

[54] **ELECTROPHOTOGRAPHIC
DEVELOPING APPARATUS**

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355/10

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[58] Field of Search **117/37 LE; 118/DIG. 23, 637;**
95/89, 94; 355/10

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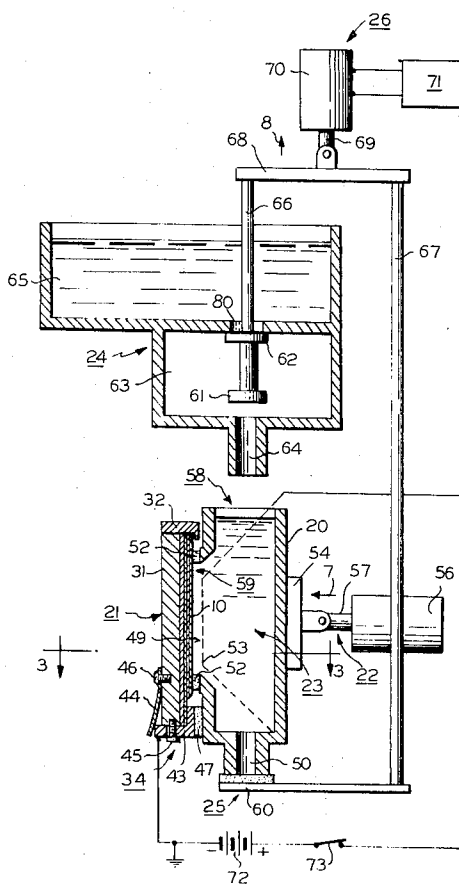
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[57] **ABSTRACT**

An apparatus for developing an electrophotographic film carrying an electrostatic latent image, wherein said film is supported by film supporting means in a substantially vertical plane, and is opposed to an aperture of a developing chamber which has an outlet formed at a lower portion thereof and an air introducing opening formed at an upper portion thereof. Engaging means causes the film to be engaged over and close to said aperture by relative movement between the chamber and the film so as to form a space within the chamber capable of receiving a predetermined volume of liquid developer from a developer supply means. After the liquid developer is kept in the space for a predetermined time for development of the film, developer discharge means discharges the developer from the space through the outlet under the control of control means, and air is introduced into said space from said air introducing opening as the level of the liquid developer falls as the developer is discharged from the space.

