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- **Egawa, Go**
Tokyo 143-8555 (JP)
- **Umayahara, Tatsushi**
Tokyo 143-8555 (JP)
- **Suzuki, Sakae**
Tokyo 143-8555 (JP)
- **Takagi, Kifuku**
Tokyo 143-8555 (JP)
- **Hosokawa, Kenji**
Tokyo 143-8555 (JP)

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(71) Applicant: **Ricoh Company**
Tokyo 143-8555 (JP)

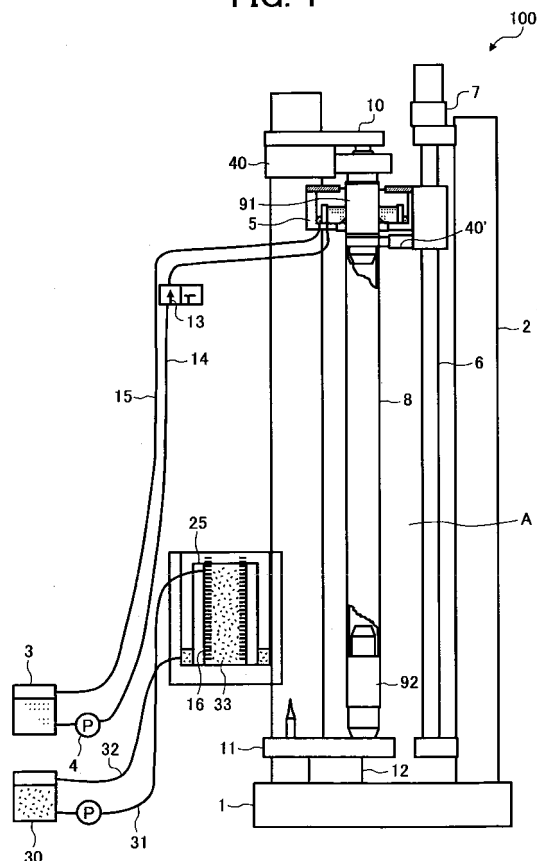
(72) Inventors:
• **Iiyama, Akihiro**
Tokyo 143-8555 (JP)
• **Yamaguchi, Yoshihiro**
Tokyo 143-8555 (JP)

(74) Representative: **Barz, Peter**
Patentanwalt
Kaiserplatz 2
80803 München (DE)

(54) **Method and device for applying an electrophotographic photoreceptor layer onto a substrate**

(57) A method and device for coating a coating liquid (17) on a cylindrical substrate (8) with a washing liquid (33) contained in the washing device, wherein the coating liquid is circulated between the coating head and a coating liquid tank (3), and wherein the washing liquid is circulated between the washing device and a washing liquid tank (30) at a flow rate of from 0.1 to 10 liter/min.

FIG. 1



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Description**BACKGROUND OF THE INVENTION****Field of the Invention**

[0001] The present invention relates to a method for preparing an electrophotographic photoreceptor. More particularly, the present invention relates to a method for preparing a cylindrical electrophotographic photoreceptor in which a peripheral surface of a cylindrical substrate is coated with a coating liquid by moving a coating head relative to the substrate. In addition, the present invention also relates to a coating device for use in the method.

Discussion of the Background

[0002] Electrophotographic photoreceptors are typically prepared by coating a photosensitive material on a peripheral surface of a cylindrical substrate. When such photoreceptors are mass-produced, a dip coating method in which an electroconductive substrate is dipped into a coating liquid vessel containing a photosensitive layer coating liquid and then pulled up is typically used. In this case, the substrate is moved relative to the coating liquid vessel.

[0003] However, the dip coating method has the following drawbacks:

- (1) Since a cylindrical substrate to be coated has to be dipped into a coating liquid vessel so that the entire peripheral surface of the substrate is dipped into the coating liquid vessel, the coating device becomes large in size and a large amount of coating liquid is needed;
- (2) Since the dipping time of the lower portion of a substrate is longer than that of the upper portion thereof, the layer previously formed on the substrate tends to be dissolved by the photosensitive layer coating liquid if the coating liquid includes a solvent dissolving the previously formed layer.

[0004] In attempting to miniaturize the coating device and reduce the amount of the coating liquid used, a so-called ring coating method in which a coating head containing a coating liquid is moved along the cylindrical substrate to be coated to reduce the dipping time and uniformize the dipping time for the upper and lower portions of the substrate is used.

[0005] In such a ring coating method, a sealing member is typically provided between the coating liquid vessel in the coating head and the cylindrical substrate to prevent leakage of the coating liquid from the coating liquid vessel. Therefore, when the coating operation is not performed (i.e., the coating device is in a waiting state), a substrate supporting member, which is configured to hold the cylindrical substrate during coating is performed, is arranged in the coating vessel to prevent leakage of the coating liquid. When coating operation is started, the substrate supporting member is coated with the coating liquid, thereby causing a problem in that a coating liquid residue (i.e., a dried or semi-dried coating liquid) inevitably adheres on the substrate supporting member when coating is continuously performed.

[0006] Recently, a need exists for high speed and high quality electrophotographic full color image formation. Therefore, the photoreceptor used therefor is required to have a photosensitive layer with a uniform thickness. In attempting to form such a uniform photosensitive layer, published unexamined Japanese patent application No. (hereinafter referred to as JP-A) 05-297606 discloses a method in which the thickness of the coated layer is uniformized by controlling the supply amount of the coating liquid. In addition, JP-A 10-80656 discloses a method in which the coated liquid is uniformly scraped. However, the former method has a drawback in that the thickness of the layer varies when the pump used for feeding the coating liquid causes pulsation. The latter method has a drawback in that the gap between the scraper and the surface of the substrate easily varies, resulting in variation of the layer thickness. In addition, these methods have a drawback in that the coating devices have a complex mechanism and therefore the devices become large in size.

[0007] By using the coating methods disclosed by JP-As 2004-184722 and 2004-279918, the uneven layer thickness problem can be solved. However, the coating methods have a drawback in that a coating liquid residue which includes the resin and the filler in the coating liquid is adhered to the substrate supporting member. When such a coating liquid residue is adhered to the surface of the resultant photoreceptor, a coating defect is caused. Such a coating defect causes a fatal image defect. In attempting to avoid the problem, JP-A 2004-279918 proposes to use a washing liquid vessel in which the substrate supporting member is washed. However, the coating defect problem caused by adhesion of coating liquid residues to the photoreceptor cannot be fully solved only by performing such a washing operation. In addition, it is also proposed to replace the substrate supporting member with a spare thereof. However, it takes too long to perform such a replacing operation, resulting in decrease in productivity.

[0008] When the ring coating method mentioned above is used, it is necessary to stop the supply of the coating liquid or to lower the surface of the coating liquid in the coating liquid vessel in order to prevent leakage of the coating liquid

from the coating vessel. Even in this case, a small amount of the coating liquid remaining in the coating liquid vessel is solidified, thereby forming coating liquid residues. In addition, when the coating liquid includes a filler, a problem in that the filler precipitates in the coating liquid vessel, resulting in formation of residues. These residues cause coating defects, resulting in formation of image defects.

