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(54) **INKJET PRINTING APPARATUS**

(71) Applicant: **Samsung Display Co., LTD.**, Yongin-si (KR)

(72) Inventors: **Kyong Sub KIM**, Yongin-si (KR); **Jae Hoon KIM**, Yongin-si (KR); **Sang Hoon PARK**, Yongin-si (KR); **Dong Woo SHIN**, Yongin-si (KR)

(73) Assignee: **Samsung Display Co., LTD.**, Yongin-si (KR)

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(57) **ABSTRACT**

An inkjet printing apparatus may include a stage on which a substrate is seated; a nozzle part disposed above the stage and spraying an ink onto the substrate, the ink containing a solvent and solid substances; and a head part that supplies the ink to the nozzle part. The nozzle part includes an internal flow path extended in a first direction, through which the ink is supplied from the head prat; and an inlet in which an entrance area is defined. The ink is introduced in a second direction intersecting the first direction from the internal flow path through the entrance area. The inlet includes an inclined surface adjacent to the entrance area and defining the entrance area; and a flat surface parallel to the first direction. An angle between the inclined surface and the flat surface is an acute angle.

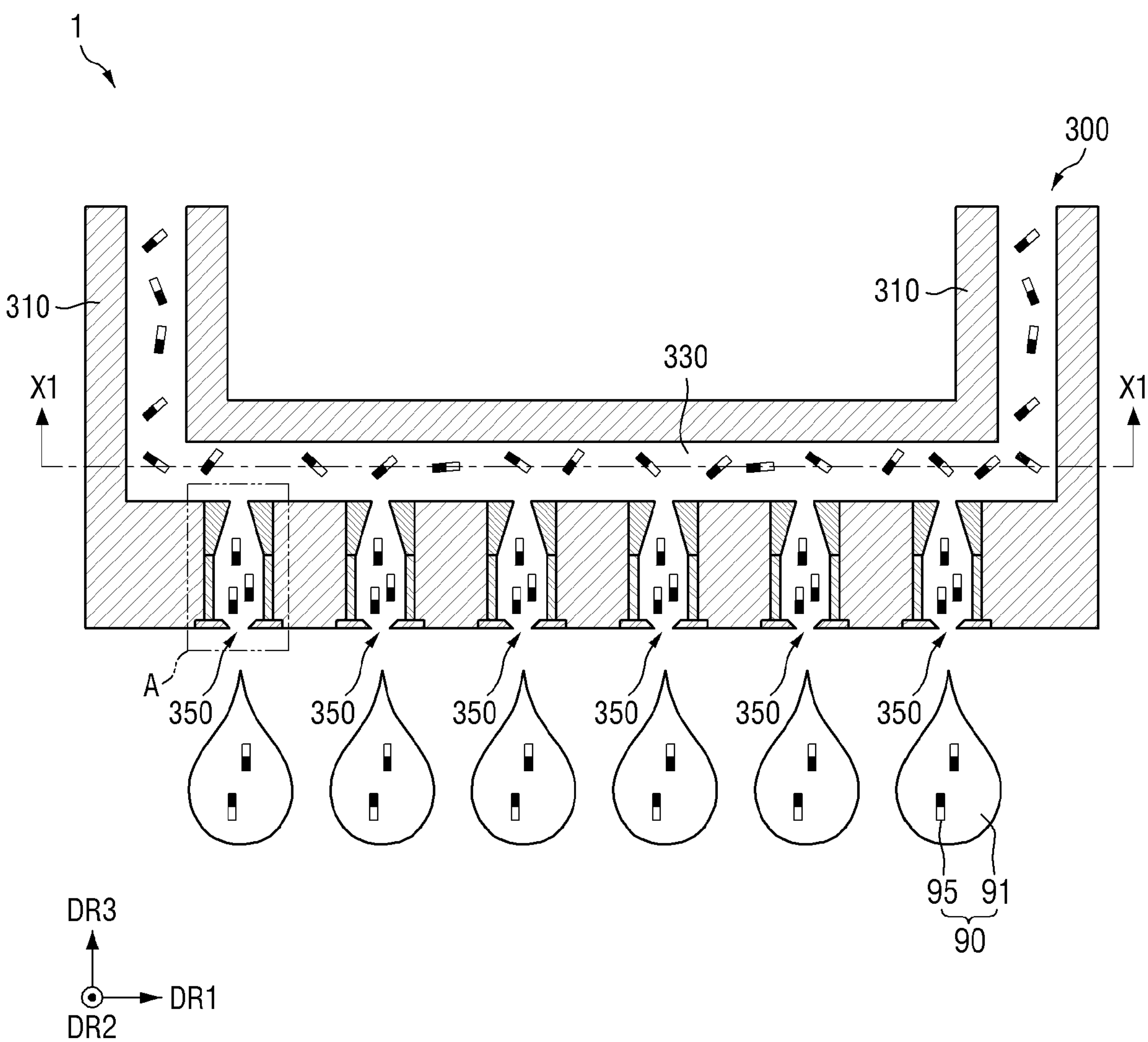


FIG. 1

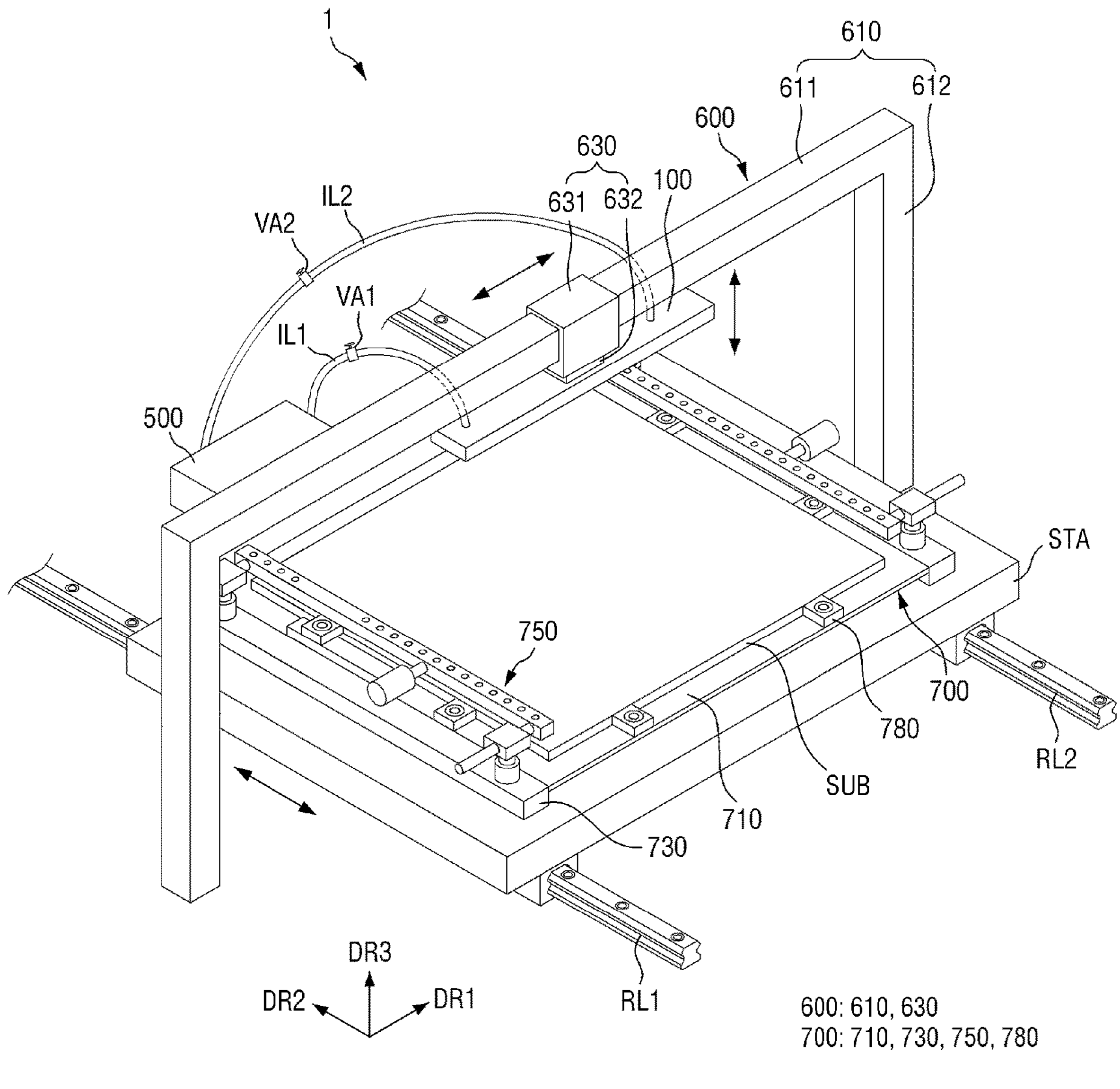

1
610
611
612
600
630
631
632
100
IL2
VA2
VA1
IL1
500
STA
750
700
780
RL2
SUB
710
730
DR3
DR2
DR1
RL1
600: 610, 630
700: 710, 730, 750, 780

