartomer CN3216	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00
Photoinitiators									
Irgacure 379	2.00	2.20		2.00	2.00	2.00	1.80	2.00	2.00
Irgacure 819	2.40	2.40		0.75	1.50	0.75	2.40	1.50	0.94
Esacure KIP 150	3.50	3.85		3.50	3.50	3.50	3.15	3.50	3.50
Irgacure 184	0.48	0.48		0.00	0.00	3.00	0.48	3.00	2.25
Total	100.00	100.00		100.00	100.00	100.00	100.00	100.00	100.00
# Double MEK rubs to image failure	28	29		16	16	13	23	13	14

[0068] FIG. 6 is a plot of viscosity data for the proposed ink set in accordance to an embodiment. As shown in FIG. 6 the disclosed ink set have similar high frequency viscosities, needed for best imaging performance , with an average viscosity of 228 Pa·s +/- 15.4%.

[0069] FIG. 7 illustrates a process flow diagram for making a three (3) photoinitiator digital advanced lithography imaging ink set in accordance to an embodiment. In action 705, the process 700 begins by adding or combining monomers, dispersants, stabilizers, and the like. In action 710, the process blends the added monomers and dispersants. In action 715, the three or more photoinitiators being used at very specific ratios to each other are added and blended into the mixture. In action 720, the process performs pigment wetting comprising anchor impelling and high shear mixing. In action 725, the process blends pigments and additives like CLAYTONE HY. In action 730, the process performs milling on the mixture and in action 740 the milled mixture is discharged into a brown glass bottle.

[0070] It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also that various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

Claims

1. An ink composition for variable data lithography printing comprising:

an ink vehicle and at least one colorant component suspended in solution in the ink composition; and
the solution comprising two or more of
at least one dispersant;
a thermal stabilizer; and
a photo initiator system comprising at least three or more photoinitiators being used at very specific ratios to each other;
wherein the at least three or more photoinitiator improve curing efficiency through multiple short UV light exposure in variable lithography printing.

2. The ink composition of claim 1, the solution further comprising:

a rheology modifying agent.

3. The ink composition of claim 2, wherein the vehicle is a radiation-curable compound that comprises monomer compounds selected from the group of compounds comprising mono-, di-, and tri-functional acrylate monomers, tetra-functional acrylates and oligomers.

4. The ink composition of claim 3, wherein the at least one colorant component comprises a pigment, the pigment component is in a proportion of at least 15% by weight.

5. The ink composition of claim 3, wherein the at least three or more photoinitiators are selected from a group consisting of free-radical photoinitiators or photoinitiator moieties, wherein the photoinitiator comprises 1-hydroxy-cyclohexyl-phenyl-ketone, bis(2,4,6-trimethylbenzoyl)-phenylphosphineoxide, Oligo[2-hydroxy-2-methyl-1-[4-(1-methylvinyl)phenyl]propanone], 2-Dimethylamino-2-(4-methyl-benzyl)-1-(4-morpholin-4-yl-phenyl)-butan-1-one and 2-methyl-1[4-methylthio]phenyl]-2-morpholinopropane-lone, or a mixture or combination thereof.

6. A process for variable lithographic printing, comprising:

applying a dampening fluid to an imaging member surface;
forming a latent image by evaporating the dampening fluid from selective locations on the imaging member surface to form hydrophobic non-image areas and hydrophilic image areas;
developing the latent image by applying an ink composition comprising an ink component to the hydrophilic image areas; and
transferring the developed latent image to a receiving substrate;
wherein the ink composition comprises an ink vehicle and at least one colorant component suspended in solution in the ink composition; and
the solution comprising two or more of
at least one dispersant;
a thermal stabilizer; and
a photo initiator system comprising at least three or more photoinitiators being used at very specific ratios to each other;
wherein the at least three or more photoinitiator improve curing efficiency through multiple short UV light exposure in variable lithography printing.

7. The process for variable lithographic printing of claim 6, the solution further comprising:

a rheology modifying agent;
wherein the rheology modifying is present in the ink composition in a range of about 1 weight percent to about 10 weight percent.