[0009] Because of these reasons, a need exists for a coating method by which a layer (such as photosensitive layers) having good film properties (such as uniform thickness) can be formed with hardly causing coating defects.

SUMMARY OF THE INVENTION

[0010] Accordingly, an object of the present invention is to provide a coating method which solves the above-mentioned problems and by which a layer having good film properties can be formed with hardly causing the coating defects caused by coating liquid residues.

[0011] Another object of the present invention is to provide a coating device which can form a layer having good film properties with hardly causing the coating defects caused by coating liquid residues.

[0012] Briefly these objects and other objects of the present invention as hereinafter will become more readily apparent can be attained by a method for coating a coating liquid on a cylindrical substrate, including:

inserting first and second substrate supporting members into upper and lower ends of the cylindrical substrate, respectively, to support the substrate while contacting the coating liquid in a coating liquid vessel of a coating head with the first substrate supporting member;
moving the coating head downward relative to the substrate while contacting the coating liquid with the peripheral surface of the substrate to coat the coating liquid thereon;
removing the first substrate supporting member from the upper end of the substrate after the surface of the coating liquid reaches the second substrate supporting member;
removing the substrate bearing a coating layer thereon from the second substrate supporting member; and
upwardly moving the second substrate supporting member together with the coating head to insert the second substrate supporting member into an upper end of next one of the substrate while transporting the first substrate supporting member to a washing device to wash the first substrate supporting member with a washing liquid contained in the washing device,

wherein the coating liquid is circulated between the coating head and a coating liquid tank, and wherein the washing liquid is circulated between the washing device and a washing liquid tank at a flow rate of from 0.1 to 10 liter/min.

[0013] The washing liquid is preferably replaced with a fresh washing liquid at a frequency not less than 3 times per a 1 hour coating operation.

[0014] The washing device preferably has a washing element configured to wash the surface of the first substrate supporting member while contacting the surface.

[0015] The washing operation is preferably performed while the surface of the washing liquid in the washing liquid vessel is controlled to be constant.

[0016] The washing liquid preferably includes a solvent of the same kind as that included in the coating liquid.

[0017] The washing operation is preferably performed while irradiating the first substrate supporting member with an ultrasonic wave with a frequency of from 20 to 100 kHz.

[0018] The washing operation is preferably performed while oscillating and/or rotating the first substrate supporting member.

[0019] The washing operation is preferably performed while oscillating and/or rotating the washing device.

[0020] As another aspect of the present invention, a coating device is provided which includes:

upper and lower substrate supporting members configured to hold upper and lower ends of a cylindrical substrate, respectively;
a holding member configured to hold the upper substrate supporting member;
a transport member configured to transport the upper substrate supporting member while holding the upper supporting member;
a coating head configured to contain a coating liquid in a coating liquid vessel, wherein the coating head is moved relatively to the substrate while contacting the coating liquid with the peripheral surface of the substrate to coat the coating liquid thereon, wherein the coating liquid contacts the upper substrate supporting member before the coating operation and contacts the lower substrate supporting member after the coating operation;
a coating liquid tank configured to contain the coating liquid therein;
a washing device configured to wash the upper substrate supporting member, which has been transported by the first transport member, with a washing liquid after performing the coating operation and removing the upper sub-

strate supporting member from the upper end of the cylindrical substrate, wherein the washing operation is performed while moving the lower substrate supporting member together with the coating head to insert the lower substrate supporting member into an upper end of next one of the substrate; and
 a washing liquid tank configured to contain the washing liquid,

wherein the coating liquid is circulated between the coating head and the coating liquid tank, and wherein the washing liquid is circulated between the washing device and the washing liquid tank at a flow rate of from 0.1 to 10 liter/min.

[0021] The washing device preferably includes an overflow wall configured to control the surface of the washing liquid to be constant.

[0022] It is preferable that the transport member holds the upper substrate supporting member with a positional pin, and a holding member.

[0023] It is preferable for the coating device that each of the upper and lower substrate supporting members has an upper narrow portion and a lower narrow portion thereof, wherein at least one of the upper and lower narrow portions has a recessed portion, and wherein the holding member has a projected portion configured to engage with the recessed portion of the upper substrate supporting member.

[0024] These and other objects, features and advantages of the present invention will become apparent upon consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Various other objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the detailed description when considered in connection with the accompanying drawings in which like reference characters designate like corresponding parts throughout and wherein:

FIG. 1 is a schematic view illustrating an embodiment of the coating device of the present invention;
 FIG. 2 is an enlarged view illustrating the coating head of the coating device illustrated in FIG. 1;
 FIGs. 3A and 3B are schematic views illustrating embodiments of the holding member of the coating device of the present invention;
 FIG. 4 is a schematic view illustrating a conventional coating device; and
 FIG. 5 is a schematic view illustrating a conventional holding member.

DETAILED DESCRIPTION OF THE INVENTION

[0026] The coating method and device of the present invention will be explained in detail referring to drawings.

[0027] FIG. 1 is a schematic view illustrating the entire of an embodiment of the coating device of the present invention. A coating device 100 includes a table 1 and a wall 2 which is located on the table 1 and forms a cylindrical space A. A coating liquid is fed by a pump 4 from a coating liquid tank 3 to a coating liquid vessel 51 in a coating head 5, which is located at an upper portion of the space A before a coating operation.

[0028] In the space A, a ball screw 6 is provided along the wall 2. The ball screw 6 is driven by a motor 7. On a side of the space A opposite to the ball screw 6, an upper substrate supporting member 91 and a lower substrate supporting member 92 are provided to sandwich a cylindrical substrate 8 to be coated.

[0029] The upper substrate supporting member 91 is engaged with a transport member 10, and the lower substrate supporting member 92 is provided on a substrate supporting member table 11. A reversing mechanism 12 is provided between the table 1 and the substrate supporting member table 11. The reversing mechanism 12 changes the coated substrate with the following substrate to be coated.

[0030] The coating liquid tank 3 and the coating liquid vessel 51 are connected by a feeding pipe 14 and a collection pipe 15, wherein a valve 13 is provided in the feed pipe 14, to circulate the coating liquid between the coating liquid tank 3 and the coating liquid vessel 51. Numeral 16 denotes a washing device configured to wash the substrate supporting members 91 and 92.

[0031] The coating liquid vessel 51 is elevated (i.e., is moved up and down) by the motor 7, and thereby the coating liquid in the coating liquid vessel 51 is coated on the peripheral surface of the cylindrical substrate 8, resulting in formation of a layer constituting an electrophotographic photoreceptor.

[0032] FIG. 2 is an enlarged view illustrating the coating head 5. In the coating head 5, a sealing member 18 is provided. During the coating operation, the sealing member 18 is brought into contact with the cylindrical substrate 8. In the waiting state, the sealing member 18 is brought into contact with the substrate supporting member 91 or 92. Thus, a coating liquid 17 is prevented from leaking from the coating head 5. Since the coating liquid vessel 51 is always

filled with the coating liquid 17 and in addition the coating liquid 17 is circulated, occurrence of residues due to solidification of the coating liquid can be prevented. The inner and outer surfaces of the coating liquid vessel 51 are subjected to an electroconductive treatment.