FIG. 2

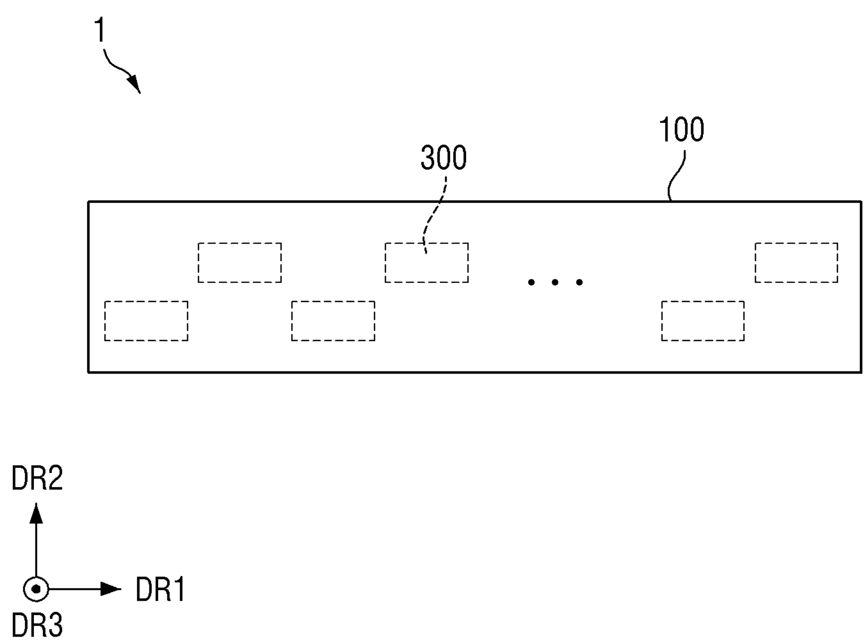


FIG. 3

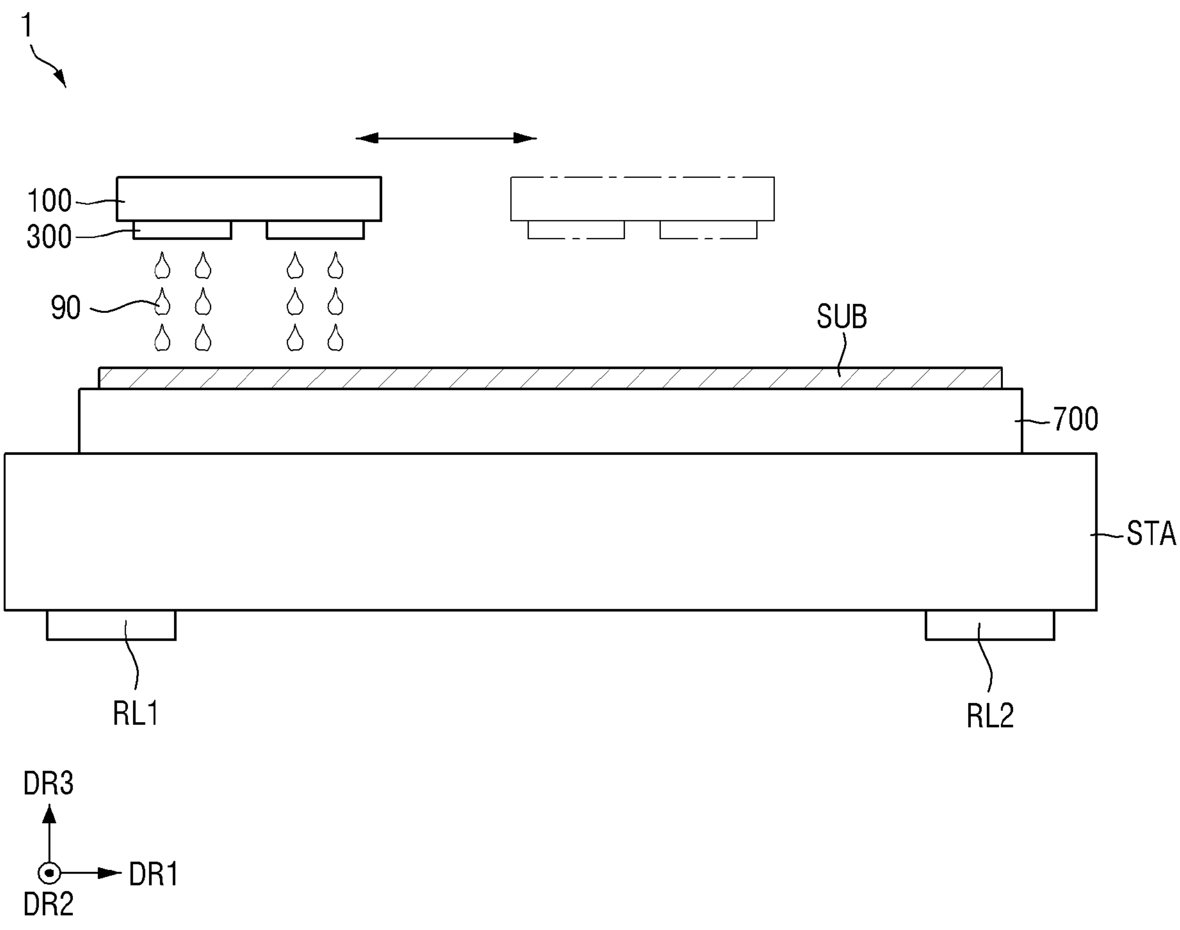


FIG. 4

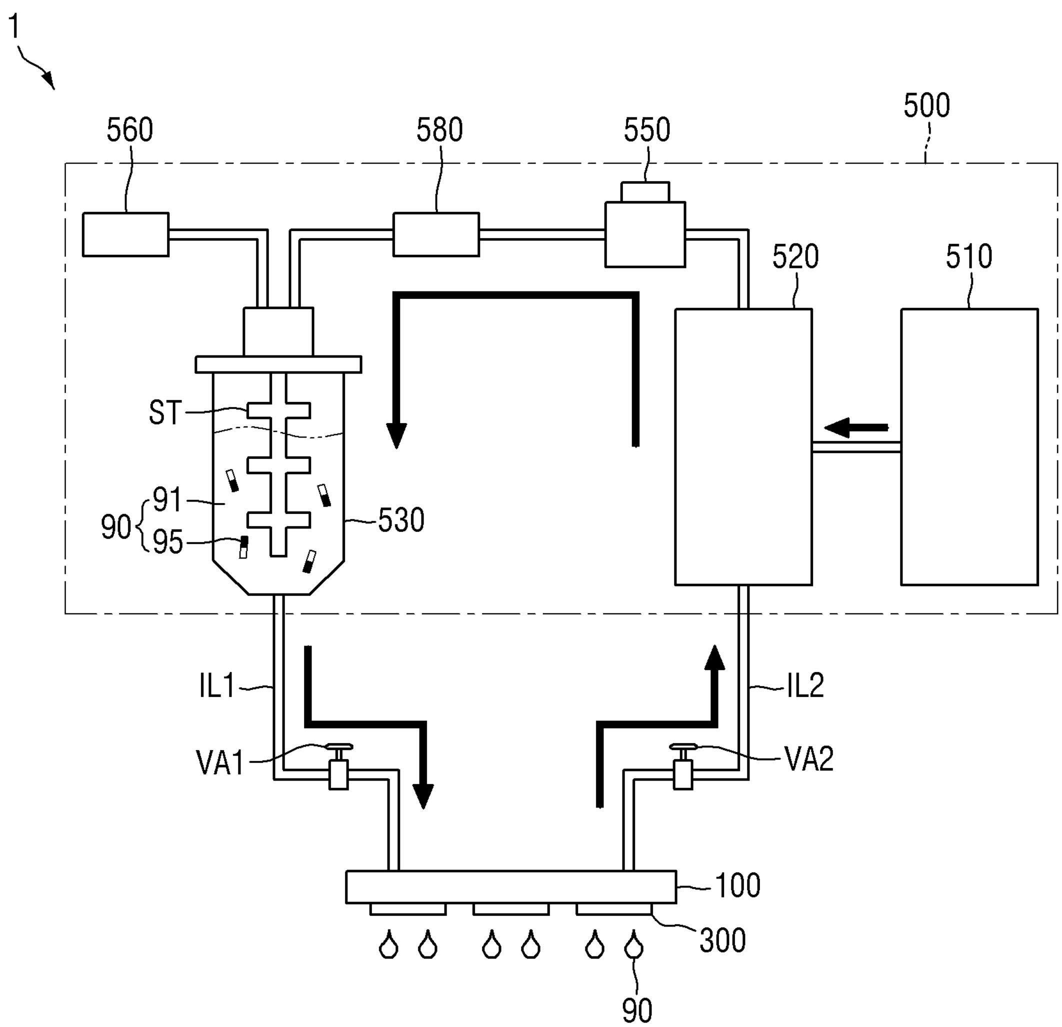

1
560
580
550
