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**(54) Ink-jet recording method and device**

Tintenstrahlaufzeichnungsverfahren und -vorrichtung

Procédé et dispositif d'enregistrement à jet d'encre

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(73) Proprietor: **FUJIFILM Corporation**  
**Minato-ku**  
**Tokyo (JP)**

(72) Inventor: **Yokota, Yasuyo**  
**Kanagawa (JP)**

(74) Representative: **Höhfeld, Jochen**  
**Klunker Schmitt-Nilson Hirsch**  
**Patentanwälte**  
**Destouchesstrasse 68**  
**80796 München (DE)**

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## Description

## BACKGROUND OF THE INVENTION

**[0001]** The present invention relates to an ink-jet recording method and device, and more specifically to an ultraviolet light-curable ink-jet recording method and device using an ink that is curable by exposure to active energy rays such as ultraviolet light (hereinafter also referred to as "UV light"), as it is specified in the preamble of claim 1 and claim 9. Such a method and such a device are known from the document EP 1826005A1.

**[0002]** An ink-jet recording device is a small inexpensive device that directly forms image on a recording medium by ejecting ink droplets only on necessary image areas, and is therefore used in many printers for such reasons as efficient use of inks and low running costs.

**[0003]** In particular, an ink-jet recording device using an active energy ray-curable ink that is curable by exposure to active energy rays has various advantages including its ability to record on a nonabsorbable recording medium, fast drying and environmental responsiveness.

**[0004]** However, a conventional ink-jet recording device that uses light sources for generating active energy rays such as a high-pressure mercury vapor lamp and a metal halide lamp is upsized as a whole with increased costs because the mercury vapor lamp and the metal halide lamp are of appreciable size and expensive.

**[0005]** On the other hand, in cases where small light sources such as a hot cathode tube, a cold cathode tube, an LED and a laser diode are used as the light sources for generating active energy rays, such small light sources have low illuminance and only emit UV light at a single peak wavelength, and therefore an ink which is less sensitive to the peak wavelength at which the light source emits light does not cure with ease, thus deteriorating the quality of the image formed.

**[0006]** JP 2004-188864 A proposes an ink-jet printer which cures an ink containing an oxetane compound using a UV irradiating device having a plurality of UV light sources emitting light at different peak wavelengths. It is described that this printer uses any of a hot cathode tube, a cold cathode tube, an LED and a semiconductor laser for the light source and that although the individual light sources have low illuminance, a combination of such light sources emitting light at different peak wavelengths enables light irradiation at wavelengths suitable to the sensitivities of the individual inks and efficient ink curing at low illuminance levels whereby an excellent image can be formed regardless of the type of the ink used.

**[0007]** However, this method that depends on the use of the plurality of light sources makes it difficult to downsize the UV irradiating device and to reduce the weight of a carriage when applied to the carriage system. Use of the plurality of light sources also impedes cost reduction. In addition, the oxetane compound-containing ink as described in this document has low sensitivity so that the ink cannot be fully cured by using in combination the foregoing low illuminance light sources emitting light at different peak wavelengths as exemplified by the hot cathode tube, cold cathode tube, LED and semiconductor laser.

**[0008]** JP 5-305259 A discloses a highly efficient UV irradiation unit in which a temperature control mechanism for controlling the tube wall temperature of a fluorescent lamp used within a fixed temperature range is provided to control the mercury vapor pressure within the tube in a proper range to achieve high conversion efficiency.

**[0009]** JP 2004-82452 A describes an ink-jet image forming method that applies the fluorescent lamp disclosed in JP 5-305259 A. However, this method cannot achieve formation of a high-resolution image due to curing insufficiently performed because of the low sensitivity of the oxetane compound-containing ink described in JP 2004-82452 A and insufficient power of the fluorescent lamp with respect to the ink sensitivity.

**[0010]** When a cationic polymerizable ink composition for use in an ultraviolet light-curable ink which exhibits relatively high curing sensitivity and contains a cationic polymerization initiator and a cationic polymerizable monomer is cured at low illuminance levels, the film strength depends on the ambient temperature. In other words, the film strength is increased with higher ambient temperatures whereas it is decreased with lower ambient temperatures.

**[0011]** In addition to the foregoing problem, in a hot cathode tube such as a fluorescent lamp (also called "hot cathode discharge lamp" and hereinafter typified by the fluorescent lamp) which is generally used as a light irradiation unit in this type of image recording device, an increase in discharge current for obtaining high power generally causes the temperature near the cathode to elevate, thus leading to discharge of impurities and gases from the parts of the fluorescent lamp and their adsorption onto the phosphor, cathode and other portions in the fluorescent lamp, whereby the fluorescent lamp has a partially reduced amount of emitted light (intensity) and hence a shortened service life.

**[0012]** In order to solve such a problem, it is effective to use, for example, a method as described in JP 2002-245966 A in which an element made of a material for adsorbing gases and impurities which is called "getter" is disposed on the periphery of the cathode serving as the discharge electrode of the fluorescent lamp. By thus disposing the getter element having such a function on the periphery of the cathode, it is possible to extend the service life of the fluorescent lamp while preventing the gases and impurities within the fluorescent lamp from adsorbing onto the phosphor, cathode or other portions and also preventing the light intensity distribution from being made nonuniform.

**[0013]** However, in disposing the getter element on the periphery of the discharge electrode of the fluorescent lamp, the getter element must be heated to about several hundred degrees to initiate its chemical reaction, although the heating temperature depends on the type of the getter element used. Therefore, it is general to dispose the getter element in the vicinity of the cathode or to heat its periphery from outside in order to obtain heat. However, an increase in discharge current for obtaining high power causes the periphery of the cathode to have a high temperature of not less than 1000°C, as a result of which the getter element and a holding member adsorbing or holding the getter element evaporate, and vapors are deposited onto the inner wall of the hot cathode fluorescent tube to cause early blackening.

## SUMMARY OF THE INVENTION

**[0014]** In order to solve the above-described problems, advantageous use may be made of the light irradiation unit described in Japanese Patent Application No. 2008-93690 filed by the common assignee on the same date as the present application, which uses a hot cathode fluorescent tube having a getter element disposed in the vicinity of at least one electrode within a bulb of the fluorescent lamp and which is provided with a cooling mechanism for cooling the getter element disposed in the hot cathode fluorescent tube from outside the bulb.

**[0015]** The present invention has been made to solve the problems occurring in the prior art and an object of the invention is to provide an ink-jet recording method and device which uses a small inexpensive UV irradiation unit and is capable of forming high-resolution images for a long period of time and producing prints having a high film strength without depending on the ambient temperature.

**[0016]** In order to achieve the above object, the present invention provides an ultraviolet light-curable ink-jet recording method, comprising the steps of: ejecting an ink composition curable by exposure to UV light onto a recording medium transported by a transport unit from an ink-jet head to form an image; and irradiating the ink composition ejected onto the recording medium with the UV light generated by a light source for generating the UV light to cure the ink composition, wherein the light source is an aperture-type hot cathode fluorescent tube having a getter element therein, and the ink composition contains an oxirane compound, an oxetane compound and a photocationic polymerization initiator.

**[0017]** In order to achieve the above object, the present invention also provides an ultraviolet light-curable ink-jet recording device according to claim 9.

**[0018]** In the ink-jet recording method and device of the present invention, it is preferable that the aperture-type hot cathode fluorescent tube includes: a bulb; a reflective film formed on a large part of an inner wall of the bulb and having a first aperture formed on a side of the recording medium; and a phosphor film formed on the reflective film and optionally a part of the inner wall of the bulb and having a second aperture formed on the side of the recording medium, and that a formula  $30^\circ \leq A \leq 90^\circ$  where A represents an aperture angle of one of the first aperture for the reflective film and the second aperture for the phosphor film which is smaller than the other, is satisfied.

**[0019]** Preferably, the ink-jet recording method of the present invention further comprises the step of cooling the getter element disposed in the vicinity of at least one electrode within the bulb of the hot cathode fluorescent tube from outside the bulb by means as a cooling mechanism, and the ink-jet recording device of the present invention further comprises a cooling mechanism for cooling the getter element as above from outside the bulb. The cooling mechanism is preferably of the type utilizing air-cooling with a fan, heat-pipe cooling, or both in combination.

**[0020]** The content ratio of the oxirane compound to the oxetane compound in the ink composition is preferably from 90/10 to 10/90, more preferably from 70/30 to 30/70, and even more preferably 1/1.

**[0021]** As the content ratio of the oxirane compound to the oxetane compound reaches 1/1, the ink composition has more improved curing properties under exposure to UV light.

**[0022]** The invention uses an aperture-type small inexpensive hot cathode fluorescent tube as the light source for UV irradiation to achieve high power. In addition, getter elements for use in gas adsorption are introduced into the hot cathode fluorescent tube to realize a UV irradiation unit that holds high power for a long period of time.

**[0023]** What is more, the ink composition of the invention contains an oxirane compound, an oxetane compound and a photocationic polymerization initiator to enable the ink to have high sensitivity.

**[0024]** By using the above-described UV irradiation unit and the high-sensitivity ink composition in combination, the invention is markedly effective in realizing the ink-jet recording method and device which use the small inexpensive UV irradiation unit and are capable of forming high-resolution images for a long term and producing prints having a high film strength without depending on the ambient temperature.

**[0025]** More specifically, in the UV irradiation unit and the ink-jet recording method and device using this unit according to the invention, the fluorescent lamp can have a longer service life while maintaining a stable light intensity distribution for a long period of time even if the discharge current of the UV irradiation unit is increased to obtain high power.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0026]**

FIG. 1 is a front view schematically showing the structure of an embodiment of an ink-jet recording device according to the invention which implements an ink-jet recording method of the invention;  
 FIG. 2A is a longitudinal sectional view schematically showing an example of a fluorescent lamp in a light irradiation unit (UV irradiation unit) used in the ink-jet recording device of the invention;  
 FIG. 2B is a sectional view of the fluorescent lamp taken along the line B-B of FIG. 2A;  
 FIG. 2C is a sectional view showing a variant of the fluorescent lamp shown in FIG. 2B;  
 FIG. 3 is a longitudinal sectional view of another fluorescent lamp for use in illustrating the schematic structure of another light irradiation unit used in the ink-jet recording device of the invention;  
 FIG. 4 is a graph showing the initial emission intensity distribution in the width direction of a fluorescent lamp;  
 FIG. 5 is a graph showing the emission intensity distribution in the width direction of an LED;  
 FIG. 6 is a graph showing the emission intensity distribution in the width direction of a fluorescent lamp with its getter elements uncooled;  
 FIG. 7 is a graph showing the emission intensity distribution in the width direction of a fluorescent lamp with its getter elements cooled;  
 FIG. 8 is a schematic sectional view of a recording medium where ink droplets have been deposited onto a semi-cured undercoating liquid;  
 FIGS. 9A and 9B are schematic sectional views of recording media where ink droplets have been deposited onto an undercoating liquid that is in an uncured state;  
 FIG. 9C is a schematic sectional view of a recording medium where ink droplets have been deposited onto an undercoating liquid that is in a completely cured state;  
 FIG. 10 is a schematic sectional view of a recording medium where ink droplets have been deposited onto a semi-cured ink liquid;  
 FIGS. 11A and 11B are schematic sectional views of recording media where ink droplets have been deposited onto an ink liquid that is in an uncured state;  
 FIG. 11C is a schematic sectional view of a recording medium where ink droplets have been deposited onto an ink liquid that is in a completely cured state; and  
 FIGS. 12A to 12D are schematic views showing steps in the formation of an image on a recording medium.

## DETAILED DESCRIPTION OF THE INVENTION

**[0027]** The ink-jet recording method and device of the invention are described below in detail based on preferred embodiments shown in the accompanying drawings.

**[0028]** FIG. 1 is a front view schematically showing the structure of an embodiment of the ink-jet recording device according to the invention implementing the ink-jet recording method according to the invention, FIG. 2A is a longitudinal sectional view schematically showing an example of a fluorescent lamp in a UV irradiation unit of the ink-jet recording device shown in FIG. 1, and FIG. 2B is a sectional view of the fluorescent lamp taken along the line B-B of FIG. 2A.

**[0029]** The embodiment discussed below is directed to an active light-curable ink-jet recording device which uses an ultraviolet light-curable ink (UV-curable ink) as the active light-curable ink (also referred to as "active energy ray-curable ink") that cures under irradiation with active light (also referred to as "active energy ray"). However, the invention is not limited to this embodiment, and may apply to ink-jet recording devices in which various types of active light-curable inks are used. Examples of the active light include UV light and visible light.

**[0030]** As shown in FIG. 1, an ink-jet recording device 10 has a transport section 12 which transports a recording medium P, an undercoat forming section 13 which coats an undercoating liquid onto the recording medium P, an undercoating liquid semi-curing section 14 which semi-cures the undercoating liquid that has been coated onto the recording medium P, an image recording section 16 which records an image on the recording medium P, an image fixing section 18 which fixes the image recorded on the recording medium P, and a control unit 20 which controls the ejection of ink droplets from the image recording section 16.

**[0031]** An input unit 22 is connected to the control unit 20 of the ink-jet recording device 10. The input unit 22 may be an image reading unit such as a scanner or any of various types of devices which transmit image data, including image processing devices such as a personal computer. Any of various connection methods, whether wired or wireless, may be used to connect the input unit 22 and the control unit 20.

**[0032]** The transport section 12, which has a feed roll 30, a transport roll 32, a transport roller pair 34 and a recovery roll 36, feeds, transports and recovers the recording medium P.

**[0033]** The feed roll 30 has a web-type recording medium P wrapped thereon in the form of a roll, and feeds the recording medium P.

**[0034]** The transport roll 32 is disposed downstream of the feed roll 30 in the direction of travel of the recording medium P, and transports the recording medium P that has been let out from the feed roll 30 to the downstream side in the direction of travel.

**[0035]** The transport roller pair 34 is a pair of rollers which are disposed on the downstream side of the transport roll 32 in the travel path of the recording medium P and which nip therebetween the recording medium P that has passed around the transport roll 32 and transport it to the downstream side in the direction of travel.

**[0036]** The recovery roll 36 is disposed the furthest downstream in the travel path of the recording medium P. The recovery roll 36 takes up the recording medium P which has been fed from the feed roll 30, has been transported by the transport roll 32 and the transport roller pair 34, and has passed through positions facing the subsequently described undercoat forming section 13, undercoating liquid semi-curing section 14, image recording section 16 and image fixing section 18.

**[0037]** Here, the transport roll 32, the transport roller pair 34 and the recovery roll 36 are connected to drive units (not shown) and rotated by the drive units.

**[0038]** The transport roll 32 is disposed above the feed roll 30 in a vertical direction and at a position further away from the recovery roll 36 than from the feed roll 30 in a horizontal direction. Moreover, the transport roll 32, the transport roller pair 34 and the recovery roll 36 are disposed linearly in the horizontal direction.

**[0039]** The transport section 12 has the layout as described above. The recording medium P is let out from the feed roll 30 and transported in a direction in which it is moved away from the recovery roll 36 with respect to the vertical direction while being inclined at a specified angle, in other words, in an obliquely upward direction. Then, the recording medium P changes the direction of travel at the transport roll 32, passes the transport roll 32 and horizontally travels toward the recovery roll 36.

**[0040]** That is, the recording medium P having been let out from the feed roll 30 is moved in an obliquely upward direction with the surface on which images are to be recorded facing downward. Then, the recording medium P having passed around the transport roll 32 is horizontally moved with the surface on which images are to be recorded facing upward.

**[0041]** The undercoat forming section 13 is situated between the feed roll 30 and the transport roll 32; that is, on the downstream side of the feed roll 30 and on the upstream side of the transport roll 32 in the direction of travel of the recording medium P.

**[0042]** The undercoat forming section 13 has a coating roll 60 for coating an undercoating liquid onto the recording medium P, a drive unit 62 which drives the coating roll 60, a reservoir 64 which supplies the undercoating liquid to the coating roll 60, a scraper roll 66 which adjusts the amount of undercoating liquid picked up by the coating roll 60, a scraper roll drive unit 67 which drives the scraper roll 66 (hereinafter referred to simply as the "drive unit 67"), and a positioning unit 68 which supports the recording medium P so that the recording medium P assumes a predetermined position relative to the coating roll 60.

**[0043]** The coating roll 60 is disposed between the feed roll 30 and the transport roll 32 in the travel path of the recording medium P so as to be in contact with the surface of the recording medium P on which images are to be formed. That is, the coating roll 60 is in contact with the downwardly facing surface of the recording medium P being transported from the feed roll 30 to the transport roll 32.

**[0044]** The coating roll 60, which is a roll that is longer than the width of the recording medium P, is a so-called gravure roll on the surface (peripheral face) of which recessed features are formed at fixed, i.e., uniform, intervals. Here, the shapes of the recessed features formed on the coating roll 60 are not subject to any particular limitation. Any of various shapes may be used, including round, rectangular, polygonal or star-like shapes. Alternatively, the recessed features may be formed as grooves extending over the entire circumference of the coating roll. The coating roll surface preferably has recessed features formed at regular intervals because the amount of undercoating liquid held on the coating roll surface can be made constant. However, the invention is not limited to this but may use a roll in which no recessed features are formed.