8. The process for variable lithographic printing of claim 7, wherein the vehicle is a radiation-curable compound that comprises monomer compounds selected from the group of compounds comprising mono-, di-, and tri-functional acrylate monomers, tetra-functional acrylates and oligomers.

9. The process for variable lithographic printing of claim 8, wherein the at least three or more photoinitiators are selected from a group consisting of free-radical photoinitiators or photoinitiator moieties, wherein the photoinitiator comprises 1-hydroxy-cyclohexyl-phenyl-ketone, bis(2,4,6-trimethylbenzoyl)-phenylphosphineoxide, Oligo[2-hydroxy-2-methyl-1-[4-(1-methylvinyl)phenyl]propanone], 2-Dimethylamino-2-(4-methyl-benzyl)-1-(4-morpholin-4-yl-phenyl)-butan-1-one and 2-methyl-1[4-methylthio]phenyl]-2-morpholinopropane-lone, or a mixture or combination thereof.

10. The process for variable lithographic printing of claim 8, wherein the at least one colorant component comprises a pigment, the pigment component is in a proportion of at least 15% by weight.

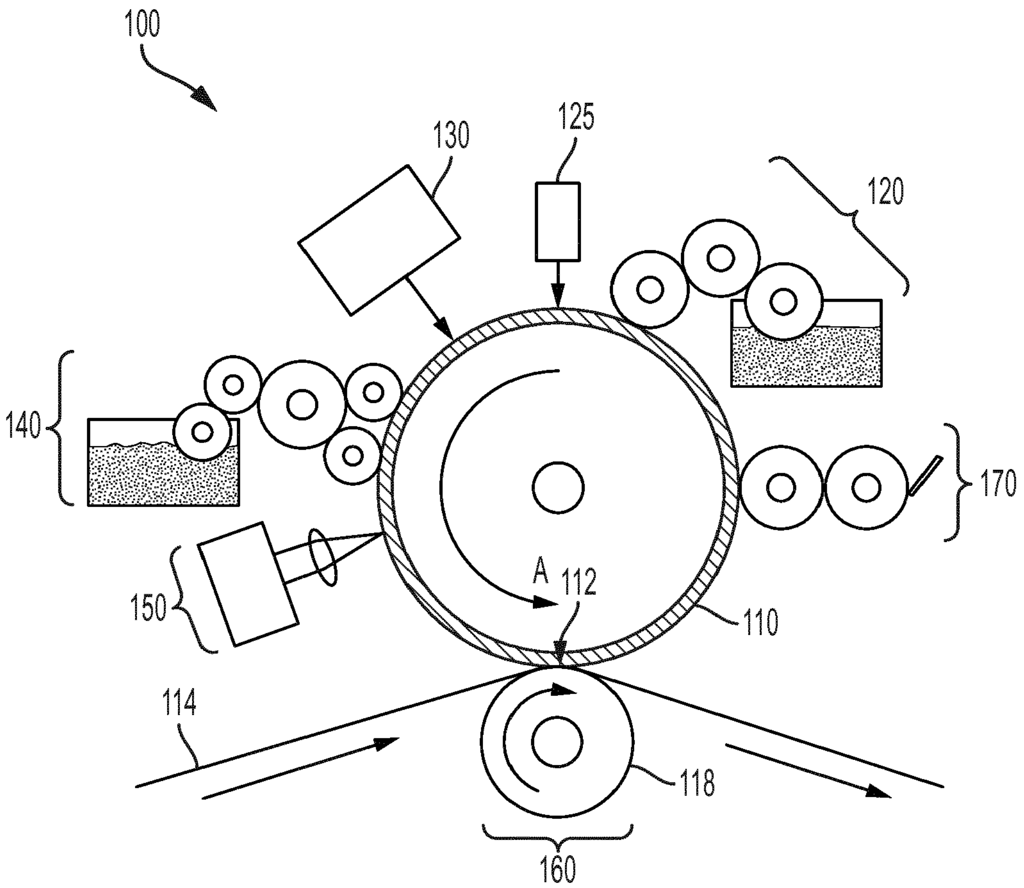

FIG. 1
RELATED ART

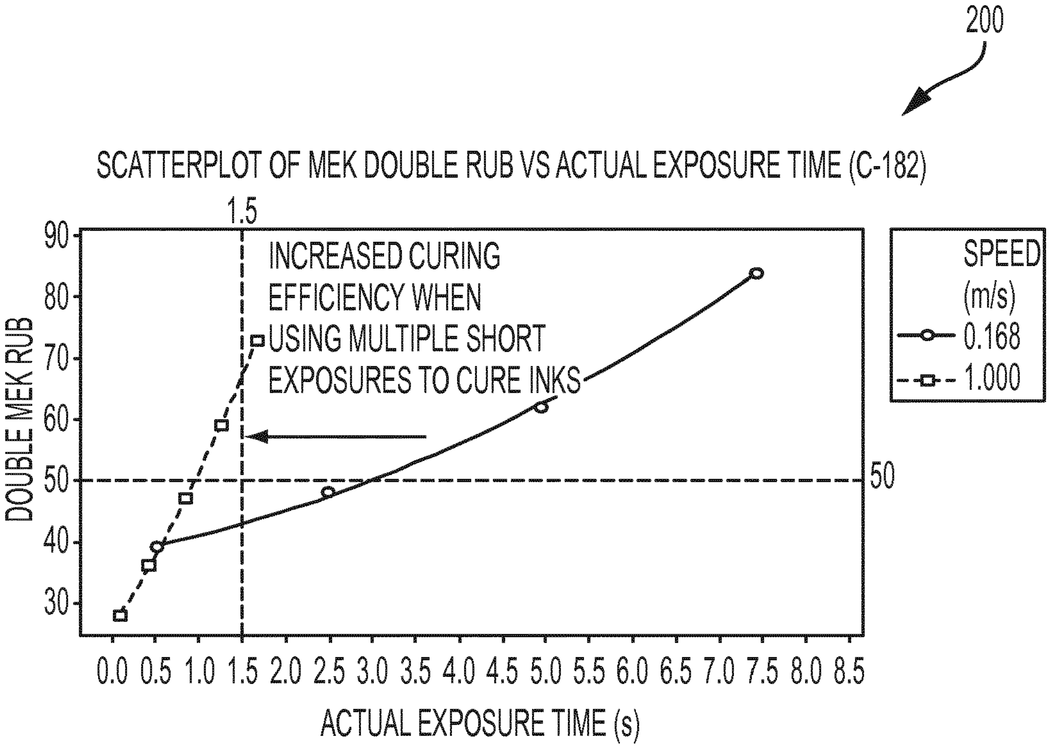
200
SCATTERPLOT OF MEK DOUBLE RUB VS ACTUAL EXPOSURE TIME (C-182)
1.5
INCREASED CURING
EFFICIENCY WHEN
USING MULTIPLE SHORT
EXPOSURES TO CURE INKS
50
DOUBLE MEK RUB
90
80
70
60
50
40
30
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5
ACTUAL EXPOSURE TIME (s)
SPEED
(m/s)
0.168
1.000

