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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(54) Title: PHOTORECEPTOR ELEMENTS HAVING RELEASE LAYERS WITH TEXTURE AND MEANS FOR PROVIDING SUCH ELEMENTS

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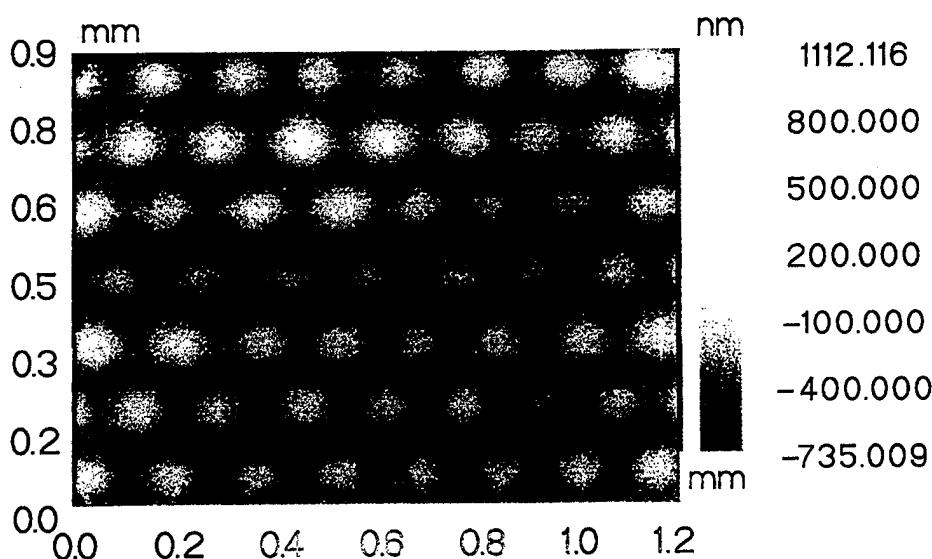
(57) Abstract

The invention is textured surface release layers for photoreceptors used in liquid electrophotography. The release surface is preferably directionally textured in the image processing direction. The invention also includes means of providing textured release surfaces for photoreceptors, systems using directionally textured photoreceptors, and a method of liquid electrophotographic imaging using directionally textured photoreceptors.

Photoreceptor Elements Having Release Layers with Texture and Means for Providing Such Elements

Field of Invention

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The present invention relates to photoreceptors for electrophotographic imaging. More specifically this invention relates to release layers for photoreceptors having texture and a method for making such photoreceptors.

10   Background of Invention

Electrophotography forms the technical basis for various well known processes, including photocopying and some forms of laser printing. The basic electrophotographic process involves placing a uniform electrostatic charge on a photoconductive element (also referred to as a photoconductor element or a

15   photoreceptor), imagewise exposing the photoconductive element to activating electromagnetic radiation, also referred to herein as "light", thereby dissipating the charge in the exposed areas, developing the resulting electrostatic latent image with a toner, and transferring the toner image from the photoconductor element to a final substrate, such as paper, either by direct transfer or via an intermediate transfer

20   material. Liquid toners are often preferable because they are capable of giving higher resolution images.

In electrophotographic printing, particularly liquid electrophotographic printing, the temporary receptor is a photoreceptor. The structure of a photoreceptive element may be a continuous belt, which is supported and circulated

25   by rollers, or a rotatable drum. All photoreceptors have a photoconductive layer which conducts electric current when exposed to activating electromagnetic radiation. The photoconductive layer is generally affixed to an electroconductive support. The surface of the photoreceptor is either negatively or positively charged such that when activating electromagnetic radiation strikes the photoconductive

30   layer, charge is conducted through the photoconductor in that region to neutralize or reduce the surface potential in the illuminated region.

Other layers, including surface release layers and interlayers, such as priming layers, charge injection blocking layers, or barrier layers may also be used in some

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photoreceptive elements. These photoreceptors are typically multilayer constructions comprised of an underlying photoconductive layer sensitive to actinic radiation and various top coats which impart barrier and/or release properties to the photoreceptor. See R.M. Schaffert, "Electrophotography" (John Wiley: NY,

5   1975), pp. 260-396.

When multi-colored images are desired, one may apply each toner color to the photoconductor element and transfer each color image to the final substrate separately. Alternatively, all the colors may be first assembled in registration on the photoconductor element and then transferred to a final receptor, either directly or

10   via an intermediate transfer element. This method is referred to herein as simplified color electrophotography (SCE). See e.g. WO 97/12288. Specifically, a photoreceptor is movably positioned to pass at least one exposure station and at least one developing station. If there is only one exposure station or one developing station, the photoreceptor will have to move past the stations several

15   times to create a multicolor image on the photoreceptor, e.g. two or more rotations. If there are several exposure and developing stations the image may be created in a single pass of the photoreceptor. To begin creating a multi-color image, any previously accumulated charge is erased from the photoreceptor. The photoreceptor is charged to a predetermined charge level. The photoreceptor is

20   first image-wise exposed to radiation modulated in accordance with the image data for one of a plurality of colors in order to partially discharge the photoreceptor to produce an image-wise distribution of charges on the photoreceptor corresponding to the image data for the one of the plurality of colors. A first color liquid toner is applied to the image-wise distribution of charges on the photoreceptor to form a

25   first color image. The photoreceptor may then optionally be recharged by any known means, e.g. by corona charging, or the application of the first toner liquid may itself recharge the photoreceptor to a second predetermined charge level. The exposure, liquid toner application and optional recharging steps are repeated as necessary for each desired color.

30   A problem that may arise during electrophotographic imaging is poor transfer from the photoreceptor to the intermediate transfer member. Poor transfer

may be manifested by images that are light, speckled, fuzzy, or smeared. These transfer problems may be reduced by the use of a surface release coating on the photoreceptor.

5   The release layer may be applied over the photoconductive layer or over an interlayer. The release layer should be durable and resistant to abrasion. The release layer should also resist chemical attack or excessive swelling by the toner carrier fluid. The release layer should also not significantly interfere with the charge dissipation characteristics of the photoconductor construction. Other desirable attributes of release surfaces include good adhesion to the underlying interlayer or

10   photoconductor, excellent transparency to actinic radiation (i.e. laser scanning devices), and simple manufacturing processes and low cost.

Surface release layers are commonly low surface energy coatings such as silicones, fluorosilicones or fluoropolymers. Various silicone release layers useful as topcoats on photoreceptive elements are described in PCT Patent Publication

15   No. WO96/34318 as well as U.S. Pat. No. 4,600,673, U.S. Pat. No. 5,320,923 and U.S. Pat. No. 5,733,698.

For liquid electrophotographic printing in particular, it may be desirable to avoid beading of toner excess carrier liquid on the surface of the release layer because the beads of carrier liquid can disturb the toner image. Specifically, the

20   presence of the toner carrier liquid on the surface may allow the toned image to continue to flow with adverse effects on image resolution. Moreover, when a multi-color image is formed on the photoreceptor in a single pass without drying between imaging stages, such beading may cause diffraction of the exposing light during imaging resulting in lack of sharp lines or clarity in the final image.

25   Therefore, release layers which control the liquid on the surface of the photoreceptor are needed. However, the liquid toner should not cause smearing or diffusional broadening (i.e., blooming or bleeding) of the image. Desirably, the surface release layers permit virtually 100% image transfer from the photoreceptor to an intermediate transfer member, thereby maintaining optimum image quality

30   eliminating or reducing the need to clean the photoreceptor between images.

Color liquid electrophotography, particularly SCE, imposes a number of critical requirements on the release surface of the photoreceptor. The photoreceptor release surface must, in general, provide a low energy surface for transfer of the toner. Moreover, systems that use differential adhesive transfer rely on the

5   relationship of the surface energies of the photoreceptor surface, the liquid toner, the toner film, and any rollers that contact the toner surface. See, for example, U.S. Patent No. 5,652,282. For some systems, the relative surface energies should be in the following hierarchy from the element with the lowest surface energy to the element with the highest surface energy: drying element, release layer of

10   photoreceptor, intermediate transfer material, toner, final receptor.

U.S. 5,099,256 teaches the random roughening of a silicone-coated intermediate drum to prevent movement of aqueous ink droplets applied to the drum using an ink jet print head. This patent does not teach the roughening of a photoreceptor release surface to prevent beading of a solvent-based ink, but rather

15   teaches roughness to promote beading of the droplets.

R. H. Wenzel, Industrial and Engineering Chemistry, 28 (8), pp. 988-991 (1936) teaches that the effect of surface roughness on wetting or beading characteristics of a liquid is determined largely by the apparent contact angle of the liquid measured on the non-roughened surface. Liquids which exhibit contact

20   angles less than 90 degrees on a non-roughened surface will exhibit improved wetting (i.e. lower contact angle) on the same surface when roughened. Alternatively, liquids which exhibit contact angles greater than 90 degrees on a non-roughened surface will exhibit improved de-wetting (i.e. higher contact angle) on the same surface when roughened.

25   While many references in the electrophotographic field teach providing smooth surfaces, some references do teach roughening of a photoreceptor. For example, JP 4122945, JP 6089036 and 8076388 disclose photoreceptors having an average surface roughness of 0.3 to 1.5 micron or 0.15-5 microns ten point average surface roughness in 2.5 mm standard length or a maximum surface roughness

30   (R_{max}) of 0.3-1.5 microns. These patents are primarily directed towards random

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roughening of the photoreceptor to prevent optical interference effects during exposure with coherent radiation sources.

U.S. 5,187,039 teaches a roughened photoreceptor surface useful in preventing wear and reducing toner impaction during cleaning with a blade, and

5   claims a specific relationship between surface roughness and various cleaning blade characteristics.

U.S. 4,804,607 discloses an inorganic overcoat layer for a photosensitive layer formed such that a rough surface is provided having convexities and concavities with a maximum depth difference of 0.5 to 1.5 microns. The

10   convexities and concavities are formed by vacuum evaporating the overcoat layer onto the photosensitive layer and heating the resulting photoreceptor to form wrinkle-shaped convexities and concavities.

JP 4120551 discloses photoreceptors having an average surface roughness of 0.1-3 microns with a maximum of 5 microns to enable improved cleaning of the

15   surface. This patent teaches roughening by use of an abrasive material, sand blasting, a solvent exposure technique, and addition of powdered particles to the surface release layer.

U.S. 3,383,209 describes a liquid electrophotographic process which makes use of the selective wetting characteristics of toner on the photoreceptor to improve

20   image quality and produce dryer images. The wetting properties (i.e. contact angle) of a liquid toner relative to a photoreceptor surface are controlled using an electric field.

GB 1528458 and GB 1520898 disclose a surface release layer on a photoconductor having regular periodic ribs generated using a precision die coating

25   process. The ribs are oriented longitudinally in the downweb direction and exhibit an essentially sinusoidal cross section having peaks and valleys such that the underlying photoconductor surface is exposed at the base of the valleys.

U.S. 5,162,183 discloses an imaging member comprising at least a photosensitive layer and an overcoat formed from a solution having a surface

30   roughness defined by asperities formed by circulation patterns formed in the layer during drying, wherein said surface roughness comprises a lateral roughness of

between about 1 micrometer and about 200 micrometers, and a vertical roughness less than or equal to about 1 micrometer. This patent is directed primarily at creating a surface roughness on a photoreceptor which reduces the force necessary for blade cleaning, reducing blade edge truck, reducing blade/substrate friction,

5   inhibiting the formation of toner-type deposits on the imaging surface and/or reducing or eliminating interference patterns from coherent light sources.

U.S. 4,551,406, describes a liquid electrophotographic recording process utilizing a textured photoconductor coating and a coating carrier. The surface texture is periodic and substantially sinusoidal in cross section, with a surface

10   roughness of from five microns to about 75 microns and a repetition length of from about 100 to 3000 microns. The texture is obtained using a variety of methods including mechanical removal of material, etching, spot wise application of material, embossing or adding functionally inert texturing elements to the solution or dispersion containing the photoconductive coating.

15   U.S. Patent No. 5,733,698 discloses photoreceptor release surfaces in which the surface is roughened to improve image quality. Lehman et al. teach that the surface roughness (Ra) should be greater than about 10 nm. The degree of roughness of the release layer must not be so high as to disturb print quality and should preferably be less than 500 nm, more preferably less than 100 nm, most

20   preferably less than 50 nm.

Lehman et al. further disclose that there are various means for obtaining a roughened release surface on a photoreceptive element, including addition of particulates to the release surface. Lehman et al. teach that low surface energy fillers are preferred.

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Summary of Invention

This invention provides excellent imaging performance in liquid electrophotographic systems by utilization of photoreceptors having release surfaces having texture. Specifically, according to one embodiment the invention relates to

30   release surfaces for photoreceptors in which the texture is non-random. The inventors have discovered that texture, which is substantially directionalized in the

image processing direction, provides improved imaging performance. The photoconductive layer is not exposed but rather is completely covered by the release layer, i.e. the release layer is continuous.

