United States Patent [19]

Kasuya

[11] **3,862,849**

[45] **Jan. 28, 1975**

[54] **METHOD FOR PREPARATION OF DEVELOPING SOLUTION FOR DEVELOPING ELECTROSTATIC LATENT IMAGES**

[75] Inventor: **Shozo Kasuya,** Tokyo, Japan

[73] Assignee: **Kabushiki Kaisha Ricoh,** Tokyo, Japan

[22] Filed: **Apr. 4, 1973**

[21] Appl. No.: **347,888**

Related U.S. Application Data

[60] Continuation of Ser. No. 136,214, April 21, 1971, abandoned, which is a division of Ser. No. 780,672, Dec. 3, 1968, Pat. No. 3,603,289.

[30] **Foreign Application Priority Data**

Dec. 5, 1967 Japan 42-78108

[52] **U.S. Cl.** ..... **117/37 LE,** 96/1 LY, 355/10

[51] **Int. Cl.** **G03g 13/10**

[58] **Field of Search** . 117/37 LE; 118/637, DIG. 23; 96/1 R, 1 LY; 252/62.1; 355/10, 17; 95/89 R, 89 F; 346/75, 135; 222/DIG. 1

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Primary Examiner—Michael Sofocleous

[57] **ABSTRACT**

Method for preparation of developing solution for developing electrostatic latent images in which the liquid has a high electrical resistance to prevent deterioration of the latent image and a low dielectric constant to prevent dissipation of the charge of image-producing particles. A charge potential is applied between the nozzle which supplies the particles and the liquid container.