FIG. 2

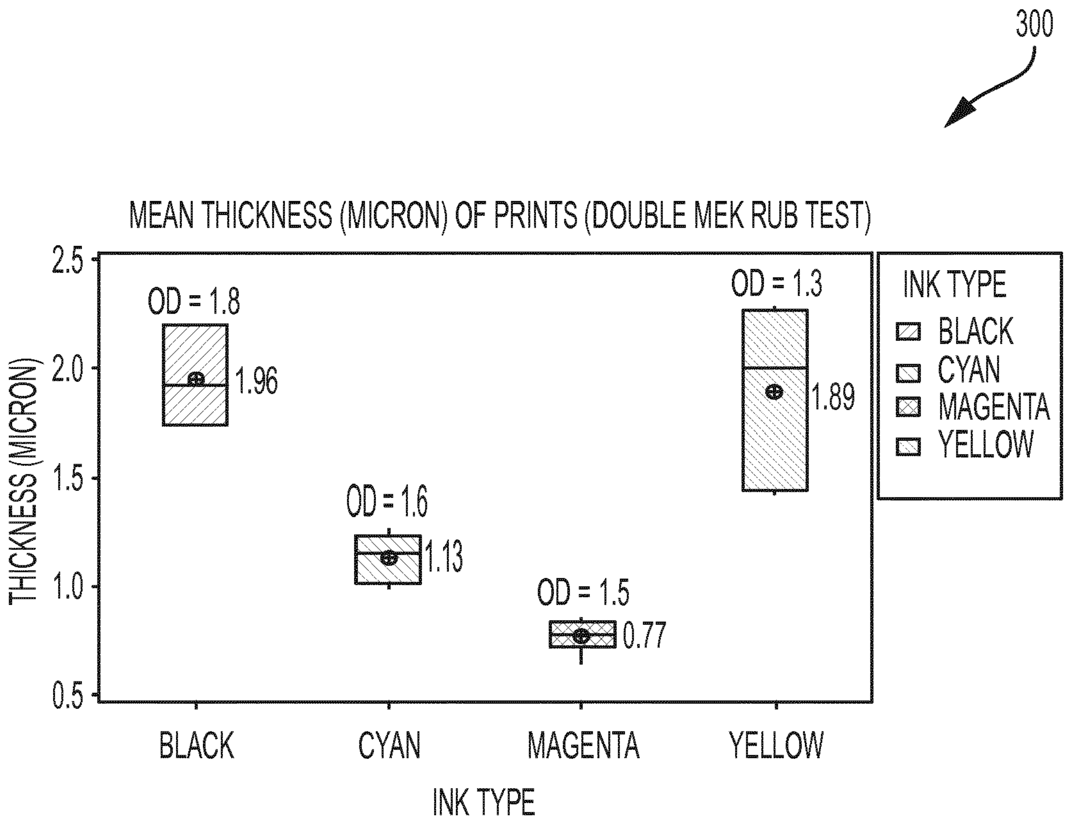
300
MEAN THICKNESS (MICRON) OF PRINTS (DOUBLE MEK RUB TEST)
THICKNESS (MICRON)
2.5
2.0
1.5
1.0
0.5
OD = 1.8
1.96
OD = 1.6
1.13
OD = 1.5
0.77
OD = 1.3
1.89
BLACK
CYAN
MAGENTA
YELLOW
INK TYPE
INK TYPE
BLACK
CYAN
MAGENTA
YELLOW

FIG. 3

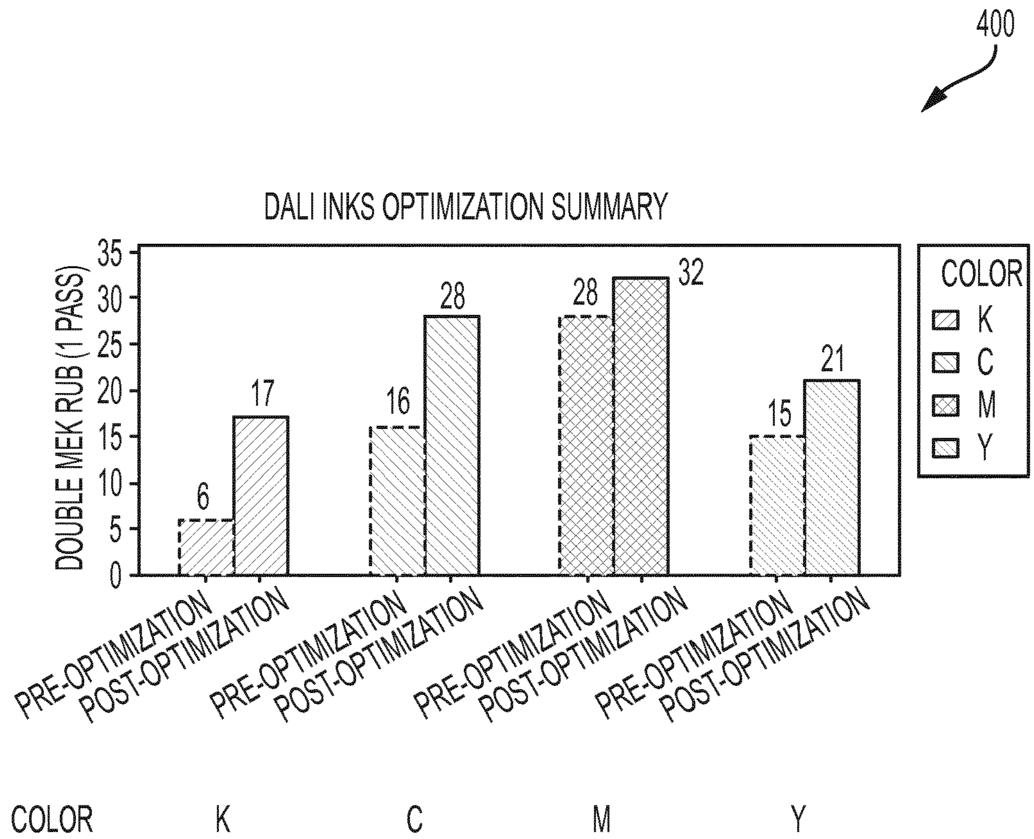
400
DALI INKS OPTIMIZATION SUMMARY
DOUBLE MEK RUB (1 PASS)
35
30
25
20
15
10
5
0
6
17
16
28
28
32
15
21
COLOR
K
C
M
Y
PRE-OPTIMIZATION
POST-OPTIMIZATION
PRE-OPTIMIZATION
POST-OPTIMIZATION
PRE-OPTIMIZATION
POST-OPTIMIZATION
PRE-OPTIMIZATION
POST-OPTIMIZATION
COLOR
K
C
M
Y