[0033] The sealing member 18 has a circular opening 18a through which the cylindrical substrate 8 is inserted. The sealing member 18 is preferably made of a material (such as fluorine-containing resins or rubbers) having a good resistance to the solvent included in the coating liquid 17. The coating liquid 17 is circulated by the pump 4. The coating liquid vessel 51 includes an overflow wall 19, and an excess of the coating liquid 17 overflows from an overflow surface 21. Therefore, a fresh coating liquid is contained in the coating liquid vessel 51 while the surface of the coating liquid 17 is maintained so as to be a constant level.

[0034] When the coating liquid 17 is not circulated (i.e., the coating liquid remains in the coating liquid vessel 51), solidified residues are formed in the coating liquid vessel 51. In order to prevent the solvent included in the coating liquid 17 from evaporating, a cover 20 is provided on the coating head 5. An excess of the coating liquid overflowing from the overflow surface 21 is returned to the coating liquid tank 3 through the collection pipe 15.

[0035] The coating liquid 17 is preferably circulated at a flow rate of from 0.01 to 1 liter/min and preferably from 0.1 to 0.5 liter/min.

[0036] Referring to FIG. 1, the washing device 16 has an overflow wall 25 from which a washing liquid 33 overflow, and thereby the surface of the washing liquid is controlled so as to be on a constant level. Therefore, the washing device 16 has a constant washing ability, i. e. , the washing device produces a good washing effect. The washing device 16 is connected with a washing liquid tank 30 by a washing liquid feed pipe 31 and a washing liquid collection pipe 32. Therefore, an excess of the washing liquid overflowing from the overflow wall 25 is fed through the washing liquid collection pipe 32 and a fresh washing liquid is fed from the washing liquid tank 30 to the washing device 16 through the washing liquid feed pipe 31. Thus, the washing liquid 33 is circulated.

[0037] The washing liquid is preferably circulated at a flow rate of from 0.01 to 10 liter/min. When the flow rate is too low, good circulation effect cannot be produced. In contrast, when the flow rate is too high, a problem in that residues of the coating liquid included in the washing liquid are adhered to the substrate supporting members 91 and 92, resulting in formation of coating defects tends to occur.

[0038] It is preferable that a washing element is provided on the inner surface of the overflow wall 25 to wash the surface of the substrate supporting members 91 and 92. Specific examples of materials for use as the washing element include brushes and sponges. Among these materials, brushes are preferably used because re-adhesion of residues on the surface of the substrate supporting members is hardly caused. For example, brushes having polypropylene fibers with a thickness of 0.2 mm are preferably used as the brush.

[0039] It is preferable to replace the washing liquid with a fresh washing liquid at proper intervals. The replacement operation is preferably performed at a frequency not less than 3 times, more preferably not less than 5 times and even more preferably not less than 10 times, per a 1 hour coating operation.

[0040] Suitable materials for use as the washing liquid include solvents of the same kind as the solvents included in the coating liquid 17. This is because the residues adhered to the substrate supporting members 91 and 92 can be dissolved and thereby the washing efficiency can be improved. Specific examples of the washing materials include tetrahydrofuran, cyclohexanone and methyl ethyl ketone.

[0041] It is preferable to provide a supersonic generating device (not shown) in the vicinity of the washing device 16 to irradiate the substrate supporting members to be washed with supersonic waves. The frequency of the supersonic waves is preferably from 20 to 100 kHz and more preferably from 40 to 70 kHz. When the frequency is too high, a problem in that the surface of the substrate supporting members is damaged tends to occur.

[0042] In addition, it is preferable that at least one of the substrate supporting members and the washing device 16 is oscillated. In this case, the residues adhered to the substrate supporting members can be easily removed therefrom, resulting in enhancement of the washing efficiency. The oscillation is preferably performed at a speed not lower than 20 mm/sec. The oscillation distance is preferably longer than the length of the substrate supporting members 91 and 92.

[0043] Further, it is preferable that at least one of the substrate supporting members and the washing device 16 is rotated. In this case, the residues adhered to the substrate supporting members can be easily removed therefrom, resulting in enhancement of the washing efficiency. The rotation operation can be performed alone but is preferably performed in combination with the oscillation operation. The rotation is preferably performed at a speed not less than 10 rpm, and more preferably not less than 60 rpm. The rotation may be performed in the same direction but it is preferable to change the rotation direction after every 180-degree rotation.

[0044] FIG. 3A is a schematic view illustrating a holding member 40. The holding member 40 holds a substrate supporting member 9 (i.e. , the substrate supporting member 91 or 92) . Upper and lower narrow portions 9a of the substrate supporting member 9 have an external diameter smaller than the internal diameter of the substrate 8 by 0.5 mm or less (from about 0.5 mm to about 0.05 mm). By inserting the lower narrow portion 9a into the substrate 8, the substrate 8 is fixedly supported by the substrate supporting member 9 while saccadic movement of the substrate is prevented. The substrate supporting member 9 is fixed by inserting a positioning pin 41, which is provided on the

transport member 10, into a hole of the substrate supporting member 9. In this case, there is a case where the substrate supporting member 9 swings. In order to prevent the substrate supporting member 9 from swinging, the holding member 40 is provided. Thus, the substrate supporting member 9 and the substrate 8 are fixedly supported, and thereby a coating liquid can be well coated on the surface of the substrate 8, and the substrate supporting member 9 can be well washed by the washing device 16.

[0045] The diameter of the positioning pin 41 is preferably smaller than the diameter of the positioning hole of the substrate supporting member 9 by 0.1 to 0.5 mm. The length of the positioning pin 41 is preferably one fifth or longer of the length of the substrate supporting member 9.

[0046] A holding member 40' holding the lower narrow portion 9a of the substrate supporting member 9 is moved by the ball screw 6 together with the coating head 5. Therefore, the coating head 5 and the substrate supporting member 9 are raised at the same speed after the coating operation is completed. The holding member 40 has a chucking mechanism having two arms. When the substrate supporting member 9 is inserted into the cylindrical substrate 8, the arms of the chuck are opened, and thereby the substrate supporting member 9 is released from holding by the holding member 40.

[0047] FIG. 3B is another embodiment of the holding member 40. Referring to FIG. 3B, the a groove 43 is formed on the narrow portion of the substrate supporting member 9, while a projection 42 is formed on the holding member 40 such that the projection 42 can be engaged with the groove 43. Therefore, the substrate supporting member 9 can be further fixedly supported by the holding member 40. Therefore, when the substrate supporting member 9 is washed, movement of the substrate supporting member 9 can be prevented, and thereby the substrate supporting member 9 can be uniformly washed. The width of the groove 43 is preferably smaller than the width of the projection 42 by 0.1 to 0.5 mm.

[0048] The external diameter of a wide portion 9b of the substrate supporting member 9 is preferably the same as that of the substrate 8 at a tolerance of ± 0.5 mm or less. When the tolerance falls in this range. (i.e., the difference in level between the outer surface of the substrate 8 and the outer surface of the wide portion 9b of the substrate supporting member 9 is small), the coating head 5 can be smoothly moved without causing a problem in that the coating liquid can be prevented from leaking when the coating head 5 passes through the joint between the substrate supporting member 9 and the substrate 8.

