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Inkjet printing apparatus

Abstract

An inkjet printing apparatus includes: an airflow stage extending in a first direction; a print head unit disposed above the airflow stage; and an electric field generating unit that moves in the first direction and generates electric field above the airflow stage.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION(S)

(1) This application is a national entry of International Application No. PCT/KR2021/007004, filed on Jun. 4, 2021, which claims under 35 U.S.C. §§ 119(a) and 365(b) priority to and benefits of Korean Patent Application No. 10-2020-0079068, filed on Jun. 29, 2020, in the Korean Intellectual Property Office (KIPO), the entire content of which are incorporated herein by reference.

BACKGROUND

1. Technical Field

(2) Embodiments relate to an inkjet printing apparatus.

2. Description of the Related Art

(3) The importance of display devices has steadily increased with the development of multimedia technology. Thus, various types of display devices such as an organic light emitting display (OLED), a liquid crystal display (LCD) and the like have been used.

(4) A display device is a device for displaying an image, and includes a display panel, such as an organic light emitting display panel or a liquid crystal display panel. The light emitting display panel may include light emitting elements, e.g., light emitting diodes (LED), and examples of the light emitting diode include an organic light emitting diode (OLED) formed of an organic material as a fluorescent material and an inorganic light emitting diode formed of an inorganic material as a fluorescent material.

SUMMARY

(5) To address the aforementioned problems, embodiments provide an inkjet printing apparatus capable of performing a printing process of spraying ink onto a target substrate at high speed by floating the target substrate up in the air over a stage and moving the target substrate in a horizontal direction.

(6) Embodiments also provide an inkjet printing apparatus capable of improving the accuracy of alignment of dipole elements by moving an electric field generating unit that generates an electric field on a target substrate, in accordance with the movement of the target substrate.

(7) However, embodiments of the disclosure are not limited to those set forth herein. The above and other embodiments will become more apparent to one of ordinary skill in the art to which the disclosure pertains by referencing the detailed description of the disclosure given below.

(8) According to an embodiment, an inkjet printing apparatus may include an airflow stage extending in a first direction, a print head unit disposed above the airflow stage, and an electric field generating unit that moves in the first direction and generates an electric field on the airflow stage.

(9) The print head unit may include a print head, and the print head may include nozzles that spray ink including dipoles.

(10) The print head may be configured to spray the ink onto the airflow stage on which the electric field is formed.

(11) The airflow stage may include a plurality of air holes formed on an upper surface of the airflow stage, and at least some of the plurality of air holes may be configured to discharge air onto the airflow stage.

(12) The inkjet printing apparatus may further include a substrate transferring unit that transfers a target substrate in the first direction over the airflow stage.

(13) The substrate transferring unit may include a first substrate transferrer disposed adjacent to a first side of the airflow stage in a second direction perpendicular to the first direction.

(14) The first substrate transferrer may further include a gripper, and the gripper may be configured to adsorb the target substrate onto a surface of the gripper by generating negative pressure between the gripper and the target substrate.

(15) The substrate transferring unit may further include a second substrate transferrer disposed adjacent to a second side of the airflow stage opposite to the first side of the airflow stage.

- (16) The electric field generating unit may be configured to generate an electric field on the target substrate in case that the target substrate moves along with the substrate transferring unit.
- (17) The electric field generating unit may include a probe unit and a probe driving device that drives the probe unit.
- (18) According to an embodiment, an inkjet printing apparatus may include an airflow stage extending in the first direction, the airflow stage including a loading part sequentially arranged in a first direction, the loader part in which a target substrate is aligned, and a printing part that sprays ink onto the target substrate, a print head unit disposed above the printing part, and an electric field generating unit disposed on a side of the airflow stage and that generates an electric field on the target substrate in case that the target substrate moves in the first direction.
- (19) The inkjet printing apparatus may further include a substrate transferring unit that transfers the target substrate in the first direction over the airflow stage.
- (20) The substrate transferring unit may be disposed adjacent to a first side of the airflow stage in a second direction perpendicular to the first direction.
- (21) The substrate transferring unit may further include a gripper, and the gripper may be configured to adsorb a surface of the target substrate onto a surface of the gripper facing the surface of the target substrate by generating negative pressure between the gripper and the target substrate.
- (22) The electric field generating unit may be configured to generate an electric field on the target substrate in case that the target substrate moves along with the substrate transferring unit.
- (23) The electric field generating unit may include a probe unit and a probe driving device that drives the probe unit.
- (24) The airflow stage may include a plurality of air holes that lift up the target substrate by discharging the air onto the airflow stage.
- (25) The inkjet printing apparatus may further include an alignment checking unit disposed above the loading part.
- (26) The inkjet printing apparatus may further include a first guide unit extending in the first direction and disposed adjacent to a first side of the airflow stage in a second direction perpendicular to the first direction, wherein the electric field generating unit may include a first base substrate disposed on the first guide unit, a probe unit disposed on the first base substrate, and a probe driving device spaced apart from the probe unit and disposed on the first base substrate.
- (27) The inkjet printing apparatus may further include a second guide unit extending in the first direction and disposed between the first guide unit and the airflow stage, and a substrate transferring unit that transfers the target substrate along the second guide unit over the airflow stage, wherein the substrate transferring unit may include a second base substrate disposed on the second guide unit, and a gripper disposed on the second base substrate and fixing the target substrate.
- (28) The inkjet printing apparatus may further include a gripper disposed on the first base substrate, the gripper that transfers the target substrate in the first direction.
- (29) The details of other embodiments are included in the detailed description and the accompanying drawings.
- (30) According to embodiments, a printing process of spraying ink onto a target substrate may be performed at high speed by floating the target substrate up in the air over a stage and moving the target substrate in a horizontal direction, and as a result, the duration of the printing process may be shortened.
- (31) For example, the accuracy of alignment of dipole elements may be improved by moving an electric field generating unit that generates an electric field on the target substrate, in accordance with the movement of the target substrate, and as a result, a display device with an improved reliability may be provided.
- (32) The effects according to the embodiments are not limited by the contents described above, and more various effects are included in this disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

- (1) FIG. 1 is a schematic perspective view of an inkjet printing apparatus according to an embodiment.
- (2) FIG. 2 is a schematic layout view illustrating the layout of an airflow stage, a support unit, and an electric field generating unit according to an embodiment.
- (3) FIG. 3 is a schematic plan view of the inkjet printing apparatus according to an embodiment.
- (4) FIG. 4 is a schematic layout view illustrating the layout of a substrate transferring unit and the electric field generating unit according to an embodiment.
- (5) FIG. 5 is a schematic cross-sectional view illustrating the layout of the inkjet printing apparatus according to an embodiment.
- (6) FIG. 6 is a schematic perspective view illustrating a gripper and a target substrate according to an embodiment.
- (7) FIGS. 7 and 8 are schematic views illustrating the states of a probe unit according to an embodiment.
- (8) FIG. 9 is a schematic plan view illustrating the step of loading a target substrate in a loading part, according to an embodiment.
- (9) FIGS. 10 and 11 are schematic cross-sectional views an example of FIG. 9.
- (10) FIG. 12 is a schematic plan view illustrating the step of placing the target substrate in a printing part, according to an embodiment.
- (11) FIG. 13 is a schematic cross-sectional view illustrating an example of FIG. 12.
- (12) FIG. 14 is a schematic view illustrating how an electric field is generated on the target substrate by the probe unit, according to an embodiment.
- (13) FIG. 15 is a schematic plan view illustrating the step of placing the target substrate in an unloading part, according to an embodiment.
- (14) FIG. 16 is a schematic cross-sectional view of an example of FIG. 15.
- (15) FIG. 17 is a schematic plan view illustrating the step of discharging the target substrate.
- (16) FIG. 18 is a schematic plan view of an inkjet printing apparatus according to an embodiment.
- (17) FIG. 19 is a schematic plan view of an inkjet printing apparatus according to an embodiment.
- (18) FIG. 20 is a schematic plan view of an inkjet printing apparatus according to an embodiment.
- (19) FIG. 21 is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment.
- (20) FIG. 22 is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment.
- (21) FIGS. 23 and 24 are schematic enlarged cross-sectional views illustrating how to drive a gripper and a probe unit of FIG. 22.
- (22) FIG. 25 is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment.
- (23) FIG. 26 is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment.
- (24) FIG. 27 is a schematic plan view of examples of a gripper and a probe unit of FIG. 26.
- (25) FIG. 28 is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment.
- (26) FIG. 29 is a flowchart illustrating a method of aligning dipoles by using an inkjet printing apparatus, according to an embodiment.
- (27) FIGS. 30 through 33 are schematic views illustrating the method of FIG. 29.
- (28) FIG. 34 is a schematic view of a light-emitting element according to an embodiment.
- (29) FIG. 35 is a schematic plan view of a display device fabricated by a method according to an

embodiment.

(30) FIG. 36 is a schematic partial cross-sectional view taken along line I-I' of FIG. 35.

DETAILED DESCRIPTION OF THE EMBODIMENTS

(31) In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of various embodiments or implementations of the invention. As used herein “embodiments” and “implementations” are interchangeable words that are non-limiting examples of devices or methods disclosed herein. It is apparent, however, that various embodiments may be practiced without these specific details or with one or more equivalent arrangements. Here, various embodiments do not have to be exclusive nor limit the disclosure. For example, specific shapes, configurations, and characteristics of an embodiment may be used or implemented in another embodiment.

(32) Unless otherwise specified, the illustrated embodiments are to be understood as providing features of the invention. Therefore, unless otherwise specified, the features, components, modules, layers, films, panels, regions, and/or aspects, etc. (hereinafter individually or collectively referred to as “elements”), of the various embodiments may be otherwise combined, separated, interchanged, and/or rearranged without departing from the invention.

(33) The use of cross-hatching and/or shading in the accompanying drawings is generally provided to clarify boundaries between adjacent elements. As such, neither the presence nor the absence of cross-hatching or shading conveys or indicates any preference or requirement for particular materials, material properties, dimensions, proportions, commonalities between illustrated elements, and/or any other characteristic, attribute, property, etc., of the elements, unless specified. Further, in the accompanying drawings, the size and relative sizes of elements may be exaggerated for clarity and/or descriptive purposes. When an embodiment may be implemented differently, a specific process order may be performed differently from the described order. For example, two consecutively described processes may be performed substantially at the same time or performed in an order opposite to the described order. Also, like reference numerals denote like elements.

(34) When an element, such as a layer, is referred to as being “on,” “connected to,” or “coupled to” another element or layer, it may be directly on, connected to, or coupled to the other element or layer or intervening elements or layers may be present. When, however, an element or layer is referred to as being “directly on,” “directly connected to,” or “directly coupled to” another element or layer, there are no intervening elements or layers present. To this end, the term “connected” may refer to physical, electrical, and/or fluid connection, with or without intervening elements. Further, the D1-axis, the D2-axis, and the D3-axis are not limited to three axes of a rectangular coordinate system, such as the X, Y, and Z-axes, and may be interpreted in a broader sense. For example, the D1-axis, the D2-axis, and the D3-axis may be perpendicular to one another, or may represent different directions that are not perpendicular to one another. Further, the X-axis, the Y-axis, and the Z-axis are not limited to three axes of a rectangular coordinate system, such as the x, y, and z axes, and may be interpreted in a broader sense. For example, the X-axis, the Y-axis, and the Z-axis may be perpendicular to one another, or may represent different directions that are not perpendicular to one another. For the purposes of this disclosure, “at least one of A and B” may be construed as understood to mean A only, B only, or any combination of A and B. Also, “at least one of X, Y, and Z” and “at least one selected from the group consisting of X, Y, and Z” may be construed as X only, Y only, Z only, or any combination of two or more of X, Y, and Z. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

(35) Although the terms “first,” “second,” etc. may be used herein to describe various types of elements, these elements should not be limited by these terms. These terms are used to distinguish one element from another element. Thus, a first element discussed below could be termed a second element without departing from the teachings of the disclosure.