6 Claims, 8 Drawing Figures

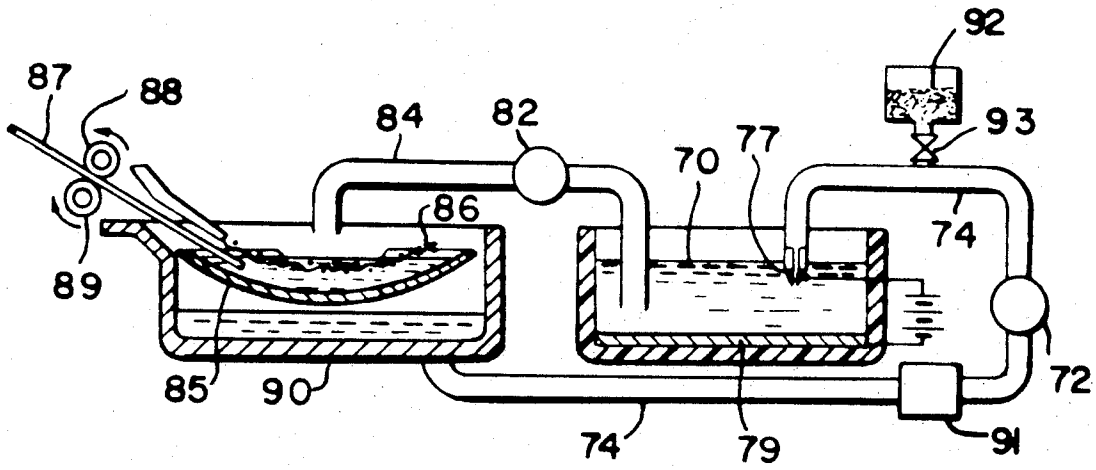


FIG. 1

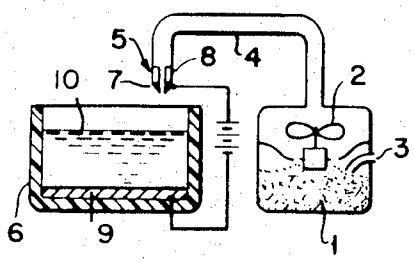


FIG. 2

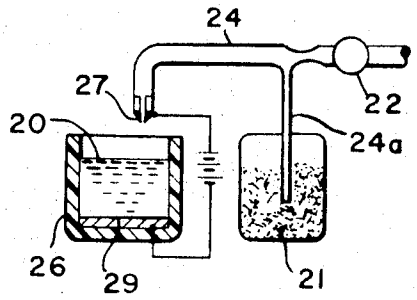


FIG. 3

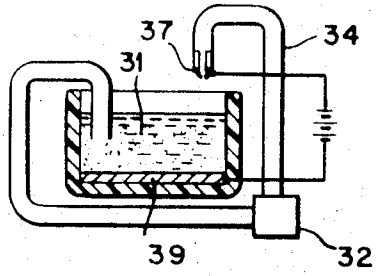


FIG. 4

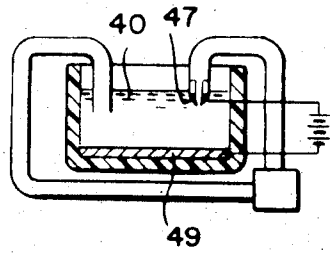


FIG. 5A FIG. 5B

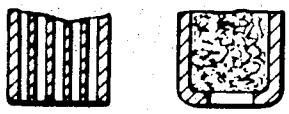


FIG. 6

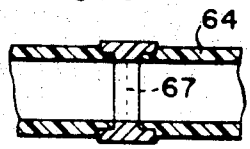
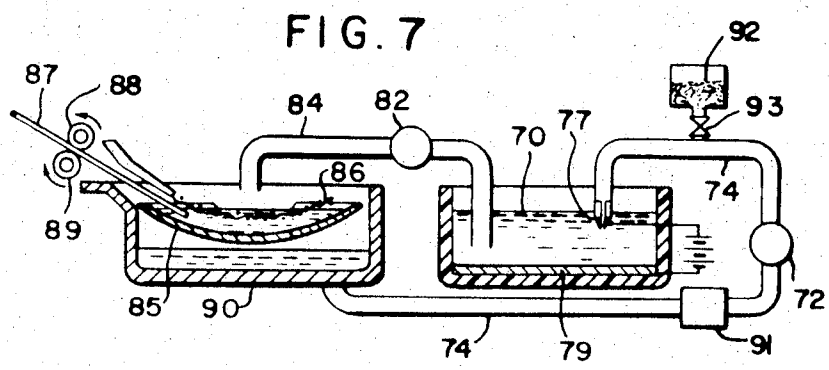


FIG. 7



METHOD FOR PREPARATION OF DEVELOPING SOLUTION FOR DEVELOPING ELECTROSTATIC LATENT IMAGES

This is a continuation of application Ser. No. **136,214**, filed Apr. **21, 1971**, and now abandoned, which was a divisional application of application Ser. No. **780,672**, filed Dec. **3, 1968**, and now U.S. Pat. No. **3,603,289**.

BACKGROUND OF THE INVENTION

The present invention relates to a method for preparation of developing solution for developing electrostatic latent images, a method for developing the same by use of this developing solution and more particularly a method for preparation of developing solution for applying to a record having thereupon an electrostatic latent image such as an electrographic photosensitive paper, electrostatic recording paper, etc. so as to make visible the electrostatic image thereupon.

The conventional developing solution used for wet developing an electrostatic latent image is a solution consisting of a carrier liquid having a high electric resistance sufficient enough to prevent the destruction of an electrostatic latent image, a pigment suspended in the carrier liquid and a control agent coating the pigment so as to render it electrically selectable by the electrostatic latent image charge, and the control agent serves to control the charge upon the pigment. Such developing solution in which are suspended in the carrier liquid the pigment and the control agent for controlling the charge upon the pigment is applied to a recording body having thereupon an electrostatic latent image so that a visible image is produced upon the electrostatic latent image by the electrophoretic method.

However, in the conventional developing solution of the type described above, there are the following defects: (1) the substances used as a control agent are limited to an extremely less extent and are effective only in a limited number of combinations with a carrier liquid; (2) since the control of the charge by the control agent is based upon the electrochemical property thereof, the chemical absorption in the thermal equilibrium state between the pigment and the control agent varies due to the temperature change of the carrier liquid so that the control becomes unstable, thereby causing instability of the polarity of the charge attached to the pigment particle; (3) when impurities, especially polarizable substance such as water, alcohol, surface active agents, etc. are mixed into the carrier liquid, the control of the charge upon the pigment particle by the control agent becomes unstable or the control power is reduced or lost so that the control agent can not function as it should do; and (4) when the substance constituting the recording body such as synthetic resins, conductivity imparting agents, etc. are dissolved into the carrier liquid by this liquid upon contact therewith, the chemical composition of the developing solution varies so that the control of the charge upon the pigment particle becomes unstable or the suspension of the pigment particles is deteriorated, whereby the developing process can not be effected as desired.

