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(54) Ink jet recording element and printing method

(57) An ink jet recording element including a substrate having thereon: a) a subbing layer of a polymeric binder and a borate or a borate derivative, the borate or borate derivative being present in an amount of from up to 3 g/m^2, and the weight ratio of the polymeric binder to the borate or borate derivative is from 0.2:1 to 3:1; and b) an image-receiving layer including inorganic particles and a cross-linkable polymer containing hydroxyl groups, the cross-linkable polymer being present in an amount of less than 25 g/m^2, and the weight ratio of the cross-linkable polymer to the inorganic particles is from 5:95 to 30:70.

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Description

[0001] This invention relates to an ink jet recording element and a printing method using the element. More particularly, this invention relates to a subbing layer for an ink jet recording element.

[0002] In a typical ink jet recording or printing system, ink droplets are ejected from a nozzle at high speed towards a recording element or medium to produce an image on the medium. The ink droplets, or recording liquid, generally comprise a recording agent, such as a dye or pigment, and a large amount of solvent. The solvent, or carrier liquid, typically is made up of water, an organic material such as a monohydric alcohol, a polyhydric alcohol or mixtures thereof.

[0003] An ink jet recording element typically comprises a support having on at least one surface thereof an ink-receiving or image-forming layer, and includes those intended for reflection viewing, which have an opaque support, and those intended for viewing by transmitted light, which have a transparent support.

[0004] It is well known that in order to achieve and maintain photographic-quality images on such an image-recording element, an ink jet recording element must:

- Be readily wetted so there is no puddling, i.e., coalescence of adjacent ink dots, which leads to non-uniform density
- Exhibit no image bleeding
- Exhibit the ability to absorb high concentrations of ink and dry quickly to avoid elements blocking together when stacked against subsequent prints or other surfaces
- Exhibit no discontinuities or defects due to interactions between the support and/or layer(s), such as cracking, repellencies, comb lines and the like
- Not allow unabsorbed dyes to aggregate at the free surface causing dye crystallization, which results in bloom or bronzing effects in the imaged areas
- Have an optimized image fastness to avoid fade from contact with water or radiation by daylight, tungsten light, or fluorescent light

[0005] An ink jet recording element that simultaneously provides an almost instantaneous ink dry time and good image quality is desirable. However, given the wide range of ink compositions and ink volumes that a recording element needs to accommodate, these requirements of ink jet recording media are difficult to achieve simultaneously.

[0006] Ink jet recording elements are known that employ porous or non-porous single layer or multilayer coatings that act as suitable image receiving layers on one or both sides of a porous or non-porous support. Recording elements that use non-porous coatings typically have good image quality but exhibit poor ink dry time. Recording elements that use porous coatings typically contain colloidal particulates and have poorer image quality but exhibit superior dry times.

[0007] While a wide variety of different types of porous image-recording elements for use with ink jet printing are known, there are many unsolved problems in the art and many deficiencies in the known products which have severely limited their commercial usefulness. A major challenge in the design of a porous image-recording layer is to be able to obtain good quality, crack-free coatings with as little non-particulate matter as possible. If too much non-particulate matter is present, the image-recording layer will not be porous and will exhibit poor ink dry times.

[0008] U.S. Patent 4,877,686 relates to a recording sheet for ink jet printing wherein boric acid or its derivative is used to cause gelling in a polymeric binder containing hydroxyl groups and a filler comprising particles. However, there is a problem with this element in that the amount of boric acid used does not provide an element which, when printed with an ink jet printer, will have a fast dry time without cracking.

[0009] It is an object of this invention to provide an ink jet recording element that has a fast dry time when used in ink jet printing. It is another object of this invention to provide a porous recording element that has good coating quality, especially reduced cracking. It is still another object of this invention to provide an ink jet recording element that exhibits good image quality after printing.

[0010] Still another object of the invention is to provide a printing method using the aobve-described element.