(36) Spatially relative terms, such as “beneath,” “below,” “under,” “lower,” “above,” “upper,”

“over,” “higher,” “side” (e.g., as in “sidewall”), and the like, may be used herein for descriptive purposes, and, thereby, to describe one elements relationship to another element(s) as illustrated in the drawings. Spatially relative terms are intended to encompass different orientations of an apparatus in use, operation, and/or manufacture in addition to the orientation depicted in the drawings. For example, if the apparatus in the drawings is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the term “below” can encompass both an orientation of above and below.

Furthermore, the apparatus may be otherwise oriented (e.g., rotated 90 degrees or at other orientations), and, as such, the spatially relative descriptors used herein interpreted accordingly.

(37) The terminology used herein is for the purpose of describing particular embodiments and is not intended to be limiting. As used herein, the singular forms, “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. Moreover, the terms “comprises,” “comprising,” “includes,” and/or “including,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, components, and/or groups thereof, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It is also noted that, as used herein, the terms “substantially,” “about,” and other similar terms, are used as terms of approximation and not as terms of degree, and, as such, are utilized to account for inherent deviations in measured, calculated, and/or provided values that would be recognized by one of ordinary skill in the art.

(38) Various embodiments are described herein with reference to sectional and/or exploded illustrations that are schematic illustrations of embodiments and/or intermediate structures. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments disclosed herein should not necessarily be construed as limited to the particular illustrated shapes of regions, but are to include deviations in shapes that result from, for instance, manufacturing. In this manner, regions illustrated in the drawings may be schematic in nature and the shapes of these regions may not reflect actual shapes of regions of a device and, as such, are not necessarily intended to be limiting.

(39) As customary in the field, some embodiments are described and illustrated in the accompanying drawings in terms of functional blocks, units, and/or modules. Those skilled in the art will appreciate that these blocks, units, and/or modules are physically implemented by electronic (or optical) circuits, such as logic circuits, discrete components, microprocessors, hard-wired circuits, memory elements, wiring connections, and the like, which may be formed using semiconductor-based fabrication techniques or other manufacturing technologies. In the case of the blocks, units, and/or modules being implemented by microprocessors or other similar hardware, they may be programmed and controlled using software (e.g., microcode) to perform various functions discussed herein and may optionally be driven by firmware and/or software. It is also contemplated that each block, unit, and/or module may be implemented by dedicated hardware, or as a combination of dedicated hardware to perform some functions and a processor (e.g., one or more programmed microprocessors and associated circuitry) to perform other functions. Also, each block, unit, and/or module of some embodiments may be physically separated into two or more interacting and discrete blocks, units, and/or modules without departing from the scope of the invention. Further, the blocks, units, and/or modules of some embodiments may be physically combined into more complex blocks, units, and/or modules without departing from the scope of the invention.

(40) Hereinafter, embodiments will be described with reference to the accompanying drawings.

(41) FIG. 1 is a schematic perspective view of an inkjet printing apparatus according to an embodiment. FIG. 2 is a schematic layout view illustrating the layout of an airflow stage, a support unit, and an electric field generating unit according to an embodiment. FIG. 3 is a schematic plan view of the inkjet printing apparatus according to an embodiment.

(42) An inkjet printing apparatus **1000** according to an embodiment may spray ink onto a target

substrate SUB in case that the target substrate SUB moves in a direction with an electric field generated thereon. As an electric field is formed on the target substrate SUB, particles dispersed in the ink, i.e., dipoles, may be aligned and may be sprayed onto the target substrate SUB.

(43) First, second, and third directions **D1**, **D2**, and **D3** are defined as illustrated. The first and second directions **D1** and **D2** may be directions that reside on one plane and are orthogonal to each other, and the third direction **D3** may be orthogonal to each of the first and second directions **D1** and **D2**.

(44) Unless specified otherwise, the term “top” or “upper” refers to a first side in the third direction **D3**, and the term “top surface” or “upper surface” refers to a surface in the first side in the third direction **D3**. Also, the term “bottom” or “lower” refers to a second side in the third direction **D3**, and the term “bottom surface” or “lower surface” refers to a surface in the second in the third direction **D3**. Also, the terms “left”, “right”, “upper”, and “lower” refer to their respective directions in case that the inkjet printing apparatus **1000** is viewed from thereabove. For example, the term “left” refers to the opposite direction to the second direction **D2**, the term “right” refers to the second direction **D2**, the term “upper” refers to the first direction **D1**, and the term “lower” refers to the opposite direction to the first direction **D1**.

(45) Referring to FIGS. **1** through **3**, the inkjet printing apparatus **1000** may include a stage unit **100**, a substrate transferring unit **200**, an electric field generating unit **300**, an alignment checking unit **400**, a print head unit **500**, and an ejection amount checking unit **600**. The inkjet printing apparatus **1000** may further include guide units (e.g., **910** and **920**).

(46) The stage unit **100** may include an airflow stage **110**. The stage unit **100** may further include base frame **120**, which is disposed below the airflow stage **110** and supports the airflow stage **110**, but embodiments are not limited thereto. In another example, the base frame **120** may be omitted.

(47) The airflow stage **110** may provide space in which a target substrate SUB is disposed. The target substrate SUB may be disposed on the top surface (or upper surface) of the airflow stage **110**. The target substrate SUB may be moved in a direction over the stage unit **100** during a printing process.

(48) The airflow stage **110** may lift up the target substrate SUB in the third direction **D3** (or a vertical direction) by spraying the air onto the bottom surface (or lower surface) of the target substrate SUB disposed on the airflow stage **110**. The target substrate SUB may be moved in the first direction **D1** (or a horizontal direction) over the airflow stage **110** during a printing process, in case that the target substrate SUB is lifted up above the airflow stage **110**.

(49) The airflow stage **110** may have a rectangular shape having long sides in the first direction **D1** and short sides in the second direction **D2**. The direction of the long sides of the airflow stage **110**, i.e., the first direction **D1**, may be the direction in which the target substrate SUB is moved during a printing process. For example, the airflow stage **110** may have a rectangular shape that extends in the direction in which the target substrate SUB is moved during a printing process, i.e., in the first direction **D1**, but embodiments are not limited thereto. In another example, the airflow stage **110** may have various shapes such as an elliptical shape or a polygonal shape that extends in the first direction **D1**.

(50) The airflow stage **110** may include a loading part LA, a printing part PA, and an unloading part ULA. The unloading part ULA may be spaced apart in the first direction **D1** from the loading part LA. The printing part PA may be disposed between the loading part LA and the unloading part ULA. For example, the loading part LA, the printing part PA, and the unloading part ULA may be sequentially arranged along the first direction **D1**.

(51) The loading part LA may be an area where the target substrate SUB is disposed on the airflow stage **110** for a printing process. For example, the target substrate SUB may be an area where target substrate SUB is loaded from the outside and the alignment of the target substrate SUB on the airflow stage **110** is performed for the printing process. For example, a moving unit, which moves the target substrate SUB over to the airflow stage **110** from the outside, may be further provided.

(52) The printing part PA may be an area where the printing process is performed on the target substrate SUB via the print head unit **500**.

(53) The unloading part ULA may be an area where the target substrate SUB is released to the outside after the printing process. For example, the unloading part ULA may be an area where the amount and the landing positions of ink droplets sprayed by the print head unit **500** are checked via the ejection amount checking unit **600**.

(54) Air holes AH may be formed on the surface of the airflow stage **110**. The air holes AH may be formed on the surface of each of the loading part LA, the printing part PA, and the unloading part ULA of the airflow stage **110**. The air holes AH may control the target substrate SUB to be lifted up by as much as a certain height (hereinafter, the floating height) from the airflow stage **110** by discharging or sucking the air between the airflow stage **110** and the target substrate SUB. For example, some of the air holes AH may discharge the air from the airflow stage **110** onto the bottom surface (or lower surface) of the target substrate SUB, and some of the air holes AH may suck the air in the space between the airflow stage **110** and the target substrate SUB. The airflow stage **110** may control the floating height of the target substrate SUB by controlling the pressure of the air discharged through the air holes AH, between the airflow stage **110** and the target substrate SUB, and the pressure of the air sucked through the air holes AH, between the airflow stage **110** and the target substrate SUB.

(55) The guide units (e.g., **910** and **920**) may be disposed on a side of the airflow stage **110**. The substrate transferring unit **200** and the electric field generating unit **300** that will be described below may be disposed on the guide units (e.g., **910** and **920**). The guide units (e.g., **910** and **920**) may extend in the first direction D1 and may move the substrate transferring unit **200** and the electric field generating unit **300** in the first direction D1. The guide units (e.g., **910** and **920**) may function as guides for moving the substrate transferring unit **200** and the electric field generating unit **300** in the first direction D1.

(56) The guide units (e.g., **910** and **920**) may include first and second guide units (e.g., **910** and **920**).

(57) The first guide unit **910** may be disposed on a side of the stage unit **100**. The first guide unit **910** may be disposed on the left side of the airflow stage **110**, in a plan view. The first guide unit **910** is illustrated as being spaced apart from the airflow stage **110**, but embodiments are not limited thereto. In another example, the first guide unit **910** may be attached (or coupled) to a side surface (e.g., the left side surface) of the airflow stage **110**.

(58) The first guide unit **910** may extend in the first direction D1. The direction in which the first guide unit **910** extends may be the same as the direction in which the airflow stage **110** extends. The substrate transferring unit **200** may be disposed on the first guide unit **910**. The substrate transferring unit **200** may be disposed on the first guide unit **910** and may thus be movable along the first direction D1 by the first guide unit **910**.

(59) The second guide unit **920** may be disposed on a side of the stage unit **100**. The second guide unit **920** may be disposed on the left side of the airflow stage **110**, in a plan view. The first guide unit **910** may be disposed between the second guide unit **920** and the stage unit **100**, e.g., in the second direction D2.

(60) The second guide unit **920** may extend in the first direction D1. The direction in which the second guide unit **920** extends may be the same as the direction in which the airflow stage **110** extends. The electric field generating unit **300** may be disposed on the first guide unit **910**. The electric field generating unit **300** may be disposed on the second guide unit **920** and may thus be movable along the first direction D1 by the second guide unit **920**.

(61) During the printing process, the substrate transferring unit **200** may move the target substrate SUB in the first direction D1 with maintaining the target substrate SUB a certain height on the stage unit **100**.

(62) The substrate transferring unit **200** may be disposed on the outside of, and near, a first long

side (e.g., the left side in a plan view) of the airflow stage **110**. The substrate transferring unit **200** may be disposed on at least one side of the airflow stage **110**. One substrate transferring unit **200** is illustrated as being disposed on the outside of, and near, a side of the airflow stage **110**. In another example, more than one substrate transferring unit **200** may be provided.