"Directionalized" as used herein means that rows, grooves or the like are detectable in a first direction and the variation in surface roughness is predominantly detectable in a second direction substantially perpendicular to the first direction. The "image processing direction" means the direction in which the photoreceptor element is moving during imaging. The image processing direction is generally the direction in which the photoreceptor forms a continuous surface, for example the surface of a belt or cylinder. Therefore, a photoreceptor directionalized in the image processing direction has rows, grooves, or the like oriented in the image processing direction. For example, a cylindrical drum photoreceptor having texture directionalized in the image processing direction, would have rows, grooves, or the like circumscribing the cylindrical surface of the drum, i.e. the rows, grooves, etc. are substantially parallel to the top and bottom of the cylinder. Similarly, for a belt photoreceptor having a front and backside and top and bottom edges, the rows, grooves, or the like would be substantially parallel to the top and bottom edges of the belt.

Therefore, according to one embodiment, this invention is a photoreceptor comprising an electroconductive substrate, a photoconductive layer, an optional barrier layer and a release layer having a texture. The texture is directionalized as described above. The release layer completely covers the underlying layer.

According to a second embodiment, this invention is an electrophotographic system comprising a photoreceptor;

a charge producing means for producing an image-wise distribution of charges on the photoreceptor;

a liquid toner comprising toner particles in a carrier liquid;

an application means for applying the liquid toner to the photoreceptor forming an image-wise distribution of the toner particles on the photoreceptor to form the image; and

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an intermediate transfer element receiving the image from the
photoreceptor and transferring the image to the receptor,

wherein, the photoreceptor moves in an image process direction and
comprises an electroconductive substrate, a photoconductive layer, an optional

5   barrier layer and a release layer having a texture directionalized in the image process
direction. The system may or may not include a drying means prior to the
intermediate transfer element.

According to a third embodiment, this invention is a method of making a
photoreceptor having a directionalized, textured release layer comprising a method

10   selected from use of textured substrates, texturing during the process of coating the
surface release layer, texture generation on the uncured release surface immediately
following the coating process, texture generation during the release surface curing
process, texturing of the cured release surface after the curing process, and texture
generation on the underlying photoconductive substrate prior to coating the surface

15   release layer. Some specific methods include abrading, buffing, scribing,
embossing, extrusion die coating, carrier fluid process coating, roll coating and
gravure coating.

According to a fourth embodiment, this invention is a method of making a
textured photoreceptor comprising the steps

20   providing a photoreceptor element comprising an electroconductive
substrate and a photoconductive layer,

applying a textured release layer which completely covers the surface of the
photoreceptor to the photoreceptor element by a non-leveled coating process.
According to this embodiment the texture need not be random. Examples of

25   preferred non-leveled coating processes include roll coating, gravure coating,
carrier fluid coating, extrusion, die coating, flexographic printing, and Langmuir-
Blodgett bath coating. Gravure coating is especially preferred.

It will be understood by those skilled in the art that the rheology of the
surface release formulation, its relative hydrophilicity, surface tension, etc. may

30   influence the release surface patterns and their performance by the physical
modification processes outlined here.

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Further features and advantages of the invention are described in the following Embodiments and Examples.

Brief Description of Drawings

5   Fig. 1 is a representation of an electrophotographic imaging system.

Fig. 2 is a photomicrograph at 50x magnification of a release layer containing silica.

Fig. 3 is a Wyko Interferometer figure showing the roughness of a gravure coated release layer.

10   Fig. 4 is a photomicrograph at 50x of a carrier fluid coated release layer.

Fig. 5 shows providing texture that is directionalized.

Detailed Description of the Invention

A. Electrophotographic Systems

15   The textured photoreceptors of this invention may be used in any known electrophotographic system but are particularly useful in liquid electrophotography. Especially preferred electrophotographic systems are disclosed in WO 97/12288 and U.S. Pat. No. 5,650,253.

Figure 1 diagrammatically illustrates an apparatus 42 and method for

20   producing a multi-colored image. Photoreceptor 10 is mechanically supported by belt 44 which rotates in a clockwise direction around rollers 46 and 48. Alternatively the photoreceptor can be supported on some other moveable object such as a drum as shown for example in WO 97/12288. Photoreceptor 10 is first conventionally erased with erase lamp 14. Any residual charge left on

25   photoreceptor 10 after the preceding cycle is preferably removed by erase lamp 14 and then conventionally charged using charging device 18, such procedures being well known in the art. When so charged, the surface of photoreceptor 10 is uniformly charged to around 600 volts, preferably. Laser scanning device 50 exposes the surface of photoreceptor 10 to radiation in an image-wise pattern

30   corresponding to a first color plane of the image to be reproduced.

With the surface of photoreceptor so image-wise charged, charged pigmented toner particles in liquid toner 54 corresponding to the first color plane will migrate to and plate upon the surface of photoreceptor 10 in areas where the surface voltage of photoreceptor 10 is less than the bias of electrode 56 associated

5 with liquid toner developer station 52. The charge neutrality of liquid toner 54 is maintained by negatively charged counter ions which balance the positively charged pigmented toner particles. Counter ions are deposited on the surface of photoreceptor 10 in areas where the surface voltage is greater than the bias voltage of electrode 56 associated with liquid toner developer station 52.

10 At this stage, photoreceptor 10 contains on its surface an image-wise distribution of plated "solids" of liquid toner 54 in accordance with a first color plane. The surface charge distribution of photoreceptor 10 has been made uniform with plated toner particles as well as with transparent counter ions from liquid toner 54, both being governed by the image-wise discharge of photoreceptor 10 due to

15 laser scanning device 58 and the bias voltage of electrode 56. Although not all of the original surface charge of photoreceptor 10 may have been obtained, a substantial portion of the previous surface charge of photoreceptor 10 has been recaptured. With such solution recharging, photoreceptor 10 is now ready to be processed for the next color plane of the image to be reproduced. Alternatively, the

20 surface can be recharged by another means.

As belt 44 continues to rotate, photoreceptor 10 next is image-wise exposed to radiation from laser scanning device 58 corresponding to a second color plane. Note that this process occurs during a single revolution of photoreceptor 10 by belt 44 and without the necessity of photoreceptor 10 being subjected to erase

25 subsequent to exposure to laser scanning device 50 and liquid toner development station 52 corresponding to a first color plane. The remaining charge on the surface of photoreceptor 10 is subjected to radiation corresponding to a second color plane. This produces an image-wise distribution of surface charge on photoreceptor 10 corresponding to the second color plane of the image.

30 The second color plane of the image is then developed by developer station 60 containing liquid toner 62. Although liquid toner 62 contains "solid" color

pigments (or toner particles) consistent with the second color plane, liquid toner 62 also contains substantially transparent counter ions which, although they may have differing chemical compositions than substantially transparent counter ions of liquid toner 54, still are substantially transparent and oppositely charged to the "solid"

5   color pigments. Electrode 64 provides a bias voltage to allow "solid" color pigments of liquid toner 62 create a pattern of "solid" color pigments on the surface of photoreceptor 10 corresponding to the second color plane. The plated toner particles and the transparent counter ions make the surface charge distribution of photoreceptor 10 substantially uniform so that another color plane may be placed

10   upon photoreceptor 10 without the necessity of erase nor corona charging.

A third color plane of the image to be reproduced is deposited on the surface of photoreceptor 10 in similar fashion using laser scanning device 66 and developer station 68 containing liquid toner 70 using electrode 72. Again, the surface charge existing on photoreceptor 10 following development of the third

15   color plane may be somewhat less than existed prior to exposure to laser scanning device 66 but will be quite uniform allowing application of the fourth color plane without the necessity of erase or corona charging.

Similarly, a fourth color plane is deposited upon photoreceptor 10 using laser scanning device 74 and developer station 76 containing liquid toner 78 using

20   electrode 80.

Preferably, excess liquid from liquid toners 54, 62, 70 and 78 is "squeezed" off using a roller 82, 84, 86, and 88 respectively. The plated solids from liquid toners 54, 62, 70 and 78 may then be dried in an optional drying mechanism 34 such as air blowers, drying rollers, vacuum devices, coronas, etc. However, such a

25   drying step is not needed in order to provide good image quality if the novel transfer element of copending application bearing U.S. Patent Application Serial No. 08/833,169 is used. If such a drying step is used it preferably dries the image to a volume % solids of no less than about 95%.

The completed four color image is then transferred, either directly to the

30   medium 36 to be printed, or preferably and as illustrated in the Figure, indirectly by

way of transfer rollers 38 and back-up roll 40. Typically, heat and/or pressure are utilized to fix the image to medium 36. The resultant "print" is a hard copy manifestation of the four color image.

5   With proper selection of charging voltages, photoreceptor capacity and liquid toner, this process may be repeated any desired number of times to produce a multi-colored image having any desired number of color planes. Although the process and apparatus has been described above for conventional four color images, the process and apparatus are suitable for multi-color images having two or more color planes. Or, of course, a single scanning device and application station may be

10   used to provide single color images or to provide multi-color images by repeating the single application method with various colors. According to the latter multi-color method, the colors may be superimposed on each other prior to transfer or each color may be transferred prior to application of a new color to the photoreceptor.

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B. Photoreceptors

The photoreceptors of this invention comprise an electroconductive substrate, a photoconductive layer, optional interlayers, such as barrier layers, priming layers, and charge blocking layers, and a textured release layer. The

20   photoreceptor may be of any known structure but is preferably a belt or a drum.

Electroconductive substrates for photoconductive systems are well known in the art and are generally of two general classes: (a) self-supporting layers or blocks of conducting metals, or other highly conducting materials; (b) insulating materials such as polymer sheets, glass, or paper, to which a thin conductive

25   coating, e.g. vapor coated aluminum, has been applied.

The photoconductive layer can be any type known in the art, including (a) an inorganic photoconductor material in particulate form dispersed in a binder or, more preferably, (b) an organic photoconductor material. The thickness of the photoconductor is dependent on the material used, but is typically in the range of 5

30   to 150 μm.

Photoconductor elements having organic photoconductor material are discussed in Borsenberger and Weiss, "Photoreceptors: Organic Photoconductors", Ch. 9 Handbook of Imaging Materials, ed. Arthur S. Diamond, Marcel Dekker, Inc. 1991. When an organic photoconductor material is used, the photoconductive layer

5   can be a bilayer construction consisting of a charge generating layer and a charge transport layer. The charge generating layer is typically about 0.01 to 20 μm thick and includes a material, such as a dyestuff or pigment, which is capable of absorbing light to generate charge carriers. The charge transport layer is typically 10-20 μm thick and includes a material, such as poly-N-vinylcarbazoles or derivatives of bis-

10   (benzocarbazole)-phenylmethane in a suitable binder. The material must be capable of transferring the generated charge carriers.

In standard use of bilayer organic photoconductor materials in photoconductor elements, the charge generation layer is located between the conductive substrate and the charge transport layer. Such a photoconductor

15   element is usually formed by coating the conductive substrate with a thin coating of a charge generation layer, overcoated by a relatively thick coating of a charge transport layer. During operation, the surface of the photoconductor element is negatively charged. Upon imaging, in the light-struck areas, hole/electron pairs are formed at or near the charge generation layer/charge transport layer interface.

20   Electrons migrate through the charge generation layer to the conductive substrate while holes migrate through the charge transport layer to neutralize the negative charge on the surface. In this way, charge is neutralized in the light-struck areas.

Alternatively, an inverted bilayer system may be used. Photoconductor elements having an inverted bilayer organic photoconductor material require

25   positive charging which results in less deterioration of the photoreceptor surface. In a typical inverted bilayer system, the conductive substrate is coated with a relatively thick coating (about 5 to 20 μm) of a charge transport layer, overcoated with a relatively thin (0.05 to 1.0 μm) coating of a charge generation layer. During operation, the surface of the photoreceptor is typically positively charged. Upon

30   imaging, in the light-struck areas, hole/electron pairs are formed at or near the charge generation layer/charge transport layer interface. Electrons migrate through

the charge generation layer to neutralize the positive charge on the surface while holes migrate through the charge transport layer to the conductive substrate. In this way, charge is again neutralized in the light-struck areas.

As yet another alternative, an organic photoconductive layer can comprise a

5   single-layer construction containing a mixture of charge generation and charge transport materials and having both charge generating and charge transport capabilities. Examples of single-layer organic photoconductive layers are described in U.S. Patent Nos. 5,087,540 and 3,816,118, incorporated by reference herein.

Suitable charge generating materials for use in a single layer photoreceptor

10   and/or the charge generating layer of a dual layer photoreceptor include azo pigments, perylene pigments, phthalocyanine pigments, squaraine pigments, and two phase aggregate materials. The two phase aggregate materials contain a light sensitive filamentary crystalline phase dispersed in an amorphous matrix.

The charge transport material transports the charge (holes or electrons)

15   from the site of generation through the bulk of the film. Charge transport materials are typically either molecularly doped polymers or active transport polymers. Suitable charge transport materials include enamines, hydrazones, oxadiazoles, oxazoles, pyrazolines, triaryl amines, and triaryl methanes. A suitable active transport polymer is polyvinyl carbazole. Especially preferred transport materials

20   are polymers such as poly(N-vinyl carbazole) and acceptor doped poly(N-vinylcarbazole). Additional materials are disclosed in Borsenberger and Weiss, "Photoreceptors: Organic Photoconductors", Ch. 9 Handbook of Imaging Materials, ed. Arthur S. Diamond, Marcel Dekker, Inc. 1991.