In view of the above, one of the objects of the present invention is to provide a method for preparation of developing solution of the type described in which the above described defects encountered in the conventional developing solution can be completely eliminated based upon the novel principle which is quite different from that of the conventional method and a method for developing an electrostatic latent image which can be directely coupled with the developing solution preparation method of the present invention.

SUMMARY OF THE INVENTION

According to the present invention, the developing solution is a mixture of a liquid having a high electric resistance sufficient enough to prevent the destruction of an electrostatic latent image upon a recording body and image-producing particles which have been charged by a pair of electrodes between which is applied a potential. The prepared developing solution may be applied to the surface of the recording body having thereupon the electrostatic latent image so that charged image-producing particles are caused to settle down to the surface of the recording body along line of electric force produced by the charge forming the electrostatic latent image, thereby visualizing the electrostatic latent image.

The above described charged image-producing particles are charged artificially by a high-tension so that the method of the present invention is quite differenct from the conventional method in which the charge of the particles is controlled by the control agent. The present invention has an advantage that the charge and the polarity of the imageproducing particle may be suitably determined by determining suitable voltage and polarity applied to the electrode which contacts the image-producing particles. The present invention is not utilizing the electrochemical property of the substance such as a control agent for charging the particles so that it will be clear that the charged condition of the image-producing particles remains unchanged due to the temperature change of the liquid into which are mixed the charged image-producing particles and due to the mixture of impurities into the liquid. Therefore, an excellent stable developing solution may be obtained.

The liquid into which are mixed the charged image-producing particles must have a high electric resistance sufficient enough to prevent the deterioration of an electrostatic latent image and a high electric resistance and a low dielectric constant sufficient to prevent the dissipation of the charge of the image-producing particles at least while the recording body having thereupon the electrostatic latent image is being developed. Preferably, the liquid has a specific resistance of the order higher than 10^{12} ohm cm and a dielectric constant less than three. For example, paraffin hydrocarbons, aromatic hydrocarbons, mixtures of aromatic hydrocarbons and aliphatic hydrocarbons, halogenated hydrocarbons, etc. may be used as a carrier liquid. But it is to be understood that the liquid used in the present invention is not limited to the above described liquids, but other liquids whose properties satisfy the above described conditions may be also used. Furthermore, the mixtures of one of the above described liquids and a natural high molecular compounds or synthetic high molecular compounds which can be dissolved into said liquid can be also used as a carrier liquid as long as such mixtures satisfy the above described conditions.

As to the charged image-producing particles, pulverized compounds are provided which can be charged by electrodes to which is applied a relatively high potential. For example, the compounds which can be used as image-producing particles are conductive compounds,

non-conductive compounds (insulating compounds), semi-conductor compounds, etc. and more particularly various metallic powder and carbon powder as conductive compounds. More specifically, black gold particles called "gold black," black silver particles called "silver black," black carbon pigment particles called "carbon black," metallic aluminum powder particles and other metallic powder may be used. As non-conductive and semi-conductor compounds, metallic oxides, powder of single elements having a semi-conductor property such as sulfur powder, selenium powder, solicon powder, etc. organic pigment powder, inorganic pigment powder, natural and synthetic resin powder, natural and synthetic high molecular compound powder, etc. may be used. The compounds which are used as image-producing particles are not limited to those described above, but any other compound as far as they can be charged by application of a potential may me used as image-producing particles in the present invention. Furthermore, it is not required to use as image-producing particles only one of the compounds as described above, but any combinations of them can be advantageously used. For example, mixtures of metallic powder with natural or synthetic resins; and metallic or non-metallic powder coated with natural or synthetic resins or high molecular compounds may be used. Any colorants such as dyes in order to color image-producing particles and any binding agent for binding the image-producing particles to the recording bodies may be selected freely as far as the properties of image-producing particles which are charged by a high potential are not lost by addition of these agents. As to the particle sizes of image-oroducing particles, principally the particle sizes are not limited at all, but in view of the formation of an image over the recording body and the floating characteristics of the image-producing particles mixed in a carrier liquid, it is preferable that the size is less than 50μ.