(63) The substrate transferring unit **200** may be disposed on the first guide unit **910**. The substrate transferring unit **200** may be disposed on the first guide unit **910** and may thus be movable along the first direction **D1**, but embodiments are not limited thereto. In another example, the substrate transferring unit **200** may be movable along the first direction **D1** on the first guide unit **910** via an air bearing or a moving member.

(64) The substrate transferring unit **200** may move the target substrate **SUB** in the first direction **D1** with uniformly maintaining the floating height of the target substrate **SUB**. For example, the substrate transferring unit **200** may fix an edge portion of the target substrate **SUB** lifted up in the third direction **D3** from the airflow stage **110**. As a result, the floating height of the target substrate **SUB** lifted up in the third direction **D3** from the airflow stage **110** may be uniformly maintained during the printing process. As the substrate transferring unit **200** moves in the first direction **D1** on the first guide unit **910**, the target substrate **SUB** may move in the first direction **D1** in case that the target substrate **SUB** is fixed to the substrate transferring unit **200**.

(65) The electric field generating unit **300** may generate an electric field on the target substrate **SUB** during the printing process. The electric field generating unit **300** may move in the first direction **D1** together with the target substrate **SUB** and the substrate transferring unit **200** and may generate an electric field on the target substrate **SUB**. The electric field generating unit **300** may move together with the target substrate **SUB** and the substrate transferring unit **200** with the moving direction and speed synchronized with the moving direction and speed of the target substrate **SUB** and the substrate transferring unit **200**.

(66) The electric field generating unit **300** may be disposed on the second guide unit **920**. The electric field generating unit **300** may be disposed on the second guide unit **920** and may thus be movable in the first direction **D1**, but embodiments are not limited thereto. In another example, the electric field generating unit **300** may be movable along the first direction **D1** on the second guide unit **920** via an air bearing or a moving member.

(67) The alignment checking unit **400**, the print head unit **500**, and the ejection amount checking unit **600** of the inkjet printing apparatus **1000** may be sequentially arranged in the first direction **D1**. The alignment checking unit **400**, the print head unit **500**, and the ejection amount checking unit **600** may be spaced apart from one another in the first direction **D1**.

(68) The alignment checking unit **400** may be disposed on the loading part **LA** of the stage unit **100**. In case that the target substrate **SUB** is disposed on the loading part **LA** of the airflow stage **110**, the alignment checking unit **400** may check the alignment of the target substrate **SUB**.

(69) The alignment checking unit **400** may include an alignment support unit (e.g., **410** and **420**) and a first sensing unit (e.g., **CA1** and **CA2**). The alignment support unit (e.g., **410** and **420**) may include first and second supports **410** and **420**. The first sensing unit (e.g., **CA1** and **CA2**) may include first alignment sensors **CA1**, which are mounted on the first support **410**, and second alignment sensors **CA2**, which are mounted on the second support **420**.

(70) The first support **410** may include a first horizontal support **411**, which extends in the horizontal direction, and first vertical supports **412**, which are connected to end portions (e.g., opposite end portions) of the first horizontal support **411** and extend in the vertical direction, i.e., in the third direction **D3**. The direction in which the first horizontal support **411** extends may be the same as the direction of the short sides of the stage unit **100**, i.e., the second direction **D2**.

(71) The second support **420** may be spaced apart from the first support **410** in the first direction **D1**. The second support **420** may include a second horizontal support **421**, which extends in the horizontal direction, and second vertical supports **422**, which are connected to end portions (e.g., opposite end portions) of the second horizontal support **421** and extend in the vertical direction,

i.e., in the third direction D3. The direction in which the second horizontal support **421** extends may be the same as the direction of the short sides of the stage unit **100**, i.e., the second direction D2.

(72) The first alignment sensors CA1 may be disposed above the loading part LA of the airflow stage **110**. The first alignment sensors CA1 may be mounted on the first support **410**. The first alignment sensors CA1 may be mounted on the first horizontal support **411** and may thus be a certain distance apart from the airflow stage **110** in the third direction D3.

(73) The second alignment sensors CA2 may be disposed above the loading part LA of the airflow stage **110**. The second alignment sensors CA2 may be mounted on the second support **420**. The second alignment sensors CA2 may be mounted on the second horizontal support **421** and may thus be a certain distance apart from the airflow stage **110** in the third direction D3.

(74) The distance between the first alignment sensors CA1, the second alignment sensors CA2, and the airflow stage **110** may be controlled within the range in which the first alignment sensors CA1 and the second alignment sensors CA2 are able to be a certain distance apart from the target substrate SUB and are able to thus ensure alignment-checking space in case that the target substrate SUB is disposed on the airflow stage **110**.

(75) The alignment checking unit **400** may include first alignment sensors CA1 and second alignment sensors CA2. Two first alignment sensors CA1 are illustrated as being mounted on the first support **410**, and two second alignment sensors CA2 are illustrated as being mounted on the second support **420**. However, the numbers of first alignment sensors CA1 and second alignment sensors CA2 are not limited thereto.

(76) The first alignment sensors CA1 and the second alignment sensors CA2 may detect the position of the target substrate SUB on the airflow stage **110** and may align the target substrate SUB with a reference position. In an embodiment, the first alignment sensors CA1 and/or the second alignment sensors CA2 may include cameras. In a case where the first alignment sensors CA1 and/or the second alignment sensors CA2 include cameras, the first alignment sensors CA1 and/or the second alignment sensors CA2 may detect the position of the target substrate SUB by capturing an image of the target substrate SUB on the loading part LA of the airflow stage **110**.

(77) For example, the alignment checking unit **400** may further include a separate target substrate alignment mover for moving the target substrate SUB in the horizontal direction on the airflow stage **110**, to align the target substrate SUB with the reference position.

(78) The print head unit **500** may be disposed on the printing part PA of the stage unit **100**. The print head unit **500** may print ink on the target substrate SUB moved in the first direction D1 from the loading part LA to the printing part PA of the airflow stage **110**. The inkjet printing apparatus **1000** may further include an ink supply unit such as an ink cartridge, ink from the ink supply unit may be sprayed (or ejected) toward the target substrate SUB via the print head unit **500**.

(79) The print head unit **500** may include a third support **510** and a print head **520**.

(80) The third support **510** may include a third horizontal support **511**, which extends in the horizontal direction, and third vertical supports **512**, which are connected to end portions (e.g., opposite end portions) of the third horizontal support **511** and extend in the vertical direction, i.e., in the third direction D3. The direction in which the third horizontal support **511** extends may be the same as the direction of the short sides of the stage unit **100**, i.e., the second direction D2.

(81) The print head **520** may spray ink including dipoles onto the target substrate SUB. The print head **520** may be disposed above the printing part PA of the airflow stage **110**.

(82) The print head **520** may be mounted on the third horizontal support **511** of the third support **510**. The print head **520** may be mounted on the third horizontal support **511** and may thus be a certain distance apart from the airflow stage **110** in the third direction D3. The print head **520** may be mounted on the third horizontal support **511**, but may protrude in a direction from the third horizontal support **511**. For example, the print head **520** may protrude from a second side in the first direction D2 (e.g., the lower side in a plan view) of the third horizontal support **511**.

(83) The ejection amount checking unit **600** may be disposed above the unloading part ULA of the stage unit **100**. The ejection amount checking unit **600** may check the amount and the landing positions of droplets of ink sprayed by the print head unit **500**. The ejection amount checking unit **600** may analyze ink applied to a test area of the target substrate SUB moved from the printing part PA to the unloading part ULA of the airflow stage **110** or ink applied to a separate test substrate. A process of spraying ink from the print head unit **500** onto the target substrate SUB will be described below.

(84) The ejection amount checking unit **600** may include a fourth support **610** and a second sensing units **650**.

(85) The fourth support **610** may include a fourth horizontal support **611**, which extends in the horizontal direction, and fourth vertical supports **612**, which are connected to end portions (e.g., opposite end portions) of the fourth horizontal support **611** and extend in the vertical direction, i.e., in the third direction D3. The direction in which the fourth horizontal support **611** extends may be the same as the direction of the short sides of the stage unit **100**, i.e., the second direction D2.

(86) The second sensing units **650** may be disposed above the unloading part ULA of the airflow stage **110**. The second sensing units **650** may be mounted on the fourth support **610** and may thus be a certain distance apart from the airflow stage **110** in the third direction D3. The second sensing units **650** may be movable in the second direction D2 on the fourth horizontal support **611** of the fourth support **610**.

(87) The distance between the second sensing units **650** and the airflow stage **110** may be controlled within the range in which the second sensing units **650** is able to be a certain distance apart from the target substrate SUB or the test substrate and is able to thus ensure processing (or checking) space in case that the target substrate SUB or the test substrate is disposed on the airflow stage **110**.

(88) The ejection amount checking unit **600** may include second sensing units **650**. Three second sensing units **650** are illustrated as being provided, but embodiments are not limited thereto. The second sensing units **650** may be spaced apart from the airflow stage **110** and may detect ink applied on the target substrate SUB.

(89) FIG. 4 is a schematic layout view illustrating the layout of the substrate transferring unit and the electric field generating unit according to an embodiment. FIG. 5 is a schematic cross-sectional view illustrating the layout of the inkjet printing apparatus according to an embodiment. FIG. 6 is a schematic perspective view illustrating a gripper and the target substrate SUB according to an embodiment.

(90) Referring to FIGS. 4 through 6, the substrate transferring unit **200** may be disposed on the outside of, and near, one long side of the airflow stage **110**.

(91) The substrate transferring unit **200** may include a first base substrate **210** and a gripper **220**.

(92) The first base substrate **210** may be disposed on the first guide unit **910**. The first base substrate **210** may be movable in the first direction D1 on the first guide unit **910**. The gripper **220** may be disposed on the first base substrate **210**. In a case where the target substrate SUB is fixed to the gripper **220**, the first base substrate **210** may move the target substrate SUB in the first direction D1 by moving on the first guide unit **910**.

(93) The first base substrate **210** may have a planar shape extending in the first direction D1.

(94) The gripper **220** may be disposed on the first base substrate **210**. The gripper **220** may be disposed on the first base substrate **210** and may extend in the first direction D1. In an embodiment, the gripper **220** may include an adsorption device. For example, the adsorption device may be a vacuum device, a vacuum chuck, or the like, but embodiments are not limited thereto.

(95) The gripper **220** may fix the target substrate SUB with uniformly maintaining the floating height of the target substrate SUB. In an embodiment, in case that the target substrate SUB is disposed on the airflow stage **110** and is lifted up from the airflow stage **110** by spraying the air from the air holes AH formed on the surface of the airflow stage **110**, the gripper **220** may generate

negative pressure in the area of contact with the bottom surface (or lower surface) of an edge part of the target substrate SUB, and as a result, the edge part of the target substrate SUB may be adsorbed and fixed to the gripper **220**. For example, the gripper **220** may fix the target substrate SUB on the top surface (or upper surface) thereof by generating negative pressure in the opposite direction to the third direction D3, from below the bottom surface (or lower surface) of the target substrate SUB. As the target substrate SUB is fixed to the gripper **220**, the printing process may be performed with uniformly maintaining the floating height of the target substrate SUB from the airflow stage **110**. As the target substrate SUB is fixed to the gripper **220** and the first base substrate **210** where the gripper **220** is disposed moves in the first direction D1, the target substrate SUB may be transferred in the first direction D1.