**[0045]** The drive unit 62 is a drive mechanism including a motor, and gears which transmit rotation of the motor to the coating roll 60 and rotates the coating roll 60. However, the drive unit 62 is not limited to this embodiment. Any of various other drive mechanisms may instead be used to rotate the coating roll 60, including pulley driving, belt driving and direct driving.

**[0046]** As indicated by an arrow in FIG. 1, the drive unit 62 causes the coating roll 60 to rotate in the direction opposite to the direction of travel of the recording medium P at the portion of contact therebetween (i.e., in the clockwise direction in FIG. 1).

**[0047]** The reservoir 64 has a dish-like shape open at the top, and holds in the interior thereof the undercoating liquid. The reservoir 64 is disposed underneath and adjacent to the coating roll 60, such that a portion of the coating roll 60 is immersed in the undercoating liquid held within the reservoir 64. When necessary, the undercoating liquid is fed to the reservoir 64 from a feed tank (not shown).

**[0048]** The scraper roll 66 is a roll having substantially the same axial length as the coating roll 60. The scraper roll 66 is rotatably disposed in a state in which it is in contact with the surface of the coating roll 60. More specifically, the scraper roll 66 is disposed downstream of the reservoir 64 and upstream of the recording medium P in the rotational direction of the coating roll 60.

**[0049]** The scraper roll 66 scrapes off that portion of the undercoating liquid picked up by the coating roll 60 when immersed in the reservoir 64 which is not needed, thereby setting the quantity of undercoating liquid adhering to the coating roll 60 to a fixed amount. In this embodiment, except for the undercoating liquid retained in the recessed features formed on the surface of the coating roll 60, the scraper roll 66 scrapes off undercoating liquid adhering to other portions of the coating roll 60 so that the portion of the coating roll 60 which comes in contact with the recording medium P has the undercoating liquid substantially only held in the recessed features.

**[0050]** The scraper roll 66 scrapes off undercoating liquid excessively adhering to the surface of the coating roll 60 (i.e., surplus undercoating liquid) to make the amount of undercoating liquid adhering to the surface of the coating roll 60 constant, thus enabling the coating layer to be more uniformly formed on the recording medium.

**[0051]** As shown by an arrow in FIG. 1, the drive unit 67 rotates the scraper roll 66 in the opposite direction from the rotational direction of the coating roll 60 so that the direction of movement of the scraper roll 66 surface and the direction of movement of the coating roll 60 at the position of contact between the scraper roll 66 and the coating roll 60 are the same (in the counterclockwise direction in FIG. 1). As in the drive unit 62, various drive mechanisms may be used to rotate the roll, including gear driving, pulley driving, belt driving and direct driving. The drive unit 67 rotates the scraper roll 66 in the opposite direction from the rotational direction of the coating roll 60 to prevent abrasion of the scraper roll 66 and the coating roll 60, thus enabling their replacement frequency to be reduced while enhancing the device durability.

**[0052]** Since the device can have higher durability, undercoating liquid excessively adhering to the coating roll 60 is preferably scraped off by a scraper roll as in the embodiment under consideration. However, this is not the sole case of the invention but use may be made of a method using a blade in which the blade is brought into contact with the coating roll 60 to scrape off undercoating liquid excessively adhering to the coating roll 60.

**[0053]** The positioning unit 68 has a first positioning roll 70 and a second positioning roll 72, and supports the recording medium P in such a way as to ensure that the recording medium P comes into contact with the coating roll 60 at a specified position.

**[0054]** The first and second positioning rolls 70 and 72 are each situated on the opposite side of the recording medium P from the coating roll 60 and, in the direction of travel of the recording medium P, on either side of the coating roll 60; that is, one is situated on the upstream side, and the other is situated on the downstream side, of the coating roll 60. These first and second positioning rolls 70 and 72 support the recording medium P from the side of the recording medium P opposite to the side on which images are to be formed (i.e., the side to be coated with undercoating liquid).

**[0055]** It is preferable to provide a positioning mechanism for fixing the mutual positions of the coating roll 60, the first positioning roll 70 and the second positioning roll 72 in the undercoat forming section 13. By thus providing the positioning mechanism, departures from the correct positional relationships between the coating roll 60 and the positioning rolls 70 and 72 can be prevented from occurring.

**[0056]** Any positioning mechanism may be used as long as it is configured such that members which individually support the coating roll 60 and the first and second positioning rolls 70 and 72 are placed in mutual contact. For example, use may be made of a mechanism in which the bearings of the respective members are placed in mutual contact, and a mechanism in which fixing members which fix in place the bearings are placed in mutual contact.

**[0057]** In the foregoing arrangement of the undercoat forming section 13, the drive unit 62 causes the coating roll 60 to rotate in the direction opposite to the direction of travel of the recording medium P. After being immersed in the undercoating liquid which has accumulated in the reservoir 64, the surface of the rotating coating roll 60 comes into contact with the scraper roll 66 to adjust the amount of undercoating liquid retained on the surface to a fixed amount, then comes into contact with the recording medium P, thereby coating the undercoating liquid onto the recording medium P. By thus rotating the coating roll 60 in the direction opposite to the direction of travel of the recording medium P and coating the undercoating liquid onto the recording medium P, a layer of undercoating liquid (referred to below as the "undercoat") that has been smoothened and has a good, even, coating surface state can be formed on the recording medium P. The coating roll 60 that came into contact with the recording medium P is further rotated to be immersed again in the coating liquid within the reservoir 64.

**[0058]** Next, the undercoating liquid semi-curing section 14 is described.

**[0059]** The undercoating liquid semi-curing section 14 includes a UV irradiation unit and is disposed so as to face the recording medium P.

**[0060]** The UV irradiation unit has a fluorescent lamp emitting UV light, a housing which is disposed so as to surround the fluorescent lamp, has an opening formed on the recording medium P side and reflects light emitted from the fluorescent lamp, and a cooling mechanism which is disposed in the housing and blows air to the fluorescent lamp for its cooling, and irradiates UV light onto the recording medium P. The UV irradiation unit will be described later in detail in connection with the image fixing section 18.

**[0061]** The undercoating liquid semi-curing section 14 exposes to UV light the entire width of the recording medium P which has been coated on the surface with the undercoating liquid and passes through an opposed position, thereby rendering the undercoating liquid coated onto the surface of the recording medium P into a semi-cured state. Semi-curing of the undercoating liquid will be described later in further detail.

**[0062]** Next, the image recording section 16 in which ink droplets are ejected onto the recording medium to record an image and the image fixing section 18 in which the image formed on the recording medium in the image recording section 16 is cured to fix it on the recording medium are described.

**[0063]** The image recording section 16 has a full-line recording head unit 46 and ink tanks 50X, 50Y, 50C, 50M and 50K.

**[0064]** The recording head unit 46 has recording heads 48X, 48Y, 48C, 48M and 48K.

**[0065]** It is needless to say that the recording head unit 46 used may be of any other type than the full-line type such as shuttle scanning type.

**[0066]** The recording heads 48X, 48Y, 48C, 48M and 48K are arranged in this order from the upstream side to the downstream side in the direction of travel of the recording medium P. Moreover, in the recording heads 48X, 48Y, 48C, 48M and 48K, the tips of the respective ink ejection portions are disposed so as to face the path of travel of the recording medium P; that is, so as to face the recording medium P which is transported over the travel path by the transport section 12 (also referred to below as simply "facing the recording medium P").

**[0067]** The recording heads 48X, 48Y, 48C, 48M and 48K are full-line, piezoelectric ink-jet heads in which a large number of orifices (nozzles, ink ejection portions) are arranged at fixed intervals throughout in a direction perpendicular to the direction of travel of the recording medium P, that is, over the entire width of the recording medium P. These recording heads are connected to the subsequently described control unit 20 and the ink tanks 50X, 50Y, 50C, 50M and 50K. The amount of ink droplets ejected by the recording heads 48X, 48Y, 48C, 48M and 48K and the ejection timing of the droplets are controlled by the control unit 20. The recording heads 48X, 48Y, 48C, 48M and 48K eject inks of special color (X), yellow (Y), cyan (C), magenta (M) and black (K), respectively.

**[0068]** A color image can be formed on the recording medium P by ejecting inks of various colors--special color (X), yellow (Y), cyan (C), magenta (M) and black (K)--from the respective recording heads 48X, 48Y, 48C, 48M and 48K toward the recording medium P while at the same time having the transport section 12 transport the recording medium P.

**[0069]** In the present embodiment, the recording heads are piezoelectric (piezo) elements. However, the invention is not limited in this regard. Any of various types of systems may be used in place of a piezo system, as exemplified by a thermal jet system which uses a heating element such as a heater to heat the ink and generate bubbles. In this latter system, the pressure of the bubbles propels the droplets of ink.

**[0070]** Any of various inks, such as white, orange, violet or green ink may be used as the special colored ink ejected from the recording head 48X. The number of inks ejected from the recording head 48X is not limited to one but a plurality of inks may be ejected therefrom. As for the order in which the recording heads 48X, 48Y, 48C, 48M and 48K are arranged, this embodiment is not the sole case but the recording heads may be arranged in various orders.

**[0071]** The inks ejected from the recording heads in the present embodiment are UV-curable inks.

**[0072]** The ink tanks 50X, 50Y, 50C, 50M and 50K are provided for the recording heads 48X, 48Y, 48C, 48M and 48K. The respective ink tanks 50X, 50Y, 50C, 50M and 50K store inks of various colors for the recording heads, and supplies the stored inks to the corresponding recording heads 48X, 48Y, 48C, 48M and 48K.

**[0073]** In addition, a tabular platen 56 is disposed at a position facing the recording heads 48X, 48Y, 48C, 48M and 48K on the side of the recording medium P where images will not be formed.

**[0074]** The platen 56 supports the recording medium P which is transported through positions facing the respective recording heads from the side of the recording medium P on which images will not be formed; that is, from the opposite side of the recording medium P to that on which the recording head unit 46 is disposed. In this way, the distance between the recording medium P and the respective recording heads can be made constant, enabling high-resolution images to be formed on the recording medium P.

**[0075]** The shape of the platen 56 is not limited to a flat plate, and may have a raised, curved surface shape on the recording head side. In such a case, the recording heads 48X, 48Y, 48C, 48M and 48K are disposed at fixed distances from the platen.

**[0076]** Then, the image fixing section 18, which has UV irradiation units 52X, 52Y, 52C and 52M, and a final UV irradiation unit for curing 54, irradiates UV light onto the image formed on the recording medium P by the recording head unit 46, thereby semi-curing the image (that is, the inks) with the UV irradiation units 52X, 52Y, 52C and 52M, then curing it with the final UV irradiation unit for curing 54, thus fixing the image.

**[0077]** The UV irradiation units 52X, 52Y, 52C and 52M are disposed on the downstream sides of the respective recording heads 48X, 48Y, 48C and 48M along the travel path of the recording medium P. In addition, the final UV irradiation unit for curing 54 is disposed on the downstream side of the recording head 48K along the travel path of the recording medium P. That is, the final UV irradiation unit for curing 54 is positioned on the downstream side of the recording head situated the furthest downstream of all the recording heads along the travel path of the recording medium P.

**[0078]** In other words, as shown in FIG. 1, the respective recording heads 48X, 48Y, 48C, 48M and 48K, the respective UV irradiation units 52X, 52Y, 52C and 52M, and the final UV irradiation unit for curing 54 are disposed in the following order, from the upstream to the downstream side of the travel path: recording head 48X, UV irradiation unit 52X, recording head 48Y, UV irradiation unit 52Y, recording head 48C, UV irradiation unit 52C, recording head 48M, UV irradiation unit 52M, recording head 48K, final UV irradiation unit for curing 54.

**[0079]** Here, the UV irradiation units 52X, 52Y, 52C and 52M and the final UV irradiation unit for curing 54 differ only in the size of the units, the target to be irradiated with UV light and the degree of cure. Specifically, the UV irradiation units 52X, 52Y, 52C and 52M semi-cure the images formed by the respective recording heads, whereas the final UV irradiation unit for curing 54 differs only in that it irradiates higher intensity light than the other UV irradiation units so as to reliably cure both the undercoating liquid coated onto the recording medium P and images of all the respective inks. Because the final UV irradiation unit for curing 54 has the same basic construction as the UV irradiation units 52X, 52Y, 52C and 52M, the description given below for the UV irradiation unit 52X applies collectively to all of the above UV irradiation units, including the final UV irradiation unit for curing 54.

**[0080]** Now, the UV irradiation unit 52X is described with reference to FIGS. 1, 2A and 2B.

**[0081]** The UV irradiation unit 52X has a fluorescent lamp 80 emitting UV light, a housing 82 which is disposed so as to surround the fluorescent lamp 80 and which has an opening formed on the recording medium P side, and cooling mechanisms 84 which are disposed within the housing 82 and which blow air to the fluorescent lamp 80 for its cooling. The UV irradiation unit 52X is disposed so as to face the travel path of the recording medium P.

**[0082]** The fluorescent lamp 80 is a linear light source which emits UV light and is disposed so that a direction orthogonal to the direction of travel of the recording medium P is parallel to the axial direction in which the fluorescent lamp 80 extends. The fluorescent lamp 80 has a length which is larger than that of the recording medium P in the width direction, and is disposed over the entire width of the recording medium P.

**[0083]** As shown in FIGS. 2A and 2B, the fluorescent lamp 80 has a bulb 86, electrodes 88, a protective film 90, a reflective film 91, and a phosphor film 92.

**[0084]** The bulb 86 is a tubular (or cylindrical) member made of a material such as soda glass or fused silica (sterile glass). Tubes having a length in the range of from 500 mm to 800 mm may be used for the bulb 86. Tubes having diameters of 15.5 mm, 20 mm, 25.5 mm, 28 mm, 32 mm, and 38 mm may be used for the bulb 86.

**[0085]** As shown in FIG. 2B, the electrodes 88 are each composed of a cathode 88a in filament form and anodes 88b in such a shape as to surround the cathode 88a, protrude into the space formed in the bulb 86 and are disposed at both ends of the bulb 86. Getter elements 89 are vapor-deposited on the surfaces of the anodes 88b.

**[0086]** The bulb 86 and the electrodes 88 at both ends of the bulb 86 are disposed so as to hermetically seal the bulb 86, and mercury or other material is sealed within the bulb 86.

**[0087]** The protective film 90 is formed on the inner wall surface of the bulb 86 to hold the reflective film 91 and the phosphor film 92 thereon. The phosphor film 92 is made of a phosphor which emits UV light at 280 to 400 nm.

**[0088]** In this way, the fluorescent lamp 80 is of a structure in which the bulb 86, the protective film 90, the reflective film 91 and the phosphor film 92 are stacked on top of each other from the outside toward the center of the fluorescent lamp 80.

**[0089]** In addition, as shown in FIG. 2B, neither the reflective film 91 nor the phosphor film 92 is formed on the bulb 86 on the recording medium P side (on the bottom side in FIG. 2B) and these portions corresponding to the reflective film 91 and the phosphor film 92 are hereinafter referred to as apertures 94 and 96, respectively.

**[0090]** The reflective film 91 and the phosphor film 92 preferably have shapes satisfying the condition:  $30^\circ \leq \gamma \leq 90^\circ$  wherein  $\gamma$  represents the aperture angle of the apertures for the reflective film 91 and the phosphor film 92. The aperture angle as used herein refers to an angle formed between a first line segment that connects the center of the section of the fluorescent lamp 80 which is orthogonal to the longitudinal direction (i.e. the center of the reflective film 91 or the phosphor film 92 formed on the circumference of the bulb 86) and a first aperture end, and a second line segment that connects the center of the section and a second aperture end.

**[0091]** The aperture angle is not limited to the foregoing case where the aperture angle for the reflective film 91 is completely the same as that for the phosphor film 92, and advantageous use may be made of the embodiment shown in FIG. 2C in which the bulb aperture for the reflective film 91 has an aperture angle  $\alpha$  which is larger than an aperture angle  $\beta$  of the bulb aperture for the phosphor film 92.

**[0092]** In this case, the reflective film 91 and the phosphor film 92 preferably have shapes satisfying the conditions  $\beta < \alpha$ ,  $60^\circ \leq \alpha \leq 150^\circ$  and  $30^\circ \leq \beta \leq 90^\circ$ .

**[0093]** In other words, it is preferred that either the aperture angle  $\alpha$  of the bulb aperture for the reflective film 91 or the aperture angle  $\beta$  of the bulb aperture for the phosphor film 92 satisfies the condition  $30^\circ \leq \alpha(\beta) \leq 90^\circ$ . If the aperture angle  $\alpha$  or  $\beta$  satisfies the condition, the irradiation efficiency of the UV light emitted from the fluorescent lamp 80 will be improved in specified directions corresponding to the relevant aperture.

**[0094]** The fluorescent lamp 80 has the arrangement as described above. When the filaments (cathodes 88a) of the electrodes 88 are preheated by application of electric current, electrons are released from emitters having an elevated temperature (emitters being coated on the filaments) to collide with mercury atoms sealed within the bulb 86. Mercury generates UV light. Then, upon exposure to the thus generated UV light, the phosphor film 92 emits light at the respective wavelengths. The emitted light then travels through the aperture 94 toward the recording medium P directly or after having been reflected on the reflective film 91.