FIG. 4

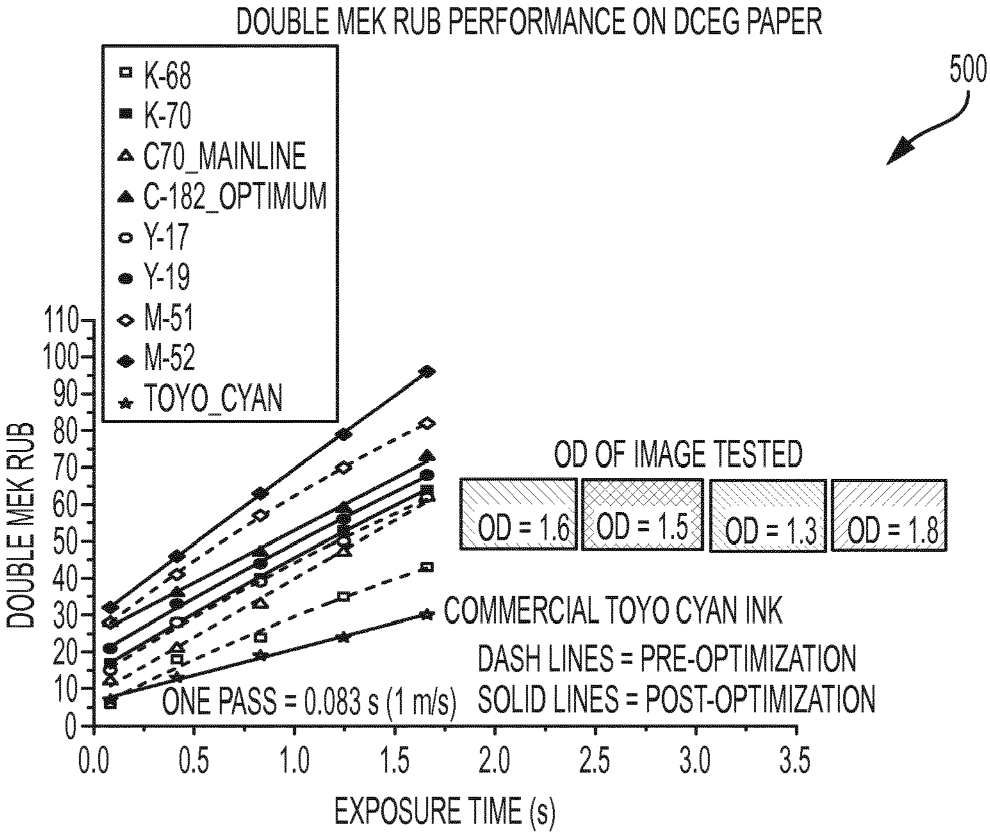
DOUBLE MEK RUB PERFORMANCE ON DCEG PAPER
500
K-68
K-70
C70_MAINLINE
C-182_OPTIMUM
Y-17
Y-19
M-51
M-52
TOYO_CYAN
DOUBLE MEK RUB
110
100
90
80
70
60
50
40
30
20
10
0
OD OF IMAGE TESTED
OD = 1.6
OD = 1.5
OD = 1.3
OD = 1.8
COMMERCIAL TOYO CYAN INK
DASH LINES = PRE-OPTIMIZATION
SOLID LINES = POST-OPTIMIZATION
ONE PASS = 0.083 s (1 m/s)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
EXPOSURE TIME (s)