Other objects and advantages of the present invention will become apparent from the following description of preferred embodiments thereof, taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. **1** to **4** are schematic sectional views each illustrating a different embodiment of a device used in preparation of developing solution according to the present invention;

FIGS. **5**–A and B are sectional views illustrating nozzles used for issuing image-producing particles in the above development solution preparation devices;

FIG. **6** is a sectional view of one portion of an image-producing particle transporting pipe illustrating a screen-shaped electrode interposed therein; and

FIG. **7** is a sectional view of one embodiment of a developing device of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

According to the present invention, the developing solution is prepared by, prior to or after mixing the image-producing particles of the type described above into the carrier liquid of the type described above, applying a potential to said image-producing particles so as to charge them. The method of the preparation of the developing solution and the device for developing latent images by using said developing solution of the present invention will be described hereinafter in more detail with reference to the accompanying drawing. Referring to FIG. **1**, a blower **2** is disposed in a container in which is disposed powder **1** consisting of image-producing particles. The powder **1** mixed with the air which is introduced in to the container through a suction hole **3** is transferred into a transportation pipe **4** by driving the blower **2**. The discharge end **5** of the pipe **4** is disposed above a carrier liquid chamber **6** and is provided with an electrode **7** in the form of a nozzle. The electrode **7** may be directly attached to the pipe **4** when the latter is made of an insulating material while when the pipe **4** is made of a conductive material, the electrode **7** is attached to the pipe through a suitable insulating body **8.** A potential is applied between the electrode **7** and an opposing electrode **9** which is disposed in the liquid chamber **6** made of an insulating material. On the other hand, when the carrier liquid chamber **6** is made of a conductive material, the liquid chamber **6** itself may be used as an opposing electrode **9.** Since the potential applied therebetween is relatively high, it is preferable to make the carrier liquid chamber from the insulating material in view of safeguarding the operation.

When it is desired to charge the image-producing particles with a positive charge, the electrode **7** is applied with a positive potential while when it is desired to charge the image-producing particles with negative charge, the electrode **7** is applied with a negative potential. While a positive or negative potential is applied to the electrode **7**, the image-producing particles are made to pass through the electrode together with the air and thereafter mixed with the carrier liquid **10**, whereby the developing solution containing the charged image-producing particles can be prepared.

EXAMPLE

Aluminum powder was used as the image-producing particles and refined white kerosene was used as the carrier liquid. The diameter of the nozzle **7** made of the electrode was approximately 0.5mm; the distance between the nozzle **7** and the electrode **9**, approximately 200mm; the issuing speed of the image-producing particles from the nozzle, approximately 1m/sec.; and the potential applied to the nozzle, +2,000V. The developing solution was prepared from the above materials under the above conditions. A photoconductive material consisting of a mixture of resin and zinc oxide was applied to the base so that the electrostatic photocopying paper was prepared. Upon this paper was formed a negatively charged electrostatic latent image and the above developing solution was applied to this electrostatic latent image in the dark room. Then, the positive having an excellent metallic silver luster was obtained. Since the positive image was composed of aluminum powder, aluminum powder tends to separate from the photocopying sheet under the light so that a transparent vinyl resin coating was applied thereupon by aerosol or spraying method, whereby the positive image having metallic silver luster which can be recorded was obtained.