**[0095]** The getter elements 89 are vapor-deposited on the surfaces of the anodes 88b in the fluorescent lamp 80 of



the embodiment under consideration. As described above, in cases where an increased amount of current is passed through for improving the power, the cathodes 88a often have a temperature in excess of 1000°C, and the getter elements 89 themselves and members to which the getter elements 89 are attached have conventionally been evaporated to adhere to the inner surface of the bulb 86. However, the fluorescent lamp 80 of this embodiment deals with this problem by providing small air cooling fans (cooling mechanisms 84 of the UV irradiation unit 52X) in the vicinities of the electrodes 88 (in the vicinities of the upper portions of the electrodes 88).

**[0096]** More specifically, as shown in FIG. 2A, the fluorescent lamp 80 of this embodiment has such an arrangement that heat generated in the electrodes 88 is dissipated by providing the small fans 84 in the vicinities of the upper portions of the respective electrodes 88 at both ends of the fluorescent lamp 80 and rotating them at an appropriate rpm. Such an arrangement enables heat generated in the electrodes 88 to be dissipated to suppress the temperature increase of the electrodes 88, whereby the temperature of the electrodes 88 can be reduced to the range within which the getter elements 89 and the members to which the getter elements 89 are attached are not evaporated, thus solving the problem that the evaporated material adheres to and hence blackens the inner surface or other portion of the bulb 86.

**[0097]** The fluorescent lamp 80 of this embodiment is provided with the small air cooling fans in order to cool the vicinities of the electrodes 88 of the bulb 86. However, the cooling system is not limited to this. In addition to this, advantageous use may be made of a system shown in FIG. 3 in which heat pipes 95 are disposed around the electrodes 88 of the bulb 86 along the outer wall of the bulb 86 to cool the getter elements and the members to which the getter elements are attached. A member using any of various media may be appropriately employed for the heat pipes 95 as long as it has a required capacity (cooling capacity).

**[0098]** Returning to FIG. 1, the entire arrangement of the UV irradiation unit 52X is continuously described.

**[0099]** The housing 82 of the UV irradiation unit 52X is in the shape of a rectangular parallelepiped box and is disposed so as to surround the periphery of the fluorescent lamp 80. The housing 82 has an open surface on the side of the recording medium P. In other words, the surface of the housing 82 on the recording medium P side is opened and light emitted from the fluorescent lamp 80 passes through the opened surface of the housing 82 to strike on the recording medium P.

**[0100]** The cooling mechanisms 84 are each an air blowing machine such as the foregoing cooling fan or an air blower, and are disposed within the housing 82 on the side of the fluorescent lamp 80 away from the recording medium P (i.e., on the upper side of the fluorescent lamp 80 in FIG. 1). The cooling mechanisms 84 blow air toward the fluorescent lamp 80 for its cooling.

**[0101]** Each cooling mechanism 84 also has a temperature sensor for detecting the temperature of the fluorescent lamp 80. The volume of air and the time of air blowing are adjusted to regulate the amount of cooling thereby maintaining the fluorescent lamp 80 at a constant temperature.

**[0102]** An opening is preferably formed at the upper or lateral surface of the housing 82 so that the cooling mechanisms 84 can aspirate air to be blown to the fluorescent lamp 80 through the opening.

**[0103]** The UV irradiation unit 52X has basically the arrangement as described above.

**[0104]** Next, the control unit 20 is connected to the respective recording heads 48X, 48Y, 48C, 48M and 48K of the recording head unit 46 and, using image data sent from the input unit 22 as the image recording signals, controls ink ejection/non-ejection from the respective recording heads 48X, 48Y, 48C, 48M and 48K so as to form images on the recording medium P.

**[0105]** The ink-jet recording device 10 is basically configured as described above.

**[0106]** Now described is the semi-curing of the undercoating liquid and ink in the inventive ink-jet recording method that is implemented by the ink-jet recording device 10.

**[0107]** In the practice of the invention, the term "semi-curing the undercoating liquid" as used herein signifies partial curing, and refers to the undercoating liquid in a partially cured, i.e., an incompletely cured, state. When the undercoating liquid that has been applied onto the recording medium (base material) P is semi-cured, the degree of cure may be non-uniform; preferably, the degree of cure proceeds in the depth direction of the undercoating liquid. In the present embodiment, the undercoating liquid which is semi-cured is an undercoating liquid which forms an undercoat.

**[0108]** For example, when a radical-polymerizable undercoating liquid is cured in air or air that is partially flushed with an inert gas, due to the radical polymerization-suppressing effect of oxygen, radical polymerization tends to be inhibited at the surface of the undercoating liquid. As a result, semi-curing is non-uniform, there being a tendency for curing to proceed at the interior of the undercoating liquid and to be delayed at the surface.

**[0109]** In the practice of the invention, by using a radical-photopolymerizable undercoating liquid in the presence of oxygen which tends to inhibit radical polymerization, the undercoating liquid partially photocures, enabling the degree of cure of the undercoating liquid to be higher at the interior than at the exterior.

**[0110]** Alternatively, in cases where a cationic-polymerizable undercoating liquid is cured in air containing humidity, because moisture has a cationic polymerization-inhibiting effect, there is a tendency for curing to proceed at the interior of the undercoating liquid and to be delayed at the surface.

**[0111]** It is likewise possible for the degree of cure in the undercoating liquid to be made higher at the interior than at

the exterior by using this cationic-polymerizable undercoating liquid under humid conditions that have a cationic polymerization-inhibiting effect so as to induce partial photocuring.

**[0112]** By thus semi-curing the undercoating liquid and depositing ink droplets on the semi-cured undercoating liquid, technical effects that are advantageous for the quality of the resulting print can be achieved. The mechanism of action can be confirmed by examining a cross-section of the print.

**[0113]** The semi-curing of the undercoating liquid (i.e., the undercoat formed of undercoating liquid on the recording medium) is described in detail below. As one illustration, high-density areas obtained by depositing about 12 pL of liquid ink (that is, droplets of ink) on the undercoating liquid in a semi-cured state having a thickness of about 5  $\mu\text{m}$  that has been provided on a recording medium P are described below.

**[0114]** FIG. 8 is a schematic sectional view of a recording medium where ink droplets have been deposited onto a semi-cured undercoating liquid. FIGS. 9A and 9B are schematic sectional views of recording media where ink droplets have been deposited onto an undercoating liquid that is in an uncured state, and FIG. 9C is a schematic sectional view of a recording medium where ink droplets have been deposited onto an undercoating liquid that is in a completely cured state.

**[0115]** When the undercoating liquid is semi-cured according to the invention, the degree of cure on the recording medium P side is higher than the degree of cure at the surface layer. In this case, three features are observable. That is, as shown in FIG. 8, when ink d is deposited as droplets on a semi-cured undercoating liquid U, (1) a portion of the ink d emerges at the surface of the undercoating liquid U, (2) a portion of the ink d lies within the undercoating liquid U, and (3) the undercoating liquid is present between the bottom side of the ink d and the recording medium P.

**[0116]** When the ink d is deposited on the undercoating liquid U, if the undercoating liquid U and the ink d satisfy the above states (1), (2) and (3), the undercoating liquid U can be regarded as being in a semi-cured state.

**[0117]** By semi-curing the undercoating liquid U, that is, by curing the undercoating liquid U so that it satisfies above (1), (2) and (3), the droplets of ink d (i.e., the ink droplets) which have been deposited to a high density mutually connect, forming a film of the ink d (i.e., an ink film or ink layer), and thus providing a uniform and high color density.

**[0118]** By contrast, when the ink is deposited on the undercoating liquid which is in an uncured state, either or both of the following occur: all of the ink d lies within the undercoating liquid U as shown in FIG. 9A; a state arises where, as shown in FIG. 9B, the undercoating liquid U is not present below the ink d.

**[0119]** In this case, even when the ink is applied to a high density, the liquid droplets are mutually independent, causing the color density to decrease.

**[0120]** When the ink is deposited on an undercoating liquid that is completely cured, as shown in FIG. 9C, a state will arise where the ink d does not lie within the undercoating liquid U.

**[0121]** In this case, interference in the deposition of the droplets arises, as a result of which a uniform ink film cannot be formed and a high color reproducibility cannot be achieved (i.e., this leads to a decrease in color reproducibility).

**[0122]** Here, when the droplets of ink are applied to a high density, the droplets are not independent of each other. To form a uniform ink film, and also to suppress the occurrence of deposition interference, the quantity of regions where the undercoating liquid (i.e., the undercoat) is uncured per unit surface area is preferably smaller, and more preferably substantially smaller, than the maximum quantity of droplets of ink applied per unit surface area. That is, the relationship between the weight  $M_u$  (also referred to as  $M_{\text{undercoating liquid}}$ ) of uncured regions of the undercoat per unit surface area and the maximum weight  $m_i$  (also referred to as  $m_{\text{ink}}$ ) of the ink ejected per unit surface area preferably satisfies the condition  $(m_i/30) < M_u < m_i$ , more preferably satisfies the condition  $(m_i/20) < M_u < (m_i/3)$ , and most preferably satisfies the condition  $(m_i/10) < M_u < (m_i/5)$ . As used herein, the "maximum weight of the ink ejected per unit surface area" refers to the maximum weight per color.

**[0123]** By letting  $(m_i/30) < M_u$ , deposition interference can be prevented from occurring. Moreover, a high dot size reproducibility can be achieved. By letting  $M_u < m_i$ , the ink film can be uniformly formed and a decrease in density can be prevented.

**[0124]** Here, the weight of uncured regions of the undercoating liquid per unit surface area is determined by a transfer test. Specifically, after completion of the semi-curing step (e.g., after exposure to active energy rays) and before deposition of the ink droplets, a permeable medium such as plain paper is pressed against the undercoating liquid which is in a semi-cured state, and the amount of the undercoating liquid that transfers to the permeable medium is determined by weight measurement. The measured value is defined as the weight of the uncured regions of the undercoating liquid.

**[0125]** For example, if the maximum amount of ink ejected is set to 12 picoliters per pixel at a deposition density of 600x600 dpi, the maximum weight  $m_i$  of the ink ejected per unit surface area becomes  $7.37 \times 10^{-4} \text{ g/cm}^2$  (assuming the density of the ink is about  $1.1 \text{ g/cm}^3$ ). Therefore, in this case, the weight  $M_u$  per unit surface area of uncured regions of the undercoating liquid is preferably greater than  $2.46 \times 10^{-5} \text{ g/cm}^2$  but less than  $7.37 \times 10^{-4} \text{ g/cm}^2$ , more preferably greater than  $3.69 \times 10^{-5} \text{ g/cm}^2$  but less than  $2.46 \times 10^{-4} \text{ g/cm}^2$ , and most preferably greater than  $7.37 \times 10^{-5} \text{ g/cm}^2$  but less than  $1.47 \times 10^{-4} \text{ g/cm}^2$ .

**[0126]** In the practice of the invention, as in the case of the undercoating liquid, "semi-curing the ink" signifies partial curing, and refers to a state where the liquid ink (i.e., ink, colored liquid) is in a partially cured, but not a completely cured,

state. When the ink liquid ejected onto the undercoating liquid is semi-cured, the degree of cure may be non-uniform; preferably, the degree of cure proceeds in the depth direction of the ink liquid. In the present embodiment, the ink that is to be semi-cured is in the form of ink droplets which land on the undercoat or recording medium and form an ink layer.

[0127] When this ink is semi-cured and an ink of a different hue is deposited on top of the semi-cured ink, there can be achieved a technical effect which is advantageous to the quality of the resulting print. The mechanism of action can be confirmed by examining a cross-section of the print.

[0128] Semi-curing of the ink (i.e., the ink droplets which have landed on the recording medium or the undercoat, or the ink layer formed from ink droplets which have landed) is explained below.

[0129] FIG. 10 is a schematic sectional view of a recording medium where a second ink  $d_b$  has been deposited onto a semi-cured first ink  $d_a$ . FIGS. 11A and 11B are schematic sectional views of recording media where droplets of the second ink  $d_b$  have been deposited onto the first ink  $d_a$  that is in an uncured state, and FIG. 11C is a schematic sectional view of a recording medium where droplets of the second ink  $d_b$  have been deposited onto the first ink  $d_a$  that is in a completely cured state.

[0130] When a secondary color is formed by depositing droplets of the second ink  $d_b$  onto the first ink  $d_a$  that has been earlier deposited as droplets, it is preferable to apply the second ink  $d_b$  onto the first ink  $d_a$  with the latter in a semi-cured state.

[0131] Here, the "semi-cured state" of the first ink  $d_a$  is similar to the above-described semi-cured state of the undercoating liquid. As shown in FIG. 10, this is a state where, when the second ink  $d_b$  is deposited as droplets onto the first ink  $d_a$ , (1) a portion of the second ink  $d_b$  emerges at the surface of the first ink  $d_a$ , (2) a portion of the second ink  $d_b$  lies within the first ink  $d_a$ , and (3) the first ink  $d_a$  is present below the second ink  $d_b$ .

[0132] By semi-curing the ink in this way, a cured film (colored film A) of the first ink  $d_a$  and a cured film (colored film B) of the second ink  $d_b$  can be suitably superimposed, enabling good color reproduction to be achieved.

[0133] By contrast, when the second ink  $d_b$  is deposited as droplets on the first ink  $d_a$  with the latter in an uncured state, either or both of the following occur: all of the second ink  $d_b$  lies within the first ink  $d_a$  as shown in FIG. 11A; a state arises where, as shown in FIG. 11B, the first ink  $d_a$  is not present below the second ink  $d_b$ . In this case, even when the second ink  $d_b$  is applied to a high density, the droplets are independent of each other, causing the color saturation of the secondary color to decrease.

[0134] When the second ink  $d_b$  is deposited as droplets on the first ink  $d_a$  which is completely cured, as shown in FIG. 11C, a state will arise where the second ink  $d_b$  does not lie within the first ink  $d_a$ . This causes interference in the deposition of the droplets to arise, as a result of which a uniform ink film cannot be formed, leading to a decline in color reproducibility.

[0135] Here, when the droplets of the second ink  $d_b$  are applied to a high density, the droplets are not independent of each other. To form a uniform film of the second ink  $d_b$ , and also to suppress the occurrence of deposition interference, the quantity of regions where the first ink  $d_a$  is uncured per unit surface area is preferably smaller, and more preferably substantially smaller, than the maximum quantity of droplets of the second ink  $d_b$  applied thereon per unit surface area. That is, the relationship between the weight  $M_{da}$  (also referred to as  $M_{ink A}$ ) of uncured regions of the first ink  $d_a$  layer per unit surface area and the maximum weight  $m_{db}$  (also referred to as  $m_{ink B}$ ) of the second ink  $d_b$  ejected thereon per unit surface area preferably satisfies the condition  $(m_{db}/30) < M_{da} < m_{db}$ , more preferably satisfies the condition  $(m_{db}/20) < M_{da} < (m_{db}/3)$ , and most preferably satisfies the condition  $(m_{db}/10) < M_{da} < (m_{db}/5)$ .

[0136] By letting  $(m_{db}/30) < M_{da}$ , deposition interference can be prevented from occurring. Moreover, a high dot size reproducibility can be achieved. By letting  $M_{da} < m_{db}$ , a film of the first ink  $d_a$  can be uniformly formed and a decrease in density can be prevented.

[0137] Here, as in the case of the undercoating liquid described above, the weight of the uncured regions of the first ink  $d_a$  per unit surface area is determined by a transfer test. Specifically, after completion of the semi-curing step (e.g., after exposure to active energy rays) and before deposition of the droplets of the second ink  $d_b$ , a permeable medium such as plain paper is pressed against the layer of the first ink  $d_a$  which is in a semi-cured state, and the quantity of the first ink  $d_a$  that transfers to the permeable medium is determined by weight measurement. The measured value is defined as the weight of the uncured regions of the ink liquid.

[0138] For example, if the maximum amount of the second ink  $d_b$  ejected is set to 12 picoliters per pixel at a deposition density of  $600 \times 600$  dpi, the maximum weight  $m_{db}$  of the second ink  $d_b$  ejected per unit surface area becomes  $7.37 \times 10^{-4}$  g/cm<sup>2</sup> (assuming the density of the second ink  $d_b$  to be about 1.1 g/cm<sup>3</sup>). Therefore, in this case, the weight  $M_{da}$  per unit surface area of uncured regions of the first ink  $d_a$  layer is preferably greater than  $2.46 \times 10^{-5}$  g/cm<sup>2</sup> but less than  $7.37 \times 10^{-4}$  g/cm<sup>2</sup>, more preferably greater than  $3.69 \times 10^{-5}$  g/cm<sup>2</sup> but less than  $2.46 \times 10^{-4}$  g/cm<sup>2</sup>, and most preferably greater than  $7.37 \times 10^{-5}$  g/cm<sup>2</sup> but less than  $1.47 \times 10^{-4}$  g/cm<sup>2</sup>.

[0139] When the semi-cured state of the undercoating liquid and/or the ink is realized by a polymerization reaction of a polymerizable compound that is initiated by the irradiation of active energy rays or heating, to enhance the scuff resistance of the print, the unpolymerization ratio (i.e.,  $A_{\text{after polymerization}}/A_{\text{before polymerization}}$ ) is preferably at least 0.2 but not more than 0.9, more preferably at least 0.3 but not more than 0.9, and most preferably at least 0.5 but not more than 0.9.