(96) The electric field generating unit **300** may be disposed on the outside of, and near, a side of the substrate transferring unit **200**. The electric field generating unit **300** may include a second base substrate **310**, a probe unit **320**, and a probe driving device **330**.

(97) The probe unit **320** may be disposed on the second base substrate **310**. The second base substrate **310** may be disposed on the second guide unit **920**. During the printing process, the second base substrate **310** may be movable in the first direction D1 on the second guide unit **920**. The second base substrate **310** may be integral with the target substrate SUB by being synchronized with the target substrate SUB and the substrate transferring unit **200** and may thus be movable simultaneously with the target substrate SUB in the first direction D1.

(98) The probe unit **320** may generate an electric field on the target substrate SUB lifted up from the airflow stage **110** and fixed to the gripper **220**. The size and shape of the probe unit **320** may vary according to the shape of the target substrate SUB.

(99) The probe unit **320** may extend in the first direction D1 and may include probes. The length by which the probe unit **320** extends in the extension direction of the probe unit **320** may cover the entire target substrate SUB. The probes of the probe unit **320** may be in contact with electrode pads of the target substrate SUB.

(100) The probe driving device **330** may be disposed on the second base substrate **310**, and outside the probe unit **320**. The probe driving device **330** may be a device transmitting electrical signals to the probe unit **320**. The probe driving device **330** may provide a voltage, for example, an alternating voltage, to the electrode pads of the target substrate SUB via the probe unit **320**, which is in contact with the electrode pads of the target substrate SUB. Voltages may be applied at the same time or sequentially by the probe unit **320**.

(101) The probe unit **320** may include a probe support **321**, a probe driver **323**, a probe jig **325**, a probe horizontal mover **327**, and a probe vertical mover **329**.

(102) The probe support **321** may be disposed on the second base substrate **310**.

(103) The probe driver **323** may be disposed on the probe support **321**. The probe driver **323** may drive the probe horizontal mover **327** and the probe vertical mover **329** such that the probe jig **325** may move in the horizontal and vertical directions, for example, in the second and third directions D2 and D3, and may thus be disposed on the electrode pads of the target substrate SUB.

(104) As the probe horizontal mover **327** and the probe vertical mover **329** are driven by the probe driver **323**, the probe jig **325** may be connected to (or disconnected from) the electrode pads of the target substrate SUB. The probe horizontal mover **327** may drive the probe jig **325** to move in the horizontal direction, for example, in the second direction D2. The probe vertical mover **329** may drive the probe jig **325** to move in the vertical direction, for example, in the third direction D3. The probe driver **323** may drive the probe jig **325** to be connected to the target substrate SUB in the step of generating an electric field on the target substrate SUB, for example, during or before the printing process, during the operation of the inkjet printing apparatus **1000** and may drive the probe jig **325** to be disconnected from the target substrate SUB in other steps of the operation of the inkjet printing apparatus **1000**.

(105) The probe jig **325** may generate an electric field on the target substrate SUB via electrical

signals transmitted from the probe driving device **330**. The probe jig **325** may be connected to the target substrate SUB to transmit the electrical signals to the target substrate SUB and thus to generate an electric field on the target substrate SUB. For example, the probe jig **325** may be in contact with the electrode pads or power pads of the target substrate SUB, and the electrical signals transmitted from the probe driving device **330** may be delivered to the electrode pads or the power pads. The electric signals transmitted to the target substrate SUB may generate an electric field on the target substrate SUB. For example, the probe jig **325** may be in contact with the top surface (or upper surface) of the target substrate SUB to help the gripper **220** of the substrate transferring unit **200** fix the target substrate SUB. As the probe jig **325** presses the top surface (or upper surface) of the target substrate SUB lifted up from the airflow stage **110** in the opposite direction to the third direction D3, the target substrate SUB may be fixed to the probe jig **325** and the gripper **220**.

(106) The probe unit **320** is not limited thereto. The structure and the layout of the probe unit **320** are not limited as long as the probe unit **320** generates an electric field on the target substrate SUB on the airflow stage **110**.

(107) FIGS. **7** and **8** are schematic views illustrating the states of the probe unit according to an embodiment.

(108) As mentioned above, the probe driver **323** of the probe unit **320** may operate in accordance with the steps of the operation of the inkjet printing apparatus **1000**.

(109) Referring to FIGS. **7** and **8**, as the target substrate SUB is disposed on the airflow stage **110** and is lifted up by spraying the air to the bottom surface (or lower surface) of the target substrate SUB through the air holes AH formed on the top surface (or upper surface) of the airflow stage **110**, an edge part of the target substrate SUB may be fixed by the gripper **220** of the substrate transferring unit **200**. In case that the target substrate SUB is yet to be fixed on the gripper **220** or yet to be lifted up, the probe jig **325** may be disposed on the probe support **321** to be spaced apart from the target substrate SUB and the gripper **220**. The probe driver **323** of the probe unit **320** may drive the probe jig **325** in the second and third directions D2 and D3, which are the horizontal and vertical directions, respectively, not to overlap the target substrate SUB and/or the gripper **220**.

(110) In a second state of forming an electric field on the target substrate SUB by preparing the target substrate SUB on the airflow stage **110** and fixing the target substrate SUB to the gripper **220** with the gripper **220** disposed on the bottom surface (or lower surface) of an edge part of the target substrate SUB, the probe driver **323** of the probe unit **320** may drive the probe jig **325** to be connected to the target substrate SUB. The probe driver **323** may drive the probe vertical mover **329** in the vertical direction, i.e., in the third direction D3, and drive the probe horizontal mover **327** in the horizontal direction, i.e., in the second direction D2, to place the probe jig **325** in contact with the electrode pads formed on the top surface (or upper surface) of the target substrate SUB. Electrical signals may be transmitted to the target substrate SUB via the probe jig **325** of the probe unit **320**, and as a result, an electric field may be generated on the target substrate SUB.

(111) FIG. **9** is a schematic plan view illustrating the step of loading a target substrate SUB in a loading part, according to an embodiment. FIGS. **10** and **11** are schematic cross-sectional views an example of FIG. **9**.

(112) Referring to FIGS. **9** through **11**, the target substrate SUB may be disposed on the loading part LA of the airflow stage **110**. As the air is sprayed onto the target substrate SUB on the loading part LA of the airflow stage **110**, through the air holes AH formed on the top surface (or upper surface) of the airflow stage **110**, the target substrate SUB may be fixed to the gripper **220**. The bottom surface (or lower surface) of the target substrate SUB may be in contact with the top surface (or upper surface) of the gripper **220**.

(113) Referring to FIG. **10**, the first sensing unit (e.g., CA1 and CA2) may be disposed above the target substrate SUB, which is fixed to the gripper **220**, and may capture an image of the target substrate SUB. The first sensing unit (e.g., CA1 and CA2) may check whether the target substrate SUB is disposed at the reference position by capturing an image of the target substrate SUB and

detecting the position of the target substrate SUB. For example, the target substrate SUB may be aligned with the reference position by moving the target substrate SUB in the horizontal direction via a separate moving member in case that the position of the target substrate SUB, detected by the first sensing unit (e.g., CA1 and CA2), differs from the reference position.

(114) Thereafter, in case that the target substrate SUB is aligned with the reference position, the probe unit **320** of the electric field generating unit **300** may be in contact with (or electrically connected to) the electrode pads on the top surface (or upper surface) of the target substrate SUB.

(115) For example, referring to FIG. **11**, the probe driver **323** of the probe unit **320** may drive the probe horizontal mover **327** and the probe vertical mover **329** and may thus move the probe jig **325** to be positioned on the electrode pads of the target substrate SUB. The probe jig **325** may be disposed in contact with the top surface (or upper surface) of the target substrate SUB by the probe driver **323**. In an embodiment, the probe jig **325** may be in contact with the top surface (or upper surface) of an edge part of the target substrate SUB, and the gripper **220** may be in contact with the bottom surface (or lower surface) of the edge part of the target substrate SUB. The target substrate SUB may be fixed such that the floating height of the target substrate SUB from the airflow stage **110** may be uniformly maintained by the probe jig **325** and the gripper **220**.

(116) FIG. **12** is a schematic plan view illustrating the step of placing the target substrate SUB in the printing part, according to an embodiment. FIG. **13** is a schematic cross-sectional view illustrating an example of FIG. **12**. FIG. **14** is a schematic view illustrating how an electric field is generated on the target substrate by the probe unit, according to an embodiment.

(117) Referring to FIGS. **12** through **14**, after the alignment of the target substrate SUB on the airflow stage **110** is complete, the target substrate SUB may be moved along the first and second guide units **910** and **920** in the first direction D1, together with the substrate transferring unit **200** and the electric field generating unit **300**. For example, as the bottom surface (or lower surface) of the edge part of the target substrate SUB is fixed to the gripper **220** and the electrode pads on the top surface (or upper surface) of the edge part of the target substrate SUB are in contact with the probe jig **325**, the target substrate SUB may be movable in the first direction D1 together with the substrate transferring unit **200** and the electric field generating unit **300**. The target substrate SUB may be lifted up from above the airflow stage **110** and may be transferred from the loading part LA to the printing part PA by the substrate transferring unit **200**.

(118) Ink I may be sprayed onto the target substrate SUB, lifted up from the airflow stage **110** and transferred in the first direction D1 to the printing part PA, via the print head **520**. The direction in which the print head **520** extends may be the same as the direction in which the third horizontal support **511** of the third support **510** extends. For example, the direction in which the print head **520** extends may be the direction of the short sides of the airflow stage **110**, i.e., the second direction D2.

(119) The print head **520** may include nozzles NZ, from which the ink I is ejected. The print head **520** may include an inner tube IP, and the inner tube IP may be formed in the direction in which the print head **520** extends and may deliver the ink I. The nozzles NZ may be arranged along the direction in which the print head **520** extends. The nozzles NZ may be arranged in one or more rows.

(120) Each of the nozzles NZ may be connected to the inner tube IP of the print head **520**. The ink I may be supplied into the inner tube IP of the print head **520**, may flow along the inner tube IP, and may be sprayed through the nozzles NZ. The ink I sprayed through the nozzles NZ may be supplied to the top surface (or upper surface) of the target substrate SUB. The amount of ink I sprayed through the nozzles NZ may be controlled by a voltage applied to the nozzles NZ. In an embodiment, the amount of the ejected ink of each of the nozzles NZ may be about 1 pl to about 50 pl, but embodiments are not limited thereto.

(121) A single print head **520** is illustrated as being provided, but embodiments are not limited thereto. For example, for a process that provides multiple types of inks I to the target substrate

SUB, the number of print heads **520** corresponding to the number of types of inks I may be provided.

(122) Referring to FIG. **14**, the ink I may be provided as a solution. The ink I may include, for example, a solvent SV and dipoles DP dispersed in the solvent SV. The solvent SV may be acetone, water, alcohol, toluene, or the like. The solvent SV may be a material that is vaporized or volatilized by room temperature or heat. The dipoles DP may be dispersed in the solvent SV. The dipoles DP may be solid materials that finally remain on the target substrate SUB after the removal of the solvent SV.