7 Claims, 6 Drawing Figures



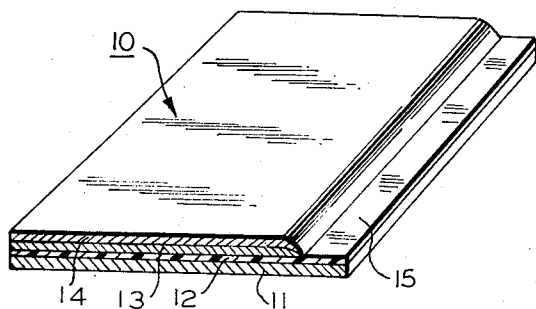


FIG. 1

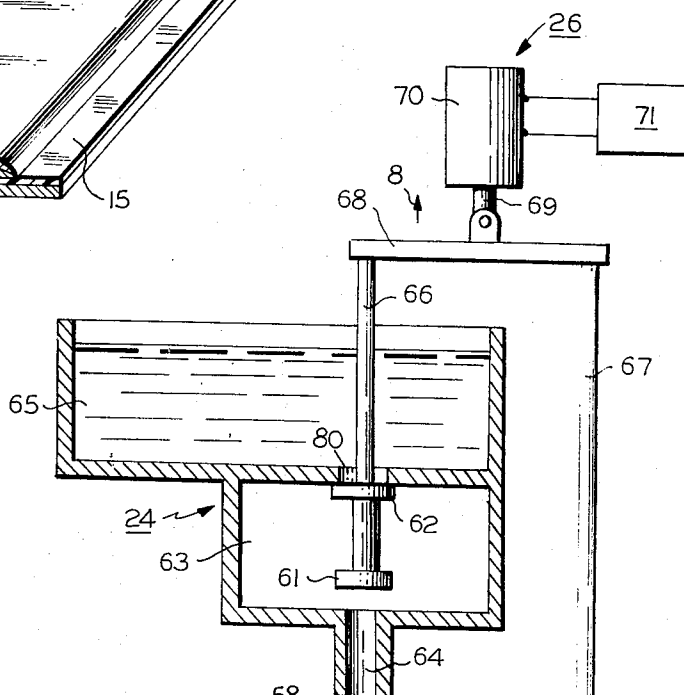
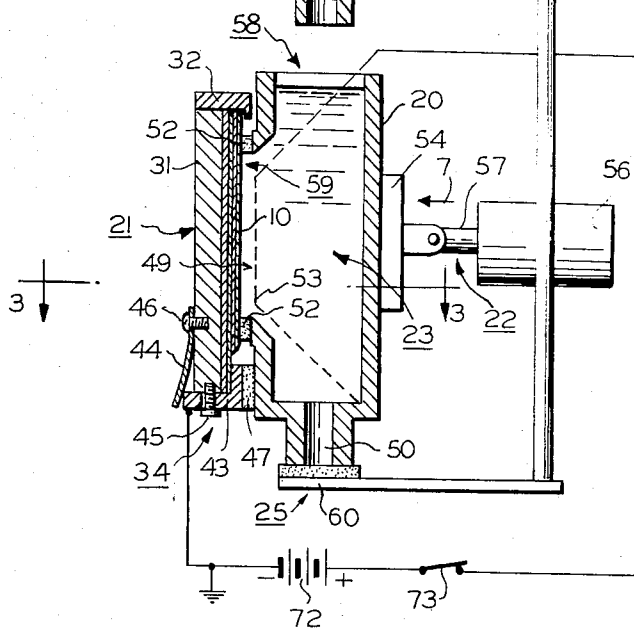


FIG. 2



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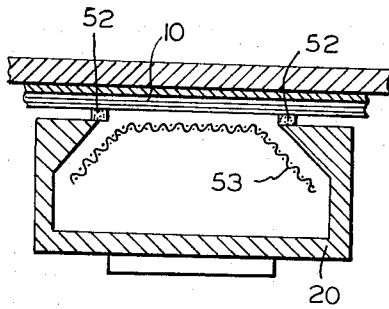


FIG. 3

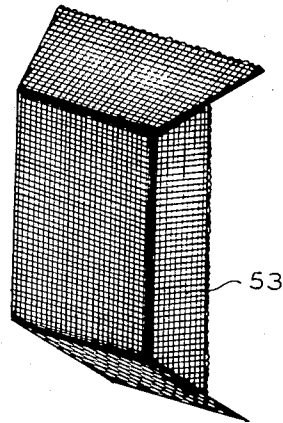


FIG. 4

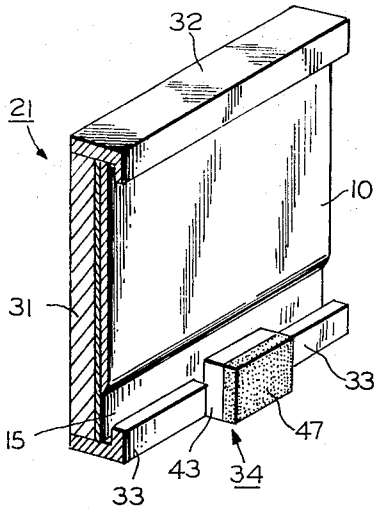


FIG. 5

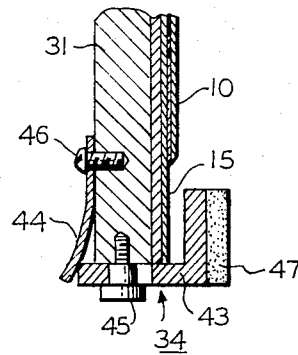


FIG. 6

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ELECTROPHOTOGRAPHIC DEVELOPING APPARATUS

FIELD OF THE INVENTION

This invention relates to a developing apparatus for an electrophotographic film carrying an electrostatic latent image. More particularly, the present invention is directed to an apparatus for developing an electrophotographic film by means of liquid developer which contains finely-divided particles with selective polarity.