According to another embodiment of the present invention, a better developing solution may be obtained by first mixing the image-producing particles with the carrier liquid, and then passing the liquid containing the image-producing particles through the electrode nozzle. In FIG. **2**, the image-producing particles **21**

mixed with a liquid equivalent to the carrier liquid in a carrier liquid chamber **26** is stored in a container which is intercommunicated with a transporting pipe **24** through a fine diameter tube **24***a*. When air is blown toward a nozzle-shaped electrode **27** disposed at the open end of the pipe **24** by means of a blower **22** interposed in the pipe **24**, the image-producing particles **21** are sucked through the fine diameter tube **24***a* into the transporting pipe **24** by the negative pressure produced at the upper end of the fine diameter tube **24***a*, and are finally ejected through the electrode nozzle **27**. When a potential is applied between the nozzle electrode **27** and an opposing electrode **29**, the image-producing particles passing through the electrode nozzle are charged with the same polarity as that of the nozzle electrode **27**, and the charged image-producing particles are mixed into the liquid **20** whereby the developing solution can be prepared.

EXAMPLES

Carbon black was used as the image-producing particles and was mixed into an aromatic hydrocarbon, that is toluene. The mixture was ejected from the nozzle made of the electrode **27** having the diameter of approximately 0.3mm. The issuing velocity could not be measured accurately, but it was observed that the spray was similar to those produced by the ordinary spraying. In the carrier liquid chamber **26** was contained a polyhalogenated derivative of hydrocarbon, that is freon. The mixture was made to pass through the nozzle to which was applied a potential of +1,000V and further mixed with the carrier liquid. The distance between the electrode **27** and the opposing electrode **29** was 200mm. The prepared developing solution was applied to the electrostatic latent image produced upon the electrostatic photocopying paper in the dark room and the excellently sharp positive was obtained. Alternatively, the electrode **27** was applied with a potential of −5,000V with other conditions remaining unchanged in order to prepare the developing solution. The obtained developing solution was applied in the same manner as described above and the reversed image, that is the negative having more or less edge effect was obtained. Furthermore, pulverized acrylic resin colored with red, yellow, blue and green was mixed into the mixture of refined white kerosene and approximately 15% toluole. The mixture was made to pass through the electrode nozzle to which was applied a potential of +5,000V and mixed into the carrier liquid of refined white kerosene, whereby the developing solution was prepared. The electrostatic photocopying paper having a negatively charged electrostatic latent image was immersed into this developing solution, so that the positive colored with the above described colors was obtained. The positive is naturally fixed to the paper as the developing solution dries so that the paper can be recorded without any further image fixing process.

The third embodiment of the present invention will be described hereinafter with reference to FIG. **3**. The non-charged image-producing particles are mixed in a carrier liquid **31** which is circulated through a transportation pipe **34**. When the carrier liquid is ejected through an electrode **37** which is made into the form of a nozzle, the image-producing particles are charged continuously by a potential applied between the electrode **37** and an opposing electrode **39**. When this operation is continued, the developing solution containing the charged image-producing particles can be prepared. In FIG. **3**, reference numeral **32** designates a liquid circulating pump interposed in the transportation pipe **34**.

According to the fourth embodiment of the present invention, as shown in FIG. **4**, a nozzle **47** from which are issued image-producing particles or liquid containing these particles is immersed in a carrier liquid **40** and a potential is applied between the electrode, that is the nozzle **47**, and an opposing electrode plate **49**, so that the developing solution having the same effects as those of the developing solution described above can be prepared.

As to a nozzle which is used as an electrode, a nozzle having only one hole, a nozzle in which are assembled a plurality of relatively fine diameter tubes as shown in FIG. **5**–A or a nozzle in which conductive fibers are packed in the nozzle as shown in FIG. **5**–B may be used.

FIG. **6** illustrates a device wherein instead of a nozzle which is used as an electrode, a screen-shaped electrode **67** is interposed in a transporting pipe **64** and a potential is applied to this screen-shaped electrode **67** and an opposing electrode disposed within a carrier liquid chamber, whereby the image-producing particles passing through the screen-shaped electrode are charged.

In addition to the use of the nozzles and the screen-shaped electrode interposed in a transporting pipe for obtaining charged image-producing particles, a portion of a liquid circulating pump, for example, a rotor, may be advantageously used as an electrode when the circulating pump is interposed in the transporting pipe for circulating the developing solution.