[0049] The basic coating operations of the coating device of the present invention are the same as those illustrated in FIGs. 4-21 of JP-A 2004-179918. Specifically, the coating operations are as follows. When the cylindrical substrate 8 is supplied to the coating device by a transporter (not shown), the coating liquid 17 is circulated between the coating liquid vessel 51 and the coating liquid tank 3. After the cylindrical substrate 8 is supplied to the coating device, an end of substrate 8 is set on the upper narrow portion 9a of the lower substrate supporting member 9 (i. e. , 92) and then the lower narrow portion 9a is inserted into the upper substrate supporting member 9 (i. e. , 91). Then the positioning pin 41 of the transport member 10 is inserted into the upper substrate supporting member 9 (i.e. , 91), and in addition the upper narrow portion 9a of the upper substrate supporting member 9 (i.e. , 91) is held by the holding member 40. In this case, the coating head 5 is also lowered while synchronized with the movement of the holding member 40. Then the coating head 5 is lowered until the surface of the coating liquid 17 in the coating vessel 5 reaches the lower substrate supporting member 9 (i.e., 92). Thus, the coating liquid 17 is coated on the entire peripheral surface of the cylindrical substrate 8. After the coating operation, the upper substrate supporting member 9 (91) is raised to be released from the substrate 8. Then the substrate bearing a coated layer thereon is discharged with a transporter (not shown) so as to be subjected to the next treatment.

[0050] Then the upper substrate supporting member 9 held by the transport member 10 is lowered so as to be washed by the washing device 16. In this case, the holding member 40 is also lowered together with the transport member. The washed upper substrate supporting member 9 is then set on the substrate supporting member table 11 to serve as a lower substrate supporting member configured to hold the lower end of the next one of the substrate 8. On the other hand, the lower substrate supporting member 9 (92) is raised together with the coating head 5 to hold the upper end of the next one of the substrate 8. Thus, the positions of the substrate supporting members 91 and 92 are exchanged.

[0051] In the above-mentioned embodiment, the coating head 5 is lowered while the cylindrical substrate 8 is stopped. However, another method in which the cylindrical substrate 8 is raised while the coating head 5 is stopped can also be used. Namely, one or both of the coating head 5 and the substrate 8 are moved relatively to the other.

[0052] In the above-mentioned coating device, the coating liquid 17. is always circulated. However, a method in which the circulation is stopped during the device is in a waiting state or the coating operation is performed can also be used.

[0053] In the above-mentioned coating device, two substrate supporting members are used while the positions of the substrate supporting members are exchanged. However, it is possible to use three or more substrate supporting members. In this case, the washing operation can be performed in parallel with the coating operation, and thereby the coating efficiency can be enhanced.

[0054] Referring to FIG. 2, the sealing member 18 prevents leakage of the coating liquid 17 by contacting the cylindrical substrate 8. However, another sealing member which has an opening slightly larger than the outer diameter of the cylindrical substrate 8 so as not to contact the substrate 8 can also be used. In this case, the coating liquid 17 does not leak from the gap between the sealing member 18 and the cylindrical substrate 8 because of having a surface tension.

[0055] The substrate supporting member 9 is preferably grounded for safety. In order to ground the substrate supporting member 9, the surface thereof is preferably subjected to an electroconductive treatment using a material such as electroconductive fluorine-containing resins having good resistance to the solvents included in the coating liquid 17. Alternatively, the substrate supporting member 9 may be made of a metal subjected to an electroconductive treatment. Alternatively, the substrate supporting member 9 may be electrically connected with the substrate 8 by contacting an earth plate (not shown) provided thereon with the substrate 8.

[0056] Specific examples of the substrate supporting member having such an earth plate include members which are made of a material such as aluminum, stainless steels and iron and the surface of which is subjected to a TUFRAM treatment (i.e., a hard alumite layer including a fluorine-containing resin therein) or a Ni-P-PTFE plating treatment, or which is coated with an electroconductive fluorine-containing resin having good resistance to the solvents included in the coating liquid.

[0057] Specific examples of the materials for use in the cylindrical substrate 8 include drums or sheets made of a metal such as aluminum, copper, iron, zinc and nickel; and drums, plates or sheets which are made of a material such as papers, plastics and glasses and on which a metal such as aluminum, copper, gold, silver, platinum, palladium, titanium, nickel-chromium alloys, stainless steels and copper-indium alloys or an electroconductive metal oxide such as indium oxide and tin oxide is deposited, or an electroconductive layer in which a material such as carbon blacks, indium oxide, tin oxide-antimony oxide powders, metal powders and copper iodide which is dispersed in a binder resin is formed, but are not limited thereto.

[0058] The surface of the substrate 8 can be subjected to various treatments, such as oxidation treatments, treatments using a chemical and coloring treatments, to an extent such that the treatment does not cause any problems concerning image qualities.

[0059] In addition, an undercoat layer can be formed on the surface of the cylindrical substrate 8 before the photosensitive layer is formed. By forming such an undercoat layer, injection of charges from the substrate to the photosensitive layer can be prevented; the adhesiveness of the photosensitive layer to the substrate 8 can be improved; and reflection of light from the surface of the substrate can be prevented.

[0060] Specific examples of the materials for use in the undercoat layer include known resins such as polyethylene, polypropylene, acrylic resins, methacrylic resins, polyamide resins, vinyl chloride resins, vinyl acetate resins, phenolic resins, epoxy resins, polyester resins, alkyd resins, polycarbonate resins, polyurethane resins, polyimide resins, polyvinylidene chloride resins, polyvinyl acetal resins, vinyl chloride - vinyl acetate copolymers, polyvinyl alcohol, water-soluble polyester resins, nitrocellulose, casein, gelatin, etc. The thickness of the undercoat layer is preferably from 0.01 to 10 μm , and more preferably from 0.3 to 7 μm .

[0061] A photosensitive layer formed on the surface of the substrate 8 optionally the undercoat layer therebetween by coating a coating liquid. The photosensitive layer is not particularly limited and may be a single-layered photosensitive layer or a multi-layered photosensitive layer.

[0062] As an example of the photosensitive layer, a multi-layered photosensitive layer including a charge generation layer and a charge transport layer will be explained below.

[0063] The charge generation layer typically include a charge generation material and a binder resin, wherein the charge generation material is dispersed in the binder resin. Specific examples of the charge generation materials include pigments and dyes such as azo compounds (e.g., monoazo dyes, disazo dyes and trisazo dyes), perylene compounds (e.g., perylene acid anhydride and perylene acid imide), indigo compounds (e.g., indigo and thioindigo), polycyclid quinone compounds (e.g., anthraquinones, pyrene quinones and flavanthrones), quinacridone compounds, bisbenzimidazole compounds, indanthrone compounds, squarilium compounds, phthalocyanine compounds (metal-containing phthalocyanine and metal-free phthalocyanine), eutectic complexes of a pyrylium salt compound or a thiopyrylium salt compound with a polycarbonate resin, etc. The charge generation layer coating liquid is prepared by dissolving or dispersing such a charge generation material and a binder resin in a proper solvent. The charge generation layer coating liquid can include other additives such as charge transport materials.