BACKGROUND OF THE INVENTION

In the process of electrophotography, an electrophotographic film is first electrostatically charged and exposed to an image, so that an electrostatic latent image is formed on the photosensitive surface of the film. Subsequently the film is developed by liquid developer which usually contains finely divided graphite particles in a volatile solvent.

In the conventional developing method using liquid developer, the exposed film is dipped in the liquid developer so as to produce a visible image corresponding to the latent image thereon. If a film mounted beforehand on a slide mount or an aperture card is dipped into the liquid developer, not only the film but also the slide mount or the aperture card may get wet in the developer. Therefore, the slide mount or the aperture card may be stained with the liquid developer.

In addition, the visible image tends to be damaged by the blurs which are often generated by the ripple at the surface of the liquid developer when the film is removed from the liquid developer after the development.

Further, scale-like spots of the graphite particles tend to remain on the surface of the film after it dries because the evaporation rate of the liquid developer differs for different portions of the film. Upon transportation of the film into the liquid developer, the film stirs the liquid developer so that the graphite particles are deposited in such a way as to produce a mottled appearance, and occasionally the visible image which is produced is partly washed away by the stirred liquid developer.

Therefore, in conventional developing methods, it is difficult to produce a micro image having a resolution power of more than 30 lines per millimeter.

The visible image produced by the conventional developing method has fringe effects, that is, large black or dark areas of the image do not always develop uniformly throughout their whole area but tend to develop more heavily around the edges than in the middle of the areas.

SUMMARY OF THE INVENTION

It is an object of the present invention to produce a novel apparatus for developing an electrophotographic film by means of a liquid developer containing finely divided particles with selective polarity in a volatile solvent.

Another object of this invention is to provide a developing apparatus wherein the liquid developer is in contact with the front surface of the film, and is out of contact with the other surface of the film during the developing process.

Another object of this invention is to provide a developing apparatus wherein a desired portion of the film is partially developed by a first developing operation, and the other portion of the film is kept undeveloped so that it can be developed by another developing operation, if necessary.

Another object of this invention is to provide a developing apparatus for developing an electrophotographic film to produce a visible image with no scale-like spots caused by graphite particles.

Another object of this invention is to provide an electrophotographic developing apparatus for producing a micro image having a resolution power of more than 30 lines per millimeter.

Another object of this invention is to provide a developing apparatus which is utilized to bring about a realignment of the electrostatic field surrounding the electrostatic images during development and is effective in the development of continuous-tone images and images containing large dark areas.

The other object of this invention is to provide a developing apparatus having an improved developing chamber which does not cause deposition of the charged graphite particles thereon.

These objects are achieved by the developing apparatus according to the present invention, which includes film supporting means for supporting the film in a substantially vertical plane, a developing chamber having an aperture formed in a vertical wall thereof and having an air introducing opening formed in upper portion thereof, and an outlet formed in a lower portion thereof, engaging means for bringing the film and the developing chamber into engagement with the film over said aperture by relative movement between said chamber and said film so as to form a space within the chamber capable of receiving a predetermined volume of liquid developer, developer supply means for supplying predetermined volume of developer to the space, developer discharge means for discharging the developer from the space through said outlet, control means for controlling said developer supply means to supply the developer into said space up to a predetermined level and further controlling said developer discharge means to maintain said developer in the space for a predetermined time, whereby said discharge means discharges the developer from said space after termination of developing of said film, and air is introduced into said space from said air introducing opening as the level of the liquid developer falls as it is discharged from said space. The developing apparatus according to the present invention further includes mesh electrode and a potential source for applying an electric potential to said developing chamber and the mesh electrode which are insulated from the rest of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an electrophotographic film which can be utilized in the developing apparatus according to the present invention;