It is preferable that an insulating layer is applied to the carrier liquid chamber when the chamber is used as an opposing electrode or to the opposing electrode within the chamber made from an insulating material so that the direct contact of the charged image-producing particles with the chamber or the opposing electrode may be prevented, thereby prolonging the life of the charged particles as long as possible.

FIG. **7** illustrates schematically a method of developing a electrostatic latent image produced upon an electrostatic photocopying paper by applying the developing solution prepared by one of the methods described above. A developing solution **70** is discharged into a developing tray **85** located in a chamber **90** through a supply pipe **84** by means of a circulating pump **82**. A guide plate **86** made from a conductive screen is disposed upwardly of the developing solution tray **85** and a paper **87** having an electrostatic latent image is made to pass between the tray **85** and the guide plate **86** by means of a pair of feed rollers **88** and **89**, whereby the paper **87** is developed while it passes through the developing solution. The developed paper is discharged out of the tray by suitable means not shown. The developing solution overflowing from the tray **85** is returned to the carrier liquid chamber **79** through a transportation pipe **74** intercommunicated with the chamber **90** and through a nozzle **77**. Reference numeral **72** designates a circulation pump for returning the developing solution; **91**, an instrument for detecting the concentration of the developing solution; **92**, auxiliary image-producing particles; and **93**, a valve which is used to add a suitable quantity of auxiliary image-producing particles into the transportation pipe **74**. The valve **93**

may be actuated manually or automatically in response to the decrease of the concentration of the developing solution, that is when the quantity of image-producing particles per unit volume of the carrier liquid is decreased, so that a suitable amount of image-producing particles may be added into the carrier liquid. In case of the automatic supply, the valve **93** may be interlocked with the detecting instrument **91**.

The present invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the present invention as described hereinabove and as defined in the appended claims.

I claim:

1. Method of supplying a developing solution to a developing chamber in which a sensitized paper having a latent image thereon is electrostatically developed comprising

flowing a developing solution comprised of a liquid having a specific resistance greater than 10^{12} ohm cm and a dielectric constant less than three, and electrically chargeable image producing particles, from a liquid supply container spaced from the developing chamber to said developing chamber thereby developing said latent image;

returning the developing solution from the developing chamber to the supply container by transporting the liquid through a conduit, part of the return flow spaced to pass above the supply container;

locating a particle container above the spaced part of the flow;

flowing a quantity of particles into the spaced part of the flow to provide increased concentration of the developing solution;

electrically charging the particles in the spaced part of the flow; and

discharging developing solution including the charged particles from the spaced part of the flow into the supply container.

2. Method according to claim **1** including establishing an electrical path between an electrode located in the spaced part of the flow and the supply container, and applying a voltage of −5,000 volts therebetween.

3. Method according to claim **1** including establishing an electrical path between an electrode located in the spaced part of the flow and the supply container, and applying a voltage of +2,000 volts therebetween.

4. Method according to claim **1** including selectively admitting a quantity of particles to the spaced part of the flow in response to change in concentration of the developing solution as determined by a concentration indicator located in the return flow conduit.

5. Method according to claim **1** including applying the electrical charge in a flow path extending between an electrode mounted in a nozzle located in a terminal portion of the conduit in the spaced part of the flow and the supply container, the nozzle being immersed in the developing solution.

6. A method of supplying a developing solution to a developing chamber in which a sensitized paper having a latent electrostatic image is to be developed, comprising

providing a developing solution containing image producing particles in a container separate from said developing chamber and

passing said solution from said container to said chamber thereby developing said latent image,

said step of providing a developing solution comprising

supplying a liquid to said container having a specific resistance greater than 10^{12} ohm cm and a dielectric constant less than three,

returning said developing solution from said chamber to said container by transporting said solution from said chamber by way of conduit means to nozzle means spaced above the top of the level of the liquid in said container, whereby developing solution is discharged from said nozzle means into said container,

applying a non-zero electric potential between a point in the liquid in said container and a point in said nozzle means contacting solution therein, and

ejecting electrically chargeable image producing particles in the solution in said conduit means, whereby particles passing in said conduit means through said nozzle means are charged by said potential.

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