**[0140]** Here,  $A_{\text{before polymerization}}$  is the infrared absorption peak absorbance attributable to polymerizable groups before the polymerization reaction, and  $A_{\text{after polymerization}}$  is the infrared absorption peak absorbance attributable to polymerizable groups after the polymerization reaction.

**[0141]** For example, when the polymerizable compound included in the undercoating liquid and/or the ink is an acrylate monomer or a methacrylate monomer, absorption peaks based on polymerizable groups (acrylate groups, methacrylate groups) can be observed near  $810\text{ cm}^{-1}$ . Accordingly, the above unpolymerization ratio is preferably defined in terms of the absorbances of these peaks. When the polymerizable compound is an oxetane compound, an absorption peak based on polymerizable groups (oxetane rings) can be observed near  $986\text{ cm}^{-1}$ . The above unpolymerization ratio is thus preferably defined in terms of the absorbance of this peak. When the polymerizable compound is an epoxy compound, an absorption peak based on the polymerizable groups (epoxy groups) can be observed near  $750\text{ cm}^{-1}$ . Hence, the above unpolymerization ratio is preferably defined in terms of the absorbance of this peak.

**[0142]** A commercial infrared spectrophotometer may be used as the means for measuring the infrared absorption spectrum. The spectrophotometer may be either a transmission-type or reflection-type system. Suitable selection according to the form of the sample is preferred. Measurement may be carried out using, for example, an FTS-6000 infrared spectrophotometer manufactured by Bio-Rad.

**[0143]** In the case of a curing reaction based on an ethylenically unsaturated compound or a cyclic ether, the unpolymerization ratio may be quantitatively measured from the percent conversion of ethylenically unsaturated groups or cyclic ether groups.

**[0144]** The method used to semi-cure the undercoating liquid and/or the ink is exemplified by known thickening methods, e.g., (1) methods that use an agglomerating effect, such as by furnishing a basic compound to an acidic polymer or by furnishing an acidic compound and a metal compound to a basic polymer; (2) methods wherein the undercoating liquid and/or the ink is prepared beforehand at a high viscosity, then the viscosity is lowered by adding thereto a low-boiling organic solvent, after which the low-boiling organic solvent is evaporated so as to return the liquid to its original high viscosity; (3) methods in which the undercoating liquid and/or the ink prepared at a high viscosity is first heated, then is cooled so as to return the liquid to its original high viscosity; and (4) methods in which the undercoating liquid and/or the ink is semi-cured through a curing reaction induced by exposing the undercoating liquid and/or the ink to active energy rays or heat. Of these, (4) methods in which the undercoating liquid and/or the ink is semi-cured through a curing reaction induced by exposing the undercoating liquid and/or the ink to active energy rays or heat are preferred.

**[0145]** "Methods in which the undercoating liquid and/or the ink is semi-cured through a curing reaction induced by exposing the undercoating liquid and/or the ink to active energy rays or heat" refers herein to methods in which the polymerization reaction on polymerizable compounds at the surface of the undercoating liquid and/or the ink furnished to the recording medium is carried out incompletely. At the surface of the undercoating liquid and/or the ink, compared with the interior thereof, the polymerization reaction tends to be inhibited by the influence of oxygen present in air. Therefore, by controlling the conditions of exposure to active energy rays or heat, it is possible to trigger the reaction for semi-curing the undercoating liquid and/or the ink.

**[0146]** The amount of energy required to semi-cure the undercoating liquid and/or the ink varies with the type and content of polymerization initiator. When the energy is applied by active energy rays, an amount of about 1 to about  $500\text{ mJ/cm}^2$  is generally preferred. When the energy is applied as heat, from 0.1 to 1 second of heating under temperature conditions where the surface temperature of the recording medium falls within a temperature range of  $40$  to  $80^\circ\text{C}$  is preferred.

**[0147]** The application of active energy rays or heat, such as with active rays or heating, promotes the generation of active species by decomposition of the polymerization initiator. At the same time, the increase in active species or the rise in temperature promotes the curing reaction through polymerization or crosslinking of polymerizable or crosslinkable materials induced by the active species.

**[0148]** A thickening (rise in thickness) may also be suitably carried out by exposure to active rays or by heating.

**[0149]** The light irradiation unit and the ink-jet recording device using the same according to the invention as well as the ink-jet recording method of the invention are described below in further detail by referring to the operation of the ink-jet recording device 10, that is, its recording action on the recording medium P.

**[0150]** FIGS. 12A to 12D are schematic views showing steps in the formation of an image on a recording medium.

**[0151]** First, the recording medium P having been let out from the feed roll 30 is transported in a specified direction (direction "Y" in FIG. 1) by rotation of the transport roll 32 and the transport roller pair 34 or rotation of the feed roll 30 and the recovery roll 36. As described above, the recording medium P in this embodiment is a web with a certain length or more and is transported without being cut.

**[0152]** As shown in FIG. 12A, the recording medium P having been let out from the feed roll 30 comes into contact with the coating roll 60 of the undercoat forming section 13 and the undercoating liquid is applied onto the surface thereof to form an undercoat U. The drive unit 62 causes the coating roll 60 to rotate in the direction opposite to the direction of travel of the recording medium P.

**[0153]** The recording medium P on which the undercoat U has been formed by application of the undercoating liquid

is further transported by the transport roll 32 and the transport roller pair 34 of the transport section 12 and passes through the position facing the undercoating liquid semi-curing section 14.

[0154] As shown in FIG. 12B, the undercoating liquid semi-curing section 14 irradiates with ultraviolet light, the recording medium P onto which the undercoating liquid has been applied and which is passing through the position facing the section 14, thereby semi-curing the undercoat U on the recording medium P.

[0155] The recording medium P having thereon the semi-cured undercoating liquid is further transported by the transport roll 32 and the transport roller pair 34 of the transport section 12 and passes through the position facing the recording head 48X.

[0156] The recording head 48X ejects ink droplets from its ejection orifices to form an image on the recording medium P which is being transported by the transport section 12 and passing through the position opposed thereto.

[0157] More specifically, the recording head 48X ejects a first ink droplet d1 onto the recording medium P. As shown in FIG. 12C, the first ink droplet d1 ejected from the recording head 48X is deposited onto the surface of the undercoat U. The undercoat U is in a semi-cured state and has an uncured surface, and is therefore receptive to the ink droplet d1.

[0158] As shown in FIG. 12D, the recording head 48X ejects a second ink droplet d2 in proximity to the position where the previously ejected first ink droplet d1 was deposited. In this case, the undercoat U is also in a semi-cured state and has an uncured surface, and is therefore receptive to the ink droplet d2.

[0159] In the case where the ink droplets d1 and d2 have been deposited in proximity to each other on the recording medium P, a force acts to make the ink droplets d1 and d2 coalesce, but interference between the ink droplets having been deposited onto the recording medium P is suppressed by the resistance force of the undercoat U against coalescence of the ink droplets because the undercoat U is semi-cured and has an increased viscosity.

[0160] Ink droplets are thus ejected from the recording head 48X in accordance with the control by the control unit 20 and deposited onto the recording medium P to form an image.

[0161] The recording medium P having the image formed by the recording head 48X is further transported by the transport section 12 and passes through the position facing the UV irradiation unit 52X disposed downstream from the recording head 48X.

[0162] The UV irradiation unit 52X irradiates the recording medium P passing through the position opposed thereto with UV light to semi-cure the image formed by the recording head 48X on the recording medium P, that is, semi-cure the ink droplets having been deposited onto the recording medium P.

[0163] As shown in FIGS. 2A and 2B, the UV irradiation unit 52X has such an arrangement that heat generated in the electrodes 88 is dissipated by providing the small fans 84 in the vicinities of the upper portions of the respective electrodes 88 at both ends of the fluorescent lamp 80 and rotating them at an appropriate rpm. Such an arrangement enables heat generated in the electrodes 88 to be air-cooled and dissipated to reduce the temperature of the electrodes 88 to the range within which the getter elements 89 and the members to which the getter elements 89 are attached are not evaporated, thus solving the problem that the evaporated material adheres to and hence blackens the inner surface or other portion of the bulb 86.

[0164] The cooling mechanisms 84 serve to maintain the fluorescent lamp 80 at a constant temperature, so that the amount of light emitted from the fluorescent lamp 80 is prevented from varying with the temperature and can be made constant. Ink and/or undercoating liquid can be thus consistently semi-cured or cured with a constant amount of light.

[0165] The cooling mechanisms 84 preferably adjust the surface temperature of the fluorescent lamp 80 and more specifically the temperature of its surface away from the recording medium P in the range of from 30°C to 60°C and also the temperature variations within 5°C. The amount of light emitted from the fluorescent lamp 80 can be made constant while offering high power by maintaining the temperature within the above-defined range.

[0166] Thereafter, the recording medium P is further transported and passes in order through the positions facing the recording head 48Y, the UV irradiation unit 52Y, the recording head 48C, the UV irradiation unit 52C, the recording head 48M, the UV irradiation unit 52M, and the recording head 48K, respectively. As in the case where the recording medium P passed through the positions facing the recording head 48X and its corresponding UV irradiation unit 52X, formation of an image and semi-curing of the formed image are performed each time the recording medium P passes through the positions facing the recording head of each color and its corresponding UV irradiation unit.

[0167] After an image has been formed by the recording head 48K, the recording medium P passes through the position facing the final UV irradiation unit for curing 54.

[0168] The final UV irradiation unit for curing 54 irradiates the recording medium P with more intense UV light than the other UV irradiation units to cure the whole of the images on the recording medium P formed by the various recording heads including the image recorded by the recording head 48K as well as the undercoating liquid.

[0169] A color image is thus formed on the recording medium P. The recording medium P having the color image formed thereon is further transported by the transport roll 32 and the transport roller pair 34 or by the feed roll 30 and the recovery roll 36 to be taken up onto the recovery roll 36.

[0170] The ink-jet recording device 10 thus forms the image on the recording medium P.

[0171] By thus forming the undercoat on the recording medium P, the ink droplets having been deposited onto the

recording medium can be prevented from permeating the recording medium to cause image bleed, thus enabling a high-resolution image to be formed. It also becomes possible to use a recording medium which has a low adhesion to ink droplets, namely, may repel ink droplets having been deposited thereonto. In other words, image recording on various recording media becomes possible. By using the coating roll 60 and, moreover, by rotating the coating roll 60 in a direction opposite to the direction of travel of the recording medium P to coat undercoating liquid onto the recording medium P, disruption of the surface of the undercoating liquid on the recording medium P when the coating roll 60 separates from the recording medium P after having applied undercoating liquid to the recording medium P can be prevented, enabling the undercoat U having an improved surface state to be formed on the recording medium P.

**[0172]** By semi-curing the undercoat in the undercoating liquid semi-curing section as in the present embodiment, even when ink droplets having portions which mutually overlap are deposited on the recording medium, the coalescence of these neighboring ink droplets can be suppressed through interactions between the undercoating liquid and the ink droplets.

**[0173]** That is, by forming a semi-cured undercoat on the recording medium, the migration of ink droplets can be prevented in cases where ink droplets ejected from the recording heads are deposited in close proximity on the recording medium, such as when ink droplets of a single color having portions which mutually overlap are deposited on a recording medium or even when ink droplets of different colors having portions which mutually overlap are deposited on a recording medium.

**[0174]** In this way, image bleed, line width non-uniformities such as of fine lines in the image, and color unevenness on colored surfaces can be effectively prevented from occurring, enabling the formation of uniform-width, sharp line shapes, and thus making it possible to carry out the recording of ink-jet images of a high deposition density, such as reversed letters, with good reproducibility of fine features such as fine lines. That is, higher-resolution images can be formed on the recording medium.

**[0175]** By placing a UV irradiation unit between the adjacent recording heads and semi-curing the ink droplets deposited onto (i.e., the image formed on) the recording medium using the respective recording heads, it is possible to prevent different-color ink droplets deposited at adjacent positions from overlapping and to keep the deposited ink droplets from migrating.

**[0176]** On the travel path of the recording medium, the UV irradiation unit corresponding to the recording head disposed on the furthest downstream side serves as the final UV irradiation unit for curing and, because it emits higher intensity UV light than the other UV irradiation units, has the ability to reliably cure images that have been formed on the recording medium.

**[0177]** In view of further device downsizing, energy saving and cost reduction, the final UV irradiation unit for curing 54 is configured in the same manner as the UV irradiation units 52X, 52Y, 52C and 52M in the embodiment under consideration. However, use may also be made of various UV light sources such as metal halide lamps and high-pressure mercury vapor lamps for the final UV irradiation unit for curing 54.

**[0178]** It is also preferable to use metal halide lamps and high-pressure mercury vapor lamps for the final UV irradiation unit for curing 54. In other words, the ink-jet recording device is preferably configured so that the UV irradiation units each including the fluorescent lamp 80 are used for semi-curing the undercoating liquid and/or ink, whereas a metal halide lamp, high-pressure mercury vapor lamp or other lamp is used for the final UV irradiation unit for curing 54.

**[0179]** Use of a metal halide lamp, high-pressure mercury vapor lamp or other lamp for the final UV irradiation unit for curing 54 leads to device upsizing but enables higher intensity light to be irradiated onto the undercoating liquid and ink on the recording medium, thus achieving complete curing of the undercoating liquid and ink more reliably.

**[0180]** In view of prevention of clogging of the recording head nozzles, production of prints at a high rate, appropriate semi-curing as well as further device downsizing, energy saving and cost reduction, it is preferable for the fluorescent lamp 80 to be provided in every UV irradiation unit for semi-curing the undercoating liquid and/or ink. However, this is not the sole case of the invention. The ink-jet recording device may also be configured so that at least one of the UV irradiation units includes the fluorescent lamp 80 and the other UV irradiation units each include a metal halide lamp or a high-pressure mercury vapor lamp.

**[0181]** The fluorescent lamp 80 is preferably disposed at such a position that the shortest distance  $h$  (mm) between the irradiation surface of the fluorescent lamp 80 and the recording medium P is in the range of from 0.5 mm to 1.5 mm. The recording medium P can be irradiated with light with high efficiency by disposing the fluorescent lamp 80 at the position satisfying the above-defined range.

**[0182]** In a preferred embodiment, in the case where  $h$  is equal to or larger than 0.5 mm but is smaller than 1.0 mm ( $0.5 \leq h < 1.0$ ), the housing 82 is disposed at such a position that the shortest distance  $H$  (mm) between the housing 82 and the recording medium P is equal to  $h$  ( $H = h$ ), whereas in the case where  $h$  is equal to or larger than 1.0 mm ( $1.0 \leq h$ ), the housing is disposed at such a position that  $H$  is equal to 1.0 mm ( $H = 1.0$ ).

**[0183]** The amount of light irradiated onto other portions than the recording medium P after having been emitted from the fluorescent lamp 80 can be reduced by disposing the housing 82 at a position satisfying the above-defined range.

**[0184]** It is preferred to irradiate the recording medium with UV light in a period of several hundred milliseconds to 5

seconds after the ink droplets from the recording head have been deposited on the recording medium to thereby semi-cure the ink droplets deposited thereon.

**[0185]** By thus semi-curing the ink droplets in the period of several hundred milliseconds to 5 seconds after their deposition, the ink droplets on the recording medium can be prevented from getting out of shape, enabling a high-resolution image to be formed.

**[0186]** The undercoating liquid has a viscosity of preferably at least 10 mPa·s but not more than 500 mPa·s, and more preferably at least 50 mPa·s but not more than 300 mPa·s.

**[0187]** At an undercoating liquid viscosity of at least 10 mPa·s, and more preferably at least 50 mPa·s, as noted above, it is possible to coat the undercoating liquid onto even a recording medium to which liquid does not readily adhere.

**[0188]** At an undercoating liquid viscosity of not more than 500 mPa·s, and more preferably not more than 300 mPa·s, it is possible to more reliably achieve a lower surface roughness in the undercoat that is formed on the recording medium P.

**[0189]** The ink-jet recording device 10 is described below in further detail with reference to a specific example.

**[0190]** In this example, the UV irradiation unit used has the getter elements introduced in the vicinities of the electrodes of the fluorescent lamp 80 and has such an arrangement that heat generated in the electrodes 88 is dissipated by providing the small fans 84 in the vicinities of the upper portions of the respective electrodes 88 at both ends of the fluorescent lamp 80 and rotating them at an appropriate rpm. Such an arrangement enables heat generated in the electrodes 88 to be dissipated to suppress the temperature increase of the electrodes 88, whereby the temperature of the electrodes 88 can be reduced to the range within which the getter elements 89 and the members to which the getter elements 89 are attached are not evaporated, thus solving the problem that the evaporated material adheres to and hence blackens the inner surface of the bulb 86.

**[0191]** A linear tube with a diameter of 32 mm was used for the bulb of the fluorescent lamp 80 and a phosphor emitting light at a central wavelength of 365 nm for the phosphor film.

**[0192]** The fluorescent lamp 80 was disposed at such a position that the shortest distance h between the irradiation surface of the fluorescent lamp and the recording medium P was 1 mm, whereas the housing 82 was disposed at such a position that the shortest distance H between the housing 82 and the recording medium P was 1 mm. The recording head used was an ink-jet head having a resolution of 600 dpi.