FIG. 2 is a schematic side elevational view, partly in section, of the developing apparatus according to the present invention;

FIG. 3 is a cross-sectional-view of the apparatus taken along the line 3—3 in FIG. 2;

FIG. 4 is a perspective view of a mesh electrode which has been removed from the apparatus;

FIG. 5 is a perspective view of film supporting means for the apparatus of the present invention; and

FIG. 6 is a fragmentary sectional view on an enlarged scale of the film supporting means shown in FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, a preferred embodiment of the apparatus constructed in accordance with the present invention will be illustrated.

As shown in FIG. 1, one example of electrophotographic film 10 to be developed in this apparatus comprises a transparent film base 11, a conductive layer 12, an adhesive layer 13 and a photoconductive layer 14. Hereinafter the electrophotographic film 10 will be called simply a film. The transparent film base 11 is made of cellulose triacetate or polyethylene terephthalate and has a thickness of approximately 70-100 microns. Cuprous iodide is vacuum deposited on the base film 11 to form the conductive layer 12. The adhesive layer 13 made of polyvinyl acetate is deposited on the conductive layer 12. The photoconductive layer 14 is an organic photoconductive layer consisting of poly-N-vinyl carbazole. The adhesive layer 13 and the photoconductive layer 14 are not coated onto an end portion 15 of the film 10, so that the conductive layer 12 is exposed at the end portion 15. Hereinafter the end portion 15 will be called the exposed conductive layer.

An embodiment of the apparatus according to the present invention is shown in FIG. 2. The apparatus comprises a developing chamber 20 for developing the film 10, film supporting means 21 for supporting the film 10 at a position adjacent to the developing chamber 20, engaging means 22 for engaging the developing chamber 20 and the film 10 in the film supporting means 21 so as to form a space 23 within the chamber capable of receiving liquid developer, developer supply means 24 for supplying a predetermined volume of liquid developer to the space 23, developer discharge means 25 for discharging the liquid developer from the space 23, and control means 26 for controlling the developer supply means 24 and the developer discharge means 25.

As shown in more detail in FIG. 5, the film supporting means 21 comprises a back plate 31, an upper guide 32 fixedly attached to an upper portion of the back plate 31, and a pair of lower guides 33 fixedly attached to a lower portion of the back plate 31. The film 10 carrying a positively charged electrostatic latent image is supported by the film supporting means 21 in a substantially vertical plane in such a way that the exposed conductive layer 15 of the film 10 is positioned at the lower guides 33. The film supporting means 21 has contact means 34 mounted on the lower portion thereof between the lower guides 33. As shown in FIG. 6, said contact means 34 comprises a contact member 43 of conductive material, a leaf spring 44, a guide pin 45, a rubber pressure pad 47 and a lock screw 46. The contact member 43 is located at a position between the lower guides 33 and is movably mounted on the lower end of the back plate 31 by the guide pin 45. The leaf spring 44 is fixed to a rear wall of the back plate 31 by

the lock screw 46, and biases the contact member 43 to the right in the drawing in order to avoid the engagement of the contact member 43 with the exposed conductive layer 15. The rubber pressure pad 47, formed of insulating material such as rubber, is secured to a surface of the contact member 43.