[0011] These and other objects are achieved in accordance with the invention which comprises an ink jet recording element comprising a substrate having thereon:

a) a subbing layer comprising a polymeric binder and a borate or a borate derivative, the borate or borate derivative being present in an amount of from up to 3 g/m^2, and the weight ratio of the polymeric binder to the borate or borate derivative is from 0.2:1 to 3:1; and
b) an image-receiving layer comprising inorganic particles and a cross-linkable polymer containing hydroxyl groups, the cross-linkable polymer being present in an amount of less than 50 g/m^2, and the weight ratio of the cross-linkable polymer to the inorganic particles is from 5:95 to 30:70.

[0012] The ink jet recording element of the invention has good coating and image quality and a fast dry time when printed in an ink jet printer.

[0013] Another embodiment of the invention relates to an ink jet printing method comprising the steps of:

A) providing an ink jet printer that is responsive to digital data signals;
B) loading the printer with an ink jet recording element as described above;
C) loading the printer with an ink jet ink composition; and
D) printing on the image-receiving layer using the ink jet ink in response to the digital data signals.

[0014] The polymeric binder in the subbing layer employed in the invention is preferably a water soluble or water dispersible polymer such as poly(vinyl alcohol), poly(vinyl pyrrolidone), gelatin, a cellulose ether, a poly(oxazoline), a poly(vinylacetamide), partially hydrolyzed poly(vinyl acetate/vinyl alcohol), poly(acrylic acid), poly(acrylamide), poly (alkylene oxide), a sulfonated or phosphated polyester or polystyrene, casein, zein, albumin, chitin, chitosan, dextran, pectin, a collagen derivative, collodian, agar-agar, arrowroot, guar, carrageenan, tragacanth, xanthan, rhamsan and the like; a latex such as poly(styrene-co-butadiene), a polyurethane latex, a polyester latex, or a poly(acrylate), poly (methacrylate), poly(acrylamide) or copolymers thereof. In a preferred embodiment, the polymeric binder is poly(vinyl alcohol), a sulfonated polyester dispersion, such as AQ29® (Eastman Chemical Co.), gelatin, a polyurethane or poly (vinyl pyrrolidone).

[0015] The polymeric binder for the subbing layer is preferably used in an amount of up to 3 g/m^2.

[0016] The borate or borate derivative employed in the subbing layer of the ink jet recording element of the invention may be, for example, borax, sodium tetraborate, boric acid, phenyl boronic acid, or butyl boronic acid. As noted above, the borate or borate derivative is used in an amount of up to 3 g/m^2. It is believed that upon coating, the borate or borate derivative in the subbing layer diffuses into the image-receiving layer to cross-link the cross-linkable binder in the image-receiving layer.

[0017] The inorganic particles which may be used include, for example, comprise metal oxides, hydrated metal oxides, boehmite, clay, calcined clay, calcium carbonate, -aluminosilicates, zeolites or barium sulfate. In a preferred embodiment, the metal oxide is silica, alumina, zirconia or titania. In another preferred embodiment, the metal oxide is fumed silica, fumed alumina, colloidal silica or boehmite. In still another preferred embodiment, the inorganic particles are present in the image-receiving layer in an amount of up to 50 g/m^2.

[0018] When the inorganic particles are fumed silica or fumed alumina, they preferably have a primary particle size up to 50 nm, but can be aggregated to give an aggregate size of less than 300 nm. When the inorganic particles are colloidal silica or boehmite, they preferably have a particle size of less than 150 nm.

[0019] The cross-linkable polymer containing hydroxyl groups employed in the image-receiving layer may be, for example, poly(vinyl alcohol), partially hydrolyzed poly(vinyl acetate/vinyl alcohol), copolymers containing hydroxyethylmethacrylate, copolymers containing hydroxyethylacrylate, copolymers containing hydroxypropylmethacrylate, hydroxy cellulose ethers such as hydroxyethylcellulose, etc. In a preferred embodiment, the cross-linkable polymer containing hydroxyl groups is poly(vinyl alcohol) or partially hydrolyzed poly(vinyl acetate/vinyl alcohol).