Suitable binder resins for the organic photoconductor materials include, but

25   are not limited to, polyesters, polyvinyl acetate, polyvinyl chloride, polyvinylidene chloride, polycarbonates, polyvinyl butyral, polyvinyl acetoacetal, polyvinyl formal, polyacrylonitrile, polyacrylates such as polymethyl methacrylate, polyvinyl carbazoles, copolymers of monomers used in the above-mentioned polymers, vinyl chloride/vinyl acetate/vinyl alcohol terpolymers, vinyl chloride/vinyl acetate/maleic

30   acid terpolymers, ethylene/vinyl acetate copolymers, vinyl chloride/vinylidene chloride copolymers, cellulose polymers and mixtures thereof. Suitable solvents

used in coating the organic photoconductor materials include, for example, nitrobenzene, chlorobenzene, dichlorobenzene, trichloroethylene, tetrahydrofuran, and the like.

Inorganic photoconductors such as, for example, zinc oxide, titanium

5   dioxide, cadmium sulfide, and antimony sulfide, dispersed in an insulating binder are well known in the art and may be used in any of their conventional versions with the addition of sensitizing dyes where required. The preferred binders are resinous materials, including, but not limit to, styrenebutadiene copolymers, modified acrylic polymers, vinyl acetate polymers, styrene-alkyd resins, soya-alkyl resins,

10   polyvinylchloride, polyvinylidene chloride, acrylonitrile, polycarbonate, polyacrylic and methacrylic esters, polystyrene, polyesters, and combinations thereof. Inorganic photoconductors such as selenium, selenium/tellurium, and arsenic triselenide are also well known in the art.

The photoconductor element of this invention may further comprise an

15   interlayer between the photoconductor layer and the release layer. The interlayer or interlayers can serve a variety of purposes such as improving the adhesion of the release layer to the photoconductor layer, protecting the photoconductor layer from the toner carrier liquid and other compounds which might damage the photoconductor, and protecting the photoconductive layer from damage that could

20   occur from charging the photoconductor element with a high voltage corona. Examples of such interlayers include charge blocking layers, primer layers, and barrier layers. The interlayer, like the release layer, must not significantly interfere with the charge dissipation characteristics of the photoconductor element and must adhere well to the photoconductive layer and the release layer, preferably without

25   the need for adhesives.

The interlayer may be any known interlayer, such as a crosslinkable siloxanol-colloidal silica hybrid as disclosed in U.S. Pat. Nos. 4,439,509; 4,606,934; 4,595,602; and 4,923,775 (the disclosures of which are incorporated by reference); a coating formed from a dispersion of hydroxylated silsesquioxane and colloidal

30   silica in an alcohol medium as disclosed by U.S. Patent No. 4,565,760; or a polymer resulting from a mixture of polyvinyl alcohol with methylvinylether/maleic

anhydride copolymer. Preferably, the interlayer is a composite which includes silica and an organic polymer selected from the group consisting of polyacrylates, polyurethanes, polyvinyl acetals, sulfonated polyesters, and mixtures of polyvinyl alcohol with methylvinylether/maleic anhydride copolymer. The organic polymer and silica are preferably present in the interlayer at a silica to polymer weight ratio ranging from 9:1 to about 1:1. Interlayers of this type are disclosed in EPO Publication 0 719 426).

Another preferred interlayer is a composite material of an organic polymer with a silanol. The silanol has the formula

$$Y_aSi(OH)_b$$
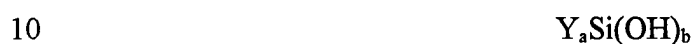
wherein:

Y includes, for example, alkyl or alkoxy groups having from 1 to 6 carbon atoms; alkoxyalkyl groups in which the alkoxy portion contains from 1 to 2 carbon atoms and the alkyl portion contains from 1 to 6 carbon atoms; halogenated alkyl groups having from 1 to 6 carbon atoms and from 1 to 2 halogen substituents; aminoalkyl groups having from 1 to 6 carbon atoms and one amino group attached to either the 2, 3, 4, 5 or 6 carbon atom; a vinyl group; a phenyl group which may contain 1 to 2 halogen substituents; a cycloalkyl group having from 5 to 6 carbon atoms and which may contain 1 to 2 substituents; and hydrogen,

a is a number ranging from 0-2,

b is a number ranging from 2-4, and

a plus b equals 4.

The organic polymer is preferably selected from the group consisting of polyacrylates, polyurethanes, polyvinyl acetals, sulfonated polyesters, and mixtures of polyvinyl alcohol with methylvinylether/maleic anhydride copolymer.

C. Surface Release Layers

1. Chemical Composition of Surface Release Layer

The release layer may be comprised of any release material known to be useful in photoreceptors. Examples of such materials include silicone or

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fluorosilicone polymers (such as ethylenically unsaturated-, hydroxy-, epoxy-terminated or pendant functional silicone pre-polymers); or other release polymers with suitable low surface energy [such as poly(organosiloxanes), condensation cure silicones, and the like].

5   One preferred release material is the crosslinked silicone polymer disclosed in WO96/34318 incorporated herein by reference. These polymers comprise the reaction product of the components comprising:

A)   35 to 80 parts by weight of a siloxane polymer with a high content of functional groups capable of crosslinking having the repeating unit:

10

$$-\left(\mathrm{Si}-\mathrm{O}\right)_x \quad \begin{matrix} R^2 \\ | \\ | \\ R^1 \end{matrix}$$
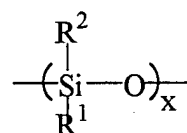
where each R^1 independently is an alkyl group, aryl group, or alkenyl group,

R^2 is, independently for each group $-SiR^1R^2O-$ either an alkyl group, an aryl

15   group, or a functional group capable of cross-linking and at least 3% of R^2 are functional groups capable of crosslinking, and

x is an integer greater than 0;

B)   greater than 0 and less than or equal to 50 parts by weight of a siloxane polymer with a low content of functional groups capable of crosslinking

20   having the repeating unit

$$-\left(\mathrm{Si}-\mathrm{O}\right)_y \quad \begin{matrix} R^3 \\ | \\ | \\ R^4 \end{matrix}$$

where each R^4 independently is an alkyl group, aryl group, or alkenyl group,

R^3 is, independently for each group $-SiR^3R^4O-$ either an alkyl group, an aryl group or a functional group capable of cross-linking and no more than 2.5% of R^3 are functional groups capable of cross-linking, and

25   y is an integer of at least 50; and, optionally,

C)   5 to 30 parts by weight of a cross-linking agent having the repeating

unit

$$-\left(\overset{\overset{\displaystyle R^5}{|}}{\underset{\underset{\displaystyle R^6}{|}}{Si}}-O\right)_{\!z}-$$

wherein each R^5 independently is hydrogen, an alkyl group, or an aryl group,

R^6 is, independently for each group -SiR^5R^6O- either an alkyl group, an aryl

5   group or a functional group capable of cross-linking and from 25 to 100% of R^6 are

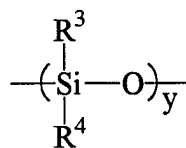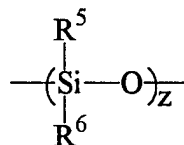functional groups capable of cross-linking,

z is an integer from 0 to 1000, and

there are at least two functional groups capable of cross-linking per

molecule.

10   "Functional groups capable of crosslinking" means groups which may

undergo free radical reactions, condensation reactions, hydrosilylation addition

reactions, hydrosilane/silanol reactions, or photoinitiated reactions relying on the

activation of an intermediate to induce subsequent cross-linking.

Optionally, the above materials may be modified by the addition of silicate

15   resins. Nonlimiting examples of silicate resins include Dow Corning 7615 (Dow

Corning, Midland, MI), Gelest vinyl Q resin VQM-135 and VQM-146 (Gelest,

Tullytown, PA). See Copending U.S. Application Serial No. 08/832,834.

If fillers are to be added to the chemical composition, nonlimiting examples

of fillers include hydrophobic fumed silica such as CAB-O-SIL™ TS530, TS610

20   and TS720 (both from Cabot Corp. of Billerica, MA) and AEROSIL™ R972 (from

Degussa Corp). A non-limiting list of low surface energy fillers includes

polymethylmethacrylate beads, polystyrene beads, silicone rubber particles, teflon

particles, and acrylic particles. Other particulate fillers which can be used but which

are higher surface energy include but are not limited to silica (not hydrophobically

25   modified), titanium dioxide, zinc oxide, iron oxide, alumina, vanadium pentoxide,

indium oxide, tin oxide, and antimony doped tin oxide. High surface energy

particles that have been treated to lower the surface energy are useful. The

preferred inorganic particles include fumed, precipitated or finely divided silicas.

More preferred inorganic particles include colloidal silicas known under the tradenames of CAB-O-SIL™ (available from Cabot) and AEROSIL™ (available from Degussa). Suitable low surface energy inorganic fillers include surface treated colloidal silica fillers such as CAB-O-SIL™ TS-530 and TS-720, Degussa R812,

5 R812S, R972, R202. CAB-O-SIL™ TS-530 is a high purity treated fumed silica which has been treated with hexamethyldisilazane (HMDZ). CAB-O-SIL™ TS-720 treated fumed silica is a high purity silica which has been treated with a dimethyl silicone fluid. CAB-O-SIL™ TS610 is a high purity fumed silica treated with dimethyldichlorosilane.

10 Non-conductive fillers are preferred. When conductive fillers are used, the electrical characteristics of the photoconductive assembly must be considered in order to avoid adverse effects due to lateral conductivity.

The composition of the filler is preferably 0.1 to 20%, more preferably 0.5 to 10% most preferably 1 to 5% w/w based on weight of release layer composition

15 excluding solvents.

According to one preferred embodiment, the release layers are applied using solventless coating methods. In that case, silicone pre-polymers having number average molecular weights from approximately 500-30,000, preferably 1000-25,000, more preferably 10,000-20,000 Da, are useful. Optionally the pre-polymers

20 may be used in combination with higher molecular weight silicones. Such higher molecular weight silicones can have number average molecular weights less than 500,000 Da, preferably less than 100,000 Da, and most preferably less than 50,000 Da.

The release layers are preferably somewhat crosslinked. The pre-polymers

25 may be prepared in a range of potential crosslinking density afforded by the presence or absence of pendant crosslinkable groups in addition to crosslinkable terminal groups. The mole percent of crosslinkable groups was preferably 0 to 25 mole%, more preferably 1 - 15 mole% and most preferably 4 - 10 mole%. Both vinyl and higher alkenyl (number of carbons greater than 2 and less than 10)

30 crosslinking groups may be used. The distribution of crosslinks in the crosslinked polymer may be monomoldal, bimodal or multimodal.

19

Additional components may be used in combination with the base polymers to improve the durability or imaging performance of the temporary image receptor. Some chemical release modifiers include silicate resins, high molecular weight crosslinkable silicones, and optionally, low surface energy fillers.

5   Nonlimiting examples of the high molecular weight crosslinkable silicones include ethylenically unsaturated organopolysiloxanes ranging in number average molecular weights from 62,000 to 160,000 Da available from Gelest, Tulleytown, PA (DMS-41, DMS-46, DMS-52) or those described in U.S. Pat. No. 5,468,815 and in European Patent Publication 0 559 575 A1 (the disclosures of which are

10   incorporated by reference herein). Preferably, alkenyl-functional silicones having from about 2 to about 10 carbon atoms are used.

Temporary image receptors have been prepared by adding hydrophobic fumed silica fillers to a variety of release formulations having higher alkenyl (e.g., hexenyl) functional silicones with crosslink densities corresponding to percent

15   swelling in toner carrier liquid ranging from about 10% swelling ("low") to about 40% swelling ("medium") to about 100% swelling ("high") by weight.

As curing catalysts, both thermal and ultraviolet ("UV") initiated catalysts can be used in the formation of release surfaces of the present invention. Nonlimiting examples of platinum thermal catalysts are Dow Corning (Midland, MI)

20   Syloff 4000 and Gelest platinum-divinyltetramethyldisiloxane complex (SIP6830.0 and SIP6831.0). A nonlimiting example of a platinum UV catalyst is disclosed in U.S. Pat. No. 4,510,094 (Drahnak). The UV catalyst does not require an additional inhibitor since the complex is effectively inhibited until exposure to UV.

A nonlimiting list of silyl hydride crosslinkers include Dow Corning as

25   homopolymers (Syl-Off™ 7048), copolymers (Syl-Off™ 7678) and mixtures (Syl-Off™ 7488). Crosslinker in the amounts corresponding to 1:1 to 10:1 silyl hydride:vinyl ratio may be used in combination with an inhibitor such as fumarate in benzyl alcohol (FBA) in the base pre-polymer to achieve good cure and adequate pot life in 100% solids coating dispersion with a thermal catalyst. In solvent coated

30   formulations the inhibitor may not be required if the % solids by weight is less than 5%.