(123) The dipoles DP may be objects having an end portion of a first polarity and another end portion of a second polarity, which is different from the first polarity. For example, an end portion of each of the dipoles DP may have a positive polarity, and another end portion of each of the dipole DP may have a negative polarity. In case that the dipoles DP having different polarities at end portions (e.g., opposite end portions) thereof are disposed in an electric field IEL generated on the target substrate SUB by the probe unit **320** of the electric field generating unit **300**, the orientation direction of the dipoles DP may be controlled by electrical forces (i.e., an attractive force and a repulse force).

(124) The dipoles DP may extend in a direction. The dipoles DP may be light-emitting diodes such as, for example, inorganic light-emitting diodes having a size of several micrometers or nanometers and formed of an inorganic material. The dipoles DP included in the ink I may include semiconductor layers doped with impurities of an arbitrary conductivity type (e.g., a p type dopant or an n type dopant). The semiconductor layers may receive electrical signals from an external power source and may thus emit light of a certain wavelength band.

(125) In the case of spraying the ink I, including the dipoles DP, onto the target substrate SUB via the print head **520**, in case that the electric field IEL is generated on the target substrate SUB, the dipoles DP having the first and second polarities may continue to receive electrical forces until the ink I is supplied from the nozzles NZ onto the target substrate SUB. Due to the electrical forces, the dipoles DP may be oriented, for example, in the direction of the electric field IEL.

(126) FIG. **14** illustrates that the probe unit **320** generates the electric field IEL in case that the ink I is sprayed through the nozzles NZ. As a result, the dipoles DP may continue to receive forces from the electric field IEL until the dipoles DP arrive at (or contact on) the target substrate SUB after being ejected from the nozzles NZ, but embodiments are not limited thereto. In another example, the probe unit **320** may generate the electric field IEL after the spraying of the ink onto the target substrate SUB. For example, the dipoles DP may be sprayed onto the target substrate SUB in random orientation directions and may be arranged in a direction, inside the sprayed ink I, by the electric field IEL.

(127) The probe unit **320** is illustrated as generating the electric field IEL on the target substrate SUB in case that the ink I is being sprayed onto the target substrate SUB, but embodiments are not limited thereto. In another example, the probe unit **320** may generate the electric field IEL on the target substrate SUB in case that the target substrate SUB is being transferred to the unloading part ULA after the spraying of the ink I.

(128) FIG. **15** is a schematic plan view illustrating the step of placing the target substrate SUB in the unloading part, according to an embodiment. FIG. **16** is a schematic cross-sectional view of an example of FIG. **15**. FIG. **17** is a schematic plan view illustrating the step of discharging the target substrate.

(129) Referring to FIGS. **15** and **16**, after the application of the ink I onto the target substrate SUB via the print head unit **500** is complete, the target substrate SUB may be moved in the first direction D1 along the first and second guide units **910** and **920**, together with the substrate transferring unit **200** and the electric field generating unit **300** and may thus be transferred to the unloading part ULA. In the unloading part ULA, the ink I sprayed to the test area of the target substrate SUB may be checked via the second sensing units **650**. For example, the second sensing units **650** may detect

the diameter and the position of the ink I sprayed onto the target substrate SUB and may measure error in the diameter and the position of the ink I. Data regarding the ink I sensed by the second sensing units **650** may be fed back to control settings of the inkjet printing apparatus **1000**.

(130) The second sensing units **650** may be connected to the fourth support **610** and may include first movers **651**, which are movable in the horizontal direction, first supports **653**, which are disposed on the surfaces of the first movers **651**, and first sensors **655**, which are disposed on the first support **653**.

(131) The first movers **651** may be mounted on the fourth horizontal support **611** of the fourth support **610** and may be movable in the second direction D2, which is the direction in which the fourth horizontal support **611** extends. As the first movers **651** move in the second direction D2, the first supports **653** mounted on the first movers **651** may move in the second direction D2.

(132) The first supports **653** may be mounted on the first movers **651**. The first supports **653** may be disposed at the bottom surfaces (or lower surfaces) of the first movers **651** and may extend in the first direction D1. First end portions of the first supports **653** may be connected to the first movers **651**, and second end portions of the first supports **653** may be connected to the first sensors **655**. For example, the first end portions and the second end portions of the first supports **653** may be opposite to each other.

(133) The first sensors **655** may be disposed above the airflow stage **110**. The first sensors **655** may be mounted on the first supports **653** to be a certain distance apart from the airflow stage **110**. The first sensors **655** may be disposed above the airflow stage **110** to detect a material applied to the test area of the target substrate SUB lifted up from the airflow stage **110** or to the test substrate. The material applied to the test area of the target substrate SUB may include the ink I, which includes the solvent SV and the dipoles DP dispersed in the solvent SV. As the first movers **651** move in the second direction D2, the first sensors **655** may detect (or capture an image of) the material applied on each area of the target substrate SUB.

(134) In an embodiment, the first sensors **655** may be high-resolution cameras. In a case where the first sensors **655** are high-resolution cameras, the first sensors **655** may be disposed above the target substrate SUB with the ink I applied thereon and may capture an image of the test area of the target substrate SUB to measure the diameter and the position of the material applied on the target substrate SUB and error in the diameter and the position of the material applied on the target substrate SUB. However, the first sensors **655** are not limited to high-resolution cameras as long as they detect the material applied on the target substrate SUB.

(135) Error may be measured by comparing the diameter and the applied position of the ink I, measured by the second sensing units **650**, with a reference set value. For example, the measured error may be compared with a threshold value, and the amount of the ink I sprayed by the print head **520** and the position of an ink ejection member of the print head **520** may be adjusted based on the results of the comparison to be close to the reference set value.

(136) Referring to FIG. **16**, in a process of placing the target substrate SUB in the unloading part ULA and checking the amount of the ejected ink I, the probe unit **320** of the electric field generating unit **300** may be spaced apart from the target substrate SUB. In a case where the target substrate SUB is disposed in the unloading part ULA, the probe driver **323** of the probe unit **320** may drive the probe horizontal mover **327** and the probe vertical mover **329** to space the probe jig **325** apart from the top surface (or upper surface) of the target substrate SUB. Thus, electric field may not be generated on the target substrate SUB. However, embodiments are not limited thereto. In another example, the probe driving device **330** may be driven not to provide electrical signals to the probe unit **320**, and the probe jig **325** may be maintained to be in contact with the top surface (or upper surface) of the target substrate SUB.

(137) Thereafter, referring to FIG. **17**, in case that the printing process of applying the ink I onto the target substrate SUB and the process of checking the amount of the ejected ink from the print head **520** are complete, the target substrate SUB may move along the first direction D1 and may

thus be discharged from the inkjet printing apparatus **1000**. As the target substrate SUB is discharged along the first direction D1, the substrate transferring unit **200** and the electric field generating unit **300** may move in the opposite direction to the first direction D1, i.e., in a downward direction, and may thus be disposed on a side of the loading part LA of the airflow stage **110**.

(138) Other embodiments will hereinafter be described, focusing on the differences with the embodiment, and descriptions of elements or features that have been described above in connection with the embodiment will be omitted or simplified for descriptive convenience.

(139) FIG. **18** is a schematic plan view of an inkjet printing apparatus according to an embodiment. FIG. **19** is a schematic plan view of an inkjet printing apparatus according to an embodiment. FIG. **20** is a schematic plan view of an inkjet printing apparatus according to an embodiment. FIGS. **18** through **20** illustrate various inkjet printing apparatuses having different numbers and/or layouts of substrate transferring units and/or different numbers and/or layouts of electric field generating units.

(140) The inkjet printing apparatus of FIG. **18** differs from the inkjet printing apparatus of FIG. **3** in that a substrate transferring unit is disposed on sides (e.g., opposite sides) of a stage unit.

(141) Referring to FIG. **18**, a substrate transferring unit **200_1** may include first and second substrate transferers **200A** and **200B**. The first substrate transferers **200A** may have substantially the same configuration, structure, and layout as the substrate transferring unit **200** of FIG. **3**. The second substrate transferer **200B** may have the same configuration and structure as the substrate transferring unit **200**. Descriptions of the configuration and structure of the first and second substrate transferers **200A** and **200B** may be replaced with the description of the substrate transferring unit **200**, and the layout of the first and second substrate transferers **200A** and **200B** relative to an airflow stage **110** will hereinafter be described.

(142) An inkjet printing apparatus **1000** may further include a third guide unit **930** on the right side of the airflow stage **110**. The third guide unit **930** may extend in the direction in which the airflow stage **110** extends, i.e., in a first direction D1.

(143) The substrate transferring unit **200_1** may be disposed on sides (e.g., opposite sides) of the airflow stage **110**.

(144) The first substrate transferer **200A** may be disposed on a first side of the airflow stage **110**. For example, the first substrate transferer **200A** may be disposed on the outside of, and near, a first long side (e.g., the left side) of the airflow stage **110**.

(145) For example, the second substrate transferer **200B** may be disposed on the outside of a second side of the airflow stage **110** that is opposite to the first side of the airflow stage **110**. For example, the second substrate transferer **200B** may be disposed on the outside of, and near, a second long side (e.g., the right side) of the airflow stage **110**. The second substrate transferer **200B** may be disposed on the third guide unit **930**.

(146) The first substrate transferer **200A** may be disposed on the bottom surface (or lower surface) of a first edge part of a target substrate SUB, and the second substrate transferer **200B** may be disposed on the bottom surface (or lower surface) of a second edge part of the target substrate SUB that is opposite to the first edge part of the target substrate SUB. As the first and second substrate transferers **200A** and **200B** fix edge portions (e.g., opposite edge portions) of the target substrate SUB, the target substrate SUB lifted up from the airflow stage **110** may be stably fixed.

(147) The inkjet printing apparatus of FIG. **19** differs from the inkjet printing apparatus of FIG. **18** in that an electric field generating unit is disposed on sides (e.g., opposite sides) of a stage unit.

(148) Referring to FIG. **19**, an electric field generating unit **300_1** may include first and second electric field generators **300A** and **300B**. The first electric field generator **300A** may have substantially the same configuration, structure, and layout as the first electric field generating unit **300** of FIG. **3**. The second electric field generator **300B** may have the same configuration and structure as the first electric field generating unit **300**. Descriptions of the configuration and

structure of the first and second electric field generators **300A** and **300B** may be replaced with the description of the substrate transferring unit **200**, and the layout of the first and second electric field generators **300A** and **300B** relative to an airflow stage **110** will hereinafter be described.

(149) An inkjet printing apparatus **1000** may further include a fourth guide unit **940**, which is disposed on the outside of a third guide unit **930**. The fourth guide unit **940** may extend in the direction in which the airflow stage **110** extends, i.e., in a first direction **D1**. The third guide unit **930** may be disposed between the airflow stage **110** and the fourth guide unit **940**.

(150) The electric field generating unit **300_1** may be disposed on sides (e.g., opposite sides) of the airflow stage **110**. The electric field generating unit **300_1** may be disposed on the outside of first and second substrate transferers **200A** and **200B**.

(151) The first electric field generator **300A** may be disposed on the outside of, and near, the first substrate transferer **200A**.

(152) The second electric field generator **300B** may be disposed on the outside of, and near, the second substrate transferer **200B**. The second electric field generator **300B** may be disposed on the fourth guide unit **940**.