[0020] An additional polymeric binder, such as any of the polymeric binders listed above for the subbing layer, may also be added to the image-receiving layer along with the cross-linkable polymer, if desired.

[0021] The amount of binder used in the image-receiving layer should be sufficient to impart cohesive strength to the ink jet recording element, but should also be minimized so that the interconnected pore structure formed by the particles is not filled in by the binder.

[0022] In addition to the image-receiving layer, the recording element of the invention may also contain a layer on top of the image-receiving layer, the function of which is to provide gloss. Materials useful for this layer include submicron inorganic particles and/or polymeric binder.

[0023] The support for the ink jet recording element used in the invention can be any of those usually used for ink jet receivers, such as resin-coated paper, paper, polyesters, or microporous materials such as polyethylene polymer-containing material sold by PPG Industries, Inc., Pittsburgh, Pennsylvania under the trade name of Teslin®, Tyvek® synthetic paper (DuPont Corp.), impregnated paper such as Duraform®, and OPPalyte® films (Mobil Chemical Co.) and other composite films listed in U.S. Patent 5,244,861. Opaque supports include plain paper, coated paper, synthetic paper, photographic paper support, melt-extrusion-coated paper, and laminated paper, such as biaxially oriented support laminates. Biaxially oriented support laminates are described in U.S. Patents 5,853,965; 5,866,282; 5,874,205; 5,888,643; 5,888,681; 5,888,683; and 5,888,714. These biaxially oriented supports include a paper base and a biaxially oriented polyolefin sheet, typically polypropylene, laminated to one or both sides of the paper base. Transparent supports include glass, cellulose derivatives, e.g., a cellulose ester, cellulose triacetate, cellulose diacetate, cellulose acetate propionate, cellulose acetate butyrate; polyesters, such as poly(ethylene terephthalate), poly(ethylene naphthalate), poly(1,4-cyclohexanedimethylene terephthalate), poly(butylene terephthalate), and copolymers thereof; polyimides; polyamides; polycarbonates; polystyrene; polyolefins, such as polyethylene or polypropylene; polysulfones; polyacrylates; polyetherimides; and mixtures thereof. The papers listed above include a broad range of papers, from high end papers, such as photographic paper to low end papers, such as newsprint.

[0024] The support used in the invention may have a thickness of from 50 to 500 μm, preferably from 75 to 300 μm. Antioxidants, antistatic agents, plasticizers and other known additives may be incorporated into the support, if desired.

[0025] In order to improve the adhesion of the image-receiving layer to the support, the surface of the support may be subjected to a corona-discharge treatment prior to applying the subbing layer.

[0026] The above coating composition can be coated either from water or organic solvents, however water is preferred. The total solids content should be selected to yield a useful coating thickness in the most economical way, and for particulate coating formulations, solids contents from 10-40 wt. % are typical.

[0027] Coating compositions employed in the invention may be applied by any number of well known techniques, including dip-coating, wound-wire rod coating, doctor blade coating, gravure and reverse-roll coating, slide coating, bead coating, extrusion coating, curtain coating and the like. Known coating and drying methods are described in further detail in Research Disclosure no. 308119, published Dec. 1989, pages 1007 to 1008. Slide coating is preferred, in which the base layers and overcoat may be simultaneously applied. After coating, the layers are generally dried by simple evaporation, which may be accelerated by known techniques such as convection heating.

[0028] The coating composition may be applied to one or both substrate surfaces through conventional pre-metered or post-metered coating methods such as blade, air knife, rod, roll coating, etc. The choice of coating process would be determined from the economics of the operation and in turn, would determine the formulation specifications such as coating solids, coating viscosity, and coating speed.

[0029] The image-receiving layer thickness may range from 1 to 60 μm, preferably from 5 to 40 μm.