2. Thickness

A release layer is a dielectric material and its thickness could affect imaging performance in electrographic imaging processes. Furthermore, the durability of the release will depend on the thickness of the release. A thicker layer as indicated is
5   necessary to provide a mechanically durable photoreceptor when a swellable polymer is used as a primary component of the release layer. Durability is particularly important when transfer of the image from the photoconductor element to the image receiver is accomplished primarily by heat and pressure and without electrostatic assist because the heat and pressure can be very harsh on the surface
10   layer of the photoconductor element. In addition, the thickness of a textured release surface may vary periodically or in a random fashion; in such cases, the thickness of the release surface is defined as the root mean square thickness averaged over the receptor surface. The thickness of the release layer is preferably less than 5 microns, more preferably 0.4 to 3 microns, and most preferably 0.5 to
15   1.5 microns.

3. Surface Roughness

The release layers of this invention preferably have a directionalized texture. The preferred magnitude of the roughness of this texture is an Ra >10nm and
20   <500nm, more preferably an Ra >20nm and <250nm. According to another embodiment the texture may be defined by-a lateral surface roughness of between about 0.1 and 1000 microns and a vertical surface roughness between about 0.01 and 5 microns.

Suitable methods of preparing surface release layers on temporary image
25   receptors include various precision coating methods known in the art. A non-limiting list of such methods includes dip coating, ring coating, extrusion die coating, roll coating, flexographic printing, gravure coating, Lanugmuir-Blodgett bath coating and carrier fluid coating methods as described in co-pending U.S. application having Serial No. 08/832,934 and the like. Either solventless or
30   solvent-based coating formulations may be used. Extrusion die coating, roll coating, gravure coating, flexographic printing, Langmuir Blodgett bath coating and

carrier fluid coating methods provide the advantage of allowing one to impart texture during the coating process.

For solvent-based coating, the solvent must dissolve the release prepolymers and additives yet not attack the underlying photoconductor layers or the dielectric

5   substrate. This disadvantage is overcome by use of solventless coating. Suitable solventless release formulations can be prepared using vinyl and alkenyl silicone pre-polymers and higher viscosity, lower mole % functionalized silicone polymers. These solventless release formulations have been rotogravure coated at thicknesses of 0.1-2 micrometers and using water carrier coating methods (as described in WO

10   96/23595 and U.S. application Serial No. 08/832,934) have been coated at 0.65 micrometers calculated thickness to yield high quality photoreceptor release surfaces.

Surface release coatings are typically thermally cured after coating in order to improve release layer durability and promote adhesion to the underlying substrate

15   which forms the temporary image receptor. In addition to or in place of thermal cure methods, the release formulations may also be cured using radiation such as ultraviolet lamps, excimer lasers, electron beams, etc.

Various means may be used for producing a textured release surface according to the present invention. Various coating processes may be operated in a

20   manner so as to obtain non-leveled coating "defects" which are permanently incorporated into the surface of the photoreceptor after drying or curing of the surface release layer. Surface textures made in this way may be random, non-random, or periodic. By "non-leveled" we mean that the surface is not even, but rather has texture and potentially varies in thickness.

25   The aforementioned coating processes may be utilized to achieve both repeated geometric patterns and random or irregular patterns in release surfaces without the use of fillers. In particular, a non-leveled gravure pattern has been found to have utility in the present invention. Such a pattern can be created when the applicator roll separates from the newly applied coating during a rotogravure

30   coating process. The gravure patterns on the release surface may be controlled by appropriate choice of gravure cell design (pyramidal, etc.), roller speeds, gravure

coating method (offset vs. direct, reverse vs. forward, and microgravure), and rheology of the formulation.

Textured release surfaces can also be obtained by operating a conventional multi-roller coater using smooth rolls in a manner in which a periodic hydrodynamic

5   instability is observed on the surface of the applied coating. Such coating instabilities, known in the art as "ribbing" instabilities if the periodic pattern repeats across the web and as "cascade" or "seashore" instabilities if the periodic pattern repeats down web, are described in detail in E. Cohen and E. Gutoff, Modern Coating and Drying Technology, (VCH Press: NY, 1992), pp. 79-94.

10   The peak to valley height and the periodicity of such coating instabilities can be controlled by manipulating the Capillary number and the coating gap/roller diameter ratio (in forward roll coating) or the relative roll speed ratios and the Capillary number (in reverse roll coating), as described in the above reference by Cohen and Gutoff at pp. 131-133. The Capillary number, which depends upon the

15   relative web speed (v) as well as the viscosity (η) and surface tension (σ) of the coating formulation, is given by:

$$Ca = v\eta/\sigma$$

Periodic surface patterns (i.e. ribs) can also be obtained from non-leveled coating instabilities created by extrusion die coating release formulations in an

20   unstable operating regime as described in Cohen and Gutoff (p.162). Non-leveled surface patterns can also be obtained using fluid carrier coating processes as described in copending, coassigned U.S. Pat Application Serial No. 08/832,934 by choice of formulation (viscosity, relative hydrophilicity, surface tension, surface active agents, etc.), coating thickness, temperature, and the like.

25   Other means for applying a non-leveled surface coating may also lead to a patterned or textured release surface as described herein. For example, screen printing, spray coating, or flexographic printing techniques could all be operated in a mode which produces a non-leveled surface pattern.

Patterns can also be generated on the release surface using post-coating

30   methods such as embossing, application of patterning rolls under conditions of pressure and/or heat, abrading or sanding rolls, and microreplicated tools.

Patterned webs (rather than patterned rolls) can also be used. A coating overlayer could be applied to a patterned web to modulate the degree of roughness. A patterning layer might be laminated to the web of interest. The inventors also envision the use of a microreplicated tool which can be filled with the coating

5   formulation, doctored, and transferred to a web where it is cured.

Patterning processes such as these have great utility in that they are capable of generating reproducible patterns continuously or semi-continuously. Some of these methods may also be used in discrete patterning processes.

As discussed above directionality of texture can be important in imaging.

10   While not wishing to be bound, the improvement in imaging may be as a result of the directionalized texture aiding squeegeeing.

4. Surface Energy

The surface energy for release layers should be selected to be appropriate

15   relative to other surfaces in the system. The surface energy of the release is preferably less than 28 dynes/cm, more preferably less than 26 dynes/cm, and most preferably less than 24 dynes/cm.

5. Coefficient of Friction

20   As discussed above textured release formulations can be prepared using alkenyl silicone pre-polymers and high molecular weight organopolysiloxanes. When prepared by solvent-free coating methods, these formulations typically yield densely crosslinked, rubbery, slip-resistant coatings.

The traditional solvent-based release formulations therefore have a much

25   more slippery surface texture, exhibiting typical coefficient of friction ("C.O.F.") of 0.05 compared to values of 0.4 or higher for solvent-free release formulations. The addition of a low weight percent of a high molecular weight gum can potentially be used with the solvent free systems to lower the coefficient of friction while maintaining the high crosslinking density. As disclosed in U.S. Pat. Nos. 5,468,815

30   and 5,520,987, the effectiveness of the gum in lowering the C.O.F. is a function of the specific functionality and molecular weight of the additive. By using

commercially available solvent-free base silicones and/or C.O.F. modifying gums in

a photoreceptor release, both the durability and printing performance of the

temporary image receptor are unexpectedly improved.

5   Materials and Methods

Silicone polymers were obtained commercially or prepared by methods

known in the art. Table 1 summarizes silicone pre-polymers used in the examples,

which include hexenyl functional organopolysiloxanes prepared according to Keryk

et al, U.S. Patent No. 4,609,574 and Boardman et al. U.S. Patent No. 5,520,978

10   and vinyl functional organopolysiloxanes obtained from Gelest (VDT-731;

Tullytown, PA) or prepared according to methods known in the art, as disclosed in

McGrath, J.E. and I. Yilgor, Adv. Polymer Science, Vol. 86, p. 1, 1989; Ashby,

U.S. Patent No. 3,159,662; Lamoreaux, U.S. Patent No. 3,220,972; Joy, U.S.

Patent No. 3,410,886. The mole percent of crosslinkable groups varied between 1 -

15   10% in the pre-polymer. The number average molecular weight of the pre-

polymers ranged from approximately 5000 - 150,000 Da, with the lower molecular

weights corresponding to useful viscosity ranges for solventless coating methods.

In addition to silicone pre-polymers, higher viscosity silicones with a mole % of

crosslinkable groups less than 1% were used as additives, as described in Table 1.

20   Hexenyl functional silicones of this type were prepared according to Boardman et

al. U.S. Patent No. 5,520,978. Vinyl functional silicone additives were obtained

commercially from Gelest (DMS-V41 and DMS-V52) or prepared according to

McGrath, J.E. and I. Yilgor, Adv. Polymer Science, Vol. 86, p. 1, 1989; Ashby,

U.S. Patent No. 3,159,662; Lamoreaux, U.S. Patent No. 3,220,972; Joy, U.S.

25   Patent No. 3,410,886.

Catalysts included Dow Corning platinum thermal catalyst, Syl-Off^{TM} 4000

(Midland, MI), and an ultraviolet initiated platinum catalyst prepared according to

Dranak, U.S. Patent No. 4,510,094. Homopolymer and/or copolymer hydride

crosslinkers such as Dow Corning Syl-Off^{TM} 7048 and Syl-Off^{TM} 7488 and

30   NM203 from United Chemical Technology (Piscataway, NJ) were used at silyl

hydride to vinyl ratios of 1.0:1 to 5:1. In order to obtain adequate pot life in

solventless (i.e., 100% solids) silicone formulations and those with a higher solids

content than 5% solids in solvent , 2.40% (w/w) of a 70:30 mixture by weight of

diethyl fumarate and benzyl alcohol (FBA) was added as an inhibitor or bath life

extender as taught in U.S. Patent Nos. 4,774,111 and 5,036,117. No inhibitor was

5   used for solvent coated mixtures with solids content less than 5%.

Materials were evaluated for performance in the presence and absence of

chemical modifiers. In addition to the silicone gums described in Table 1,

particulate fillers and silicate resins were used. Fillers included hydrophobic fumed

silica such as Cab-O-Sil^{TM} (Cabot Corp., Billerica, MA) TS-720. Surface active

10   agents such as Modaflow (Monsanto, MO) were also used.

Table 1: Summary of Material Set

Component	Description (crosslinking functionality)	mole% alkenyl	Viscosity	Mn (daltons)
PRE-POLYMERS				
I	hexenyl pendant and terminated	2.7	450mPas	9610
II	hexenyl terminated only	1	450mPas	12,400
III	hexenyl terminated only	2	450mPas	6530
V	hexenyl pendant and terminated	4	450mPas	9800
Gelest VDT-731	vinyl pendant	7.5	1000mPas	28,000
VI	vinyl pendant	10.4	275,000mPas	
LOW FUNCTIONAL SILICONES				
IX	hexenyl terminated	0.033	--	440,000
X	vinyl pendant	0.2	100 Williams Plasticity 10,000mPas	
Gelest DMS-V41	vinyl terminated	0.1	165,000mPas	
Gelest DMS-V52	vinyl terminated	0.35		

Solvent-based Release Formulations

A representative solvent-based release formulation was prepared as follows.
An 18 g mixture of silicone pre-polymer, crosslinker and chemical modifier (gum,
hydrophobic silica, silicate resin, etc.), was prepared as described in Table 2 and

5   diluted with 221.86 g heptane to form Stock A. Stock B (containing platinum

thermal catalyst) was then prepared by mixing 0.41 g of Dow Corning Syl-Off™
4000 with 6.00 g heptane. A 5.63 g sample of Stock B was then added to Stock A.
This sample was extrusion die coated as described below.

10   Solventless Release Formulations

Release formulations were also prepared at 100% solids. These
formulations were precision coated without the use of solvent using gravure coating
methods described below.

For the solventless coating formulations, Stock C differed from Stock A

15   above in that it contained the platinum catalyst, a FBA inhibitor, and lacked the
crosslinker. A fully reactive system was prepared just prior to coating by the
addition of Stock D containing the crosslinker. Examples of these formulations are
described in Table 3.

20   **Table 2: Example Preparation for Solvent Coating of Release**
for Temporary Image Receptor

Components	Final Concentration (relative to base polymer)	Amount (g)
Stock A		
Silicone pre-polymer V	--	15.00
Syl-Off™ 7048	5:1 silyl hydride:vinyl	2.46
Gum IX	2% w/w	0.3
Cab-O-Sil™ TS720	1% w/w	0.15
Heptane	6.3% solids	221.86
Stock B		
Syl-Off™ 4000	333 ppm	0.41
Heptane	--	6.00

Table 3: Example Preparation for Solventless Coating of

Release Formulations for Temporary Image Receptor

Components	Final Concentration (relative to base polymer)	Amount (g)
Stock C		
Silicone pre-polymer V	--	808.5
Gum IX	2% w/w	16.50
Cab-O-Sil™ TS720	1% w/w	8.25
Syl-Off ™ 4000	125 ppm	19.83
FBA Inhibitor	2.4% w/w	19.80
Stock D		
Syl-Off ™ 7048	5:1 silyl hydride:vinyl	135.12

5

<u>Coating methods</u>

The experimental release layers were coated onto an inverted dual

layer photoconductor and interlayer, the formulations of which have been described

10   in Example 2 and Example 4, respectively, of U.S. Patent No. 5,733,698, using

extrusion die coating, gravure, and a carrier fluid coating process (as described in

WO 96/23595 and copending U.S. application having Serial No. 08/826,571).