500
520
510
ST
91
90
95
530
IL1
IL2
VA1
VA2
100
300
90

FIG. 5

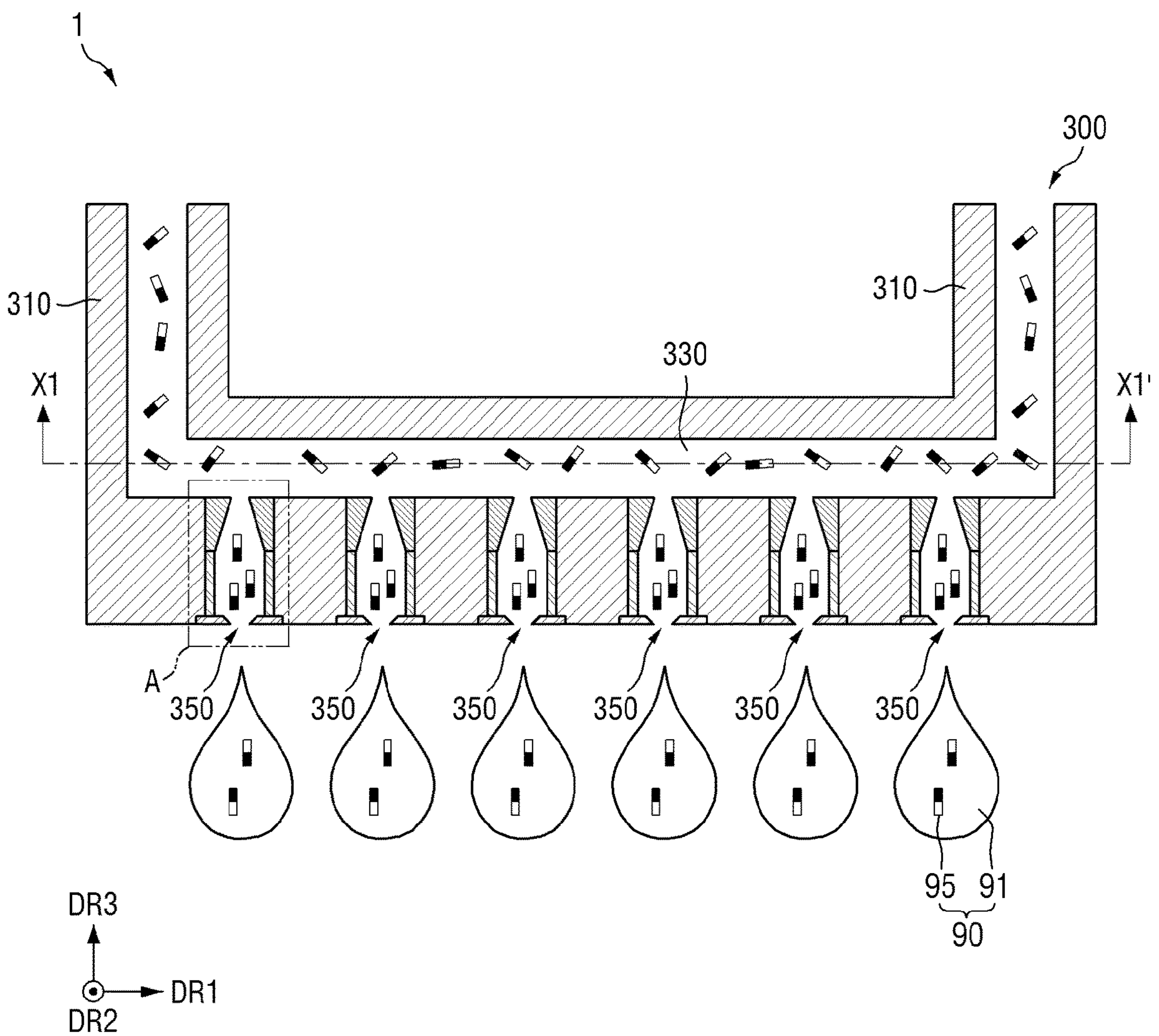

1
300
310
310
330
X1
X1'
A
350
350
350
350
350
350
95
91
90