[0030] After coating, the ink jet recording element may be subject to calendering or supercalendering to enhance surface smoothness. In a preferred embodiment of the invention, the ink jet recording element is subject to hot soft-nip calendering at a temperature of 65°C and a pressure of 14000 kg/m at a speed of from 0.15 m/s to 0.3 m/s.

[0031] In order to impart mechanical durability to an ink jet recording element, additional crosslinkers that further act upon the cross-linkable binder discussed above may be added in small quantities. Such an additive improves the cohesive strength of the layer. Crosslinkers such as carbodiimides, polyfunctional aziridines, aldehydes, isocyanates, epoxides, polyvalent metal cations, and the like may all be used.

[0032] To improve colorant fade, UV absorbers, radical quenchers or antioxidants may also be added to the image-receiving layer as is well known in the art. Other additives include pH modifiers, adhesion promoters, rheology modifiers, surfactants, biocides, lubricants, dyes, optical brighteners, matte agents, antistatic agents, etc. In order to obtain adequate coatability, additives known to those familiar with such art such as surfactants, defoamers, alcohol and the like maybe used. A common level for coating aids is 0.01 to 0.30 wt. % active coating aid based on the total solution weight. These coating aids can be nonionic, anionic, cationic or amphoteric. Specific examples are described in MCCUTCHEON's Volume 1: Emulsifiers and Detergents, 1995, North American Edition.

[0033] Ink jet inks used to image the recording elements of the present invention are well-known in the art. The ink compositions used in ink jet printing typically are liquid compositions comprising a solvent or carrier liquid, dyes or pigments, humectants, organic solvents, detergents, thickeners, preservatives, and the like. The solvent or carrier liquid can be solely water or can be water mixed with other water-miscible solvents such as polyhydric alcohols. Inks in which organic materials such as polyhydric alcohols are the predominant carrier or solvent liquid may also be used. Particularly useful are mixed solvents of water and polyhydric alcohols. The dyes used in such compositions are typically water-soluble direct or acid type dyes. Such liquid compositions have been described extensively in the prior art including, for example, U.S. Patents 4,381,946; 4,239,543 and 4,781,758.

[0034] In order to obtain the best results, the materials and amounts in the image-receiving layer and the thickness of the image-receiving layer are selected to that the pore volume of the image-receiving layer is greater than about 22 cc/m^2 and it has a median pore diameter between about 20 and about 50 nm.

[0035] The following examples are provided to illustrate the invention.

Example 1

Subbing Layer 1

[0036] Sulfonated polyester dispersion AQ29® (Eastman Chemical Co.) and borax (sodium tetraborate decahydrate), at a 70:30 ratio, were used to prepare a coating solution. The coating solution was bead-coated at 25°C on polyethylene-coated paper base that had been previously subjected to corona discharge treatment. The recording element was then dried by forced air at 43 °C for 4 minutes. The thickness of the subbing layer was 3.8 g/m^2.

Subbing Layer 2

[0037] This subbing layer was prepared the same as for Subbing Layer 1 except that the ratio of AQ29® to borax was 50:50.

Subbing Layer 3

[0038] This subbing layer was prepared the same as for Subbing Layer 1 except that Witco 240® (Uniroyal Chemical Co.) was used in place of AQ29®.

Subbing Layer 4

[0039] This subbing layer was prepared the same as for Subbing Layer 2 except that poly(vinyl alcohol) Airvol® 103 (Uniroyal Chemical Co.) was used in place of AQ29®. The thickness of the subbing layer was 0.26 g/m^2.

Element 1 of the Invention

[0040] A coating solution for the image-receiving layer was prepared by mixing 74 g of fumed silica Cab-O-Sperse® PG022 (Cabot Corp.) as a 20% solution, 25.1 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 0.9 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution. The solid of the coating solution was 17.4 wt. %. The coating solution was bead-coated at 25 ° C on Subbing Layer 1 and dried by forced air at 21 ° C. The thickness of the image-receiving layer was 50 g/m^2.