**[0193]** More specifically, the structure of the fluorescent lamp 80 is as follows:

Glass bulb: soda-lime glass (having no absorption in the ultraviolet region);

Protective film: alumina;

Phosphor:  $5\text{rB}_4\text{O}_7$ ,  $\text{Eu}^{2+}$

Filler gas: argon;

Getter: zirconium-cobalt-rare earths alloys (St787 available from SAES Getters S.p.A.)

**[0194]** A getter ribbon was disposed by cutting off part of the anode and welding it to the anode.

**[0195]** In addition to the above method, a method in which a getter ribbon superposed on at least part of the outer surface of the anode is welded, and a method in which a getter ribbon is disposed at a distance of 0.1 to 30 mm from the electrode by welding it to a highly heat-resistant metal part with neither the cathode nor the anode contacting the getter ribbon may be applied. In short, it is only necessary to dispose the getter ribbon at a distance of up to 30 mm from the electrode in order to obtain heat required for activation.

**[0196]** It is also possible to use for the fluorescent lamp 80 an aperture-type hot cathode fluorescent tube as shown in FIGS. 2A and 2B in which the phosphor film 92 is not in the sectional shape of a perfect circle, a reflective film formed between the protective film 90 and the phosphor film 92 has a transmittance of not more than 10%, and the tube has a rectangular aperture surface whose long sides are parallel to the lamp axis and where neither the reflective film nor the phosphor film 92 is formed. In this case, the irradiation efficiency improves in specified directions corresponding to the aperture surface.

**[0197]** As is seen from the reference numerals 88+89, the fluorescent lamp 80 shown in FIGS. 2A and 2B uses the getter ribbons 89 welded to the anodes 88b.

**[0198]** The fluorescent lamp 80 has such an arrangement that heat generated in the electrodes 88 is dissipated by providing the small fans 84 in the vicinities of the upper portions of the electrodes 88 at both ends of the fluorescent lamp 80 and rotating them at an appropriate rpm. Such an arrangement enables heat generated in the electrodes 88 to be dissipated to suppress the temperature increase of the electrodes 88, whereby the temperature of the electrodes 88 can be reduced to the range within which the getter ribbons 89 and the members to which the getter ribbons 89 are attached are not evaporated, thus solving the problem that the evaporated material adheres to and hence blackens the inner surface of the bulb 86.

**[0199]** Specific experimental results obtained in this regard are now described with reference to FIGS. 4 to 7.

**[0200]** FIG. 4 is a graph showing the initial emission intensity distribution in the width direction of the above-described fluorescent lamp 80 in which the getter ribbons 89 are welded to the anodes 88b. As is clear from FIG. 4, the emission

intensity distribution in the width direction of the fluorescent lamp 80 is very highly uniform. The comparison with the case of a light-emitting diode (LED) shown in FIG. 5 more clearly shows this fact. The LED has difficulty in achieving uniformity as high as with the fluorescent lamp 80 due to individual differences.

**[0201]** FIG. 6 is a graph showing the emission intensity distribution in the width direction of the fluorescent lamp 80 which has been subjected to specified aging without disposing, unlike the fluorescent lamp 80 used in FIG. 4, the getter cooling fans 84 in the vicinities of the electrodes 88 having the getter ribbons 89 attached thereto. The comparison between the graphs of FIGS. 4 and 6 shows that there is a definite decline in the emission intensity at the ends of the fluorescent lamp (i.e., in the vicinities of the electrodes) in the case shown in FIG. 6 where specified aging was performed without disposing the getter cooling fans 84 in the vicinities of the electrodes 88. A more definite decline is seen particularly on the right side in FIG. 6.

**[0202]** On the other hand, the fluorescent lamp 80 having been subjected to specified aging with the getter cooling fans 84 disposed in the vicinities of the electrodes 88 having the getter ribbons 89 attached thereto has an emission intensity distribution in its width direction as shown in the graph of FIG. 7. The comparison between the FIGS. 7 and 4 shows that the emission intensity hardly declines at the ends of the fluorescent lamp (i.e., in the vicinities of the electrodes) even in the case where specified aging has been performed with the getter cooling fans 84 disposed in the vicinities of the electrodes 88 having the getter ribbons 89 attached thereto. In other words, the getter cooling fans 84 disposed in the vicinities of the electrodes 88 having the getter ribbons 89 attached thereto substantially completely prevent the emission intensity of the fluorescent lamp 80 from declining due to the evaporation of the getter ribbons and holding members adsorbing and holding the getter ribbons.

**[0203]** The effect of preventing the emission intensity of the fluorescent lamp 80 from declining by disposing the getter cooling means in the vicinities of the electrodes 88 to which the getter ribbons 89 are attached can be achieved at substantially the same level by adopting the above-described system shown in FIG. 3 in which the heat pipes 95 for cooling the getter ribbons are disposed in the vicinities of the electrodes 88 having the getter ribbons 89 attached thereto, instead of disposing the getter cooling fans 84 in the vicinities of the electrodes 88 as described above.

**[0204]** As described above, the ink-jet recording method and device of the invention comprises the technical features that an aperture-type hot cathode fluorescent tube having getter elements disposed therein is used as the light source for generating UV light in the UV irradiation means and that the ink composition used contains an oxirane compound, an oxetane compound and a photocationic polymerization initiator.

**[0205]** The ink composition that may be advantageously used in the ink-jet recording method and device of the invention as well as the oxirane compound, oxetane compound and photocationic polymerization initiator contained in the ink composition are described below by way of illustrative examples.

**[0206]** The ink that may be advantageously used in the invention is described below in detail.

#### (1) Ink composition

**[0207]** The ink that may be advantageously used in the method of image formation in which the ink-jet recording method and device of the invention are used is composed of an ink composition which contains an oxirane compound (A), an oxetane compound (B) and a photocationic polymerization initiator (C) (hereinafter referred to as "photoacid generator"). In the following description, such ink composition is also referred to as the "ink composition of the invention" or "ink of the invention."

**[0208]** The ink composition of the invention preferably also contains a colorant (D) and a dispersant (E). It is further preferable for the ink composition to contain a surfactant (F). Other components that may be preferably contained are a sensitizer and a co-sensitizer.

**[0209]** Exemplary such ink compositions that may be used include those described in JP 2008-87252 A, especially paragraphs [0012] to [0166] of this document which contain an oxirane compound, an oxetane compound and a photocationic polymerization initiator.

#### (A) Oxirane compound

**[0210]** The oxirane compound contained in such ink composition refers to a compound having at least one oxirane ring in the molecule. In the invention, the oxirane compounds may be used singly or in combination of two or more.

**[0211]** A polyfunctional oxirane compound having two or more oxirane rings in the molecule is preferably used for the oxirane compound (A) although any of a monofunctional oxirane compound having one oxirane ring in the molecule and the polyfunctional oxirane compound may be used. Use of the polyfunctional oxirane compound is preferable because an ink composition having an excellent curability is obtained.

**[0212]** Exemplary oxirane compounds include those especially described in JP 2008-87252 A, paragraphs [0016] to [0021].



## (B) Oxetane compound

**[0213]** The oxetane compound that may be used in the invention refers to a compound having at least one oxetane ring and any known oxetane compound may be arbitrarily selected and used.

**[0214]** Compounds having 1 to 4 oxetane rings in the structure are preferable as the oxetane ring-containing compounds that may be used in the ink composition of the invention. Use of such compounds is preferable because the ink composition viscosity is easily maintained in a range in which the handling ability is favorable while achieving a high adhesion between the cured ink and a recording medium.

**[0215]** Exemplary oxetane compounds include those especially described in JP 2008-87252 A, paragraphs [0023] to [0040].

**[0216]** The total amount of the oxirane compound (A) and the oxetane compound (B) in the ink composition is preferably from 60 to 95 wt%, more preferably from 70 to 90 wt% and even more preferably from 70 to 85 wt% with respect to the total amount of the ink composition.

**[0217]** A total amount of the oxirane compound (A) and the oxetane compound (B) within the above-defined range is preferable because a high cure rate is achieved and the cured film has an increased strength.

**[0218]** As described above, the content ratio of the oxirane compound (A) to the oxetane compound (B) in the ink composition of the invention is from 90/10 to 10/90, preferably from 70/30 to 30/70, and more preferably 1/1.

**[0219]** A content ratio of the oxirane compound (A) to the oxetane compound (B) within the above-defined range is preferable because the ink composition has excellent UV curing properties and the resulting image exhibits a high flexibility.

## (C) Photoacid generator

**[0220]** Examples of the photoacid generator (photocationic polymerization initiator) that may be preferably used in the invention include compounds used in chemically amplified photoresists and photocationic polymerization.

**[0221]** Examples of the photoacid generator that may be preferably used in the invention include compounds that generate an acid by exposure to UV light which is active radiation. For the photoacid generator that may be used in the invention, photoinitiators for photocationic polymerization and photoradical polymerization, dye photodecolorizing or photochromogenic agents, and compounds which generate an acid by exposure to UV radiation or far UV radiation at 400 to 200 nm and which are used in microresists and the like may be appropriately selected and used.

**[0222]** Exemplary photoacid generators include the photoacid generators (photocationic polymerization initiators) especially described in JP 2008-87252 A, paragraphs [0044] to [0104].

**[0223]** The photoacid generators may be used singly or in combination of two or more.

**[0224]** The content of the photoacid generator in the ink composition is preferably from 0.1 to 20 wt%, more preferably from 0.5 to 10 wt% and even more preferably from 1 to 7 wt% of the ink composition.

**[0225]** The above-defined range is preferable because the ink composition can be cured by addition of at least 0.1 wt% of photoacid generator and the degree of cure is uniform at a photoacid generator amount of not more than 20 wt%.

## (D) Colorant

**[0226]** In the invention, the ink composition contains no colorant when it is used with a pretreatment liquid (undercoating liquid) or a posttreatment liquid (UV varnish or top coating agent), but desirably contains a colorant when it is used as an ink for image formation, in other words, when it is used to form a colored image.

**[0227]** There is no particular limitation on the colorant that may be used in the invention, and pigments and oil-soluble dyes which have a high weather resistance and are rich in color reproducibility are preferable. Use may be made of one arbitrarily selected from known colorants including soluble dyes. In the practice of the invention, in order to prevent the sensitivity in the curing reaction using UV light (active energy rays) from being lowered, a compound which does not function as a polymerization inhibitor in the polymerization reaction (curing reaction) is preferably selected for the colorant that may be advantageously used in the ink composition.

**[0228]** Exemplary colorants include those described in JP 2008-87252 A, paragraphs [0106] to [0118].

**[0229]** In the case of using a colorant such as a pigment which is present as a solid in the ink composition, selection of desirable colorant, dispersant and dispersion medium, and setting of the conditions for dispersion and filtration are preferably carried out so that the colorant particles may have an average particle size of preferably 0.005 to 0.5  $\mu\text{m}$ , more preferably 0.01 to 0.45  $\mu\text{m}$ , and even more preferably 0.015 to 0.4  $\mu\text{m}$ . It is preferable to control the particle size because head nozzle clogging can be suppressed while maintaining the ink storage stability, ink transparency and curing sensitivity.

**[0230]** In the invention, the content of the colorant in the ink composition is selected as appropriate for the color and intended use. It is generally preferable to use the colorant in an amount of 0.01 to 30 wt% with respect to the total weight

of the ink composition.

#### (E) Dispersant

- 5 **[0231]** A dispersant is preferably added when the colorant is dispersed. There is no particular limitation on the type of the dispersant and a polymer dispersant is preferably used.
- [0232]** A phthalocyanine derivative or a pigment derivative may be used in combination.
- [0233]** Examples of such dispersant include those especially described in JP 2008-87252 A, paragraph [0119].
- 10 **[0234]** In the invention, the content of the dispersant in the ink composition is selected as appropriate for the intended use and it is generally preferable to use the dispersant in an amount of 0.01 to 5 wt% with respect to the total weight of the ink composition.

#### (F) Surfactant

- 15 **[0235]** In the practice of the invention, a surfactant is preferably added so that the ink composition can be consistently ejected for a long period of time.
- [0236]** Exemplary surfactants include those described in JP 2008-87252 A, paragraph [0120].
- [0237]** In the invention, the content of the surfactant in the ink composition is selected as appropriate for the intended use, and it is generally preferable to use the surfactant in an amount of 0.0001 to 1 wt% with respect to the total weight of the ink composition.
- 20

#### (Other components)

- 25 **[0238]** In the invention, other components may be optionally added to the ink composition. Exemplary such components include sensitizers, co-sensitizers, other polymerizable compounds, UV absorbers, antioxidants, antifading agents, conductive salts, solvents, polymeric compounds and basic compounds.
- [0239]** Examples of such other components including sensitizers, co-sensitizers, other polymerizable compounds, UV absorbers, antioxidants, antifading agents, conductive salts, solvents, polymeric compounds and basic compounds are those described in JP 2008-87252 A, paragraphs [0121] to [0152].
- 30 **[0240]** Such ink composition preferably has ink physical properties described in JP 2008-87252 A, paragraph [0153].

#### (2) Method of image formation

- 35 **[0241]** The ink composition is preferably used in the image forming method which includes an ejecting step for ejecting the ink composition from the ink-jet nozzle onto a recording medium and a curing step for curing the ink composition ejected onto the recording medium by exposure to active energy rays (UV light) and in which the ejection portion of the ink-jet nozzle has a taper angle of 18° to 60°.
- [0242]** In this image forming method, the ink composition containing the oxirane compound, the oxetane compound, and the photoacid generator is ejected onto the recording medium (support, recording material or the like) for ink-jet recording and the ink composition ejected onto the recording medium is irradiated with active energy rays (UV light) to cure the ink, thus forming an image.
- 40 **[0243]** The foregoing ink composition can be used in the ink-jet recording device described in JP 2008-87252 A, paragraphs [0158] to [0166].
- [0244]** By employing the ink-jet recording method as above, the dot size of the landed ink can be kept uniform among various recording media with different surface wettabilities, leading to a higher image quality. In terms of color image recording, it is preferred to apply colors in increasing order of lightness. If inks different from one another in lightness are sequentially used for recording, from the lightest to darker, irradiation light will readily reach even those inks lying lower, which can realize a high curing sensitivity, reduction in residual monomers, decreased odors, and improved adhesion. While the irradiation for exposure may be carried out at a time when the inks with different colors have all been ejected, it is preferred from the viewpoint of curing acceleration to perform exposure for each color.
- 50 **[0245]** The ink composition of the present invention is thus cured with high sensitivity by the irradiation with active energy rays (UV light) so as to form an image on the surface of a recording medium.
- [0246]** The following is a description about an exemplary ink-jet recording method performed by using the ink-jet recording device as described before. In the method, the ink composition containing an oxirane compound and an oxetane compound as well as a cationic polymerization initiator, or photo acid generator, is used for ink-jet recording and ejected onto a recording medium (substrate, recording material, etc.), then the composition on the recording medium is irradiated with active energy rays so as to cure the ink and form an image.
- 55 **[0247]** In Table 1 below, the variations in film strength observed during image formation in the various ink-jet recording

devices as describe before are set forth, with the film strength being a typical property which varies as a function of the UV light source type, as well as the types of the ink composition and the initiator as used. Employing the device according to the above embodiment as an ink-jet recording device, the case where the aperture-type hot cathode fluorescent tube having a getter element of the above embodiment is used as a UV light source (Examples 1 through 9) is compared with the case where a common metal halide lamp of prior art is used (Comparative Examples 1 through 12) and the case where the hot cathode tube light source described in JP 2002-245966 A is used (Comparative Examples 13 through 24).

**[0248]** In this regard, the device using the hot cathode tube light source described in JP 2002-245966 A is such a device as using a light source lamp in which a getter is disposed on the periphery of the cathode so as to prevent the gases and impurities within the fluorescent lamp from adsorbing onto the phosphor, cathode or other portions and also prevent the light intensity distribution from being made nonuniform.

**[0249]** In Examples and Comparative Examples as referred to above, different monomers were used to prepare ink compositions, and are shown in detail in Table 2.