DR3
DR1
DR2

FIG. 6

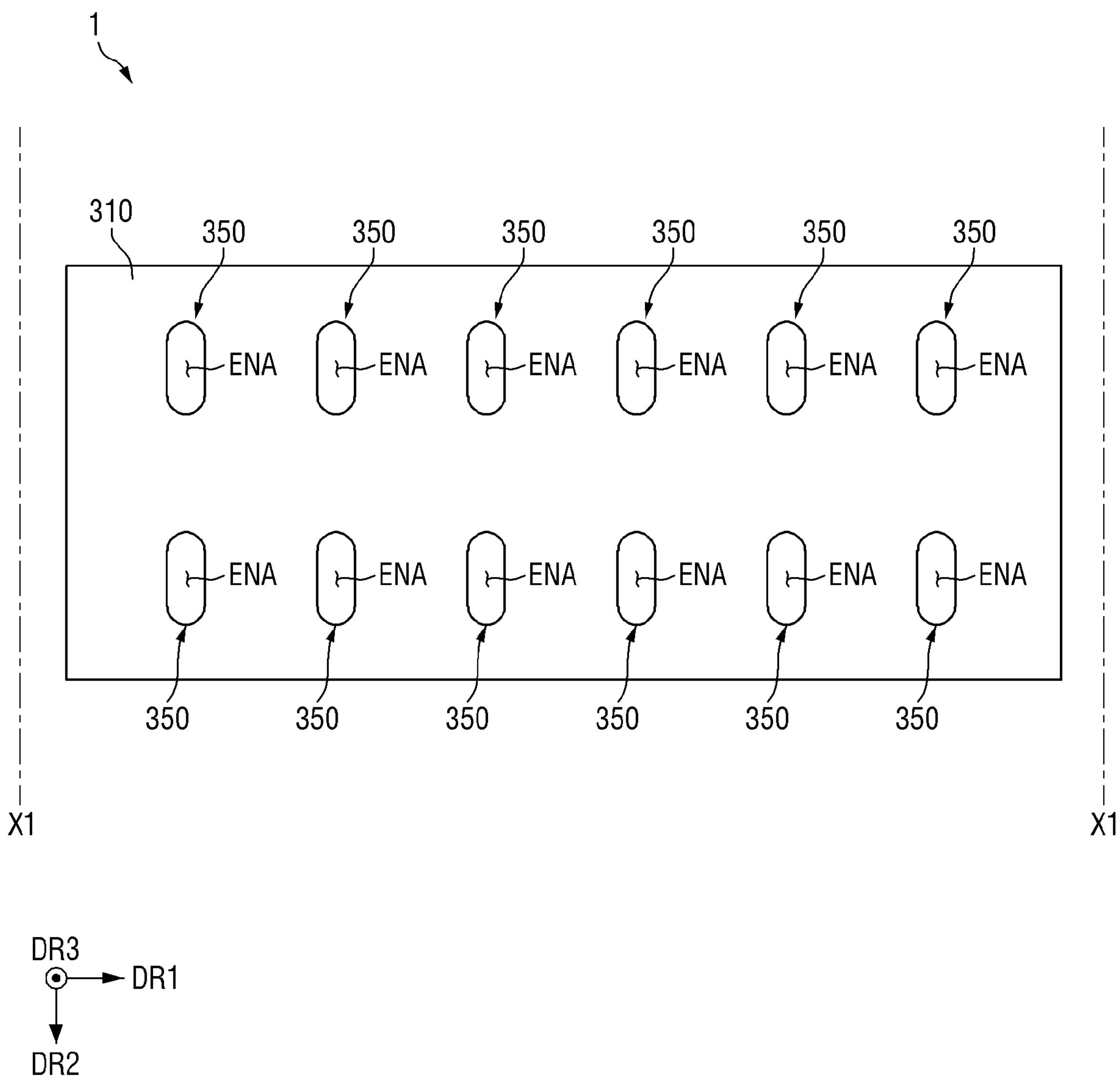


FIG. 7

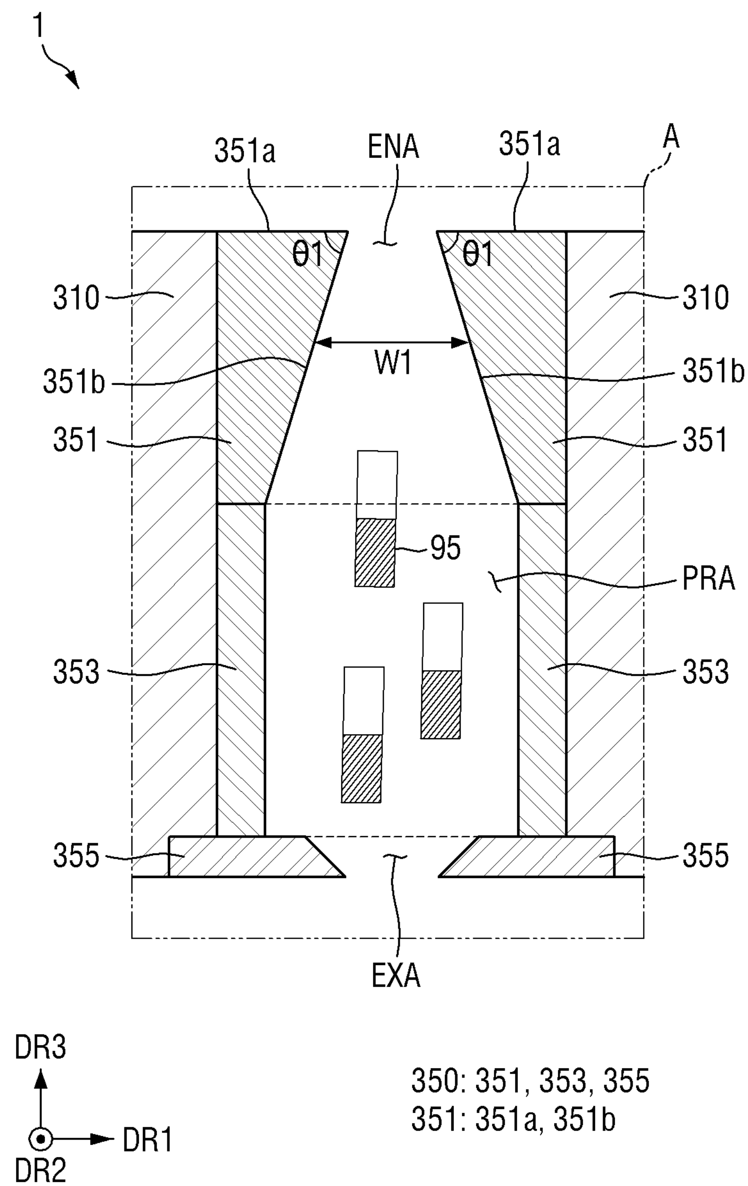

1
351a
ENA
351a
A
θ1
θ1
310
310
W1
351b
351b
351
351