As shown in FIG. 2, the developing chamber 20 has an aperture 49 formed in a vertical wall thereof, an air introducing opening 58 formed at an upper portion thereof and a developer outlet 50 formed at a lower portion thereof. A seal member 52 is secured to an edge portion of the chamber 20 around the aperture 49. The photoconductive layer of the film 10 is facing toward the aperture 49 of the developing chamber 20. The developing chamber 20 is formed of conductive material such as metal, and has a mesh electrode 53 positioned. The mesh electrode 53 is formed by a plurality of fine metal wires and has a truncated pyramidal shape as shown in FIG. 4. The plane top of the mesh electrode 53 is positioned adjacent to the aperture 49. Ideally, the mesh electrode 53 has a shape and is positioned in such a manner that the distance between said mesh electrode and the edge portion of said aperture 49 is substantially equal to a distance between said mesh electrode 53 and the surface of said film 10.

With reference to FIG. 2, the developing chamber 20 is held on a bracket 54 which is pivotally mounted on a plunger 57 of a solenoid 56 which is provided on the body of the apparatus. The bracket 54 is formed of insulating material such as bakelite, so that the developing chamber 20 is electrically insulated from the body of the apparatus. The bracket 54 moves the developing chamber 20 in the direction of the arrow 7 upon energization of the solenoid 56 so that the seal member 52 around the aperture 49 of the developing chamber 20 engages the film 10 so as to define with the rest of the developing chamber the space 23. At the same time, the developing chamber 20 engages the contact member 43 through the rubber pressure pad 47 and moves the contact member in the direction of movement of chamber 20 to cause the contact member 43 to contact the exposed layer 15 of the film 10. The seal member 52 is held in tight relationship with the film 10 around the aperture 49 of the developing chamber 20 as seen in FIG. 2. A narrow space 59 is formed between the front surface of the film 10 and the mesh electrode 53, which narrow space is in communication with the opening 58 of the developing chamber 20 and to the developer outlet 50.

The developer supply means 24 is positioned above the developing chamber 20 and comprises a valve 61, a valve 62, a developer supply chamber 63, a developer supply pipe 64, a developer storing chamber 65 and a connecting shaft 66. The developer supply means 24 supplies a predetermined volume of liquid developer to the space 23 through the opening 58 of the developing chamber 20. The volume of the developer supply chamber 63 is substantially equal to the volume of the space 23. The valve 61 and the valve 62 are attached to the connecting shaft 66, and move up and down together. A large quantity of liquid developer is stored in the developer storing chamber 65. When the valve 62 opens, the liquid developer in the developer storing chamber 65 flows into the developer supply chamber 63. During that time, the valve 61 closes the pipe 64, so

that the developer supply chamber 63 is filled with the liquid developer.

The developer discharge means 25 comprises a valve 60 which is attached to the lower end of a connecting shaft 67. The valve 60 shuts the developer outlet 50 during development, and opens to permit gravity discharge of the liquid developer from the developing chamber 20 after development. The valve 60 is formed of insulating material, so as to insulate the developing chamber 20 from the body of the apparatus.

The control means 26 for controlling the developer supply means 24 and the developer discharge means 25 comprises a bracket 68, a solenoid 70 and a timer switch 71. The connecting shaft 66 and the connecting shaft 67 are attached to the bracket 68. The bracket 68 is pivotally secured to a plunger 69 of the solenoid 70 for moving the valves 60, 61, and 62 up and down together. The solenoid 70 is supplied with electric power through the timer switch 71. The timer switch 71 interrupts the power supply to the solenoid 70 after the desired time has passed. Accordingly, the operation of the valves 60, 61 and 62 is controlled by the timer switch 71. When the timer switch 71 closes, the valves 60 and 62 close, and the valve 61 opens.

The mesh electrode 53 is connected to a positive terminal of a potential source 72 through a switch 73. The switch 73 is closed when the timer switch 71 is closed. The negative terminal of the potential source 72 is grounded on the body of the apparatus and is connected to the contact member 43.