Table 1

Example	Ink No.	Device	Film strength upon curing at given temperatures (tape peeling test)			Film strength after using UV irradiator for 1,000 hrs.	Device cost
			10°C	25°C	40°C	Ambient temperature, 40°C	
1	1	With the hot cathode tube of the present invention	fair	fair	fair	fair	low
2	2		good	good	good	good	low
3	3		fair	fair	fair	fair	low
4	4		fair	fair	fair	fair	low
5	5		good	good	good	good	low
6	6		fair	fair	fair	fair	low
7	7		fair	fair	fair	fair	low
8	8		good	good	good	good	low
9	9		fair	fair	fair	fair	low
Comparative Example	Ink No.	Device	Film strength upon curing at given temperatures (tape peeling test)			Film strength after using UV irradiator for 1,000 hrs.	Device cost
			10°C	25°C	40°C	Ambient temperature, 40°C	
1	1	With a metal halide lamp	fair	fair	fair	fair	high
2	2		good	good	good	good	high
3	3		fair	fair	fair	fair	high

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(continued)

Comparative Example	Ink No.	Device	Film strength upon curing at given temperatures (tape peeling test)			Film strength after using UV irradiator for 1,000 hrs.	Device cost
			10°C	25°C	40°C	Ambient temperature, 40°C	
4	4		fair	fair	fair	fair	high
5	5		good	good	good	good	high
6	6		fair	fair	fair	fair	high
7	7		fair	fair	fair	fair	high
8	8		good	good	good	good	high
9	9		fair	fair	fair	fair	high
10	10		unfavorable	unfavorable	unfavorable	unfavorable	high
11	11		unfavorable	unfavorable	unfavorable	no good	high
12	12		no good	no good	no good	no good	high
13	1	with the hot cathode tube of JP 2002-245966 A	no good	fair	fair	fair	low
14	2		no good	good	good	good	low
15	3		no good	fair	fair	fair	low
16	4		no good	fair	fair	fair	low
17	5		no good	good	good	good	low
18	6		no good	fair	fair	fair	low
19	7		no good	fair	fair	fair	low
20	8		no good	good	good	good	low
21	9		no good	fair	fair	fair	low
22	10		no good	no good	unfavorable	no good	low
23	11		no good	no good	unfavorable	no good	low
24	12		no good	no good	no good	no good	low

Table 2

1. Examples										
	Ink No.	1	2	3	4	5	6	7	8	9
Pigment	Non-purified copper phthalocyanine "Copper Phthalocyanine" from Toyo Ink Mfg.	5	5	5						
	Quinacridon red pigment "CINQUASIA Magenta RT-355-D" from Ciba-Geigy				5	5	5			
	Benzimidazolone yellow pigment "Hostperm Yellow H3G" from Hoechst							5	5	5
Oxirane group-containing compound	Celoxide 3000 from Daicel Chemical Industries	57	41	17	57	41	17	57	41	17
	UVR-6105 from Union Carbide									
Oxetane group-containing compound	OXT-221 from Toagosei Co., Ltd.	15	41	30	15	41	30	15	41	30
	OXT-212 from Toagosei Co., Ltd.	10		35	10		35	10		35
Vinyl compound	DVE-3	5	5	5	5	5	5	5	5	5
Radical-polymerizable monomer	NVC									
	Phenoxyethyl acrylate									
Pigment dispersing agent	Solsperse 32000 from Zeneca	3	3	3	3	3	3	3	3	3
Cationic initiator	SP-150 (triphenyl sulfonium salt) from ADEKA Corp.	5	5	5	5	5	5	5	5	5
Radical-polymerization initiator	IRGCURE 184									
	DAROCURE TPO									

II. Comparative Examples				
	Ink No.	10	11	12
Pigment	Non-purified copper phthalocyanine "Copper Phthalocyanine" from Toyo Ink Mfg.	5	5	5
	Quinacridon red pigment "CINQUASIA Magenta RT-355-D" from Ciba-Geigy			
	Benzimidazolone yellow pigment "Hosutopamu Yellow H3G" from Hoechst			
Oxirane group-containing compound	Celoxide 3000 from Daicel Chemical Industries		82	
	UVR-6105 from Union Carbide			

(continued)

II. Comparative Examples				
	Ink No.	10	11	12
Oxetane group-containing compound	OXT-221 from Toagosei Co., Ltd.	82		
	OXT-212 from Toagosei Co., Ltd.			
Vinyl compound	DVE-3	5	5	5
Radical-polymerizable monomer	NVC			65
	Phenoxyethyl acrylate			17
Pigment dispersing agent	Solsperse 32000 from Zeneca	3	3	3
Cationic initiator	SP-150 (triphenyl sulfonium salt) from ADEKA Corp.			
Radical-polymerization initiator	IRGACURE 184	2.5	2.5	2.5
	DAROCURE TPO	2.5	2.5	2.5

**[0250]** Measurement of the film strength was carried out by tape adhesion evaluation.

**[0251]** The method for tape adhesion evaluation was as follows: A film of ink having a thickness of ca. 4 to 6  $\mu\text{m}$  was formed by ink-jet ejection of the ink, then cured on one of the devices, and the cellophane tape affixed to the image-bearing surface of a printed material was peeled off so as to determine the film strength as the adhesion of the ink film to the recording medium when the tape was peeled. Evaluation was made with respect to four colors, Y, M, C and K; only those films from which none of the four colors was transferred to the tape were assumed to be "good," those films which were not comparable to such ones indeed, but practical enough were assumed to be "fair," those films from which at least one color was transferred to the tape in the proportion of less than 10% were assumed to be "unfavorable," and those films from which at least one color was transferred to the tape in the proportion of 10% or more were assumed to be "no good."

**[0252]** As seen from Table 1, the ink films of Comparative Examples 1 to 12 formed by using a metal halide lamp had adequate strengths. The films, however, are not practical because they need quite disadvantageously to be formed by the ink-jet recording device which is upsized as a whole with increased costs.

**[0253]** The ink films of Comparative Examples 13 to 24 formed by using the hot cathode tube light source described in JP 2002-245966 A are also not practical because of their low strength.

**[0254]** When the aperture-type hot cathode fluorescent tube having a getter element of the present invention was used (Examples 1 to 9), the film strength varied significantly with the type of monomers used for the preparation of ink compositions, as shown in the table. The use of the ink composition containing an oxirane compound and an oxetane compound, which is a configuration characteristic to the present invention, has distinct effects as compared to other configurations.

**[0255]** In consequence, the present invention is definitely effective.

**[0256]** The method of preparing an ink composition is explained in reference to the preparation examples below.

**[0257]** In the following descriptions the term "part" means "part by weight" unless otherwise defined.

<Preparation of cyan pigment dispersion P-1>

**[0258]**

PB 15:3 (IRGALITE BLUE GLO from Ciba Specialty Chemicals)	30 parts by weight
Triethylene glycol divinylether (DVE-3 from BASF)	28 parts by weight
BYK 168 (from BYK-Chemie)	42 parts by weight

**[0259]** The above components were mixed together and agitated with a stirrer for one hour. The mixture thus agitated was subjected to dispersion in Eiger mill to obtain cyan pigment dispersion P-1.

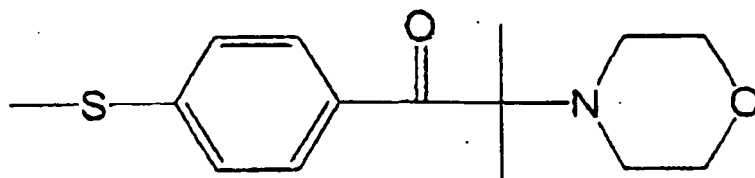
**[0260]** Dispersion was performed using zirconia beads of 0.65 mm in diameter, which were charged at a charging ratio of 70%, at a peripheral speed of 9 m/s for one hour.

## &lt;Preparation of cyan ink composition C-1&gt;

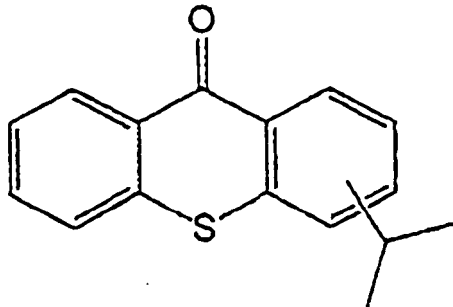
**[0261]** The components as below were mixed together at indicated ratios with agitation to obtain a solution as cyan ink composition C-1. The surface tension of cyan ink composition C-1 was 27 mN/m.

Cyan pigment dispersion P-1 as above	0.75 parts by weight
Dipropylene glycol diacrylate (polymerizable compound) (DPGDA from DAICEL-CYTEC Co., Ltd.)	11.25 parts by weight
Polymerization initiator Irg 907 as below (from Ciba Specialty Chemicals)	1.5 parts by weight
Sensitizer DAROCURE ITX as below (from Ciba Specialty Chemicals)	0.75 parts by weight
Co-sensitizer DAROCURE EDB as below (from Ciba Specialty Chemicals)	0.75 parts by weight

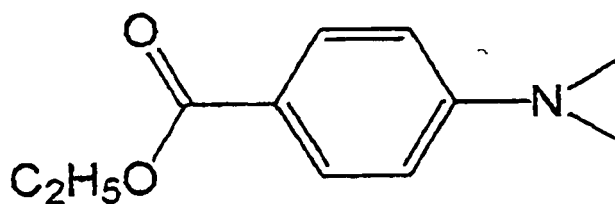
Irg907



DAROCURE ITX



DAROCURE EDB



## EP 2 106 918 B1

<Preparation of magenta pigment dispersion P-2, yellow pigment dispersion P-3, and black pigment dispersion P-4>

**[0262]** Magenta pigment dispersion P-2 was prepared following the procedure for P-1 except for the use of pigment PV 19 (CINQUANSIA MAGENTA RT-355 D from Ciba Specialty Chemicals) instead of PB 15:3 (IRGALITE BLUE GLO from Ciba Specialty Chemicals).

**[0263]** Yellow pigment dispersion P-3 was prepared following the procedure for P-1 except for the use of pigment PY 120 (NOVOPERM YELLOW H2G from Clariant) instead of PB 15:3 (IRGALITE BLUE GLO from Ciba Specialty Chemicals).

**[0264]** Black pigment dispersion P-4 was prepared following the procedure for P-1 except for the use of carbon black (SPECIAL BLACK 250 from Degussa) instead of PB 15:3 (IRGALITE BLUE GLO from Ciba Specialty Chemicals) and the change of the dispersant into Solsperse 5000 (Zeneca).

<Preparation of magenta ink, yellow ink, and black ink>

[Preparation of magenta ink composition M-1]

**[0265]** The components as below were mixed together at indicated ratios with agitation to obtain a solution as magenta ink composition M-1. The surface tension of magenta ink composition M-1 was 27 mN/m.

Magenta pigment dispersion P-2 as above	1.95 parts by weight
Dipropylene glycol diacrylate (polymerizable compound) (DPGDA from DAICEL-CYTEC Co., Ltd.)	10.05 parts by weight
Polymerization initiator Irg 907 as above (from Ciba Specialty Chemicals)	1.5 parts by weight
Sensitizer DAROCURE ITX as above (from Ciba Specialty Chemicals)	0.75 parts by weight
Co-sensitizer DAROCURE EDB as above (from Ciba Specialty Chemicals)	0.75 parts by weight

<Preparation of yellow ink composition Y-1>

**[0266]** The components as below were mixed together at indicated ratios with agitation to obtain a solution as yellow ink composition Y-1. The surface tension of yellow ink composition Y-1 was 27 mN/m.

Yellow pigment dispersion P-3 as above	1.95 parts by weight
Dipropylene glycol diacrylate (polymerizable compound) (DPGDA from DAICEL-CYTEC Co., Ltd.)	10.05 parts by weight
Polymerization initiator Irg 907 as above (from Ciba Specialty Chemicals)	1.5 parts by weight
Sensitizer DAROCURE ITX as above (from Ciba Specialty Chemicals)	0.75 parts by weight
Co-sensitizer DAROCURE EDB as above (from Ciba Specialty Chemicals)	0.75 parts by weight

<Preparation of black ink composition K-1>

**[0267]** The components as below were mixed together at indicated ratios with agitation to obtain a solution as black ink composition K-1. The surface tension of black ink composition K-1 was 27 mN/m.

Black pigment dispersion P-4 as above	0.75 parts by weight
Dipropylene glycol diacrylate (polymerizable compound) (DPGDA from DAICEL-CYTEC Co., Ltd.)	11.25 parts by weight
Polymerization initiator Irg 907 as above (from Ciba Specialty Chemicals)	1.5 parts by weight



(continued)

	Sensitizer DAROCURE ITX as above	0.75 parts by weight
	(from Ciba Specialty Chemicals)	
5	Co-sensitizer DAROCURE EDB as above	0.75 parts by weight
	(from Ciba Specialty Chemicals)	

[0268] The foregoing embodiments are merely illustrative of the invention and are by no means intended to limit the invention. It should be understood that various improvements and modifications may of course be made without departing from the scope of the invention defined by the claims.

## Claims

1. An ultraviolet light-curable ink-jet recording method, comprising the steps of:

ejecting an ink composition curable by exposure to UV light onto a recording medium (P) transported by a transport unit (30, 32, 34, 36) from an ink-jet head (48X, 48Y, 48M, 48C) to form an image; and irradiating the ink composition ejected onto said recording medium (P) with the UV light generated by a light source (80) for generating the UV light to cure the ink composition, said ink composition contains an oxirane compound, an oxetane compound and a photo cationic polymerization initiator **characterized in that** said light source (80) is an aperture-type hot cathode fluorescent tube having a getter element (89) therein,

2. The ink-jet recording method according to claim 1, wherein said aperture-type hot cathode fluorescent tube (80) includes:

a bulb (86);  
a reflective film (91) formed on a large part of an inner wall of said bulb (86) and having a first aperture (94) formed on a side of said recording medium (P); and  
a phosphor film (92) formed on said reflective film (91) and optionally a part of said inner wall of said bulb (86) and having a second aperture (96) formed on the side of said recording medium (P), and wherein a formula  $30^\circ \leq A \leq 90^\circ$  where A represents an aperture angle of one of said first aperture (94) for said reflective film (91) and said second aperture (96) for said phosphor film (92) which is smaller than the other, is satisfied.

3. The ink-jet recording method according to claim 1 or 2, further comprising:

cooling said getter element (89) disposed in the vicinity of at least one electrode (88) within said bulb (86) of said hot cathode fluorescent tube (80) from outside said bulb (86) by means of a cooling mechanism (84).

4. The ink-jet recording method according to claim 3, wherein said cooling mechanism is of an air cooling system using fans (89).

5. The ink-jet recording method according to claim 3, wherein said cooling mechanism is of a heat pipe system (95).

6. The ink-jet recording method according to claim 3, wherein said cooling mechanism is of a combined system of an air cooling system using fans (84) with a heat pipe system (95).

7. The ink-jet recording method according to any one of claims 1 to 6, wherein the ink composition contains an oxirane compound and an oxetane compound at a content ratio of the oxirane compound to the oxetane compound of 90/10 to 10/90.

8. The ink-jet recording method according to claim 7, wherein the ink composition contains an oxirane compound and an oxetane compound at a content ratio of the oxirane compound to the oxetane compound of 70/30 to 30/70.

9. An ultraviolet light-curable ink-jet recording device (10) comprising:

an ink composition curable by exposure to UV light,  
a transport unit (30, 32, 34, 36) which transports a recording medium (P);  
an ink-jet head (48X, 48Y, 48M, 48C) which is adapted to eject the ink composition onto said recording medium  
(P) transported by said transport unit (30, 32, 34, 36) to form an image; and  
an UV irradiation unit (52, 54) which has a light source (80) for generating the UV light and is adapted to irradiate  
the ink composition ejected onto said recording medium (P) with the UV light generated by said light source  
(80) to cure the ink composition,  
said ink composition contains an oxirane compound, an oxetane compound and a photocationic polymerization  
initiator **characterized in that** said light source (80) in said UV irradiation unit (52, 54) is an aperture-type hot  
cathode fluorescent tube having a getter element (89) therein,

10. The ink-jet recording device according to claim 9, wherein said aperture-type hot cathode fluorescent tube (80) includes:

a bulb (86);  
a reflective film (91) formed on a large part of an inner wall of said bulb (86) and having a first aperture (94) formed on a side of said recording medium (P); and  
a phosphor film (92) formed on said reflective film (91) and optionally a part of said inner wall of said bulb (86) and having a second aperture (96) formed on the side of said recording medium (P), and wherein  
a formula  $30^\circ \leq A \leq 90^\circ$  where A represents an aperture angle of one of said first aperture (94) for said reflective film (91) and said second aperture (96) for said phosphor film (92) which is smaller than the other, is satisfied.

11. The ink-jet recording device according to claim 9 or 10, wherein said UV irradiation unit (52, 54) further comprises:

a cooling mechanism (84) for cooling said getter element (89) disposed in the vicinity of at least one electrode (88) within said bulb (86) of said hot cathode fluorescent tube (80) from outside said bulb (86).

12. The ink-jet recording device according to claim 11, wherein said cooling mechanism is of an air cooling system using fans (84).

13. The ink-jet recording device according to claim 11, wherein said cooling mechanism is of a heat pipe system (95).

14. The ink-jet recording device according to claim 11, wherein said cooling mechanism is of a combined system of an air cooling system using fans (84) with a heat pipe system (95).

15. The ink-jet recording device according to any one of claims 9 to 14, wherein the ink composition contains an oxirane compound and an oxetane compound at a content ratio of the oxirane compound to the oxetane compound of 90/10 to 10/90.

## Patentansprüche

1. Mit unter Ultraviolettlicht aushärtbarer Tinte arbeitendes Tintenstrahl-Aufzeichnungsverfahren, umfassend folgende Schritte:

Ausstoßen einer durch Belichtung mit UV-Licht aushärtbaren Tintenzusammensetzung auf einen Aufzeichnungsträger (P), der von einer Transporteinheit (30, 32, 34, 36) transportiert wird, aus einem Tintenstrahlkopf (48X, 48Y, 48M, 48C), um ein Bild zu erzeugen; und  
Bestrahlen der auf den Aufzeichnungsträger (P) ausgestoßenen Tintenzusammensetzung mit von einer Lichtquelle (80) zum Erzeugen von UV-Licht erzeugten UV-Licht, um die Tintenzusammensetzung auszuhärten, wobei die Tintenzusammensetzung eine Ethylenoxidverbindung, eine Oxetanverbindung und einen photo-kationischen Polymerisationsinitiator enthält,  
**dadurch gekennzeichnet, dass** die Lichtquelle (80) eine Aperturtyp-Glühkathoden-Fluoreszenzröhre mit einem darin befindlichen Getterelement (39) ist.