These methods were operated so as to achieve a desired coating thickness of 0.65 -

1.3 micrometers. Coating thickness was monitored on-line by including an

15   appropriate amount of a UV fluorescent dye in a test formulation such that the

signal measured on a UV gauge was proportional to the coating thickness in the

region of interest.

a) Extrusion Die coating:

The solvent-based release compositions were extrusion die coated onto the

20   interlayer of a photoconductive web and dried in a 3.0 m air flotation dryer. The

coating compositions were applied to give a final coating thickness of 0.5 to 1.0

micrometer and cured by exposing the web to 150° C for 1 minute at a web speed
of 3.0 m/min.

b) Carrier fluid coating

Carrier fluid coating process was used to coat a number of the solventless
5   release formulations. Carrier fluid coating process is described in WO96/23595 and
copending U.S. application Serial No. 08/826,571. It is a two-layer curtain coating
process that uses a carrier fluid such as water to transport a substantially insoluble
functional layer such as silicone to a web. In these examples, the functional layer
was composed of a 100% solids release formulation. In one example, 0.25% of
10   Modaflow 2100, was added as a leveling agent.

A two layer slide die was used, as described in World Patent No. 96/23595.
Silicone flowed from the top slot, which had a 0.254 mm gap. Water flowed
through the bottom slot, which had a 0.508 mm gap. Both slots were 248 mm
wide. Municipal tap water was used as the carrier layer. The water flow rate out of
15   the bottom die slot varied between 2.2 to 2.8 L/min (corresponding to pump rates
of 21 to 22.6 rpm). The typical water temperature was 10° C. The thickness of the
coating was controlled by varying the syringe pump rate (which metered the release
formulation into the die) or by changing the web speed. Coating thickness was
varied between 0.1 - 2 microns. Typical web speeds were 3 - 30 m/min. Typical
20   syringe pump rates ranged from 1 to 5 milliliters per minute.

c) Gravure coating

Many of the solventless release compositions were gravure coated onto the
interlayer of a photoconductive web and dried in a 3 meter air flotation dryer to
give dry coating thicknesses in the range of the 0.65 - 1.5 micrometers. Gravure
25   rolls with pyramidal cells having volume factors of between 3 and 10 cubic billion
micrometers were used in a reverse gravure set-up to coat at roll speed ratios
ranging from 0.5 to 2.5. Gravure roll speeds were 1 to 13.6 m/min and web speeds
ranged from 2 to 50 m/min. The coating compositions were applied to give a final
coating weight of 1.4 to 4 g/m^2 and cured for 1 minute at 150° C using a 3.0 m/min
30   web speed.

Test Methods

Coating thickness

Coating thicknesses were measured using an Edmunds Hi Mag^{TM}

Comparator Gauge. Release layers were coated directly on electroconductive

5   substrate under the same conditions used for coating release layers onto

photoconductor plus interlayer constructions. The coated substrate to be measured

was first placed under the measurement head and the unit was zeroed. The release

coating was subsequently removed from the substrate via rubbing with pressure

with a solvent soaked cotton swab until the release was abraded away. The

10   thickness of the remaining substrate was then measured using the Edmunds Gauge,

and the release layer thickness was determined as the difference between thickness

readings with and without the release layer.

Crosslinking density

The crosslinking density of experimental release coatings was measured

15   using the solvent swelling method as disclosed in O.L. Flaningam and N.R. Langley

in The Analytical Chemistry of Silicones, E. Lee Smith (ed) (John Wiley and Sons:

New York, 1991) p. 159. For solventless formulations, a 2 g sample of silicone

formulation prepared according to Table 3 was weighed into a 2 inch (diameter)

aluminum pan which had been sprayed with 3M^{TM} Scotchgard^{TM} (Cat. No. 4101).

20   The sample was cured at 150° C for 30 minutes in an oven and allowed to sit

overnight before testing. Samples were also UV cured, as described above. The

crosslinking density of solvent based formulations was measured by placing

approximately 3 g of a solution of Stock A and B (see Table 2) into a PTFE coated

aluminum pan. The solvent was allowed to evaporate overnight in a vented hood

25   before the sample was heated at 150° C for 30 minutes.

The cured sample was allowed to sit overnight before being taken out of the

aluminum pan and carefully weighed. It was then submerged in toner carrier liquid

(Norpar 12, Exxon Corporation) in a closed glass container overnight, and then

reweighed. The percent swelling was expressed as the percent difference in weight

30   of the solvent swollen material relative to the unswollen (initial) material.

Scratch Test for Durability

Durability of the release coating was measured using a Scrape Adhesion
Tester, available from BYK Gardner USA (Columbia, MD), as described in ASTM
test method D2197. The instrument consists of a pivoted beam with a 45 degree
5   stylus holder, weight post, and holder for supporting the total test load. On one end
of the beam is mounted the stylus; on the other end of the beam is a counterweight.
A cam is rotated to lower and raise the stylus. A sample bed mounted on ball
bearings is used to move the test panel against the stationary stylus in a direction
parallel to the beam. The stylus used in this test was a 1.6 mm chrome plated drill
10   rod, bent to a 180 degree loop with a 6.5 mm OD. By moving a free edge of the
test film against this loop under variable load (expressed in grams), the durability of
the coating was expressed as the minimum load (g) required to create a continuous
scratch in the coating. More durable coatings required higher load values to mar
the surface.

15   Coefficient of Friction

The coefficient of friction was measured according to ASTM method
D1894-63, sub-procedure A using a Slip/Peel Tester Model SP-102B-3M90 made
by Instrumentors, Inc. and available from IMASS, Inc.(Hingham, MA). A strip of
release coated photoreceptor (approximately 6 cm wide) was mounted on a
20   movable platen and an uncovered friction sled, its foam surface in contact with the
coating layer, was drawn across the coating at a rate of 15 cm/min for 25 seconds.
The coefficient of friction was calculated as the ratio of the tractive (pulling) force
to the normal (sled weight) force.

Peel force

25   Slip/peel tester model SP-102B-3M90 from Instrumentors, Inc.
(Strongsville, OH) was used for tape peel force measurements. A 3.2 cm x 10 cm
sample strip was affixed to the working platen with double stick tape. A 2.5 cm
wide strip of 3M^{TM} 202 masking tape was applied to the sample release surface and
a 6.8 kg roller was rolled over the tape 6 times. Immediately after adhering the
30   tape, a MB-10 load cell was used to measure the average force (g/cm) required to
peel the tape off the surface at 180 degrees and 2.3 m/min for 2 seconds.

In order to predict the change in peel force over extended printing, the Durability Wiper Test was used to abrade samples of the release as described in PCT Patent Publication WO96/34318. The peel force was measured on fresh samples (0 wipes) and wiped samples (3200 wipes over a 360 degree arc as

5   described in Durability Wiper Test, below).

Durability Wiper Test

A durability wiper test was used to evaluate release surface durability and abrasion resistance in simulated wet cycling using pure toner carrier liquid in place of liquid toner. The toner carrier liquid was selected to be NORPAR 12 (Exxon

10   Corp.). The durability wiper consisted of a 16 cm diameter aluminum drum and 5 stainless steel shoes with concave surfaces having radii to match the drum. The drum was positioned horizontally and attached to a gear and motor which enabled rotation of the drum at a speed of 40 rev/min. The 5 stainless steel shoes rested, by their own weight (about 300 g) concave side down, on the top side curve of the

15   drum. The shoes were held in place so that they did not move with the rotation of the drum, but could move vertically.

Two layers of paper toweling were wrapped around the drum and then soaked in toner carrier liquid. One 3.2 cm x 10 cm strip of the photoconducter construction was secured onto the curved surface of each metal shoe so that, when

20   the shoes were in place, the release surface was in contact with the paper toweling. The drum was then rotated at 40 rev/min for 800 revolutions. For samples with more than 800 wiping revolutions, the paper toweling was replaced by fresh NORPAR 12 soaked toweling every 800 revolutions. After wiping, the sample strips were air dried at least overnight before peel tests were carried out.

25   Surface Energy (Dynamic Contact Angle)

Dynamic advancing contact angles were measured using the Wilhelmy plate method as disclosed in D.J. Shaw, Introduction to Colloid and Surface Science, (Butterworths: London, 1992), p 72 on a Kruss (Charlotte, NC) K12 process tensiometer controlled by the K121 software package. Samples were prepared by

30   laminating two sheets of release coated photoreceptor with a 3M^{TM} glue stick such that the silicone coating was exposed on each side and no gaps were formed. A

punch was then used to precisely cut square samples of dimensions 18.2 mm wide

x 0.22 mm thick. Each sample was measured using a caliper prior to immersion and

the appropriate measurements were entered into the wetted length (actually wetted

perimeter) calculation.

5   In order to calculate the surface energy of a given experimental release

surface, the dynamic advancing contact angles of two probe fluids (NORPAR 12

and water) were measured with respect to the sample. The geometric mean method

of Owens and Wendt (D.K. Owens and R.C. Wendt, Journal of Applied Polymer

Science, 13, pp. 1741-7 (1969)), was then used to calculate the total solid surface

10   energy as well as the polar and dispersion components of this surface energy using

Kruss K121 software. The Owens and Wendt method requires measurements of

dynamic contact angles using two probe fluids of known surface tension and known

polar and dispersion components of the surface tension. At least one of the probe

fluids must have a nonzero polar component of the surface tension; this requirement

15   is met by using water as one of the probe fluids. In addition we selected NORPAR

12 carrier liquid as a probe fluid because it is a preferred carrier for liquid toners.

NORPAR 12, is a blend of nonpolar C_{10}-C_{14} aliphatic hydrocarbons, and thus

provides a probe fluid which exhibits only a dispersion component of surface

tension.

20   Dynamic receding contact angles were measured using a 4.00 mm/minute

search rate and a 3.00 mm/minute measuring rate. The electrobalance sensitivity

was 0.005 g. The immersion depth was 3.00 mm with a wait time of 5.0 seconds at

the turning point. Two cycles were run on each of two release samples for each

probe fluid. The surface energy for the group was therefore based on 4 release

25   coated substrate samples and 8 determinations of dynamic contact angle using two

probe fluids. The surface tension values of Strom (measured at 20°C) were used

for each test fluid and verified experimentally for each reagent lot using a perfectly

wetting platinum Whilhelmy plate to measure liquid surface tension.

Surface Roughness Measurements

30   Several methods were used to characterize the surface roughness, including

atomic force microscopy, optical microscopy and interferometry. The

interferometry data reported here were derived from the WYKO HI-RES in PSI

mode at an area of 231.3um x 365.7um and WYKO RST-PLUS in VSI mode at

various areas (WYKO Corporation, Tucson, AZ). For Example 2.1 the area was

0.9 mm x 1.2mm (Figure 3) and for Examples 4.1 and 4.2 it was 112.8 μm x 150.6

5   μm.

For optical microscopy, a Zeiss Axioskope microscope was used to examine

coatings using a magnification of 50 x with a differential interference contrast lens

with both reflected and transmitted light. Images were recorded with a Polaroid

camera on black and white film.

10   Print Quality Evaluation for Electrophotographic Printing

Monochrome print quality was evaluated for each formulation using a

printing mechanism described in WO 97/12288. The SCE printer was configured

with a transfer roll and a drying roll as described in co-pending U.S. application

Serial No. 08/833,169 and U.S. Patent No. 5,552,869. A section of the release

15   coated organic photoreceptor web was adhered to the drum and an electrostatic test

was run to evaluate the charging and discharging characteristics of the unprinted

photoconducter. Monochrome black toner as described in Example 40 of U.S.

Patent No. 5,652,282, (incorporated by reference herein) was then used to develop

and transfer images from the photoconducter to consecutive paper sheets.

20   One print was first made on the printing apparatus with the drying

mechanism disengaged to allow for visual inspection of the dewetting (i.e. beading)

of the toner carrier fluid on the photoconducter release surface. Toner carrier liquid

beading is generally undesirable in multicolor liquid electrophotographic imaging

processes since it may result in fluid "lenses" on the photoconducter surface which

25   may interfere with subsequent latent image generation steps that make use of actinic

radiation to discharge the photoconducter in areas to be imaged. The printing

process was completed with the non-dried, film formed image being transferred

from the photoconducter to paper via the intermediate transfer roll. Failure to

transfer 100% of the image to the intermediate transfer roll was designated T1

30   transfer failure. This T1 transfer failure was graded by observing the amount of

toner that could be transferred off of the photoconducter to a clean sheet of paper

(i.e., the clean up sheet). This process was repeated with a drying roll engaged to evaluate T1 failure in that printing configuration.

To evaluate the release in multiple use applications, a series was run consisting of ten consecutive prints followed by one clean up sheet. This was repeated for each printer configuration. A final electrostatic test was performed after the last clean up sheet. The offset of small sections of dried toner image from the photoconducter to the drying roll (i.e. drying roll picking) was also graded by cleaning the regeneration rolls and inspecting for residual toner. The liquid toner in the developer unit was changed after every three photoreceptor evaluations.