95
PRA
353
353
355
355
EXA
DR3
DR1
DR2
350: 351, 353, 355
351: 351a, 351b

FIG. 8

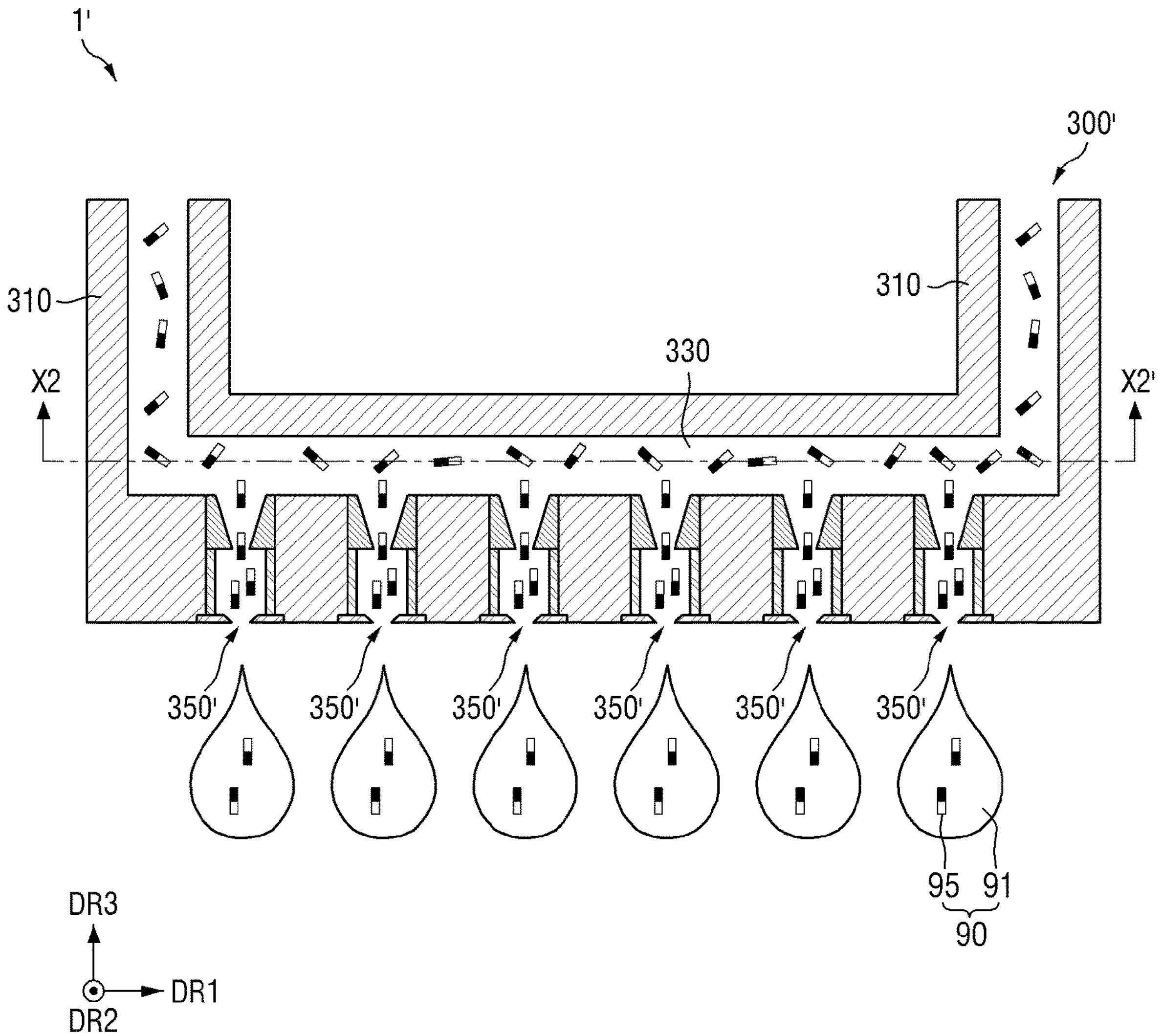
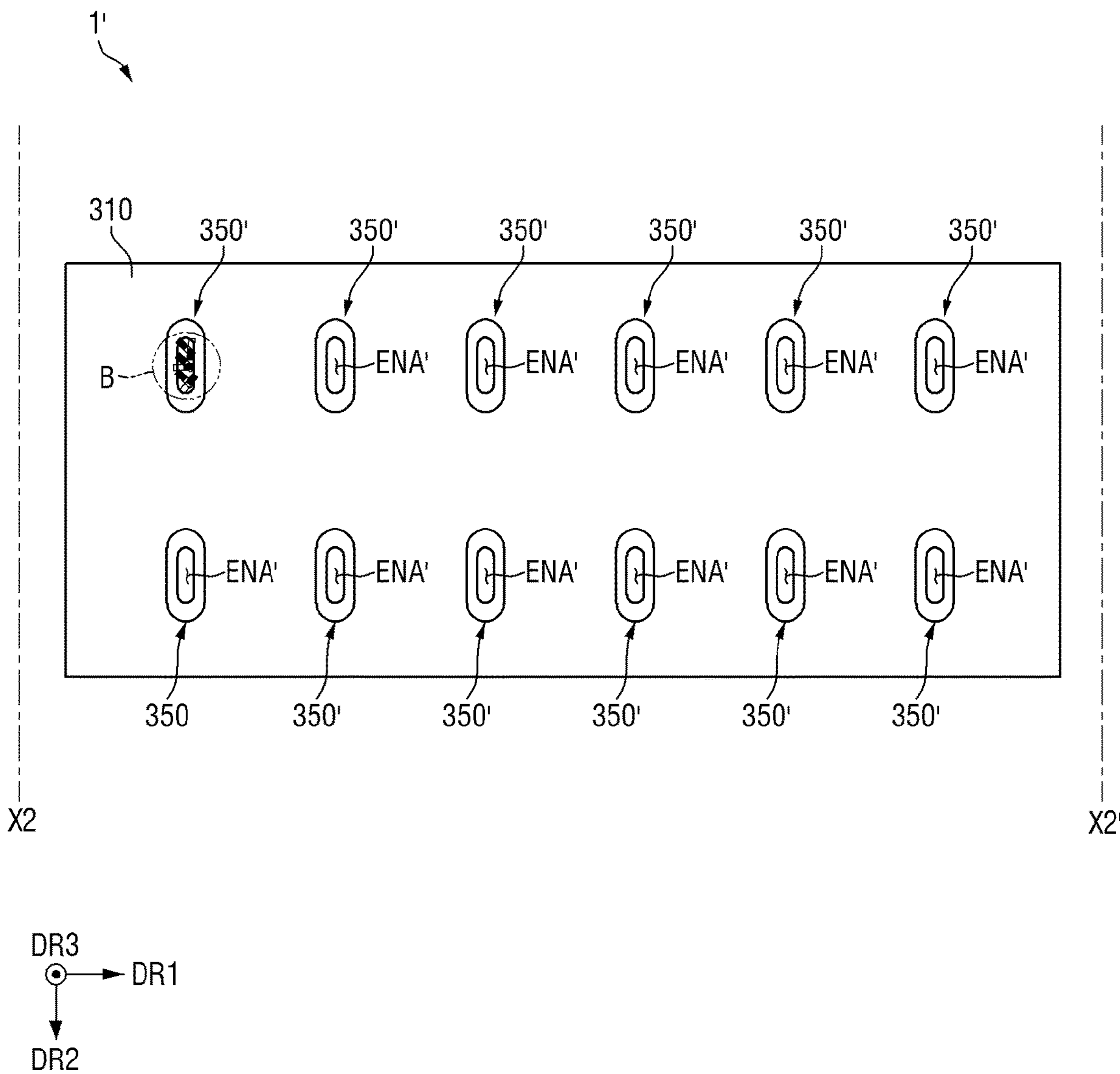