[0064] When a charge generation material is dispersed in a binder resin to prepare a charge generation layer coating liquid, a mixer such as ball mills, attritors and sand mills can be used. In this case, the charge generation material is dispersed so as to have a volume average particle diameter not greater than 5 μm , more preferably not greater than 2 μm and even more preferably not greater than 0.5 μm . The thickness of the charge generation layer is preferably from 0.1 to 5 μm , and more preferably from 0.2 to 2 μm .

[0065] The charge transport layer is typically formed on the charge generation layer by coating a charge transport layer coating liquid which is prepared by dispersing or dissolving a charge transport material and a binder resin in a

proper solvent. Specific examples of the charge transport materials include known charge transport materials such as oxadiazole derivatives (e.g., 2,5-bis(p-diethylaminophenyl)-1,3,4-oxadiazole); pyrazoline derivatives (e.g., 1,3,5-triphenylpyrazoline, and 1-pyridyl-3-(p-diethylaminostyryl)-5-(p-diethylamino-phenyl) pyrazoline); aromatic tertiary amino compounds (e.g., triphenylamine, styryl triphenylamine, and dibenzyl aniline); aromatic tertiary diamino compounds (e.g., N,N-diphenyl-N,N-bis(3-methylphenyl)-1,1-biphenyl-4,4'-diamine); etc. These charge transport materials can be used alone or in combination.

[0066] Specific examples of the binder resins for use in the charge transport layer include polycarbonate resins, polyester resins, methacrylic resins, acrylic resins, polyvinyl chloride resins, polyvinylidene chloride resins, polystyrene resins, polyvinyl acetate resins, styrene - butadiene copolymers, vinylidene chloride - acrylonitrile - copolymers, vinyl chloride - vinyl acetate copolymers, vinyl chloride - vinyl acetate - maleic anhydride copolymers, silicone resins, silicone - alkyd resins, phenol - formaldehyde resins, styrene - alkyd resins, poly-N-vinylcarbazole, etc., but are not limited thereto. These resins can be used alone or in combination.

[0067] The weight ratio (CTM/BR) of the charge transport material (CTM) to the binder resin (BR) in the charge transport layer is preferably from 10/1 to 1/5. The thickness of the charge transport layer is generally from 5 to 50 μm and preferably from 10 to 30 μm .

[0068] A single-layered photosensitive layer is formed by coating a coating liquid which is prepared by, for example, dissolving or dispersing a charge generation material, a charge transport material and a binder resin in a proper solvent, on a substrate or an undercoat layer.

[0069] A protective layer is optionally formed on the charge transport layer or the single-layered photosensitive layer to protect the photosensitive layer and the charge transport layer depending on the image forming apparatus (such as copiers and printers) for which the photoreceptor is used. The protective layer is typically formed by coating a protective layer coating liquid which is typically prepared by dissolving or dispersing a charge transport material, a filler and a binder resin in a proper solvent. Specific examples of the filler include inorganic fillers such as alumina and titanium oxide; and organic fillers. The content of the filler in the protective layer is preferably from 5 to 30 % by weight. The thickness of the protective layer is generally from 2 to 10 μm , and preferably from 4 to 8 μm .

[0070] The above-mentioned coating liquids such as the undercoat layer coating liquid, charge generation layer coating liquid, charge transport layer coating liquid, single-layered photosensitive layer coating liquid and protective layer coating liquid can be coated by the coating method of the present invention.

[0071] FIG. 4 is a schematic view illustrating a conventional coating device. The conventional coating device has a structure similar to that of the coating device illustrated in FIG. 1 except that the washing liquid in the washing device 16 is not circulated.

[0072] FIG. 5 is a schematic view illustrating a conventional holding member 44 configured to hold the substrate supporting member. The holding member 44 supports the substrate supporting member 9 only by being engaged with the hole in the substrate supporting member 9.

[0073] Having generally described this invention, further understanding can be obtained by reference to certain specific examples which are provided herein for the purpose of illustration only and are not intended to be limiting. In the descriptions in the following examples, the numbers represent weight ratios in parts, unless otherwise specified.

EXAMPLES

Example 1

1. Preparation of undercoat layer coating liquid

[0074] The following components were mixed and subjected to a dispersion treatment to prepare an undercoat layer coating liquid.

Melamine resin	5 parts
Titanium oxide	20 parts
Cyclohexanone	35 parts
Methyl ethyl ketone	35 parts

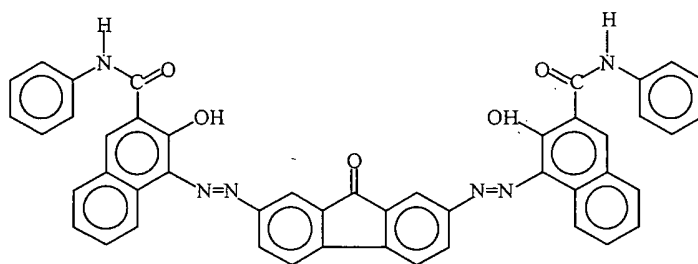
2. Preparation of charge generation layer coating liquid

[0075] The following components were mixed using a ball mill.

Charge generation material

having the following formula

1 part



Polyvinyl butyral

0.5 parts

[0076] Then 40 parts of cyclohexanone and 60 parts of methyl ethyl ketone were mixed with the resultant mixture to prepare a charge generation layer coating liquid.

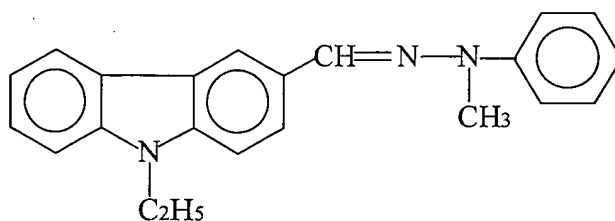
3. Preparation of charge transport layer coating liquid

[0077] The following components were mixed to prepare a charge transport layer coating liquid.

Charge transport material

having the following formula

4 parts



Polycarbonate resin

6 parts

Cyclohexanone

45 parts

Tetrahydrofuran

45 parts

Silicone oil

0.001 parts

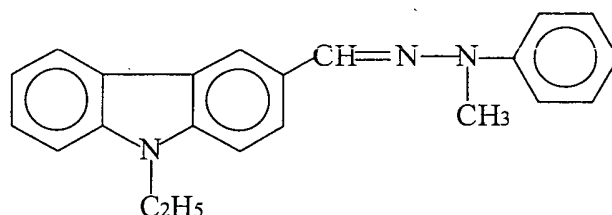
4. Preparation of protective layer coating liquid

[0078] The following components were mixed using a ball mill.

Charge transport material

having the following formula

2 parts



Alumina

2 parts

Polycarbonate resin

2 parts

[0079] Then 20 parts of cyclohexanone and 65 parts of tetrahydrofuran were mixed with the resultant dispersion to prepare a protective layer coating liquid.