FIG. 5

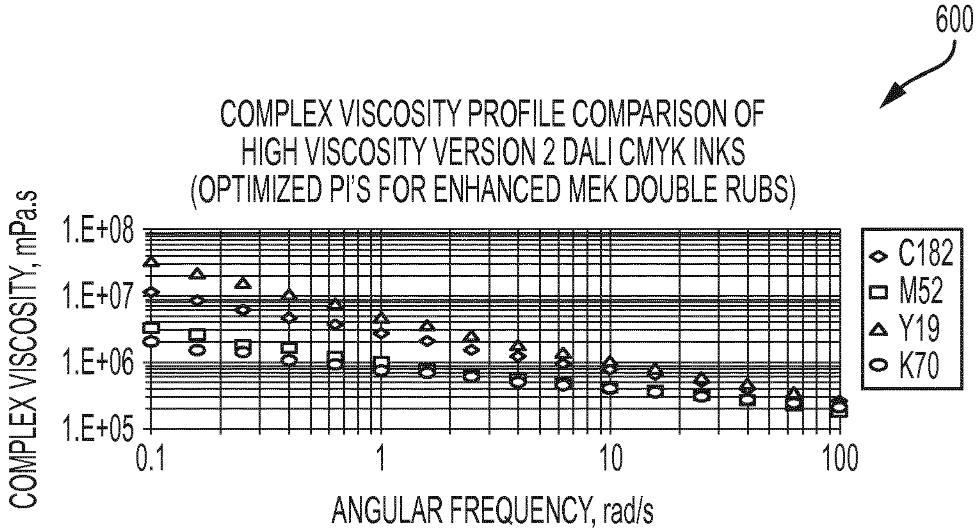
600
COMPLEX VISCOSITY PROFILE COMPARISON OF
HIGH VISCOSITY VERSION 2 DALI CMYK INKS
(OPTIMIZED PI'S FOR ENHANCED MEK DOUBLE RUBS)
COMPLEX VISCOSITY, mPa.s
1.E+08
1.E+07
1.E+06
1.E+05
0.1
1
10
100
ANGULAR FREQUENCY, rad/s
C182
M52
Y19
K70