2. Verfahren nach Anspruch 1, bei dem die Aperturtyp-Glühkathoden-Fluoreszenzröhre (80) enthält:

einen Kolben (86);

einen reflektierenden Film (91), der auf einem großen Teil einer Innenwand des Kolbens (86) ausgebildet ist und eine erste an einer Seite des Aufzeichnungsträgers (P) gebildete Apertur (94) besitzt; und einen Leuchtstofffilm (92), der auf dem reflektierenden Film (91) und optional einen Teil der Innenwand des Kolbens (86) ausgebildet ist und eine zweite Apertur (96) besitzt, die an der Seite des Aufzeichnungsträgers (P) gebildet ist, und wobei eine Formel  $30^\circ \leq A \leq 90^\circ$  mit (A) als Aperturwinkel von einer von der ersten Apertur (94) für den reflektierenden Film (91) und der zweiten Apertur (96) für den Leuchtstofffilm (92), der kleiner ist als der andere, erfüllt ist.

3. Verfahren nach Anspruch 1 oder 2, weiterhin umfassend:

Abkühlen des Getterelements (89) in der Nähe von mindestens einer Elektrode (88) innerhalb des Kolbens (86) der Glühkathoden-Fluoreszenzröhre (80) von außerhalb des Kolbens (86) mittels eines Kühlmechanismus' (84).

4. Verfahren nach Anspruch 3, bei dem der Kühlmechanismus ein Luftkühlssystem unter Verwendung von Gebläsen (84) ist.

5. Verfahren nach Anspruch 3, bei dem der Kühlmechanismus ein Wärmerohr-System (95) ist.

6. Verfahren nach Anspruch 3, bei dem der Kühlmechanismus ein kombiniertes System aus einem Luftkühlssystem mit Lüftern (84) und einem Wärmerohr-System (95) ist.

7. Verfahren nach einem der Ansprüche 1 bis 6, bei der die Tintenzusammensetzung eine Ethylenoxidverbindung und eine Oxetanverbindung in einem Anteilsverhältnis der Ethylenoxidverbindung zu der Oxetanverbindung von 90/10 zu 10/90 enthält.

8. Verfahren nach Anspruch 7, bei dem die Tintenzusammensetzung eine Ethylenoxidverbindung und eine Oxetanverbindung in einem Anteilsverhältnis der Ethylenoxidverbindung zu der Oxetanverbindung von 70/30 zu 30/70 enthält.

9. Tintenstrahl-Aufzeichnungsvorrichtung (10) unter Verwendung von unter Ultraviolettlicht aushärtbarer Tinte, umfassend:

eine Tintenzusammensetzung, die durch Belichtung mit UV-Licht aushärtbar ist, eine Transporteinheit (30, 32, 34, 36), die einen Aufzeichnungsträger (P) transportiert; einen Tintenstrahlkopf (48X, 48Y, 48M, 48C), der ausgebildet ist zum Ausstoßen der Tintenzusammensetzung auf den von der Transporteinheit (30, 32, 34, 36) transportierten Aufzeichnungsträger (P), um ein Bild zu erzeugen; und eine UV-Bestrahlungseinheit (52, 54), die eine Lichtquelle (80) zum Erzeugen des UV-Lichts aufweist und ausgebildet ist zum Bestrahlen der auf den Aufzeichnungsträger (P) ausgestoßenen Tintenzusammensetzung mit dem von der Lichtquelle (80) erzeugten UV-Licht, um die Tintenzusammensetzung auszuhärten, wobei die Tintenzusammensetzung eine Ethylenoxidverbindung, eine Oxetanverbindung und einen photokationischen Polymerisationsinitiator enthält, **dadurch gekennzeichnet, dass** die Lichtquelle (80) in der UV-Bestrahlungseinheit (52, 54) eine Aperturtyp-Glühkathoden-Fluoreszenzröhre mit einem darin befindlichen Getterelement (89) ist.

10. Vorrichtung nach Anspruch 9, bei der die Aperturtyp-Glühkathoden-Fluoreszenzröhre (80) enthält:

einen Kolben (86); einen reflektierenden Film (91), der auf einem großen Teil einer Innenwand des Kolbens (86) ausgebildet ist und eine erste an einer Seite des Aufzeichnungsträgers (P) gebildete Apertur (94) besitzt; und einen Leuchtstofffilm (92), der auf dem reflektierenden Film (91) und optional einen Teil der Innenwand des Kolbens (86) ausgebildet ist und eine zweite Apertur (96) besitzt, die an der Seite des Aufzeichnungsträgers (P) gebildet ist, und wobei eine Formel  $30^\circ \leq A \leq 90^\circ$  mit (A) als Aperturwinkel von einer von der ersten Apertur (94) für den reflektierenden Film (91) und der zweiten Apertur (96) für den Leuchtstofffilm (92), der kleiner ist als der andere, erfüllt ist.

11. Vorrichtung nach Anspruch 9 oder 10, bei der die UV-Bestrahlungseinheit (52, 54) weiterhin aufweist:

einen Kühlmechanismus (84) zum Kühlen des Getterelements (89), angeordnet in der Nähe von zumindest einer Elektrode (88) innerhalb des Kolbens (86) der Heißkathoden-Fluoreszenzröhre (80) von außerhalb des Kolbens (86).

12. Vorrichtung nach Anspruch 11, bei der der Kühlmechanismus ein Luftkühlsystem unter Verwendung von Gebläsen (84) ist.

13. Vorrichtung nach Anspruch 11, der Kühlmechanismus ein Wärmerohr-System (95) ist.

14. Vorrichtung nach Anspruch 11, bei dem der Kühlmechanismus ein kombiniertes System aus einem Luftkühlsystem mit Lüftern (84) und einem Wärmerohr-System (95) ist.

15. Vorrichtung nach einem der Ansprüche 9 bis 14, bei der die Tintenzusammensetzung eine Ethylenoxidverbindung und eine Oxetanverbindung in einem Anteilsverhältnis der Ethylenoxidverbindung zu der Oxetanverbindung von 90/10 zu 10/90 enthält.

## Revendications

1. Procédé d'enregistrement à jet d'encre durcissable à la lumière ultraviolette, comprenant les étapes consistant à :

éjecter une composition d'encre durcissable par l'exposition à la lumière UV sur un support d'enregistrement (P) transporté par une unité de transport (30, 32, 34, 36) à partir d'une tête de jet d'encre (48X, 48Y, 48M, 48C) afin de former une image ; et

irradier la composition d'encre éjectée sur ledit support d'enregistrement (P) avec la lumière UV générée par une source de lumière (80) pour générer la lumière UV afin de faire durcir la composition d'encre,

ladite composition d'encre contient un composé d'oxiranne, un composé d'oxétanne et un initiateur de polymérisation photocationique,

**caractérisé en ce que** ladite source de lumière (80) est un tube fluorescent à cathode chaude de type à ouverture ayant un élément de getter (89) à l'intérieur de ce dernier.

2. Procédé d'enregistrement à jet d'encre selon la revendication 1, dans lequel ledit tube fluorescent à cathode chaude de type à ouverture (80) comprend :

une ampoule (86) ;

un film réfléchissant (91) formé sur une grande partie d'une paroi interne de ladite ampoule (86) et ayant une première ouverture (94) formée sur un côté dudit support d'enregistrement (P) ; et

un film phosphorescent (92) formé sur ledit film réfléchissant (91) et facultativement une partie de ladite paroi interne de ladite ampoule (86) et ayant une deuxième ouverture (96) formée sur le côté dudit support d'enregistrement (P), et dans lequel :

une formule  $30^\circ \leq A \leq 90^\circ$  dans laquelle A représente un angle d'ouverture de l'une parmi ladite première ouverture (94) pour ledit film réfléchissant (91) et ladite deuxième ouverture (96) pour ledit film phosphorescent (92) qui est inférieur à l'autre, est satisfaite.

3. Procédé d'enregistrement à jet d'encre selon la revendication 1 ou 2, comprenant en outre l'étape consistant à :

laisser refroidir ledit élément de getter (89) disposé à proximité d'au moins une électrode (88) à l'intérieur de ladite ampoule (86) dudit tube fluorescent à cathode chaude (80) depuis l'extérieur de ladite ampoule (86) au moyen d'un mécanisme de refroidissement (84).

4. Procédé d'enregistrement à jet d'encre selon la revendication 3, dans lequel ledit mécanisme de refroidissement est réalisé avec un système de refroidissement par air utilisant des ventilateurs (84).

5. Procédé d'enregistrement à jet d'encre selon la revendication 3, dans lequel ledit mécanisme de refroidissement est réalisé avec un système de caloduc (95).

6. Procédé d'enregistrement à jet d'encre selon la revendication 3, dans lequel ledit mécanisme de refroidissement est réalisé avec un système combiné composé d'un système de refroidissement par air utilisant des ventilateurs (84) avec un système de caloduc (95).
- 5 7. Procédé d'enregistrement selon l'une quelconque des revendications 1 à 6, dans lequel la composition d'encre contient un composé d'oxiranne et un composé d'oxétanne à rapport de teneur du composé d'oxiranne sur le composé d'oxétanne de 90/10 à 10/90.
- 10 8. Procédé d'enregistrement à jet d'encre selon la revendication 7, dans lequel la composition d'encre contient un composé d'oxiranne et un composé d'oxétanne à rapport de teneur du composé d'oxiranne sur le composé d'oxétanne de 70/30 à 30/70.
9. Dispositif d'enregistrement à jet d'encre durcissable à la lumière ultraviolet (10) comprenant :  
15 une composition d'encre durcissable par l'exposition à la lumière UV,  
une unité de transport (30, 32, 34, 36) qui transporte un support d'enregistrement (P) ;  
une tête de jet d'encre (48X, 48Y, 48M, 48C) qui est adaptée pour éjecter la composition d'encre sur ledit support d'enregistrement (P) transporté par ladite unité de transport (30, 32, 34, 36) afin de former une image ; et  
20 une unité d'irradiation UV (52, 54) qui a une source de lumière (80) pour générer la lumière UV et est adaptée pour irradier la composition d'encre éjectée sur ledit support d'enregistrement (P) avec la lumière UV générée par ladite source de lumière (80) pour faire durcir la composition d'encre,  
ladite composition d'encre contient un composé d'oxiranne, un composé d'oxétanne et un initiateur de polymérisation photocationique,  
25 **caractérisé en ce que** ladite source de lumière (80) dans ladite unité d'irradiation UV (52, 54) est un tube fluorescent à cathode chaude de type à ouverture ayant un élément de getter (89) à l'intérieur de ce dernier.
10. Dispositif d'enregistrement à jet d'encre selon la revendication 9, dans lequel ledit tube fluorescent à cathode chaude de type à ouverture (80) comprend :  
30 une ampoule (86) ;  
un film réfléchissant (91) formé sur une grande partie d'une paroi interne de ladite ampoule (86) et ayant une première ouverture (94) formée sur un côté dudit support d'enregistrement (P) ; et  
un fil phosphorescent (92) formé sur ledit film réfléchissant (91) et facultativement une partie de ladite paroi interne de ladite ampoule (86) et ayant une deuxième ouverture (96) formée sur le côté dudit support d'enregistrement (P), et dans lequel :  
35 une formule  $30^\circ \leq A \leq 90^\circ$ , dans laquelle A représente un angle d'ouverture de l'une parmi ladite première ouverture (94) pour ledit film réfléchissant (91) et ladite deuxième ouverture (96) pour ledit film phosphorescent (92) qui est inférieur à l'autre, est satisfaite.  
40
11. Dispositif d'enregistrement à jet d'encre selon la revendication 9 ou 10, dans lequel ladite unité d'irradiation UV (52, 54) comprend en outre :  
45 un mécanisme de refroidissement (84) pour refroidir ledit élément de getter (89) disposé à proximité d'au moins une électrode (88) à l'intérieur de ladite ampoule (86) dudit tube fluorescent à cathode chaude (80) depuis l'extérieur de ladite ampoule (86).
12. Dispositif d'enregistrement à jet d'encre selon la revendication 11, dans lequel ledit mécanisme de refroidissement est réalisé avec un système de refroidissement par air utilisant des ventilateurs (84).  
50
13. Dispositif d'enregistrement à jet d'encre selon la revendication 11, dans lequel ledit mécanisme de refroidissement est réalisé avec un système de caloduc (95).
14. Dispositif d'enregistrement à jet d'encre selon la revendication 11, dans lequel ledit mécanisme de refroidissement est réalisé avec un système combiné composé d'un système de refroidissement par air utilisant des ventilateurs (84) avec un système de caloduc (95).  
55
15. Dispositif d'enregistrement à jet d'encre selon l'une quelconque des revendications 9 à 14, dans lequel la composition

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d'encre contient un composé d'oxiranne et un composé d'oxétanne à un rapport de teneur du composé d'oxiranne sur le composé d'oxétanne de 90/10 à 10/90.