(153) Since the electric field generating unit **300_1** includes electric field generators, i.e., the first and second electric field generators **300A** and **300B**, electrode pads may be provided on sides (e.g., opposite sides) of the top surface (or upper surface) of the target substrate **SUB** to generate an electric field, and electric field application signals may be transmitted to sides (e.g., opposite sides) of the target substrate **SUB** via the first and second electric field generators **300A** and **300B** on sides (e.g., opposite sides) of the target substrate **SUB**. Accordingly, signal noise may be minimized by applying the electric field application signals to sides (e.g., opposite sides) of the target substrate **SUB**.

(154) The inkjet printing apparatus of FIG. **20** differs from the inkjet printing apparatus of FIG. **19** in that a substrate transferring unit **200** is disposed on a side of the inkjet printing apparatus. The substrate transferring unit **200** may be disposed on the outside of, and near, the left side of an airflow stage **110**. An electric field generating unit **300** may include first and second electric field generators **300A** and **300B**. The first electric field generator **300A** may be disposed on the outside (e.g., on the left side) of the substrate transferring unit **200**, and the second electric field generator **300B** may be disposed on the outside of, and near, the right side of the airflow stage **110**.

(155) Various substrate transferring units and various electric field generating units of an inkjet printing apparatus will hereinafter be described with reference to FIGS. **21** through **28**. For convenience, only substrate transferring units, electric field generating units, target substrates, and airflow stages are schematically illustrated.

(156) FIG. **21** is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment. FIG. **21** shows an example in which a gripper and a probe unit of an inkjet printing apparatus are integral with each other.

(157) For example, a gripper **220_1** may be mounted on a probe horizontal mover **327** of a probe unit **320**. The gripper **220_1** may be mounted on the probe horizontal mover **327** and may fix a target substrate **SUB** by generating negative pressure. The negative pressure may be formed by sucking the air between the gripper **220_1** and the top surface (or upper surface) of the target substrate **SUB** in a third direction **D3**.

(158) FIG. **22** is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment. FIGS. **23** and **24** are schematic enlarged cross-sectional views illustrating how to drive a gripper and a probe unit of FIG. **22**. FIGS. **22** through **24** show that a probe jig is disposed in, and incorporated into, a gripper.

(159) Referring to FIGS. **22** through **24**, a probe jig **325_2** may be disposed in a groove in a gripper **220_2**. The groove may be formed on the bottom surface (or lower surface) of the gripper **220_2**. The probe jig **325_2** may be formed in the groove on the bottom surface (or lower surface) of the gripper **220_2**. A buffer member **SP** may be further disposed between the probe jig **325_2** and the

gripper **220_2**. The buffer member SP may function that the probe jig **325_2** is movable in a third direction **D3** in a case where a target substrate SUB is adhered and fixed onto the bottom surfaces (or lower surfaces) of the probe jig **325_2** and the gripper **220_2** by the gripper **220_2**.

(160) The probe jig **325_2** may include a probe base BA and a probe pin PN. The probe base BA may transmit electrical signals from a probe driving device **330** to the probe pin PN. The probe pin PN may be in contact with the target substrate SUB and may transmit electrical signals by being in contact with (e.g., in direct contact with) electrode pads formed on the top surface (or upper surface) of the target substrate SUB.

(161) FIG. **25** is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment. FIG. **25** shows that a gripper **220**, a probe unit **320**, and a probe driving device **330** are disposed together on a single base substrate.

(162) Referring to FIG. **25**, the inkjet printing apparatus may include a fifth guide unit **970**. The fifth guide unit **970** may be substantially the same as the first guide unit **910** of any one of the embodiments. A base substrate **710** may be disposed on the fifth guide unit **970**. The gripper **220**, the probe unit **320**, and the probe driving device **330** may be disposed on the base substrate **710**. The gripper **220**, the probe unit **320**, and the probe driving device **330** may be sequentially disposed on the base substrate **710** in a direction from an airflow stage **110** to the outside.

(163) The gripper **220**, the probe unit **320**, and the probe driving device **330**, which are disposed on the same base substrate, e.g., the base substrate **710**, may be movable as one body in a first direction **D1**.

(164) FIG. **26** is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment. FIG. **27** is a schematic plan view of examples of a gripper and a probe unit of FIG. **26**.

(165) Referring to FIGS. **26** and **27**, the inkjet printing apparatus may include a unit UT, and the unit UT may include a gripper **220_3** and a probe unit **320_3**, which is disposed in the gripper **220_3** and generates an electric field on a target substrate SUB without being in contact with the target substrate SUB. The unit UT may be disposed on a base substrate **710**, which is disposed on a fifth guide unit **970**. The unit UT may be disposed below the target substrate SUB, may fix the target substrate SUB by sucking the air below the bottom surface (or lower surface) of the target substrate SUB, and may apply an electric field IEL_1 onto the target substrate SUB.

(166) The probe unit **320_3** may extend in a first direction **D1**. The probe unit **320_3** may include a wireless application device, which is capable of generating an electric field in a wireless manner without being in contact with the target substrate SUB. For example, the probe unit **320_3** may include a coil, a pad, or the like.

(167) FIG. **28** is a schematic partial cross-sectional view of an inkjet printing apparatus according to an embodiment.

(168) The embodiment of FIG. **28** differs from the embodiment of FIG. **27** in that an auxiliary gripper GP is further disposed on a base substrate **710**. For example, the auxiliary gripper GP may be disposed on the base substrate **710**.

(169) The auxiliary gripper GP may include a base **810** and a fixer **720**.

(170) The base **810** may be disposed on the base substrate **710**. An end portion of the base **810** may be disposed on the top surface (or upper surface) of the target substrate SUB, and another end portion of the base **810** may be disposed on the bottom surface (or lower surface) of the target substrate SUB. The base **810** may have a “U” (or “C”) shape in a schematic cross-sectional view and may include space. Part of the target substrate SUB may be disposed in the space of the base **810**.

(171) The fixer **820** may be disposed at an end portion of the base **810**. The fixer **820** may be fixed to an end portion of the base **810**, from below the corresponding end portion of the base **810**. The fixer **820** may be disposed between the target substrate SUB and the base **810**, above the target substrate SUB, and may fix the top surface (or upper surface) of the target substrate SUB.

(172) FIG. 29 is a flowchart illustrating a method of aligning dipoles by using an inkjet printing apparatus, according to an embodiment. FIGS. 30 through 33 are schematic views illustrating the method of FIG. 29.

(173) Referring to FIGS. 1 through 3 and 29, the method may include the steps of: preparing a target substrate SUB on a stage unit 100 of an inkjet printing apparatus (S100); spraying ink I, including dipoles DP, onto the target substrate SUB with an electric field applied to the target substrate SUB (S200); and landing the dipoles DP on the target substrate SUB (S300).

(174) The step of preparing the target substrate SUB on the stage unit 100 of the inkjet printing apparatus (i.e., S100 of FIG. 29) is the step of mounting the target substrate SUB on an airflow stage 110 of the stage unit 100 and fixing the target substrate SUB to a gripper 220 by spraying the air onto the bottom surface (or lower surface) of the target substrate SUB to lift up the target substrate SUB.

(175) For example, the target substrate SUB may be mounted on the airflow stage 110. The target substrate SUB may be disposed on the top surface (or upper surface) of the airflow stage 110 by a separate moving member. Thereafter, the target substrate SUB may be lifted up in a third direction D3 from the top surface (or upper surface) of the airflow stage 110 by spraying the air onto the bottom surface (or lower surface) of the target substrate SUB through air holes AH formed on the top surface (or upper surface) of the airflow stage 110. Thereafter, the gripper 220 may be disposed on the bottom surface (or lower surface) of an edge part of the target substrate SUB, and the target substrate SUB may be fixed to the gripper 220 by negative pressure from the gripper 220.

Thereafter, the target substrate SUB may be aligned with a reference position by performing an alignment check of the target substrate SUB with the use of an alignment checking unit 400.

(176) After the alignment of the target substrate SUB is complete, the ink I, including the dipoles DP, may be sprayed onto the target substrate SUB (S200 of FIG. 29) as illustrated in FIG. 30.

(177) First and second electrodes 21 and 22 may be formed on the target substrate SUB, and the ink I may be sprayed onto the first and second electrodes 21 and 22. As mentioned above, as an electric field IEL is generated in a vertical direction via an electric field generating unit 300, the ink I may pass through a region where the electric field IEL is generated, and the dipoles DP may be aligned substantially in the vertical direction in a solvent SV. The ink I is illustrated as being sprayed onto a pair of electrodes, but embodiments are not limited thereto. For example, more than one pair of electrodes may be formed on the target substrate SUB, and the ink I may be sprayed onto each pair of electrodes by moving the target substrate SUB, lifted up from the airflow stage 110, in a first direction D1 and by moving nozzles NZ of a print head 520 of a print head unit 500.

(178) Thereafter, the step of landing the dipoles DP onto the target substrate SUB may be performed. The landing of the dipoles DP may be performed by dielectrophoresis. For example, referring to FIG. 31, an alternating current voltage or a direct current voltage is applied to the first and second electrodes 21 and 22. In an embodiment, in a case where an alternating current voltage is applied to the first and second electrodes 21 and 22, the alternating current voltage may be about $\pm(10\sim50)$ V and may have a frequency of about 10 kHz to about 1 MHz, but embodiments are not limited thereto.

(179) The alternating current voltage may be applied by using the electric field generating unit 300. A probe driving device 330 of the electric field generating unit 300 may include a function generator and an amplifier, which are for generating an appropriate alternating current voltage. For example, a signal having a certain alternating waveform and a certain frequency may be generated by the function generator, the generated signal may be amplified by the amplifier, and the amplified signal may be provided to a probe jig 325 of a probe unit 320.

(180) The first and second electrodes 21 and 22 may be connected to electrode pads provided on at least one side of the target substrate SUB, and the alternating current voltage may be applied to the electrode pads via the probe jig 325 of the probe unit 320. In a case where the probe unit 320 is disposed on only one side of the airflow stage 110, the electrode pads for the first and second

electrodes **21** and **22** may be disposed on only one side of the target substrate SUB. The alternating current voltage may be applied to the electrode pads on a side of the target substrate SUB by the probe unit **320**, but embodiments are not limited thereto. In another example, in a case where multiple probe units **320** are disposed on sides (e.g., opposite sides) of the airflow stage **110**, electrode pads may be provided on sides (e.g., opposite sides) of the target substrate SUB. For example, the multiple probe units **320** may apply the alternating current voltage at the same time or one after another.

(181) As the alternating current voltage is applied to the first and second electrodes **21** and **22**, an electric field IEF may be generated between the first and second electrodes **21** and **22**, and a dielectrophoretic force may be applied by the electric field IEF. As the dipoles DP receive the dielectrophoretic force, the orientation direction and the position of the dipoles DP may be slightly changed, and as a result, the dipoles DP may be landed finally such that end portions (e.g., opposite end portions) of each of the dipoles DP may be in contact with the first and second electrodes **21** and **22**, as illustrated in FIG. **32**. As mentioned above, in case that the dielectrophoretic force is applied, the dipoles DP may be aligned in a certain orientation direction, and the movement of the dipoles DP by the dielectrophoretic force may be performed in a substantially similar manner. As a result, the accuracy of the alignment of the landed dipoles DP may increase. As mentioned above, as the electric field IEF is generated by applying the alternating current voltage to the first and second electrodes **21** and **22** in the step of spraying the ink I, before the landing of the dipoles DP onto the first and second electrodes **21** and **22**, the accuracy of alignment of the dipoles DP may be improved.