<Coating conditions>

[0080] The undercoat layer coating liquid prepared above was coated on a peripheral surface of a cylindrical aluminum substrate having a diameter of 30 mm and a length of 340 mm by a dip coating method, followed by drying for 15 minutes at 110 °C. Thus, an undercoat layer having a thickness of 5 μm was prepared.

[0081] Then the charge generation layer coating liquid prepared above was coated on the undercoat layer by a dip coating method, followed by drying to prepare a charge generation layer with a thickness of 0.2 μm. In addition, the charge transport layer coating liquid was coated on the charge generation layer by a dip coating method, followed by drying to prepare a charge transport layer with a thickness of 23 μm. Further, the protective layer coating liquid was coated on the charge transport layer by the above-mentioned coating method (ring coating method) of the present invention, followed by drying to prepare a protective layer with a thickness of 5 μm.

[0082] The protective layer was prepared using the ring coating device illustrated in FIG. 1. The amount of the coating liquid contained in the coating liquid vessel was 0.035 liter, and the coating liquid was circulated at a flow rate of 0.01 liter/min. The coating operation was performed continuously.

[0083] The washing operation was performed while the washing liquid in the washing device was circulated at a flow rate of 1 liter/min, and the washing liquid was replaced 20 times per a 1 hour coating operation.

[0084] Each of the thus prepared photoreceptors was visually observed to determine whether the photoreceptor has a coating defect caused by residues of the protective layer coating liquid. When one or more coating defects with a size not smaller than 0.2 mm caused by residues were observed on a photoreceptor, the photoreceptor was determined to be defective.

[0085] As a result, the 30th photoreceptor was the first defective photoreceptor (i.e., the first to 29th photoreceptors had no defect).

Example 2

[0086] The procedure for preparation and evaluation of the photoreceptor in Example 1 was repeated except that a brush serving as the washing element illustrated in FIG. 1 and having polypropylene fibers with a thickness of 0.2 mm was provided on the inner surface of the vessel of the washing device to wash the substrate supporting members.

[0087] As a result, the 87th photoreceptor was the first defective photoreceptor.

Example 3

[0088] The procedure for preparation and evaluation of the photoreceptor in Example 2 was repeated except that the overflow wall was provided in the washing liquid vessel of the washing device to control the level of surface of the washing liquid to be uniform.

[0089] As a result, the 89th photoreceptor was the first defective photoreceptor.

Example 4

[0090] The procedure for preparation and evaluation of the photoreceptor in Example 3 was repeated except that during the washing operation, the substrate supporting members were oscillated at a speed of 100 mm/s so as to move back and forth 5 times, wherein the moving distance is 100 mm.

[0091] As a result, the 102nd photoreceptor was the first defective photoreceptor.

Example 5

[0092] The procedure for preparation and evaluation of the photoreceptor in Example 4 was repeated except that during the washing operation, the substrate supporting members were rotated in such a way that the rotation direction is changed after every 180 degree rotation.

[0093] As a result, all the photoreceptors (i.e., the first to 200th photoreceptors) had no defect.

Comparative Example 1

[0094] The procedure for preparation and evaluation of the photoreceptor in Example 1 was repeated except that the washing liquid was circulated at a flow rate of 0.01 liter/min.

[0095] As a result, the 8th photoreceptor was the first defective photoreceptor.

Comparative Example 2

[0096] The procedure for preparation and evaluation of the photoreceptor in Example 1 was repeated except the coating device was changed to a conventional coating device illustrated in FIG. 4 without changing the amount (0.035 liter) of the coating liquid in the coating liquid vessel and the flow rate (0.01 liter/min) of the coating liquid, and the washing liquid was not circulated.

[0097] As a result, the 5th photoreceptor was the first defective photoreceptor.

Effect of the present invention

[0098] By using the coating method and coating device of the present invention, occurrence of coating defects caused by residues adhered to the substrate supporting members can be prevented and in addition the degree of swinging of the substrate supporting members during a coating operation can be reduced. Therefore, a coating film having a uniform thickness and good film properties can be formed. Therefore this method can be preferably used for preparing photoreceptors which have good sensitivity and high resolution.

[0099] This document claims priority and contains subject matter related to Japanese Patent Application No. 2004-119039, filed on April 14, 2004.

Claims

1. A method for coating a coating liquid (17) on a cylindrical substrate (8), comprising:

inserting first and second substrate supporting members (9; 91, 92) into upper and lower ends of the cylindrical substrate, respectively, to support the substrate while contacting the coating liquid in a coating liquid vessel (51) of a coating head (5) with the first substrate supporting member;

moving the coating head downward relative to the substrate while contacting the coating liquid with the peripheral surface of the substrate to coat the coating liquid thereon;

removing the first substrate supporting member from the upper end of the substrate after the surface of the coating liquid reaches the second substrate supporting member;

removing the substrate bearing a coating layer thereon from the second substrate supporting member; and upwardly moving the second substrate supporting member together with the coating head to insert the second substrate supporting member into an upper end of next one of the substrate to be coated while transporting the first substrate supporting member to a washing device (16) to wash the first substrate supporting member with a washing liquid (33) contained in the washing device,

wherein the coating liquid is circulated between the coating head and a coating liquid tank (3), and wherein the washing liquid is circulated between the washing device and a washing liquid tank (30) at a flow rate of from

0.1 to 10 liter/min.

2. The method according to Claim 1, wherein the washing liquid is replaced with a fresh washing liquid at a frequency not less than 3 times per a 1 hour coating operation.

3. The method according to Claim 1 or 2, wherein the washing device comprises a washing element configured to wash the surface of the first substrate supporting member (91) while contacting the surface.

4. The method according to any one of Claims 1 to 3, wherein the washing is performed while the surface of the washing liquid (33) in the coating liquid vessel (51) is controlled to be constant.

5. The method according to any one of Claims 1 to 4, wherein the washing liquid (33) comprises a solvent of the same kind as that included in the coating liquid.

6. The method according to any one of Claims 1 to 5, wherein the washing is performed while irradiating the first substrate supporting member (91) with an ultrasonic wave with a frequency of from 20 to 100 kHz.

7. The method according to any one of Claims 1 to 6, wherein the washing is performed while oscillating and/or rotating the first substrate supporting member (91).

8. The method according to any one of Claims 1 to 8, wherein the washing is performed while oscillating and/or rotating the washing device (16).

9. A coating device (100) comprising:

upper and lower substrate supporting members (9; 91, 92) configured to hold upper and lower ends of a cylindrical substrate (8), respectively;

a holding member (40) configured to hold the upper substrate supporting member (91);

a transport member (10) configured to transport the upper substrate supporting member while holding the upper supporting member;

a coating head (5) configured to contain a coating liquid (17) in a coating liquid vessel (51), wherein the coating head is moved relatively to the substrate while contacting the coating liquid with the peripheral surface of the substrate to coat the coating liquid thereon, wherein the coating liquid contacts the upper substrate supporting member before the coating operation and contacts the lower substrate supporting member after the coating operation;

a coating liquid tank (3) configured to contain the coating liquid therein;

a washing device (16) configured to wash the upper substrate supporting member, which has been transported by the first transport member, with a washing liquid (33) after performing the coating operation and removing the upper substrate supporting member from the upper end of the cylindrical substrate, wherein the washing operation is performed while moving the lower substrate supporting member together with the coating head to insert the lower substrate supporting member into an upper end of next one of the substrate to be coated; and a washing liquid tank (30) configured to contain the washing liquid,

wherein the coating liquid is circulated between the coating head and the coating liquid tank, and wherein the washing liquid is circulated between the washing device and the washing liquid tank at a flow rate of from 0.1 to 10 liter/min.