In operation, the film 10 carrying an electrostatic latent image is supported on the film supporting means 21 of the apparatus for development. In this embodiment the film 10 has a positively charged latent image. The liquid developer used in this embodiment includes positively charged graphite particles and volatile solvent. The developing chamber 20 moves in the direction of the arrow 7 upon energization of the solenoid 56. The seal member 52 is pressed against the photoconductive layer 14 of the film 10 so as to form the space 23 in the developing chamber 20. The contact member 43 is engaged by the developing chamber 20 and moved so as to come into contact with the exposed conductive layer 15 of the film 10. Thus the conductive layer of the film 10 is connected to the negative terminal of the potential source 72.

After the above operation is completed, the timer switch 71 is closed to supply electric power to the solenoid 70. Upon energization of the solenoid 70, the plunger 69 pulls the bracket 68 in the direction of the arrow 8 so as to close the valves 60 and 62 and to open the valve 61. The predetermined volume of the liquid developer is supplied from the developer supply chamber 63 into the space 23 through the opening 58. Since the valve 62 is closed at an inlet 80 of the supply chamber 63, excess liquid developer is not released from the developer storing chamber 65 into the supply chamber 63. Said volume of the liquid developer fills the space 23 of the developing chamber 20 at least up to the upper edge portion of the aperture 49 so that the area of the film 10 within the aperture 49 is drenched by the liquid developer. The liquid developer remains in the space 23 in a stagnant condition for a time determined by the timer switch 71.

At the same time as timer switch 71 is closed, the switch 73 is closed by the timer switch 71 so that the mesh electrode 53 is supplied with a positive potential from the potential source 72. The potential source 72 thus produces a potential difference between the mesh electrode 53 and the conductive layer of the film 10. In this apparatus, the positively charged latent image on the film 10 can be developed by the liquid developer to produce an excellent visible image with a comparatively low voltage on the electrode 53, ranging from about 100 to 300 volts.

The conductive layer of the film 10 is held at the same potential as the body of the apparatus. Therefore, the operator is protected from receiving an electric shock even if he touches the conductive layer of the film 10 during development.

The potential difference between the mesh electrode 53 and the conductive layer of the film 10 brings about a realignment of the electrostatic field surrounding the electrostatic latent images of the film 10 during development. The mesh electrode 53 reduces the fringe effect peculiar to the electrophotographic method and promotes deposition of the graphite particles in the developer onto the surface of the film 10. As a result, large dark areas of the image are developed uniformly and half tone areas of the image are reproduced accurately. Further, the time required for developing the film 10 is shortened.

Since the developing chamber 20 is held at the same potential as the mesh electrode 53, the electrostatic field is realigned by means of the edge around the aperture 49 of the developing chamber 20. On the other hand, because the mesh electrode 53 has a shape such as is shown in FIG. 2 by which the mesh electrode 53 is spaced from the surface of the film 10 at the edge around the aperture 49, it reduces the realignment effect of the electrostatic field. Therefore, the electrostatic field at the center of the aperture 49 is mainly realigned by the mesh electrode 53, and the electrostatic field is mainly realigned at the edge around the aperture 49 by the edge of the developing chamber 20, so that uniform development is achieved throughout the film within the aperture 49 without the production of a fringe effect.

As previously mentioned, the mesh electrode 53 and the developing chamber 20 are supplied with the same positive potential relative to the film 10 by the potential source 72, and the graphite particles in the liquid developer are positively charged. Hardly any of the positively charged graphite particles are deposited on the surface of the mesh electrode 53 and the developing chamber 20. Accordingly, the mesh electrode 53 and the developing chamber 20, being free from deposited graphite particles, are always kept clean.

After sufficient time for development has passed, the timer switch 71 actuates the switch 73 to open it, and the solenoid 70 is deenergized and the valves 60 and 62 are opened and the valve 61 is closed. The liquid developer in the space 23 is discharged through the developer outlet 50, while sufficient air is introduced through the opening 58 to evaporate the solvent of the liquid developer.