Element 2 of the Invention

[0041] This element was prepared the same as Element 1 except that 75.8 g of fumed silica Cab-O-Sperse® PG022 (Cabot Corp.) as a 20% solution, 27.2 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 0.95 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution were used.

Element 3 of the Invention

[0042] This element was prepared the same as Element 1 except that 75.8 g of fumed silica Cab-O-Sperse® PG022 (Cabot Corp.) as a 20% solution, 33.4 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 0.95 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution were used.

Element 4 of the Invention

[0043] A coating solution for the image-receiving layer was prepared by mixing 449.5 g of fumed alumina W440® (DeGussa Corp.) as a 40% solution, 220g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 2 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution. The solids concentration of the coating solution was adjusted to 17.4 wt. % by adding water. The coating solution was bead-coated at 25 °C on Subbing Layer 1 and dried by forced air at 21 °C. The thickness of the image-receiving layer was 53 g/m^2.

Element 5 of the Invention

[0044] A coating solution for the image-receiving layer was prepared by mixing 75.8 g of Cab-O-Sperse® PG002 (Cabot Corp.) as a 20% solution, 33.4 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 0.95 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution. The coating solution was bead-coated at 25°C on Subbing Layer 1 and dried by forced air at 21°C. The thickness of the image-receiving layer was 50 g/m^2.

Element 6 of the Invention

[0045] This element was prepared the same as Element 1 except that 75.8 g of fumed silica Cab-O-Sperse® PG022 (Cabot Corp.) as a 20% solution, 43.4 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 0.95 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution were used.

Element 7 of the Invention

[0046] This element was prepared the same as Element 1 except that 19.9 g of colloidal silica Nalco® 1056 (Nalco Corp.) as a 30% solution, 15 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 0.38 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution were used.

Element 8 of the Invention

[0047] This element was prepared the same as Element 4 except that the solution was coated on Subbing Layer 2.

Element 9 of the Invention

[0048] This element was prepared the same as Element 4 except that the solution was coated on Subbing Layer 3.

Element 10 of the Invention

[0049] This element was prepared the same as Element 4 except that the solution was coated on Subbing Layer 4.

Comparative Element 1 (no subbing layer)

[0050] A coating solution for the image-receiving layer was prepared by mixing 42.25 g of Cab-O-Sperse® PG022 (Cabot Corp.) as a 20% solution, 15 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 0.5 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution. The coating solution was bead-coated at 25°C on polyethylene-coated paper base that had been previously subjected to corona discharge treatment, and dried by forced air at 21°C. The thickness of the image-receiving layer was 50 g/m^2.

Comparative Element 2 (no subbing layer)

[0051] This element was prepared the same as Comparative Element 1 except that 37.25 g of fumed silica Cab-O-Sperse® PG022 (Cabot Corp.) as a 20% solution and 25 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution were used.

Comparative Element 3 (no subbing layer)

[0052] This element was prepared the same as Comparative Element 1 except that 32.25 g of fumed silica Cab-O-Sperse® PG022 (Cabot Corp.) as a 20% solution and 35 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution were used.

Comparative Element 4 (no subbing layer)

[0053] This element was prepared the same as Comparative Element 1 except that 29.75 g of fumed silica Cab-O-Sperse® PG022 (Cabot Corp.) as a 20% solution and 40 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution were used.

Comparative Element 5 (no subbing layer)

[0054] This element was prepared the same as Comparative Element 1 except that 19.9 g of fumed silica Naico® 1056 (Nalco Corp.) as a 30% solution, 15 g of poly(vinyl alcohol) Gohsenol® GH-17 (Nippon Gohsei Co. Ltd.) as a 10% solution, and 0.38 g of Olin® 10G (Dixie Chemical Co.) as a 10% solution were used.