1'
300'
310
310
330
X2
X2'
350'
350'
350'
350'
350'
350'
95
91
90
DR3
DR1
DR2

FIG. 9



1'
310
350'
350'
350'
350'
350'
350'
B
ENA'
ENA'
ENA'
ENA'
ENA'
ENA'
ENA'
ENA'
ENA'
ENA'
ENA'
350
350'
350'
350'
350'
350'
X2
X2'
DR3
DR1
DR2

FIG. 10

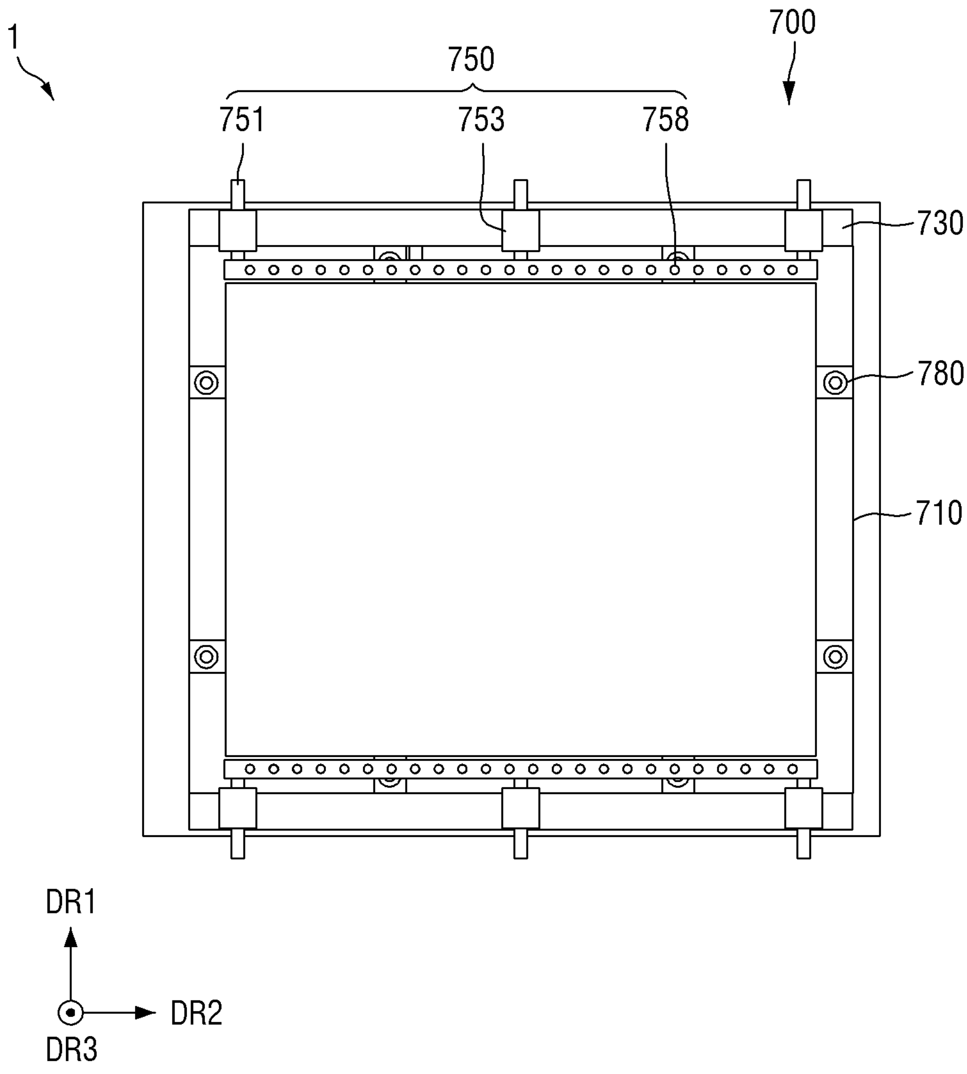


FIG. 11

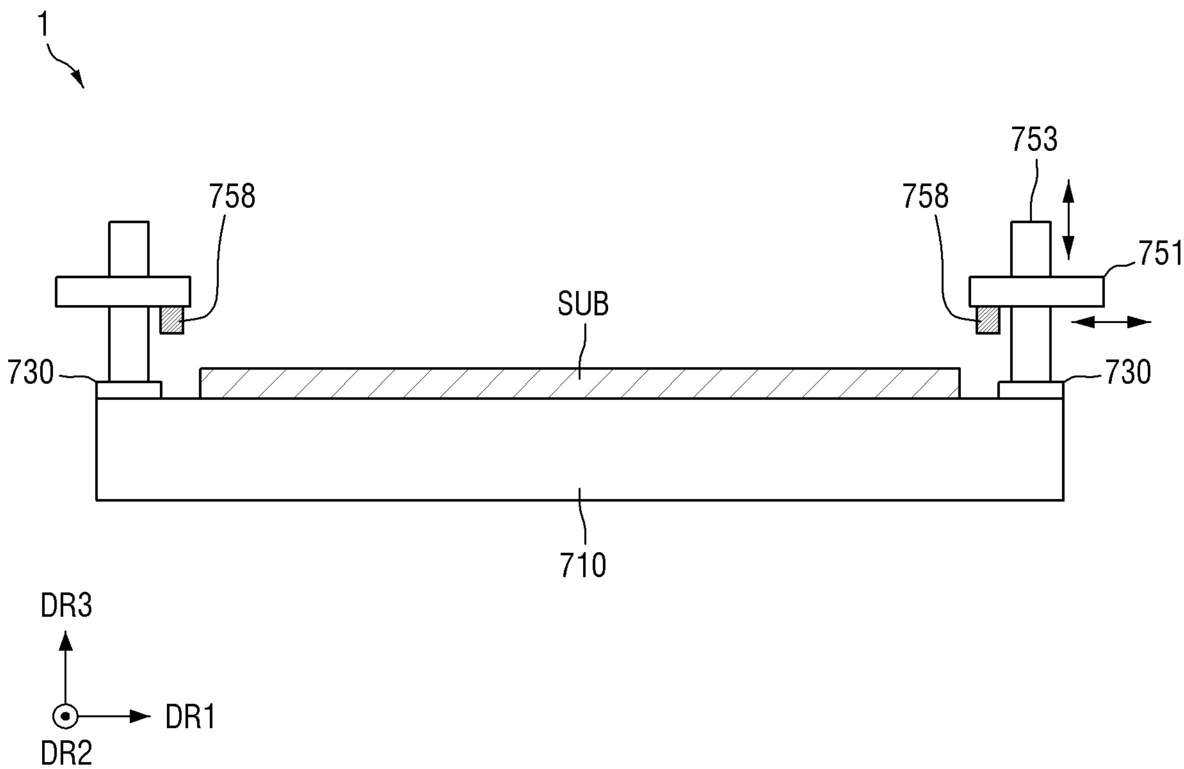