FIG. 6

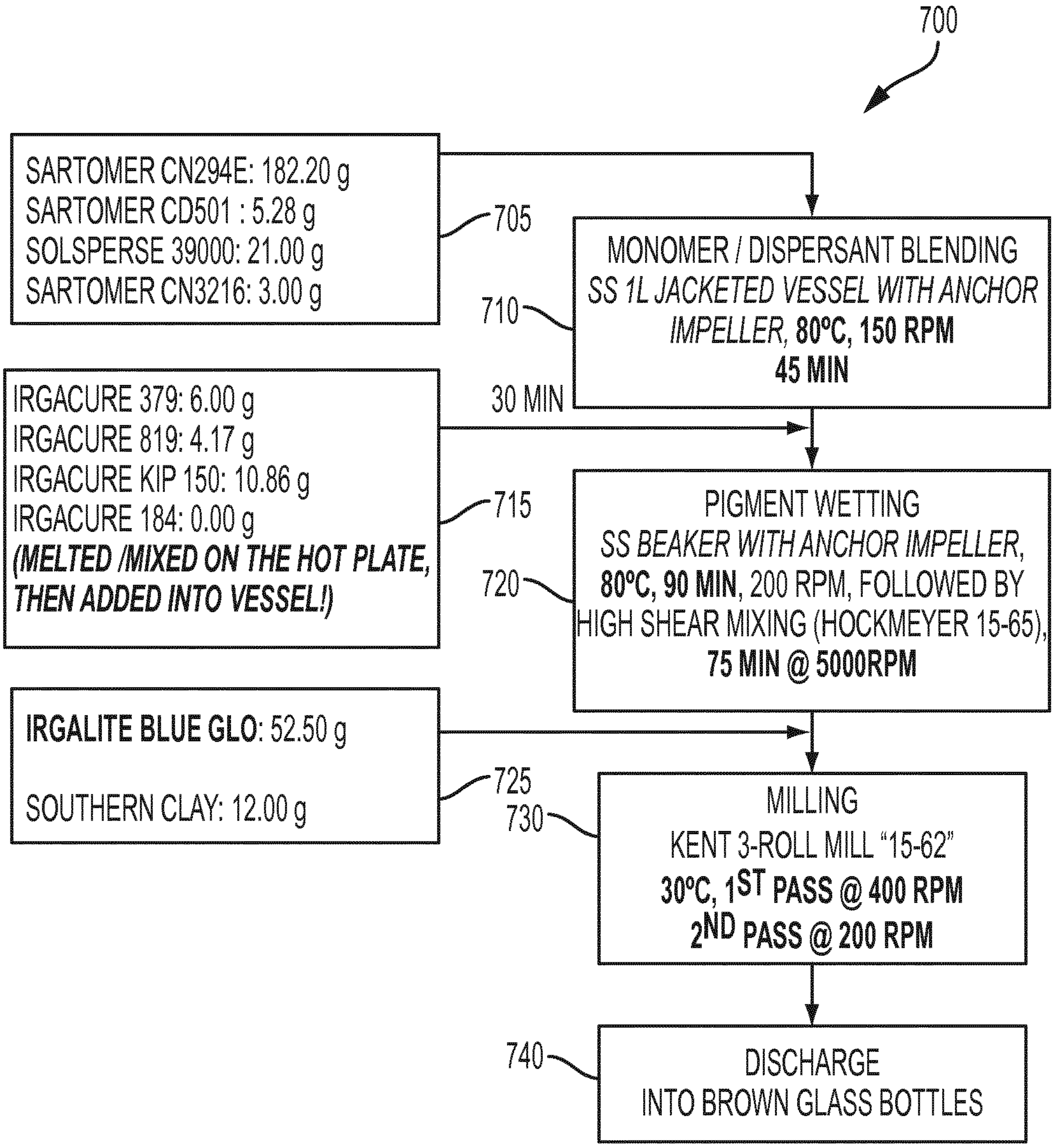
700
SARTOMER CN294E: 182.20 g
SARTOMER CD501 : 5.28 g
SOLSPERSE 39000: 21.00 g
SARTOMER CN3216: 3.00 g
705
710
MONOMER / DISPERSANT BLENDING
SS 1L JACKETED VESSEL WITH ANCHOR IMPELLER, 80ºC, 150 RPM
45 MIN
30 MIN
IRGACURE 379: 6.00 g
IRGACURE 819: 4.17 g
IRGACURE KIP 150: 10.86 g
IRGACURE 184: 0.00 g
(MELTED /MIXED ON THE HOT PLATE, THEN ADDED INTO VESSEL!)
715
720
PIGMENT WETTING
SS BEAKER WITH ANCHOR IMPELLER, 80ºC, 90 MIN, 200 RPM, FOLLOWED BY HIGH SHEAR MIXING (HOCKMEYER 15-65), 75 MIN @ 5000RPM
IRGALITE BLUE GLO: 52.50 g
SOUTHERN CLAY: 12.00 g
725
730
MILLING
KENT 3-ROLL MILL "15-62"
30ºC, 1ST PASS @ 400 RPM
2ND PASS @ 200 RPM
740
DISCHARGE
INTO BROWN GLASS BOTTLES

FIG. 7