All of the release materials were ranked based on print quality of the tenth print made both with and without the drying roll relative to each other and relative to the control sheets. A rating scale of 1 (very good performance) to 5 (very poor performance) was used to grade each of the following nine categories:

1. Beading (visible carrier liquid droplets on the surface of the photoconducter after squeegeeing),

2. Fuzzy text (text characteristics which are indistinctly defined or which are surrounded by a lightly pigmented halo of toner),

3. Fat text (text characters which exhibit broadening of the individual pixels),

4. Solid area pull down (toner smearing in the machine direction due to the developer roll or squeegee),

5. Text area pull down (vertical offset of the text characters below the image),

6. Squeegee offset (partial transfer of the wet image to the squeegee and transfer back to the photoconductor during a subsequent revolution of the squeegee),

7. Drying roll picking (partial offset of small sections of the dry toner image from the photoconducter to the drying roll; applicable only when a drying roll is used),

8. T1 offset (failure of 100% of the film-formed image to transfer to the intermediate transfer roller and transfer of the remaining untransferred image to clean up paper during a subsequent revolution of the intermediate transfer roller),

9. T2 offset (partial toner film transfer from the intermediate transfer roller to paper and transfer of the remaining untransferred image to the paper during a subsequent revolution of the intermediate).

The overall print quality was estimated as the average of these characteristics

5   (which were given equal weighting). In a second evaluation, the print performance was summarized as the average of all characteristics, excluding beading.

Color print quality was tested for the examples using yellow, cyan, magenta, and black toners as described in Example 40 of co-pending U.S. Patent No. 5,652,282. The process of imaging on a photoreceptor supported on a drum was

10   like that described in WO 97/12288, except that the photoreceptor was charged before each latent image of each color plane was written with the laser and developed with liquid toner. The printer was configured with a drying system like the comparative example in U.S. Patent 5,552,869 and transfer system like that in U.S. Patent No. 5,652,282 and co-pending U.S. application Serial No. 08/833,169.

15   The resulting color print for each release formulation was rated using a scale from 1 (very good performance) to 5 (very poor performance) in each of the following categories: bleeding (adjacent or overprinted colors bleeding into each other), soup under text (slight toner smear in the reverse process direction), drying roll picking (partial offset of small sections of the film-formed toner from the

20   photoreceptor to the drying roll), T1 dropouts (failure of 100% of the film-formed toner to transfer to the intermediate transfer roll), single dot drop out (failure of single dots to be observed on the final print). The overall relative print quality rating was defined as the average of the characteristics, each weighted equally.

25   <u>Examples</u>

Comparative Example 1.1 for electrophotographic printing is shown in Tables 4 - 6. A scaled up version of Formulation I in WO96/34318 was extrusion die coated onto a photoreceptor construction of inverted dual layer photoconductor as described in Example 2 of U.S. Patent 5,733,698, and interlayer in Example 4 of

30   U.S. Patent 5,733,698 and cured to give a crosslinked silicone polymer. High molecular weight vinyl silicones were coated out of heptane to give a smooth and

defect free release coating was obtained, as indicated by the small roughness factor
(Ra equal to 3.26 nm) in Table 5 and the visibly glossy surface.

In Comparative Example 1.2, a low molecular weight vinyl silicone (Gelest
VDT-731) with a crosslink density comparable to Comparative Example 1.1 (as
evidenced by the low %swelling in Table 5) was dispersed into heptane and solvent
coated. Similar to Comparative Example 1.1, the resulting release surface was
glossy, smooth and defect free and showed a low Ra value (Ra = 2.15).

In Comparative Example 1.3, a filler was added to the vinyl silicone of
Comparative Example 1.2 and the formulation was solvent coated to give a random
rough surface, as shown in Figure 2 and by interferometry, which yielded an Ra
value of 205.6 nm which is significantly greater than the non-filled release (i.e.,
Comparative Example 1.2). Print quality improved significantly for both printer
configurations with and without a drying roll.

Similar results are shown in Comparative Examples 1.4 and 1.5 with
swellable release surfaces coated from solvent. Comparative Example 1.4 is
composed of a hexenyl silicone (V) release formulation that has a lower crosslink
density than Comparative Examples 1.1 and 1.2, as evidenced by the higher %
swelling. This release coating gives poor print quality both with and without a
drying roll. The extremely poor ratings with a drying roll (4.0 - 4.5) result from
offset of the image onto the roll. In contrast, when silica is added as in
Comparative Example 1.5, print quality improves both with and without a drying
roll. The improvement in print quality with hydrophobic silica containing release
surfaces in Comparative Examples 1.3 and 1.5 appears to be the result of the
random surface pattern and a reduction in C.O.F. relative to the unfilled
formulation, since the peel force, durability, and surface energies do not change in a
consistent manner. The improvement in print quality is similar for both vinyl and
hexenyl silicone pre-polymers, indicating there may be a broad applicability for
release pre-polymers.

Example 2 illustrates the utility of using a coating process to generate
patterns on the release surface of a temporary image receptor, for example by
gravure coating, when both low (Example 2.1) and medium swelling (Example 2.2)

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silicones are used. Example 2 illustrates that when lower molecular weight pre-polymers are used in combination with solvent-free coating processes, useful patterns can be generated and retained which contribute to enhanced imaging performance.

5   The presence of a pattern was evidenced visually by the matte finish of the coating. The gravure pattern was visible on microscopic examination (50x magnification) and interferometry showed significantly elevated roughness values relative to solvent coated release (e.g. Ra > 50). As shown in Figure 3, solventless coating provides retention of the gravure pattern. This effect was found with both

10   direct and offset gravure. Patterns can be attenuated by adjusting the formulation viscosity, adding solvent, changing roll speeds, etc. Unlike the random roughness generated by the addition of fillers (see Figure 2), the gravure coating produces a repeated geometric pattern (Figure 3). Patterns of specific geometry and directionality can be generated by appropriate design of the gravure roll.

15   When a low swelling silicone release formulation was pattern coated with gravure (Example 2.1), the retention of a pattern improved the print quality in printing processes with and without the drying roll relative to non-patterned release (Comparative Example 1.2). When higher swelling silicones were pattern coated with gravure as in Example 2.2, improved print quality was seen without a drying

20   roll relative to a smooth release (Comparative Example 1.4). However, patterning swellable release surfaces was not sufficient to give improved print quality with a drying roll, and print quality ratings did not improve relative to the solvent coated control (Comparative Example 1.4). It is surprising that these patterns show enhanced release performance since coating processes are traditionally aimed at

25   generating glossy, defect-free (i.e. pattern-free) surfaces.

          Gravure coating did not adversely affect the other key properties of a release surface, namely its durability, surface energy, or peel force. This is shown in Examples 2.1 and 2.2, which show excellent durability and peel force for new surfaces and upon extended wear at 3200 wipes.

In addition to the choice of coating method and processing conditions, the rheology of the release formulation may be useful in attenuating, eliminating or accentuating the coating pattern.

Examples 2.1 and 2.2 illustrate the ability to generate patterns that enhance imaging performance without the use of fillers. Example 2.3 illustrates that these methods of pattern generation can be used in conjunction with fillers. When silica filler is added to a moderately swelling silicone as in Example 2.3, a roughened, patterned surface results (as evidenced by the elevated Ra value of Example 2.3 relative to Example 2.2). Print quality is enhanced without a drying roll relative to the patterned release only (Example 2.2). The incorporation of both a filler and a pattern in the release surface gives enhanced performance relative to a release with filler only (Comparative Example 1.5) for printing without a drying roll.

Other additives such as C.O.F. modifying silicone gums and silicate resins, as described in co-pending U.S. applications having Serial No. 08/832,834 can be used in conjunction with patterning processes to generate release surfaces with enhanced imaging performance. The combination of both chemical modifiers and patterning techniques enable fine-tuning of the temporary image receptor release for optimal print quality for printing processes both with and without a drying roll.

Whereas coating methods such as gravure may be used to generate regular patterns, other coating methods may be used to generate irregular or random patterns on the release surface. One such method is carrier fluid coating, described in World Patent 96/23595 and co-pending U.S. Patent application having Serial No. 08/826,571. As discussed in these applications, random, irregular patterns can be controlled in carrier fluid coating and Langmuir Bath Coating. By appropriate choice of formulation and coating conditions, these patterns may vary in size and shape from fine circles to irregular cell patterns, yielding coatings that range from glossy to matte finish. As shown in Figure 4, these patterns are readily visible by microscope (50x) and are distinguished from the regular patterns of Figure 3 and the random roughness imparted by fillers in Figure 2. As shown in Examples 3.1 to 3.7, choice of coating conditions and formulation are important in improving print performance. As shown particularly in Examples 3.2 and 3.7, these patterns enable

improvements in print quality for printer configurations both with and without a drying roll. While not wishing to be bound by any particular mechanism, improvement in print quality may be related to a fine tuning of the release peel force relative to the printer drying and/or transfer rolls.

5   Table 6 summarizes the effect of patterning on contact angles and surface energies for release surfaces. Using two probe fluids (water and toner carrier liquid), the advancing and receding contact angles were measured and the surface energy calculated for smooth, solvent coated release surfaces (Comparative Examples 1.1 and 1.2), silica filled release surfaces (Comparative Examples 1.3 and 10   1.5), gravure patterned surfaces (Example 2.1) and textured gravure surfaces (Example 2.1a). Example 2.1 was textured with a dry cotton pad after gravure coating.

It is known in the art that roughening a surface will affect the contact angles such that the liquids with contact angles less than 90 degrees will wet better on 15   roughened surfaces (i.e. show a lower contact angle) while non-wetting liquids (contact angle greater than 90 degrees) will wet more poorly (see R.H. Dettre and R.E. Johnson, Jr. in Contact Angle, Wettability and Adhesion, Advances in Chemistry Series 43, F.M. Fowkes, Ed., ACS Washington D.C. 1964). In the data shown in Table 6, water represents a non-wetting liquid while toner carrier liquid 20   (NORPAR 12) wets the silicone release surface.

Comparison of the smooth surface of the solvent coated silicones (Comparative Examples 1.1 and 1.2) with solvent coated silica filled silicones (Comparative Examples 1.3 and 1.5) and the gravure patterned release (Example 2.1), shows slight or minimal increase in the water advancing contact angle. Little 25   or no decrease is seen in the toner carrier liquid advancing contact angle. However, when Example 2.1 (Ra = 99.79nm) is textured to give a directional pattern (Ra = 116.22nm) (Examples 2.1a) there is an obvious improvement in toner carrier fluid wettability, as evidenced by the near zero contact angle. Contact angle measurements can therefore be used to distinguish between modes of improving 30   print quality by patterning, namely between regular and random patterns and

directional patterns. Directional patterns such as Example 2.1a improve wettability of the toner carrier fluid on the release surface of the temporary image receptor.

While not wishing to be bound by any particular theory, the improvement in print quality with a patterned and textured release surface may arise from a

5   combination of effects including the localization of toner in pattern micro-compartments, the formation of capillary channels which may aid in toner removal via drying or squeegeeing, and, in the case of directional texturing, a change in the relative wettability of toner carrier fluid. Patterns may also change a microscale peel force, allowing the apparent tack of the toner adhesive to be modulated in the

10   release. Furthermore, the mechanism by which gravure patterns improve print quality may be different from the mechanism whereby buffing improves print quality, as evidenced by the fact that gravure patterns and random filler roughness do not significantly affect the contact angles of the release.

Comparing Examples 4.1 and 4.2 illustrates the improvement in print quality

15   that can be attained with a release surface having texture. The release formulation was similar to that shown in Table 3 with the following exceptions: Gelest VDT-731 was the silicone pre-polymer and Gelest DMS-V41 was the higher viscosity, lower % functionalized silicone polymer, no filler was included, and the final coating solution was 7% solids in heptane. The release formulation in solution was

20   extrusion die coated, dried and cured on the same photoconductor and interlayer as previously described. Texturing of Example 4.2 was accomplished by texturing the surface in the process direction with a cotton pad (WEBRIL HANDI-PADS, Veratec, Inc., Walpole, MA) that had been soaked in a 50:1 mixture of 3M Professional Formula Machine Glaze, Part No. 051131-06051:water.

25   The color print quality test was run on both samples. The untextured release surface with an Ra of 17.33 nm (measured by WYKO RST-PLUS VSI mode) showed an average print quality rating of 3.1, while the directionally textured surface with an Ra of 114.44 nm showed an improvement in print quality as observed by its print quality rating of 1.9.

30   An untextured piece of the same type of photoreceptor construction as used in Example 4.1 was textured with a dry cotton pad, except that four different

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directions of line textures were made within one letter sized page area. The main difference between the patterns was their angular orientation with respect to the process direction, as shown in Figure 5. When a print was made on the different areas, print quality was improved in the same manner for all the areas with texture.