10. The coating device according to Claim 9, wherein the washing device comprises an overflow wall (25) configured to control the surface of the washing liquid to be constant.

11. The coating device according to Claim 9 or 10, further comprises a holding member (40), wherein the upper substrate supporting member is held by a positional pin (41) of the transport member (10) and the holding member.

12. The coating device according to Claim 11, wherein each of the upper and lower substrate supporting members has an upper narrow portion (9a) and a lower narrow portion (9a) thereof, wherein at least one of the upper and lower narrow portions has a recessed portion (43), and wherein the holding member (40) has a projected portion (42) configured to engage with the recessed portion of the upper substrate supporting member (91).

FIG. 1

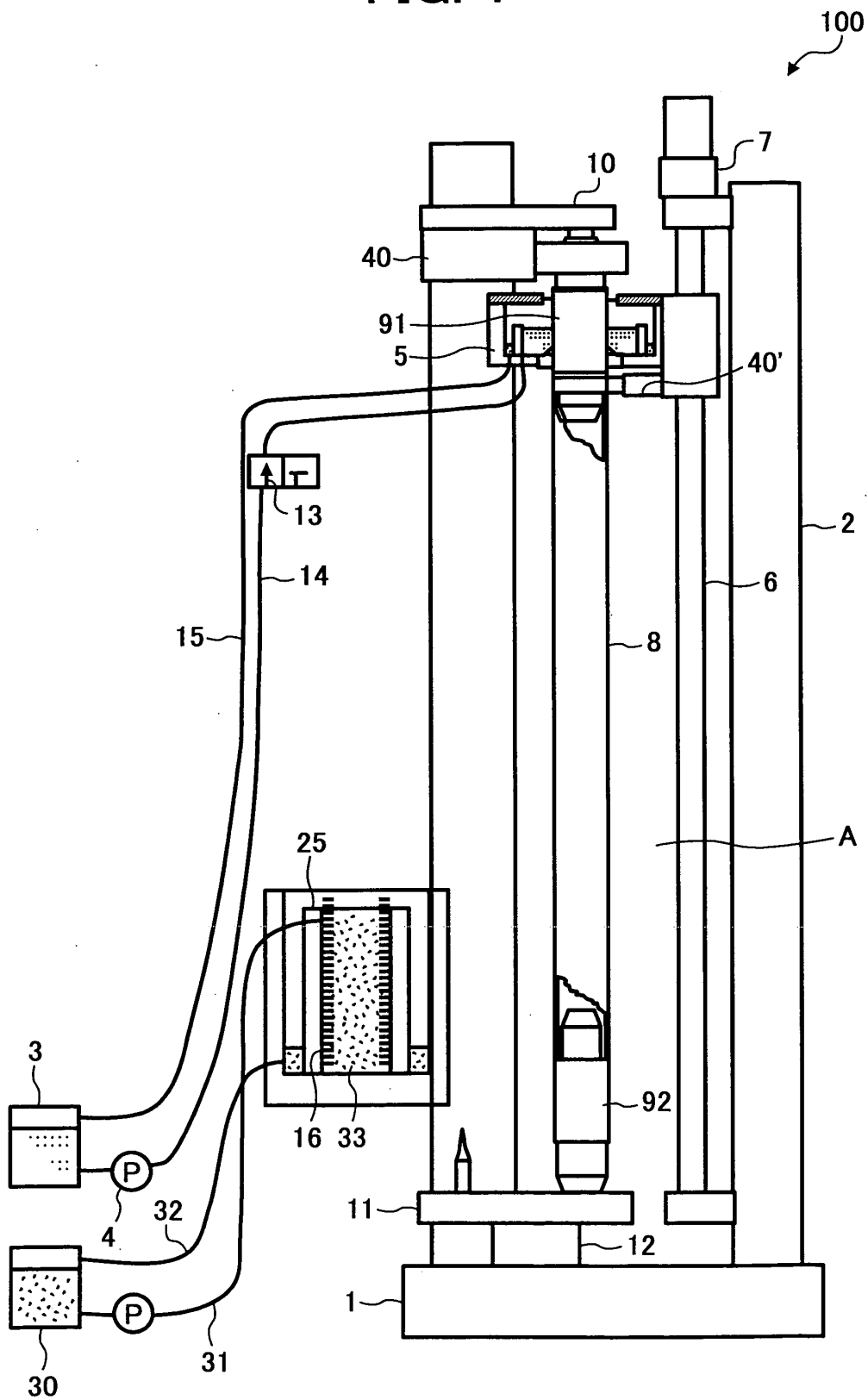


FIG. 2

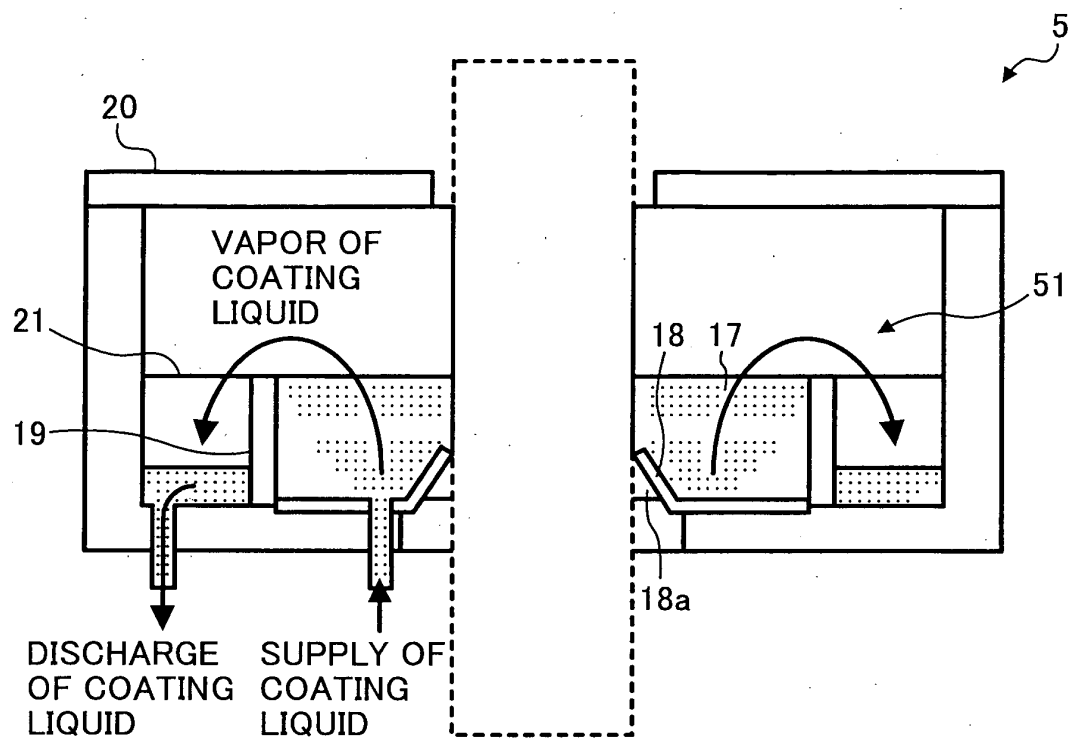


FIG. 3A

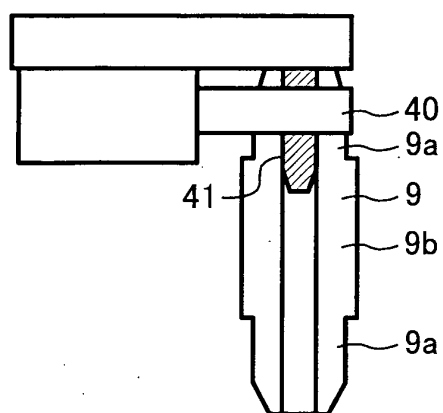


FIG. 3B

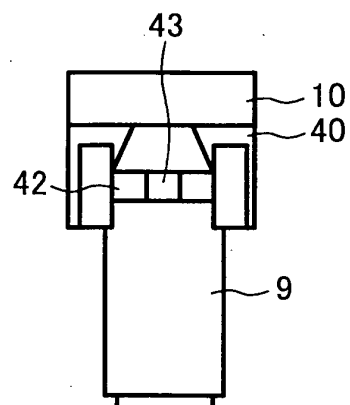