(182) Thereafter, as illustrated in FIG. **33**, the solvent SV of the ink I may be volatilized or vaporized and may thus be removed. As the solvent SV is removed, any flow (or movement) between the dipoles DP and the electrodes may be prevented, and the bonding force therebetween may be enhanced. As a result, the dipoles DP may be precisely aligned between the first and second electrodes **21** and **22**.

(183) The inkjet printing apparatus **1000** and the method of aligning the dipoles DP may be used to fabricate a display device including light-emitting elements, which are dipoles DP. This will hereinafter be described.

(184) FIG. **34** is a schematic view of a light-emitting element according to an embodiment.

(185) Referring to FIG. **34**, a light-emitting element **30** may include semiconductor crystals doped with impurities of an arbitrary conductivity type (e.g., a p type dopant or an n type dopant). The semiconductor crystals may receive electrical signals from an external power source and may thus emit light of a certain wavelength band.

(186) The light-emitting element **30** may be a light-emitting diode, e.g., an inorganic light-emitting diode having a size of several micrometers or nanometers and formed of an inorganic material. In a case where the light-emitting element **30** is an inorganic light-emitting diode, the inorganic light-emitting diode may be aligned between two opposing electrodes where polarities are generated, in response to an electric field being generated between the two opposing electrodes in a certain direction. The light-emitting element **30** may receive electrical signals from the electrodes and may thus emit light of a certain wavelength band.

(187) Referring to FIG. **34**, the light-emitting element **30** may include conductive semiconductors (e.g., **31** and **32**), an active layer **33**, an electrode material layer **37**, and an insulating film **38**. The conductive semiconductors (e.g., **31** and **32**) may transmit electrical signals, applied to the light-emitting element **30**, to the active layer **33**, and the active layer **33** may emit light of a certain wavelength band.

(188) For example, the light-emitting element **30** may include a first conductivity type semiconductor **31**, a second conductivity type semiconductor **32**, an active layer **33** disposed between the first and second conductivity type semiconductors **31** and **32**, an electrode material layer **37** disposed on the second conductivity type semiconductor **32**, and an insulating film **38**

disposed to surround the rest of the light-emitting element **30**.

(189) The first conductivity type semiconductor **31** may be an n-type semiconductor layer. The first conductivity type semiconductor **31** may be doped with a first conductive dopant. For example, the first conductive dopant may be Si, Ge, Sn, or the like.

(190) The second conductivity type semiconductor **32** may be a p-type semiconductor layer. The second conductivity type semiconductor **32** may be doped with a second conductive dopant. For example, the second conductive dopant may be Mg, Zn, Ca, Se, Ba, or the like.

(191) The active layer **33** may be disposed between the first and second conductivity type semiconductors **31** and **32** and may include a material having a single- or multi-quantum well structure. In a case where the active layer **33** includes a material having a multi-quantum well structure, the active layer **33** may have a structure in which quantum layers and well layers are alternately stacked. The active layer **33** may emit light through the combination of electron-hole pairs in response to electrical signals being applied thereto through the first and second conductivity type semiconductors **31** and **32**.

(192) The light emitted from the active layer **33** may be output through the side of the active layer **33** in the length direction of the light-emitting element **30** and the sides of the active layer **33** at end portions (e.g., opposite end portions) of the light-emitting element **30**. The direction in which light is emitted from the active layer **33** is not limited thereto.

(193) The electrode material layer **37** may be an ohmic contact electrode, but embodiments are not limited thereto. In another example, the electrode material layer **37** may be a Schottky contact electrode. The electrode material layer **37** may include a metal with conductivity.

(194) The insulating film **38** may be formed to be in contact with the first conductivity type semiconductor **31**, the second conductivity type semiconductor **32**, the active layer **33**, and the electrode material layer **37** and to surround the outer surfaces of the first conductivity type semiconductor **31**, the second conductivity type semiconductor **32**, the active layer **33**, and the electrode material layer **37**. The insulating film **38** may protect the other elements of the light-emitting element **30**. As the insulating film **38** protects the outer surfaces of the light-emitting element **30** including that of the active layer **33**, the degradation of the efficiency of emitting light may be prevented.

(195) FIG. **35** is a schematic plan view of a display device fabricated by a method according to an embodiment.

(196) Referring to FIG. **35**, a display device **1** may include a pixel PX. The pixel PX of the display device **1** may include subpixels (e.g., SPX1, SPX2, and SPX3). The pixel PX may include first, second, and third subpixels SPX1, SPX2, and SPX3.

(197) The first subpixel SPX1 may emit light of a first color, the second subpixel SPX2 may emit light of a second color, and the third subpixel SPX3 may emit light of a third color. For example, the first color may be blue, the second color may be green, and the third color may be red. However, embodiments are not limited to this. In another example, each of subpixels SPXn may emit light of the same color. FIG. **2** illustrates that the pixel PX includes three subpixels SPXn, but embodiments are not limited thereto. In another example, the pixel PX may include more than three subpixels SPXn.

(198) Each of the subpixels SPXn of the display device **1** may include an area defined as an emission area EMA. As light-emitting elements **30** included in the display device **1** are disposed in the emission area EMA, the emission area EMA may be defined as an area that emits light of a certain wavelength band. The first subpixel SPX1 may include a first emission area EMA1, the second subpixel SPX2 may include a second emission area EMA2, and the third subpixel SPX3 may include a third emission area EMA3.

(199) The emission area EMA may include an area where the light-emitting elements **30** are disposed. For example, the emission area EMA may include an area where light emitted by the light-emitting elements **30** is reflected or refracted and output. For example, light-emitting elements

30 may be disposed in each of the subpixels SPXn, and an area where the light-emitting elements **30** are disposed and the surroundings of the area where the light-emitting elements **30** are disposed may form the emission area EMA.

(200) Each of the subpixels SPXn may include a non-emission area, which is defined as an area other than the emission area EMA. The non-emission area may be an area that is not reached by light emitted from the light-emitting elements **30** and thus may not output light due to the absence of the light-emitting elements **30** therein.

(201) Each of the subpixels SPXn of the display device **10** may include light-emitting elements **30**, electrodes (e.g., **21** and **22**), contact electrodes **26**, inner banks (e.g., **41** and **40**), and an outer bank **45**.

(202) The outer bank **45** may divide (or define) the subpixels SPXn. The outer bank **45** may be disposed along the boundaries between the subpixels SPXn. The outer bank **45** may form a lattice pattern in a display area (e.g., an entire display area).

(203) The inner banks (e.g., **41** and **42**) may include first and second inner banks **41** and **42**, which are disposed adjacent to each other in the middle of the pixel PX or each of the subpixels SPXn.

(204) The first and second inner banks **41** and **42** may extend in a fifth direction DR5 and may be spaced apart from, and terminated at, the boundaries of the corresponding subpixel SPXn not to extend into other neighboring subpixels SPXn. Accordingly, the first and second inner banks **41** and **42** may be disposed in each of the subpixels SPXn to form a pattern on the front surface (or the entire surface) of the display device **1**.

(205) The first and second inner banks **41** and **42** may be spaced apart from each other in a fifth direction DR5. Light-emitting elements **30** may be disposed in the gap between the first and second inner banks **41** and **42** in the fifth direction DR5.

(206) The display device **1** may include electrodes (e.g., **21** and **22**). At least parts of the electrodes (e.g., **21** and **22**) may be disposed in each of the subpixels SPXn, may be connected (e.g., electrically connected) to the light-emitting elements **30**, and may apply electrical signals to the light-emitting elements **30** such that the light-emitting elements **30** may emit light of a certain color.

(207) For example, at least parts of the electrodes (e.g., **21** and **22**) may function to generate an electric field in each of the subpixels SPXn and thus to align the light-emitting elements **30**. As mentioned above, dielectrophoresis may be used to align the light-emitting elements **30**, which are a type of dipoles, and an alternating current voltage may be applied to the electrodes (e.g., **21** and **22**).

(208) The electrodes (e.g., **21** and **22**) may include first and second electrodes **21** and **22**.

(209) The first electrode **21** may extend in the fifth direction DR5. The first electrode **21** may extend in the fifth direction DR5 and may be spaced apart from, and terminated at, the boundaries of the corresponding subpixel SPXn not to extend into other neighboring subpixels SPXn in the fifth direction DR5.

(210) The first electrode **21** may be disposed on the first inner bank **41**, in each of the subpixels SPXn. The first electrode **21** may be disposed to overlap the first inner bank **41**.

(211) The second electrode **22** may extend in the fifth direction DR5. The second electrode **22** may be disposed to extend into other neighboring subpixels SPXn in the fifth direction DR5. For example, one second electrode **22** may be disposed in and across multiple subpixels SPXn that are adjacent to one another in the fifth direction DR5.

(212) The second electrode **22** may be disposed on the second inner bank **42**, in each of the subpixels SPXn. The second electrode **22** may be disposed to overlap the second inner bank **42**.

(213) The electrodes (e.g., **21** and **22**) may be connected (e.g., electrically connected) to the light-emitting elements **30** and may receive a voltage to emit light by the light-emitting elements **30**. For example, the electrodes (e.g., **21** and **22**) may be connected (e.g., electrically connected) to the light-emitting elements **30** through the contact electrodes **26** that will be described below, and may

transmit electrical signals, applied to the electrodes (e.g., **21** and **22**), to the light-emitting elements **30** through the contact electrodes **26**.

(214) The light-emitting elements **30** may be sprayed onto the first and second electrodes **21** and **22** by an inkjet printing process in a state of being dispersed in ink. The light-emitting elements **30** sprayed in the state of being dispersed in the ink may be aligned between the first and second electrodes **21** and **22** by a dielectrophoretic force, which is formed by applying alignment signals to the first and second electrodes **21** and **22**.

(215) Contact electrodes **26** may be disposed on the electrodes (e.g., **21** and **22**). The contact electrodes **26** may extend in a direction. The contact electrodes **26** may be in contact with the light-emitting elements **30** and the electrodes (e.g., **21** and **22**), and the light-emitting elements **30** may receive electrical signals from the first and second electrodes **21** and **22** through the contact electrodes **26**.

(216) The contact electrodes **26** may include first and second contact electrodes **26_1** and **26_2**. The first and second contact electrodes **26_1** and **26_2** may be disposed on the first and second electrodes **21** and **22**, respectively. The first and second contact electrodes **26_1** and **26_2** may extend in the fifth direction DR5. The first and second contact electrodes **26_1** and **26_2** may be spaced apart from, and face, each other in a fourth direction DR4 and may form a stripe pattern in the emission area EMA of each of the subpixels SPXn.

(217) FIG. **36** is a schematic partial cross-sectional view taken along line I-I' of FIG. **35**.

(218) Referring to FIGS. **35** and **36**, the display device **1** may include a substrate **11** and a display element layer, which is disposed on the substrate **11**. For example, the display device **1** may further include a circuit element layer, which is between the substrate **11** and the display element layer and drives the display element layer.

(219) The substrate **11** may be an insulating substrate. The substrate **11** may be formed of an insulating material such as glass, quartz, a polymer resin, or the like. The substrate **11** may be a rigid substrate or may be a flexible substrate that is bendable, foldable, or rollable.

(220) The display element layer may be disposed on the substrate **11**. The display element layer may include the light-emitting elements **30** and may include the first electrode **21**, the second electrode **22**, the first contact electrode **26_1**, and the second contact electrode **26_2**.