Comparative Element 6

[0055] This element was prepared the same as Element 4, except that no borax was used in the subbing layer.

Comparative Element 7

[0056] This element was prepared the same as Element 4, except that no AQ29® was used in the subbing layer.

Coating Quality

[0057] The above dried coatings for visually evaluated for cracking defects. The results are tabulated in Table 1.

Table 1

Recording Element	Subbing Layer	Ratio Particles:Polymer	Coating Quality
1	1	85:15	Good
2	1	85:15	Good
3	1	82:18	Good
4	1	89:11	Good
5	1	82:18	Good
6	1	78:22	Good
7	1	80:20	Good
8	2	90:10	Good
9	3	90:10	Good
10	4	90:10	Good
Comparative 1	none	85:15	Bad
Comparative 2	none	75:25	Bad
Comparative 3	none	65:35	Bad
Comparative 4	none	60:40	Good
Comparative 5	none	80:20	Bad
Comparative 6	AQ29® only	90:10	Bad
Comparative 7	borax only	90:10	Bad

[0058] The results show that the elements of the invention had better coating quality than all but one of the comparative elements. While Comparative Element 4 had good coating quality, it contained 40 wt. % binder as compared to less than 25 wt. % binder for the elements of the invention., and was worse for coalescence as will be shown in Example 2.

Example 2

Preparation of Inks

Cyan Ink

[0059] A cyan ink was prepared using Pigment Blue15:3 at 1.4 wt. %, sulfonated polyester dispersion AQ55® (Eastman Chemical Co.) at 1.1 wt. %, glycerol at 6.0 wt. %, Surfynol® 465 at 0.2 wt. %, Dowanol® EB (Dow Chemical Co.) at 2.5 wt. % and diethylene glycol at 24.0 wt. %. Small amounts of triethanol amine and lactic acid were used to adjust the pH to 8.

Magenta Ink

[0060] A magenta ink was prepared using Pigment Red 122 at 2.2 wt. %, sulfonated polyester dispersion AQ55® (Eastman Chemical Co.) at 2.0 wt %, glycerol at 6.0 wt. %, Surfynol® 465 at 0.2 wt. %, Dowanol EB (Dow Chemical Co.) at 2.5 wt.% and diethylene glycol at 19.4 wt.%. Small amounts of triethanol amine and lactic acid were used to adjust the pH to 8.

Yellow Ink

[0061] A yellow ink was prepared using Pigment Yellow 155 at 2.2 wt. %, sulfonated polyester dispersion AQ55® (Eastman Chemical Co.) at 2.0 wt. %, glycerol at 6.0 wt. %, Surfynol® 465 at 0.2 wt. %, Dowanol® EB at 2.5 wt. % and diethylene glycol at 20 wt.%. Small amounts of triethanol amine and lactic acid were used to adjust the pH to 8.

Black Ink

[0062] A black ink was prepared using Pigment Black 7 at 1.6 wt. % of the ink composition, sulfonated polyester dispersion AQ55® (Eastman Chemical Co.) at 1.485 wt. %, glycerol at 6.0 wt. %, Surfynol® 465 at 0.2 wt. %, Dowanol® EB at 2.5 wt. % and diethylene glycol at 23 wt. %. Small amounts of triethanol amine and lactic acid were used to adjust the pH to 8.

Printing

[0063] The above inks were filtered through a 0.2 μm polytetrafluoroethylene filter, degassed using ultrasonic treatment with an applied vacuum of 559 mm of mercury and placed in a clean empty cartridge used for printing with a Mutoh 4100 ink jet printer. The above inks were printed on Recording Elements1-10 and Comparative Element 4 using a Mutoh 4100 ink jet printer without color correction at 283 dots per centimeter (720 dpi) bi-directional printing, with "microdot on" setting giving a droplet size of about17 picoliters.