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FIG. 1

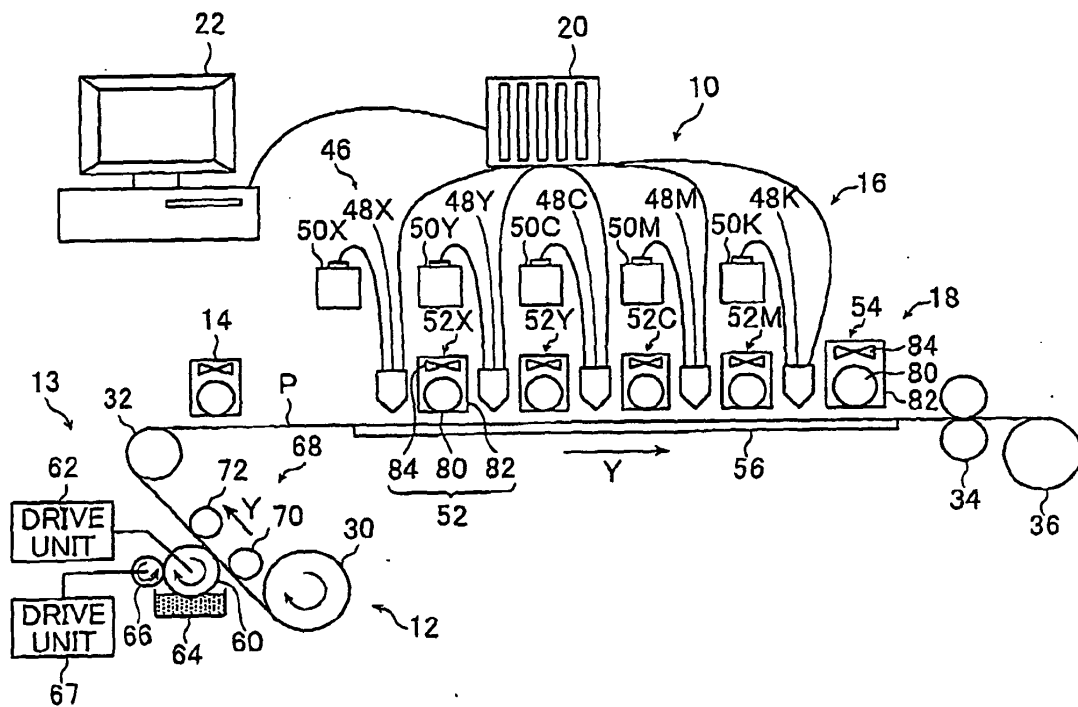


FIG. 2A

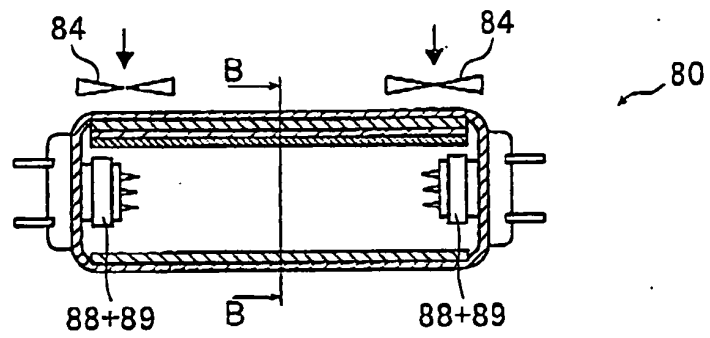


FIG. 2B

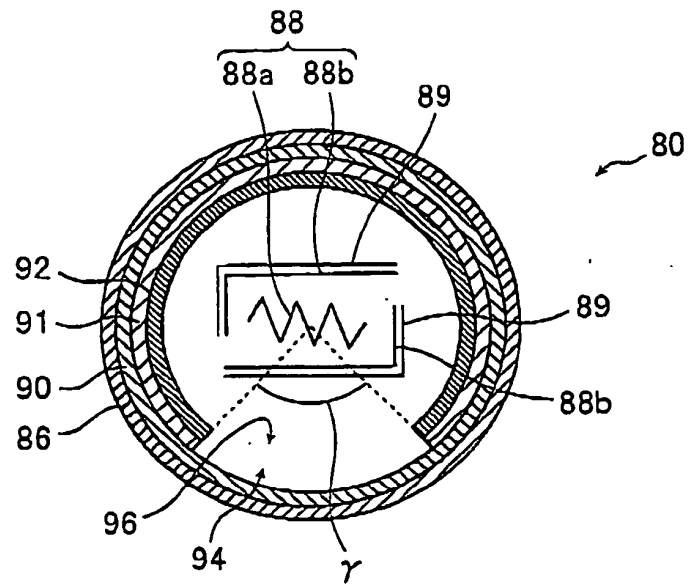


FIG. 2C

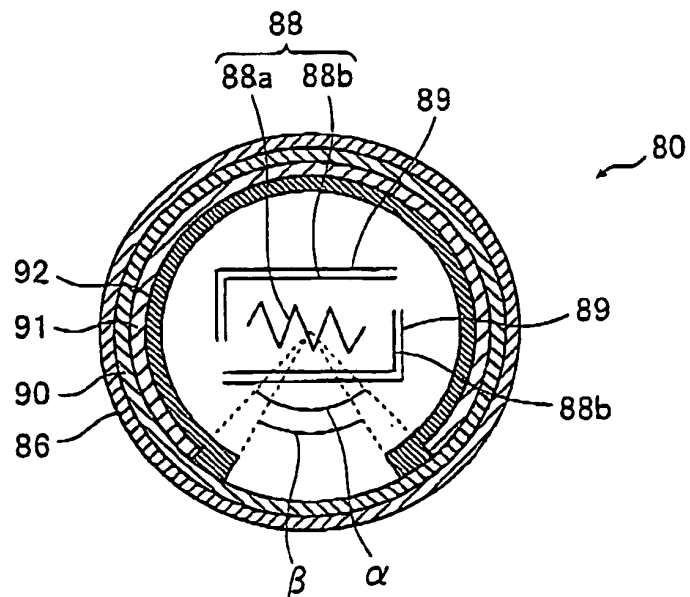




FIG. 3

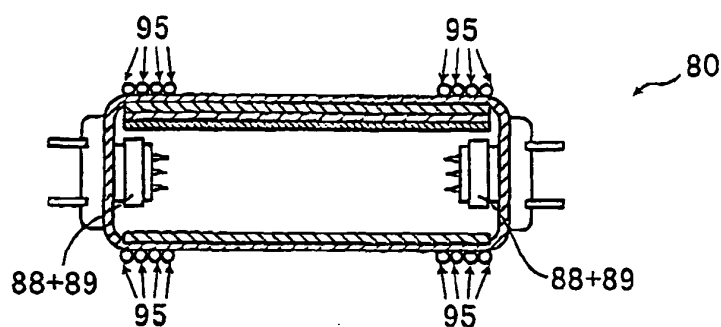


FIG. 4

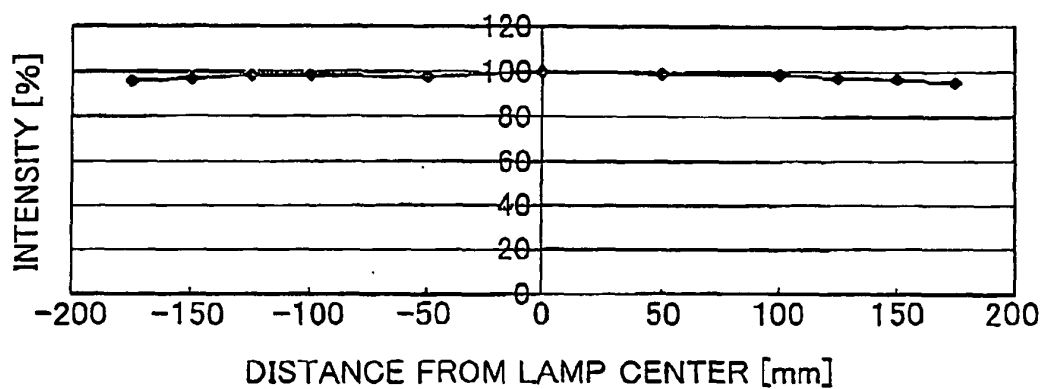


FIG. 5

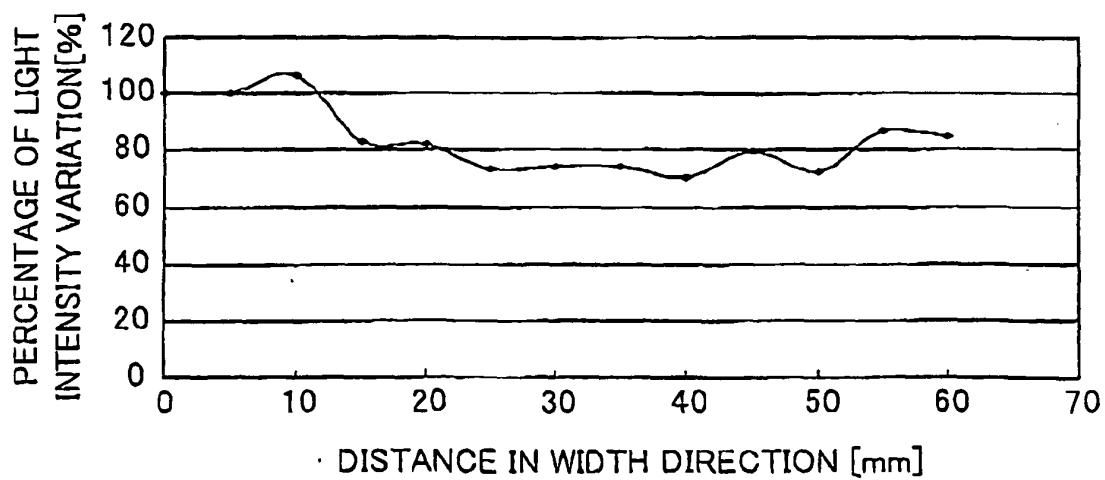


FIG. 6

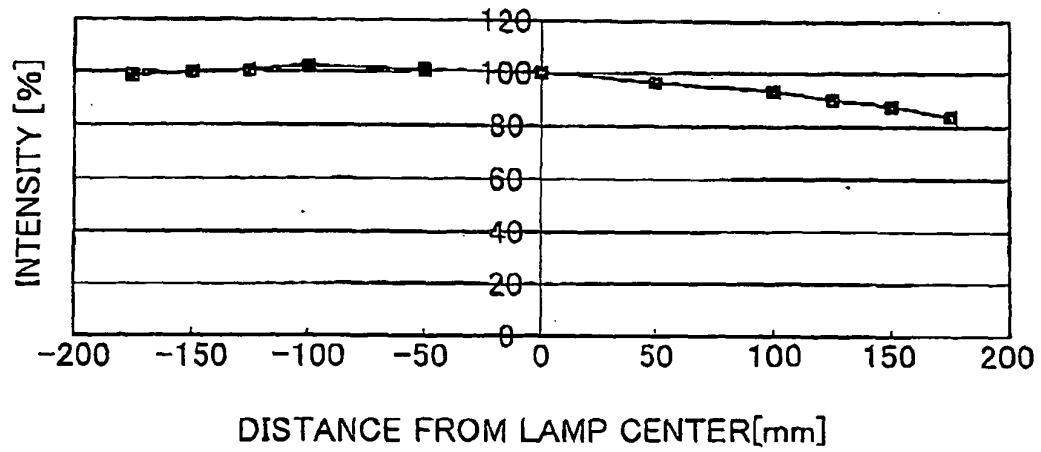


FIG. 7

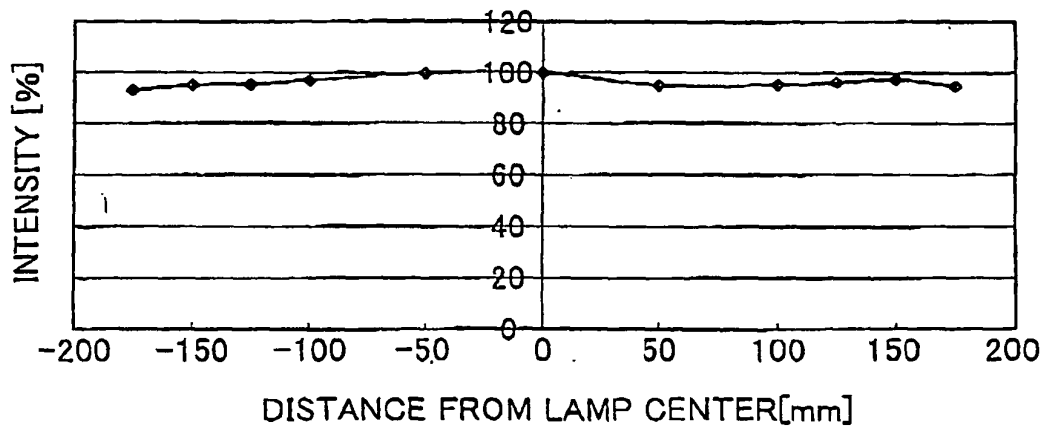


FIG. 8

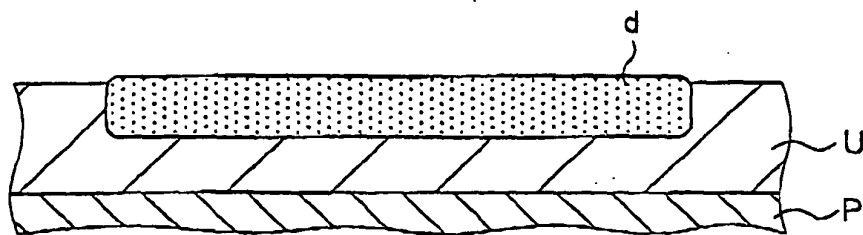


FIG. 9A

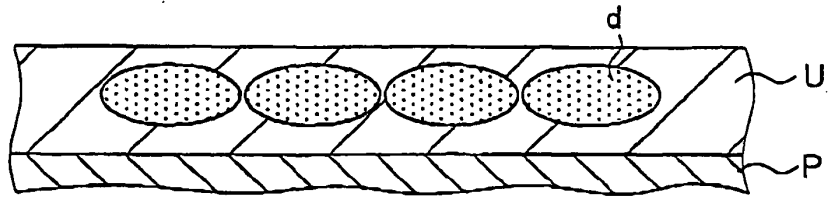


FIG. 9B

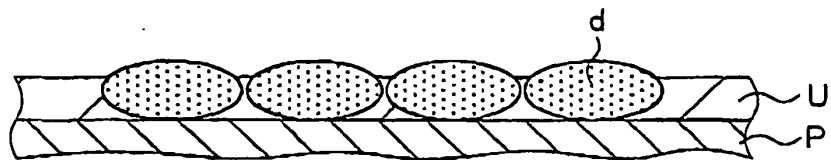


FIG. 9C

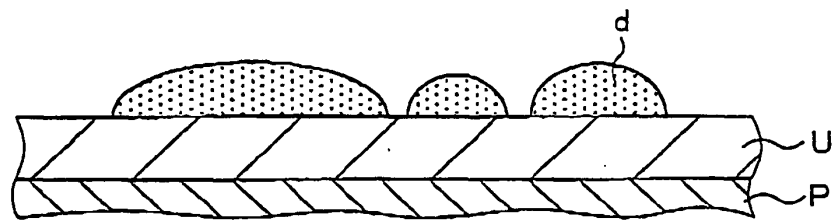


FIG. 10

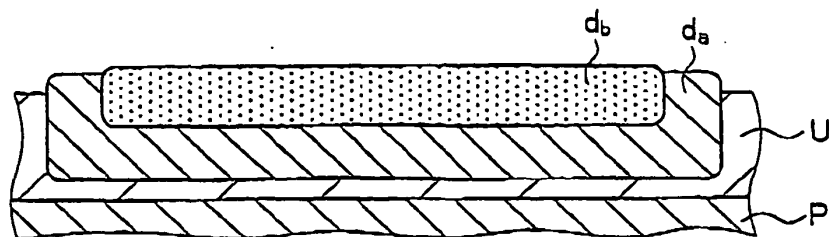


FIG. 11A

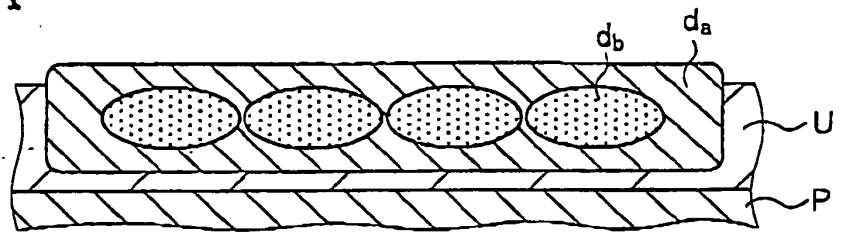


FIG. 11B

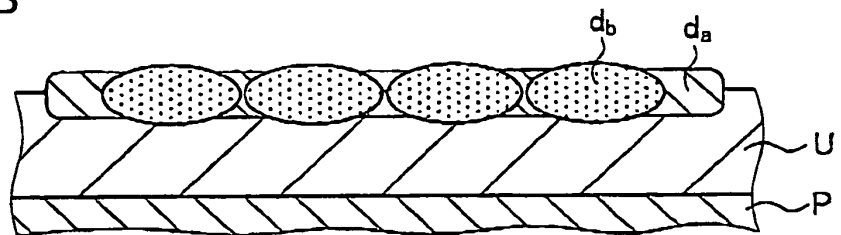


FIG. 11C

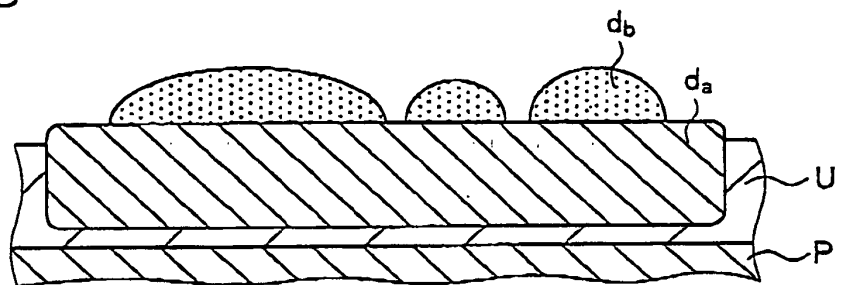


FIG. 12A

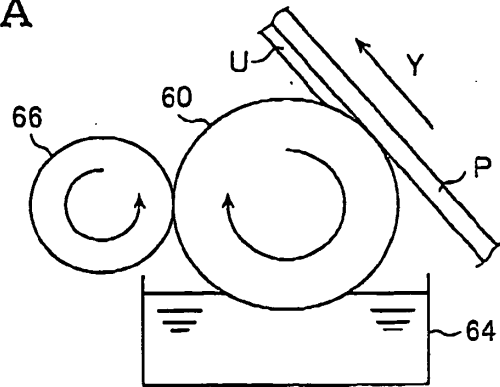


FIG. 12B

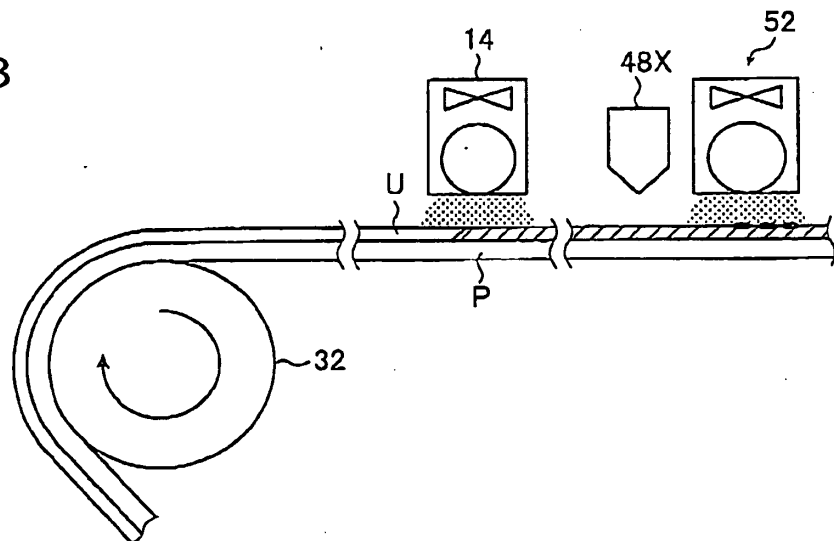


FIG. 12C

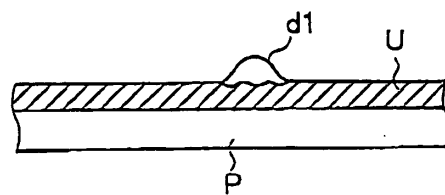
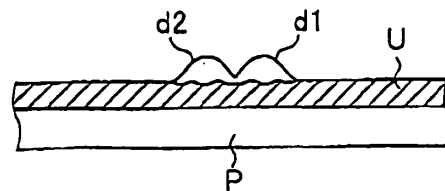


FIG. 12D



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