5   In the test of 10 monochrome prints of this same photoreceptor with four different textures, print quality was ranked on the tenth printed page, excluding beading, drying roll picking, and T2 offset which were not available due to the nature of the sample. The rankings were as follows: in the process direction was 1.15, in the crosshatch with texture perpendicular to the process direction over

10   texture in the process direction the rating was 1.31, untextured was 1.62, perpendicular to the process direction was 1.82, and in the crosshatch texture in the process direction over the perpendicular to the process direction the rating was 2.03. The best print quality was observed with a directionalized texture in the process direction.

15

Table 4: Raw Materials and Processing Methods for Inventive Temporary Image Receptors for Electrophotography

Example	Base polymer	Crosslinker	Additive 1	Additive 2	Dispersion	Coating process	Parameters
1.1	VI	United Chemicals NM203	X	none	heptane	die coated	
1.2	Gelest VDT-731	Syl-Off™ 7048	IX	none	heptane	die coated	
1.3	Gelest VDT-731	Syl-Off™ 7048	IX	1% Cab-O-Sil™ TS720	heptane	die coated	
1.4	V	Syl-Off™ 7048	IX	none	heptane	die coated	
1.5	V	Syl-Off™ 7048	IX	1% Cab-O-Sil™ TS720	heptane	die coated	
2.1	Gelest VDT-731	Syl-Off™ 7048	IX	none	100% solids	gravure coated	ML-4 roll at 5.0 m/min
2.2	V	Syl-Off™ 7048	IX	none	100% solids	gravure coated	ML-4 roll at 5.0 m/min
2.3	V	Syl-Off™ 7048	IX	3% Cab-O-Sil™ TS720	100% solids	gravure coated	ML-4 roll at 5.0 m/min
3.1	III	Syl-Off™ 7488	IX	none	100% solids	Carrier fluid coating	7.8 m/min web speed (0.65 microns)
3.2	III	Syl-Off™ 7488	IX	none	100% solids	Carrier fluid coating	3.38 m/min web speed (1.5 microns)
3.3	III	Syl-Off™ 7488	none	none	100% solids	Carrier fluid coating	7.8 m/min web speed (0.65 microns)
3.4	III	Syl-Off™ 7488	none	0.5% Modaflow	100% solids	Carrier fluid coating	3.37 m/min web speed (1.5 microns)
3.5	III	Syl-Off™ 7488	none	none	100% solids	Carrier fluid coating	7.8 m/min web speed (0.65 microns)
3.6	II	Syl-Off™ 7488	none	none	100% solids	Carrier fluid coating	7.8 m/min web speed (0.65 microns)
3.7	V	Syl-Off™ 7488	IX	none	100% solids	Carrier fluid coating	7.8 m/min web speed (0.65 microns)
4.1	Gelest VDT-731	Syl-Off™ 7048	Gelest DMS-V41	none	heptane	die coated	
4.2	Gelest VDT-731	Syl-Off™ 7048	Gelest DMS-V41	none	heptane	die coated	textured with cotton pad

Table 5: Examples of Temporary Image Receptors for Electrophotographic Printing

Example	%Silica TS720	%Swelling	Durability (g)	C.O.F.	Peel force (g/cm at 0 and 3200 wipes)		Surface Energy (mN/m)			Roughness	Print Quality (rating scale: 1.0 is excellent and 5.0 is poor; see also description in Experimental Methods)				Monochrome
					0	3200	Total	Disperse	Polar	Ra (nm)	Without Drying Roll		With Drying Roll		
											beading	no beading	beading	no beading	
1.1	0%	18%	300	0.800	3.9	21.3	23.0	23.0	0.0	3.26	2.50	2.14	1.83	1.44	
1.2	0%	11%	200	1.10	2.6	6.46	22.2	22.2	0.0	2.15	2.75	2.43	2.00	1.63	
1.3	1%	11%	200	0.781	2.2	4.45	22.1	22.0	0.1	205.6	1.69	1.79	1.44	1.50	
1.4	0%	42%	100	0.667	1.1	6.85	NA	NA	NA	6.21	2.75	2.43	4.50	4.00	
1.5	1%	43%	50	0.43	1.1	9.84	22.2	22.2	0.0	117.4	1.69	1.79	1.56	1.63	
2.1	0%	14%	300	0.790	2.4	4.09	22.2	22.2	0.0	87.2	1.88	1.61	1.71	1.44	
2.2	0%	41%	500	0.719	1.4	6.02	22.2	22.2	0.1	56.6	2.13	1.86	4.50	5.00	
2.3	3%	37%	300	0.757	1.1	6.26	22.9	22.8	0.1	86.0	1.57	1.57	3.25	5.00	
3.1	0%	93%	NA	0.762	NA	312	NA	NA	NA	NA	2.12	1.86	2.25	2.00	
3.2	0%	93%	NA	0.524	NA	4.33	NA	NA	NA	NA	1.75	1.83	1.19	1.21	
3.3	0%	98%	NA	0.743	NA	108	NA	NA	NA	NA	2.88	2.86	1.50	1.28	
3.4	0%	98%	NA	1.30	NA	15.4	NA	NA	NA	NA	2.62	2.57	1.94	1.78	
3.5	0%	169%	NA	NA	NA	NA	NA	NA	NA	NA	2.25	2.43	1.81	1.93	
3.6	0%	167%	NA	NA	NA	449	NA	NA	NA	NA	-	2.67	-	1.67	
3.7	0%	99%	NA	0.467	NA	110	NA	NA	NA	NA	1.69	1.50	1.44	1.21	

Table 6: EFFECT OF PATTERNING ON CONTACT ANGLES AND SURFACE ENERGY OF PHOTOCONDUCTER RELEASE COATINGS

Example	Probe Fluid	Contact Angles (degrees) (n=1)				Surface Energy (mN/m) (2 samples per probe fluid)		
		advance (1)	reverse (1)	advance (2)	reverse (2)	Total	Disperse	Polar
1.1	water	112.7	91.2	111.4	93.5	23.0	23.0	0.0
	norpar	26.1	19.9	24.1	20.2			
1.2	water	111.5	93.7	108.8	96.8	22.7	22.7	0.0
	norpar	29.9	14.6	27.0	14.3			
1.3	water	113.0	95.3	111.9	96.5	22.1	22.0	0.1
	norpar	30.4	18.7	30.2	17.9			
1.5	water	114.5	95.4	115.1	96.7	22.2	22.2	0.0
	norpar	29.4	18.7	29.2	17.7			
2.1	water	112.2	96.0	111.4	96.9	22.2	22.2	0.0
	norpar	29.6	19.4	30.9	20.1			
2.1a	water	116.8	90.9	114.6	93.1	NA	NA	NA
	norpar	acos(1.00)	acos(1.05)	acos(1.02)	acos(1.05)			
2.2	water	115.7	96.0	114.3	95.9	22.2	22.2	0.1
	norpar	29.2	18.8	27.1	17.9			
2.3	water	116.1	98.6	111.5	101.0	22.9	22.8	0.1
	norpar	26.6	11.1	24.1	11.2			

What is claimed is:

1.   A photoreceptor having a continuous surface with a first edge and a second edge comprising

5   an electroconductive substrate

           a photoconductive layer coated on the electroconductive substrate, and

           a release layer coated over the photoconductive layer, wherein the release layer is a continuous layer and comprises a texture directionalized along the continuous surface.

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2.   The photoreceptor of claim 1 wherein the directionalized texture is periodic.

3.   The photoreceptor of claim 1 wherein the directionalized texture is non-periodic.

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4.   The photoreceptor of claim 1 wherein the texture is defined by an Ra between 10nm and 500nm.

5.   The photoreceptor of claim 1 wherein the texture is provided by a method

20   selected from abrading, buffing, embossing, gravure coating, extrusion die coating, roll coating, carrier fluid coating, Langmuir-Blodgett bath coating and flexographic printing.

6.   A method of making a photoreceptor comprising

25   providing an electroconductive substrate bearing a photoconductive layer,

           coating a release layer over the photoconductive layer by a non-leveled coating process to provide a continuous, textured release surface.

7.   The method of claim 6 wherein the textured release surface is

30   directionalized.

8.   A system for producing an image on a receptor comprising

a photoreceptor which is transported in an imaging process direction and comprises a release layer having a texture directionalized in the imaging process direction;

5   a charge producing means for producing an image-wise distribution of charges on the photoreceptor;

a liquid toner comprising toner particles in a carrier liquid;

at least one application means for applying the liquid toner to the photoreceptor forming an image-wise distribution of the toner particles on

10   the photoreceptor to form the image; and

an intermediate transfer element.

9.   A method of producing an image on a receptor media from image data, comprising the steps of:

15   providing a photoreceptor which moves in an image processing direction and comprises an electroconductive substrate, a photoconductive layer, and a surface release layer having a texture directionalized in the image processing direction;

producing an image-wise distribution of charges on a photoreceptor

20   corresponding to the image data;

applying a liquid toner comprising solid charged pigmented toner particles in a carrier liquid to the photoreceptor forming an image-wise distribution of the toner particles on said photoreceptor to form the image;

transferring the image from the photoreceptor to an intermediate transfer

25   element forming a first transfer nip under pressure with the photoreceptor,

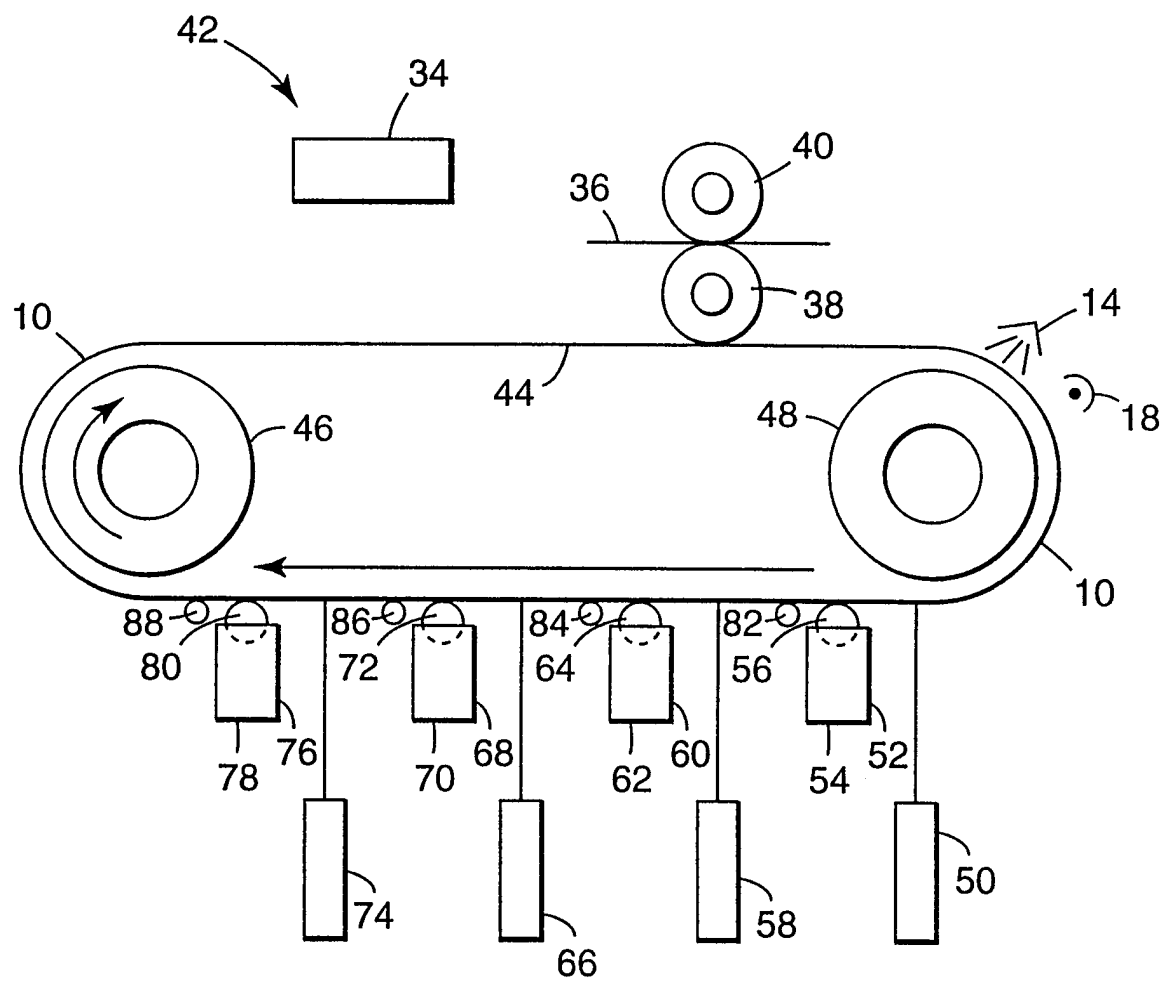transferring the image from the intermediate transfer element to a receptor media.