[0064] The test image consisted of a block 9.2 cm by 19.4 cm, divided into equally sized patches 0.7 cm by 0.4 cm to give 40 rows of patches and 12 columns of patches. The rows were numbered from 10 to 400 in increments of 10 to indicate the increasing percentage of ink laydown. Thus, patches 10 to 100 were printed with one ink, patches 110 to 200 were printed with two inks, patches 210 to 300 were printed with three inks and patches 310 to 400 were printed with four inks. The columns were labeled with the order of ink laydown for cyan, magenta, yellow and black inks as shown in Table 2.

Table 2

	Order of Ink Laydown			
Column	Rows 10-100	Rows 110-200	Rows 210-300	Rows 310-400
1	K	KCMY	KCMY	KCMY
2	CMYK	CMYK	CMYK	CMYK
3	CMY	CMYK	CMYK	CMYK
4	Y	YCM	YCM	None
5	M	MCY	MCY	None
6	C	CMY	CMY	None
7	Y	YM	YMK	YMKC
8	Y	YC	YCK	YCKM
9	M	MY	MYC	None
10	M	MC	MCK	MCKY
11	C	CY	CYM	None
12	C	CM	CMY	None

Coalescence

[0065] Coalescence varies depending on the order in which inks are printed. Coalescence was evaluated by visual inspection of each of the printed recording elements. The first row in which puddling on the surface appears was recorded. Values greater than about 150 are desirable. The results are shown in Table 3.

Table 3

Printed Recording Element	Subbing Layer	Ratio Particles:Polymer	Coalescence
1	1	85:15	400
2	1	85:15	280
3	1	82:18	290
4	1	89:11	380
5	1	82:18	220
6	1	78:22	200
8	2	90:10	390
9	3	90:10	260
10	4	90:10	180
Comparative 4	none	60:40	130

[0066] The results show that the elements of the invention were better for coalescence than Comparative Element 4.

Claims

1. An ink jet recording element comprising a substrate having thereon:

a) a subbing layer comprising a polymeric binder and a borate or a borate derivative, said borate or borate derivative being present in an amount of from up to 3 g/m^2, and the weight ratio of said polymeric binder to said borate or borate derivative is from 0.2:1 to 3:1; and
b) an image-receiving layer comprising inorganic particles and a cross-linkable polymer containing hydroxyl groups, said cross-linkable polymer being present in an amount of less than 50 g/m^2, and the weight ratio of said cross-linkable polymer to said inorganic particles is from 5:95 to 30:70.

2. The recording element of Claim 1 wherein said polymeric binder in said subbing layer comprises a water-soluble or water-dispersible polymer.

3. The recording element of Claim 1 wherein said polymeric binder in said subbing layer comprises poly(vinyl alcohol), a sulfonated polyester dispersion, gelatin, a polyurethane or poly(vinyl pyrrolidone).

4. The recording element of Claim 1 wherein said polymeric binder in said subbing layer comprises a sulfonated polyester dispersion.

5. The recording element of Claim 1 wherein said polymeric binder is present in said subbing layer in an amount of up to 3 g/m^2.

6. The recording element of Claim 1 wherein said borate or borate derivative is borax, sodium tetraborate, boric acid, phenyl boronic acid, or butyl boronic acid.

7. The recording element of Claim I wherein said inorganic particles are present in said image-receiving layer in an amount of up to 25 g/m^2.

8. The recording element of Claim 1 wherein said inorganic particles comprise metal oxides, hydrated metal oxides, boehmite, clay, calcined clay, calcium carbonate, aluminosilicates, zeolites or barium sulfate.

9. The recording element of Claim 8 wherein said metal oxide is silica, alumina, zirconia or titania.

10. An ink jet printing method comprising the steps of:

A) providing an ink jet printer that is responsive to digital data signals;
B) loading said printer with the ink jet recording element of Claim 1;
C) loading said printer with an ink jet ink composition; and
D) printing on said image-receiving layer using said ink jet ink in response to said digital data signals.