With the fall in the level of the liquid developer, a thin liquid layer of the developer is formed on the film surface. The solvent of the liquid layer is subsequently

evaporated, and the graphite particles are deposited at the film surface so as to produce a visible image. If the thickness of the liquid layer varies at different portions of the film surface, an excess of graphite particles are deposited at a portion where the relatively thick liquid layer is formed. These excess graphite particles deteriorate the visible image on the film, and sometimes lead to formation of scale-like spots on the visible image. In order to obtain a micro image having a resolution power of more than thirty lines per millimeter, it is necessary to make the thickness of the liquid layer uniform. When horizontally positioned film is removed from a liquid developer, the thickness of the liquid layer on the film surface inevitably varies at different portions of the film surface. On the contrary, in the apparatus of the present invention, the film is vertically supported and is gradually separated from the liquid developer as the level of the surface of the developer falls so that the liquid layer on the exposed film surface is apt to have uniform thickness.

In the apparatus according to the present invention, if the liquid developer in the space 23 is discharged quickly so that the level of the surface falls quickly so that there are ripples at the surface thereof, the ripples can cause the thickness of the liquid layer to vary at different portions of the film surface. In the apparatus according to this invention, the film 10 is placed in a vertical position and the liquid developer is discharged naturally due to gravity, not by a discharging device, such as a pump or a vacuum means, so that the level of the surface of the liquid developer falls smoothly so as to produce few ripples at the surface thereof.

Further, according to the present invention, the cross sectional area of the outlet 50 is smaller than the cross-sectional area of the space 23. The cross-section of the liquid developer is relatively small at the outlet 50, and the falling speed of the surface of the liquid developer is slow in the space 23. Therefore, the liquid developer falls gradually and ripples on the surface thereof are suppressed.

Furthermore, in the apparatus according to the present invention, the level of the surface of the liquid developer falls while being restricted by the surface tension of the liquid developer between the surface of the film 10 and the surface of the mesh electrode 53 so that the ripples at the surface of the developing liquid are completely eliminated in the vicinity of the film. Therefore, the film surface has a layer of the liquid developer of uniform thickness left on it throughout the image area as the liquid developer falls, and the deterioration of the visible image caused by excess graphite particles is prevented.

During the discharge of the liquid developer, the switch 73 interrupts the supply of potential to the mesh electrode 53 so as to decrease the rate of deposition of the charged particles on the surface of the film 10. Therefore, the deposition of the graphite particles is not promoted during the discharge of the liquid developer.

As mentioned hereinabove, a thin layer of liquid developer is formed on the film surface during the fall of the level of the surface of the liquid developer. It is preferable to dry the solvent of the thin liquid layer as fast as possible. In order to obtain a micro image having a resolution power more than 30 lines per millimeter, it

is also necessary to evaporate the solvent of liquid layer immediately after the formation of liquid layer. The reason for the necessity for quick evaporation is that when the solvent of liquid layer evaporates slowly, the liquid layer is apt to flow on the film surface before evaporation. Therefore, the graphite particles which form the visible image move with the liquid layer so that the visible image deteriorates.

However, according to this invention, sufficient air is introduced into the space 23 from the top opening 38 as the level of the surface of the liquid developer falls, and flows freely through the mesh electrode 53. Therefore, the solvent of the liquid layer immediately evaporates as soon as the liquid layer is formed.

As mentioned above, according to the present invention, the film 10 is supported in a vertical plane and the liquid developer is discharged through the outlet 50 formed at the lower portion of the developing chamber 20 and, in addition, sufficient air is introduced from the opening 58 during the discharge of the liquid developer. Therefore, the liquid developer falls smoothly without ripples at the surface thereof so that the liquid layer is formed on the film surface with a uniform thickness so as to prevent the deposition of the excess graphite particles. Further, air introduced from the opening 58 evaporates the solvent of the liquid layer immediately so as to eliminate the movement of the graphite particles of the produced visible image by flow of the solvent. It is possible to produce a micro image having a resolution power of more than thirty lines per millimeter according to the present invention. For example, a micro image having a resolution power of 100 lines per millimeter was obtained by employing the apparatus of this invention.