FIG. 1

FIG.2

RMS Surface Roughness (nm) 117.582 nm Date: 04 / 29 / 96   Terms Remove
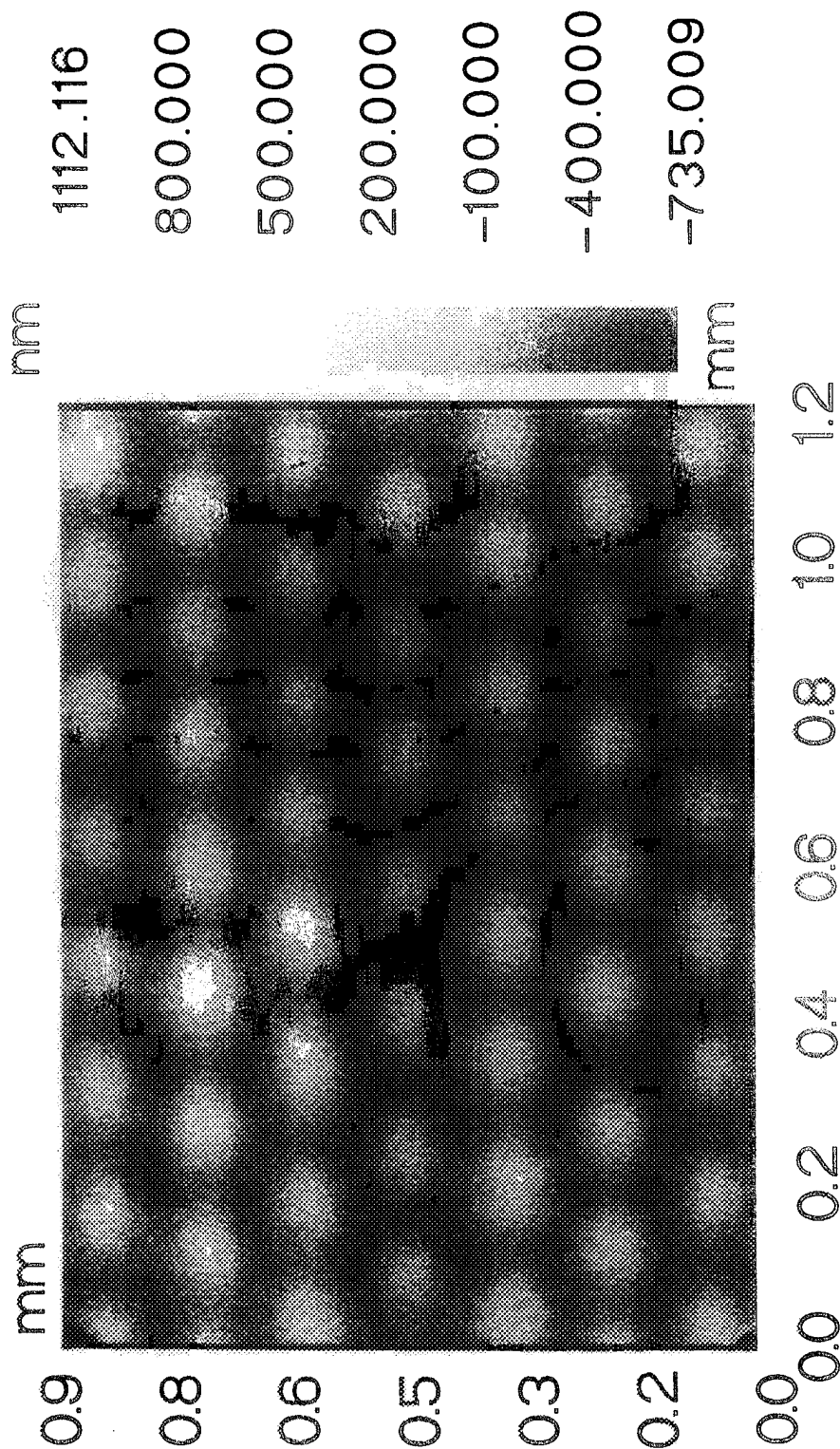
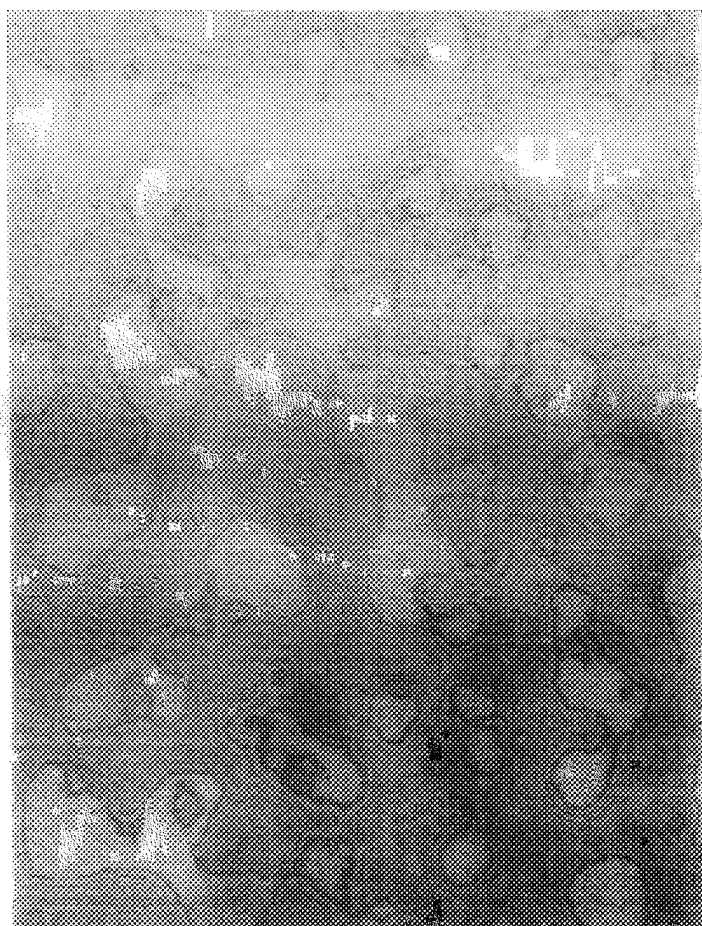Primary Magnification   5.315   Time: 10 : 04 : 32 Cylinder & Tilt
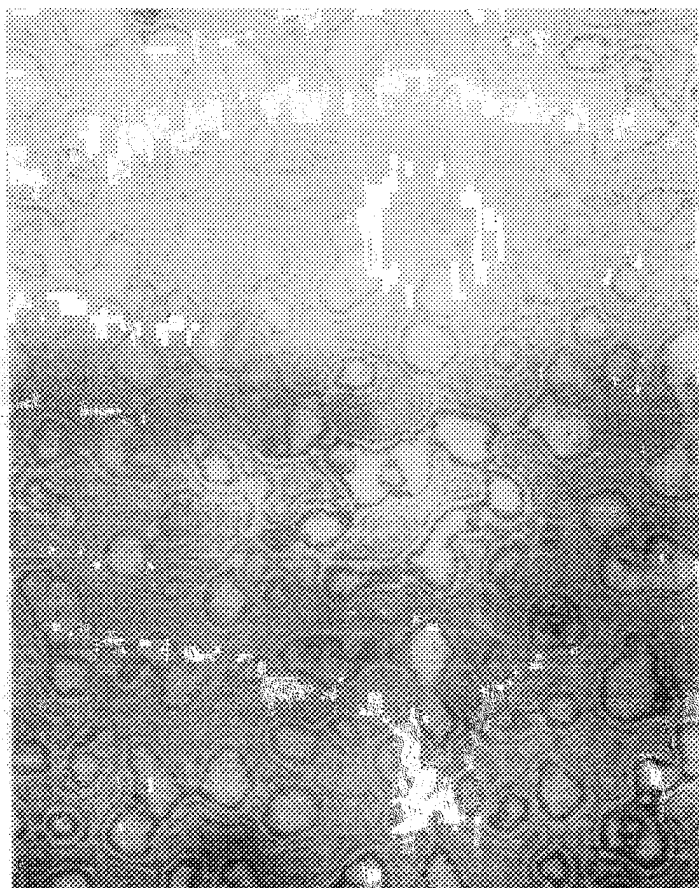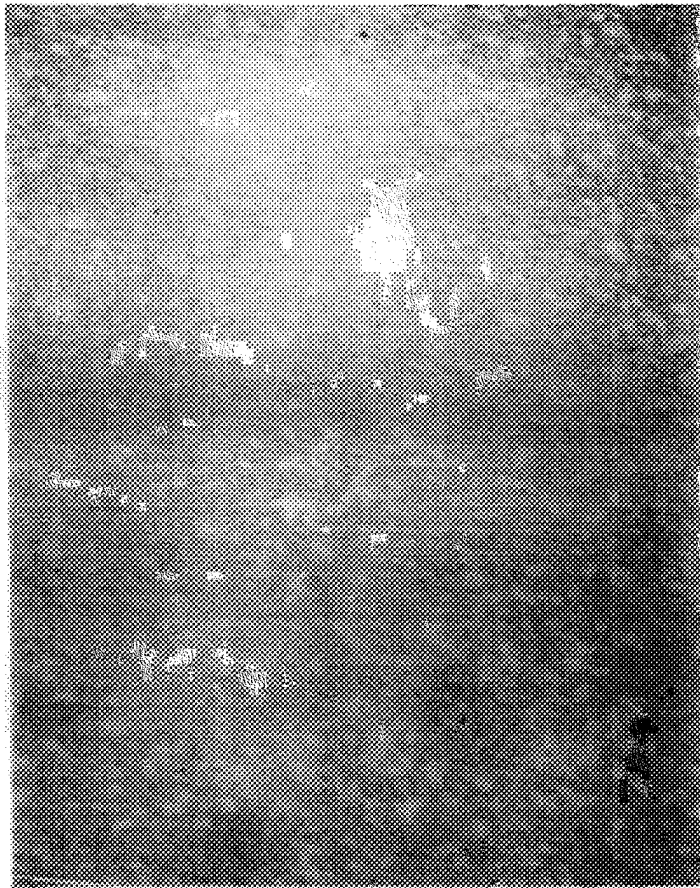
FIG. 3

FIG.4A

FIG.4B

FIG.4C

FIG.4D
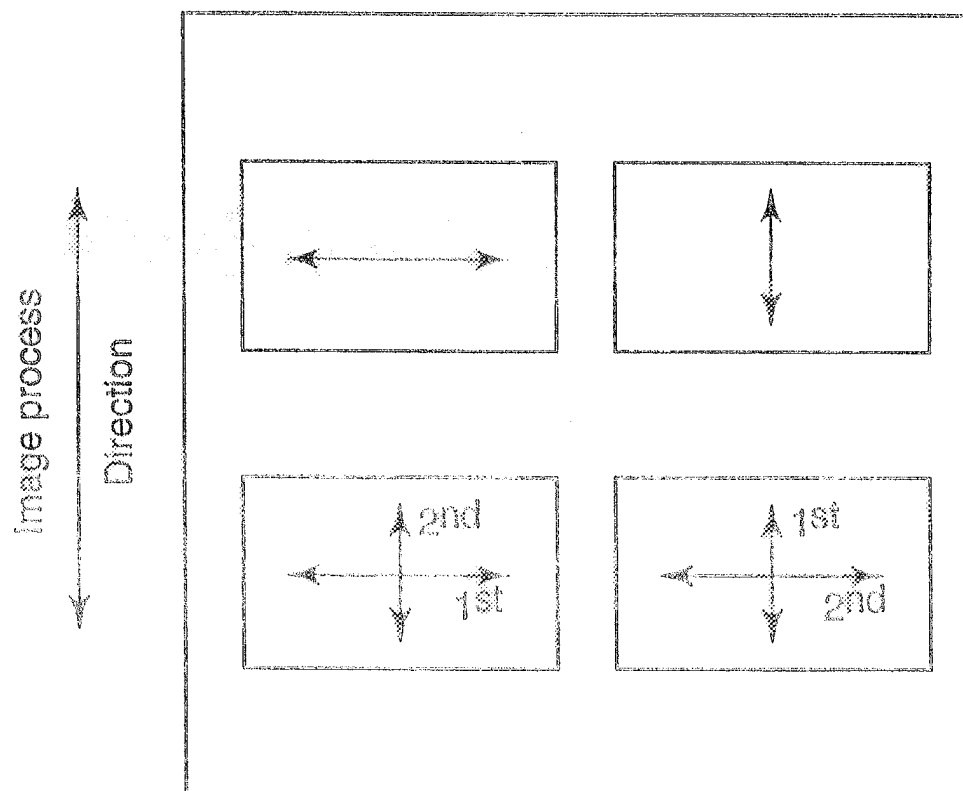
FIG. 5

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G03G5/147

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   G03G

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 473 292 A (XEROX) 4 March 1992 cited in the application see page 4, line 41 - page 5, line 31; claims 1-3,7,11; figures 5,6 see page 6, line 4 - line 13 see page 7, line 18 - page 9, line 30; figures 5,6 ---	1,5-9
X	US 5 381 211 A (R.E.GODLOVE) 10 January 1995 see column 6, line 5 - line 19; claims 1-7; figures 1-3 -----	1,2,5-9

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in 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 document but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 June 1998	01/07/1998

Name and mailing address of the ISA	Authorized officer
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Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 473292	A	04-03-1992	US JP	5162183 A 4243266 A	10-11-1992 31-08-1992
US 5381211	A	10-01-1995	NONE		