(221) The inner banks (e.g., **41** and **42**) may be disposed on the substrate **11**. The first and second inner banks **41** and **42** may protrude at least partially from the top surface (or upper surface) of the substrate **11**. Each of protruding parts of the first and second inner banks **41** and **42** may have inclined side surfaces, and light emitted from the light-emitting elements **30** may proceed toward the inclined side surfaces of each of the inner banks (e.g., **41** and **42**).

(222) As mentioned above, the inner banks (e.g., **41** and **42**) may provide space in which to arrange the light-emitting elements **30** and may function as a reflective barrier capable of reflecting light, emitted from the light-emitting elements **30**, in an upward direction. In an embodiment, the inner banks (e.g., **41** and **42**) may include an organic insulating material such as polyimide (PI), but embodiments are not limited thereto.

(223) The electrodes (e.g., **21** and **22**) may be disposed on the inner banks (e.g., **41** and **42**) and the substrate **11**. The first and second electrodes **21** and **22** may be disposed to cover (e.g., completely cover) the outer surfaces of each of the first and second inner banks **41** and **42**. At least parts of the first and second electrodes **21** and **22** may be disposed directly on the substrate **11**.

(224) The electrodes (e.g., **21** and **22**) may include a transparent conductive material. For example, the electrodes (e.g., **21** and **22**) may include a material such as indium tin oxide (ITO), indium zinc oxide (IZO), indium tin zinc oxide (ITZO), or the like, but embodiments are not limited thereto.

(225) A first insulating layer **51** may be disposed on the substrate **11**, the first electrode **21**, and the second electrode **22**. The first insulating layer **51** may be disposed in the gap between the electrodes (e.g., **21** and **22**) or between the inner banks (e.g., **41** and **42**). The first insulating layer **51** may be disposed on the opposite sides of the gap between the inner banks (e.g., **41** and **42**).

(226) The first insulating layer **51** may be disposed to cover (e.g., partially cover) the first and second electrodes **21** and **22**. The first insulating layer **51** may protect the first and second electrodes **21** and **22** and may insulate the first and second electrodes **21** and **22** from each other. For example, the first insulating layer **51** may prevent the light-emitting elements **30** thereon from being disposed in direct contact with, and damaged by, other members. The shape and the structure of the first insulating layer **51** are not limited thereto.

(227) The outer bank **45** may be disposed on the first insulating layer **51**. The height of the outer bank **45** may be greater than the height of the inner banks (e.g., **41** and **42**). As mentioned above, the outer bank **45** may divide (or define) the subpixels SPXn and may prevent ink from spilling over between the subpixels SPXn during an inkjet printing process for arranging the light-emitting elements **30**, as performed during the fabrication of the display device **1**. For example, the outer bank **45** may include PI, but embodiments are not limited thereto.

(228) The light-emitting elements **30** may be disposed on the first insulating layer **51**, between the inner banks (e.g., **41** and **42**) or between the electrodes (e.g., **21** and **22**). For example, the light-emitting elements **30** may be disposed on part of the first insulating layer **51** disposed between the inner banks (e.g., **41** and **42**).

(229) In each of the light-emitting elements **30**, layers may be disposed in a direction perpendicular to the top surface (or upper surface) of the substrate **11**. The light-emitting elements **30** of the display device **1** may extend in a direction and may have a structure in which semiconductor layers are sequentially arranged in a direction.

(230) A second insulating layer **52** may be disposed on the light-emitting elements **30** and may expose end portions (e.g., opposite end portions) of each of the light-emitting elements **30**. The exposed end portions of each of the light-emitting elements **30** may be in contact with the contact electrodes **26**. The second insulating layer **52** may be formed by a typical mask process, e.g., a patterning process by using the material of the second insulating layer **52**.

(231) Contact electrodes **26** and a third insulating layer **53** may be disposed on the second insulating layer **52**.

(232) The first and second contact electrodes **26_1** and **26_2** may be in contact with first and second end portions of each of the light-emitting elements **30** and may be disposed to cover side surfaces (e.g., opposite side surfaces) of each of the first and second electrodes **21** and **22**. As mentioned above, parts of the top surfaces (or upper surfaces) of the first and second electrodes **21** and **22** may be exposed, and the first and second contact electrodes **26_1** and **26_2** may be in contact with the exposed parts of the top surfaces (or upper surfaces) of the first and second electrodes **21** and **22**.

(233) The third insulating layer **53** may be disposed on the first contact electrode **26_1**. The third insulating layer **53** may be disposed to cover the first contact electrode **26_1** and may not overlap parts of the light-emitting elements **30** such that the light-emitting elements **30** may be connected to the second contact electrode **26_2**. The third insulating layer **53** may be partially in contact with the first contact electrode **26_1** and the second insulating layer **52**, on the top surface (or upper surface) of the second insulating layer **52**. The third insulating layer **53** may protect the first contact electrode **26_1** and may electrically insulate the first contact electrode **26_1** from the second contact electrode **26_2**.

(234) The second contact electrode **26_2** may be disposed on the second electrode **22**, the second insulating layer **52**, and the third insulating layer **53**. The second contact electrode **26_2** may be in contact with the second end portions of the light-emitting elements **30** and the exposed part of the top surface (or upper surface) of the second electrode **22**. The second end portions of the light-emitting elements **30** may be connected (e.g., electrically connected) to the second electrode **22** through the second contact electrode **26_2**.

(235) A fourth insulating layer **55** may be disposed (or entirely disposed) on the substrate **11**. The fourth insulating layer **55** may protect the members disposed on the substrate **11** from an external

environment.

(236) The first, second, third, and fourth insulating layers **51**, **52**, **53**, and **55** may include an inorganic insulating material or an organic insulating material.

(237) In concluding the detailed description, those skilled in the art will appreciate that many variations and modifications may be made to the embodiments without substantially departing from the principles of the invention. Therefore, the disclosed embodiments of the invention are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. An inkjet printing apparatus comprising: an airflow stage extending in a first direction; a print head unit disposed above the airflow stage; an electric field generating unit that moves in the first direction and generates an electric field on the airflow stage; and a substrate transferring unit that transfers a target substrate in the first direction over the airflow stage, wherein the electric field generating unit is configured to generate an electric field on the target substrate in case that the target substrate moves along with the substrate transferring unit, the electric field generating unit to apply an electric field to ink after it leaves the print head unit and both before and after the ink lands on the target substrate.
2. The inkjet printing apparatus of claim 1, wherein the print head unit includes a print head, and the print head includes nozzles that spray the ink including dipoles.
3. The inkjet printing apparatus of claim 2, wherein the print head is configured to spray the ink onto the airflow stage on which the electric field is formed.
4. The inkjet printing apparatus of claim 2, wherein the dipoles are light-emitting diodes used to produce a display device.
5. The inkjet printing apparatus of claim 1, wherein the airflow stage includes a plurality of air holes formed on an upper surface of the airflow stage, and at least some of the plurality of air holes is configured to discharge air onto the airflow stage.
6. The inkjet printing apparatus of claim 1, wherein the substrate transferring unit includes a first substrate transferer disposed adjacent to a first side of the airflow stage in a second direction perpendicular to the first direction.
7. The inkjet printing apparatus of claim 6, wherein the first substrate transferer further includes a gripper, and the gripper is configured to adsorb the target substrate onto a surface of the gripper by generating negative pressure between the gripper and the target substrate.
8. The inkjet printing apparatus of claim 6, wherein the substrate transferring unit further includes a second substrate transferer disposed adjacent to a second side of the airflow stage opposite to the first side of the airflow stage.
9. The inkjet printing apparatus of claim 1, wherein the electric field generating unit includes a probe unit and a probe driving device that drives the probe unit.
10. The inkjet printing apparatus of claim 9, wherein the probe unit of the electric field generating unit is in contact with electrode pads on the target substrate, and the electric field generating unit to transfer electric signals to the target substrate to generate an electric field on the target substrate.
11. The inkjet printing apparatus of claim 1, wherein the electric field generating unit moves together with the substrate transferring unit in a same direction and at a synchronized speed while the electric field generating unit generates an electric field on the target substrate.
12. The inkjet printing apparatus of claim 1, wherein the electric field generating unit changes a direction of the electric field based on a change in state between the ink sprayed from the print head unit and the ink landing on the target substrate.
13. An inkjet printing apparatus comprising: an airflow stage extending in a first direction, the airflow stage including: a loading part sequentially arranged in the first direction, the loading part in which a target substrate is aligned, and a printing part upon which ink is sprayed onto the target

substrate; a print head unit disposed above the printing part, the print head unit sprays the ink; an electric field generating unit disposed on a side of the airflow stage, the electric field generating unit generates an electric field on the target substrate in case that the target substrate moves in the first direction; a substrate transferring unit that transfers the target substrate in the first direction over the airflow stage, wherein the electric field generating unit is configured to generate an electric field on the target substrate in case that the target substrate moves along with the substrate transferring unit, the electric field generating unit to apply an electric field to the ink after it leaves the print head and both before and after the ink lands on the target substrate.

14. The inkjet printing apparatus of claim 13, wherein the substrate transferring unit is disposed adjacent to a first side of the airflow stage in a second direction perpendicular to the first direction.

15. The inkjet printing apparatus of claim 14, wherein the substrate transferring unit further includes a gripper, and the gripper is configured to adsorb a surface of the target substrate onto a surface of the gripper facing the surface of the target substrate by generating negative pressure between the gripper and the target substrate.

16. The inkjet printing apparatus of claim 13, wherein the electric field generating unit includes a probe unit and a probe driving device that drives the probe unit.

17. The inkjet printing apparatus of claim 13, wherein the airflow stage includes a plurality of air holes that lift up the target substrate by discharging air onto the airflow stage.

18. The inkjet printing apparatus of claim 13, further comprising: an alignment checking unit disposed above the loading part.

19. The inkjet printing apparatus of claim 13, wherein the electric field generating unit changes a direction of the electric field based on a change in state between the ink sprayed from the print head unit and the ink landing on the target substrate.

20. An inkjet printing apparatus comprising: an airflow stage extending in a first direction, the airflow stage including: a loading part sequentially arranged in the first direction, the loading part in which a target substrate is aligned, and a printing part upon which ink is sprayed onto the target substrate; a print head unit disposed above the printing part, the print head unit sprays the ink; an electric field generating unit disposed on a side of the airflow stage, the electric field generating unit generates an electric field on the target substrate in case that the target substrate moves in the first direction; and a first guide unit extending in the first direction and disposed adjacent to a first side of the airflow stage in a second direction perpendicular to the first direction, wherein the electric field generating unit includes: a first base substrate disposed on the first guide unit, a probe unit disposed on the first base substrate, and a probe driving device spaced apart from the probe unit and disposed on the first base substrate.

21. The inkjet printing apparatus of claim 20, further comprising: a second guide unit extending in the first direction and disposed between the first guide unit and the airflow stage; and a substrate transferring unit that transfers the target substrate along the second guide unit over the airflow stage, wherein the substrate transferring unit includes: a second base substrate disposed on the second guide unit, and a gripper disposed on the second base substrate and fixing the target substrate.

22. The inkjet printing apparatus of claim 20, further comprising: a gripper disposed on the first base substrate, the gripper that transfers the target substrate in the first direction.