After discharging of the liquid developer, the developing chamber 20 moves in the opposite direction to the arrow 7. The liquid developer which is necessary for the next developing process is stored in the developer supply chamber 63. Thus one circle of the developing process comes to an end.

In this apparatus, the liquid developer contacts only the desired portion of the front surface of the film so that the other portion of the film does not have graphite particles deposited thereon. Therefore an electrophotographic film mounted beforehand on a slide mount or an aperture card can be developed by the apparatus without producing any stain on the slide mount or the aperture card. In addition, the image can be formed on another portion of the film, if a large film is used.

It is thought that the invention and its advantages will be understood from the foregoing description and it is apparent that various changes may be made in the form, construction and arrangement of the parts without departing from the spirit and scope of the invention or sacrificing its material advantages, the form hereinbefore described and illustrated in the drawings being merely a preferred embodiment thereof.

What is claimed is

1. An apparatus for developing an electrophotographic film carrying an electrostatic latent image, said apparatus comprising;

a. film supporting means for supporting the film to be developed in a substantially vertical plane;

- b. a developing chamber having a vertical wall with an aperture therein, an air introducing opening in an upper portion of the chamber above said aperture, and a developer outlet in a lower portion of the chamber below said aperture, said aperture being opposed to the vertical plane in which the film is held by said film supporting means;
- c. engaging means coupled between said developing chamber and said film supporting means moving said chamber and said film supporting means relative to each other to bring the film and the edge of the developing chamber around said aperture into engagement so as to form a space within said chamber for receiving a predetermined volume of liquid developer;
- d. developer supply means adjacent said chamber for supplying a predetermined volume of developer to said space;
- e. developer discharge means operatively associated with said chamber for discharging the developer from said space through said outlet;
- f. control means coupled to said developer supply means for controlling said developer supply means to supply the developer to said space up to a predetermined level in said space, said control means also being coupled to said developer discharge means for controlling said developer discharge means to hold said developer in the space for a predetermined time and to discharge the developer from said space after termination of developing of said film; whereby air is introduced into said space through said air introducing opening as the level of the liquid developer in said space falls during discharge of the developer so as to quickly evaporate the developer which remains on the surface of the film.
2. An apparatus as claimed in claim 1, wherein said outlet of the developing chamber has a size such that the developer is discharged from the space without any ripples at the surface of the developer.

3. An apparatus as claimed in claim 1, wherein said apparatus further comprises a potential source coupled to said developing chamber for applying an electric potential to said developing chamber, said developing chamber being insulated from a body of the apparatus.

4. An apparatus as claimed in claim 3, wherein said apparatus further comprises,

a mesh electrode mounted in said developing chamber at a position adjacent to said aperture, the electrode potential source being connected to said mesh electrode, whereby said mesh electrode serves for a realignment of the electrostatic field surrounding the film, and also serves to prevent occurrence of ripples at a surface of the developer during discharging of the developer.

5. An apparatus as claimed in claim 4, wherein said mesh electrode has a shape and is positioned in such a manner that the distance between said mesh electrode and the edge of said aperture is substantially equal to a distance between said mesh electrode and the surface of said film.

6. An apparatus as claimed in claim 4, wherein said potential source is connected to said mesh electrode and said chamber so that they are at the same electric potential in comparison with the film.

7. An apparatus as claimed in claim 6, wherein said film has a base film, a conductive layer overlaying said base film, and a photoconductive layer overlaying said conductive layer, the conductive layer being partially exposed, and said apparatus further comprises,

contact means which is in contact with said exposed conductive layer when said film is in said film supporting means and is connected to a terminal of said potential source having the opposite polarity of the terminal of the potential source which is connected to said mesh electrode and said chamber, whereby said mesh electrode and said conductive layer of the film are at a potential difference equal to the potential of the potential source.

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