FIG. 4
BACKGROUND ART

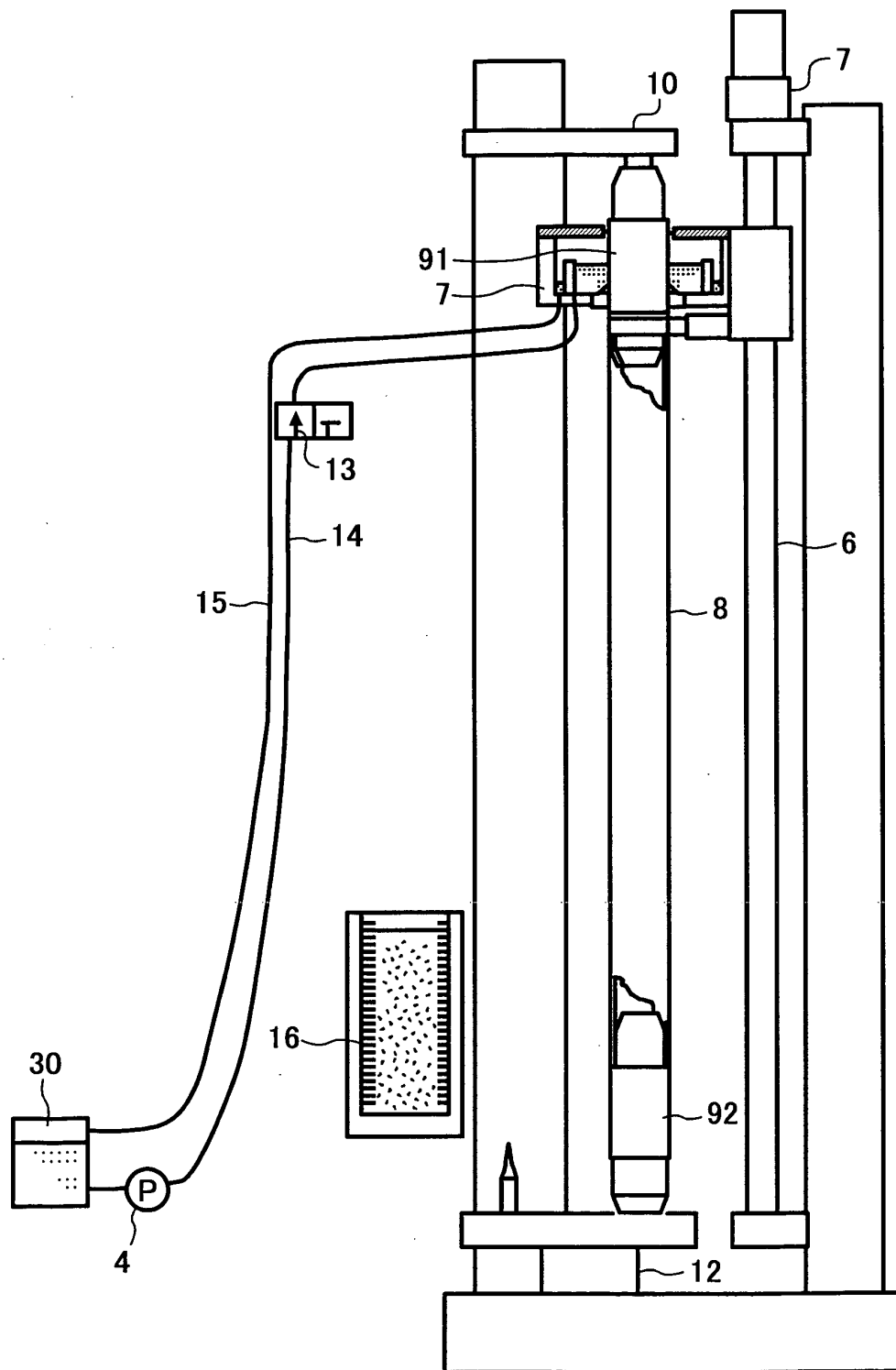
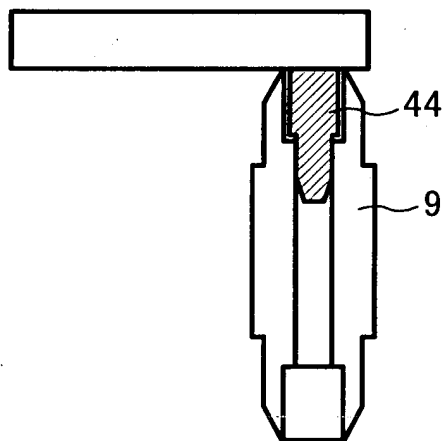


FIG. 5
BACKGROUND ART





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 00 8089

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
D,P, A	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 12, 5 December 2003 (2003-12-05) & JP 2004 279918 A (RICOH CO LTD), 7 October 2004 (2004-10-07) * abstract *	1,9	G03G5/05
A	----- US 2002/051921 A1 (MORITA TATSUHIRO ET AL) 2 May 2002 (2002-05-02) * the whole document *	1,9	
A	----- US 6 245 475 B1 (SCHARFE MERLIN E ET AL) 12 June 2001 (2001-06-12) * the whole document *	1,9	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			G03G
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 3 June 2005	Examiner Eberwein, M
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 05 00 8089

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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03-06-2005

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