FIG. 12

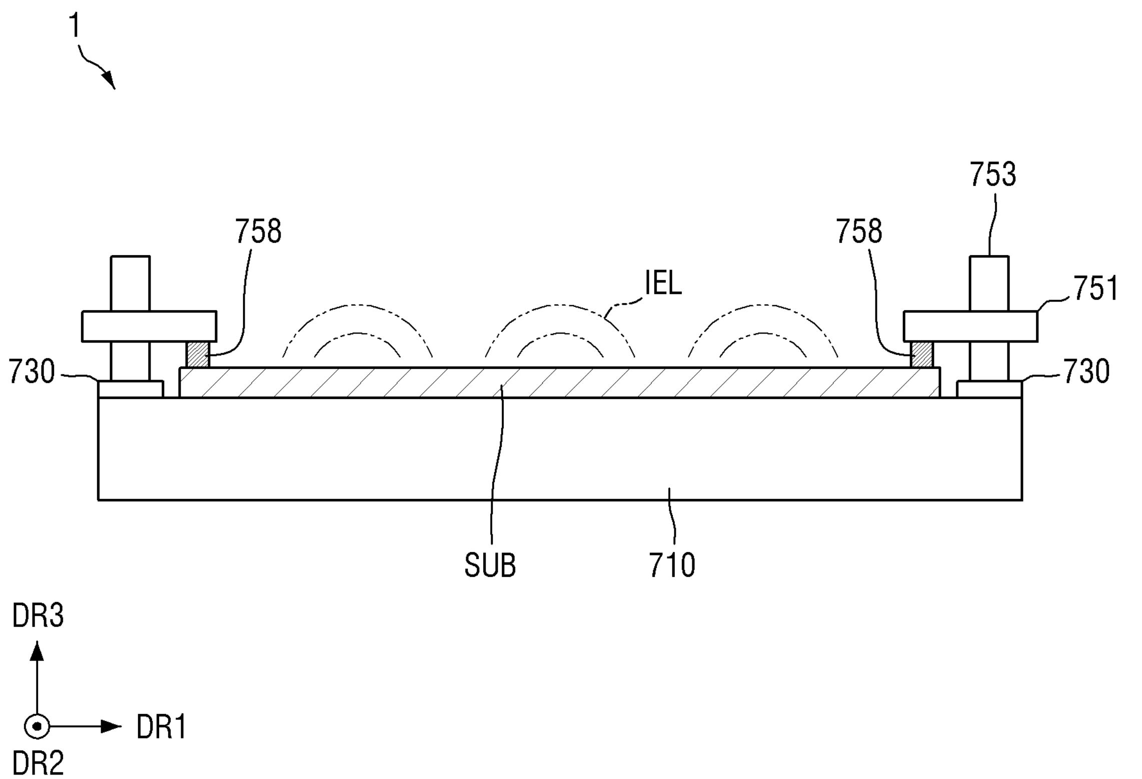


FIG. 13

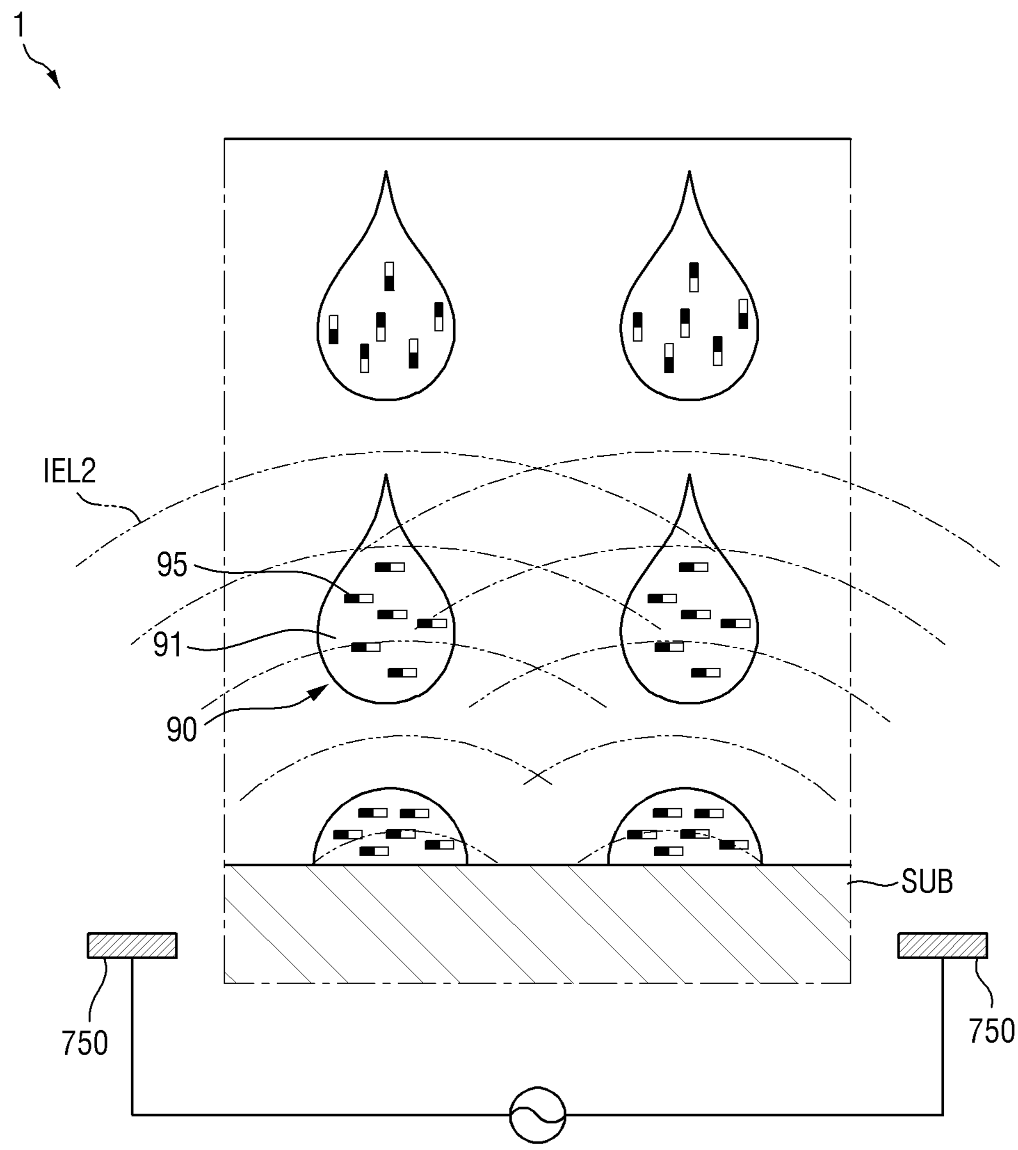


FIG. 14

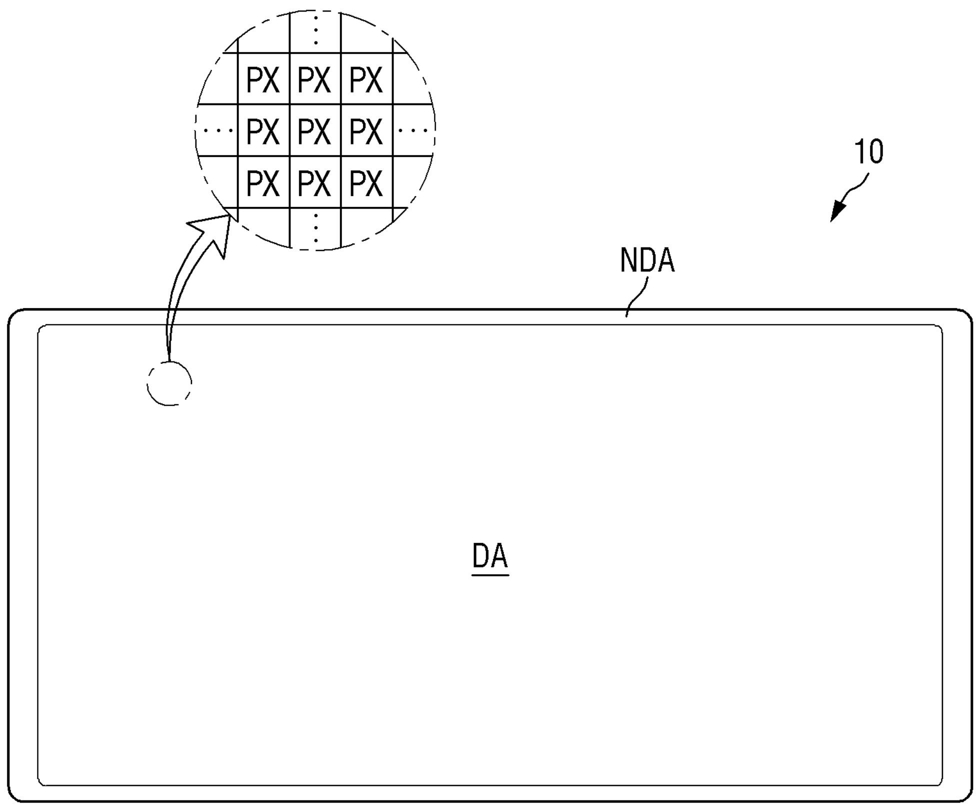
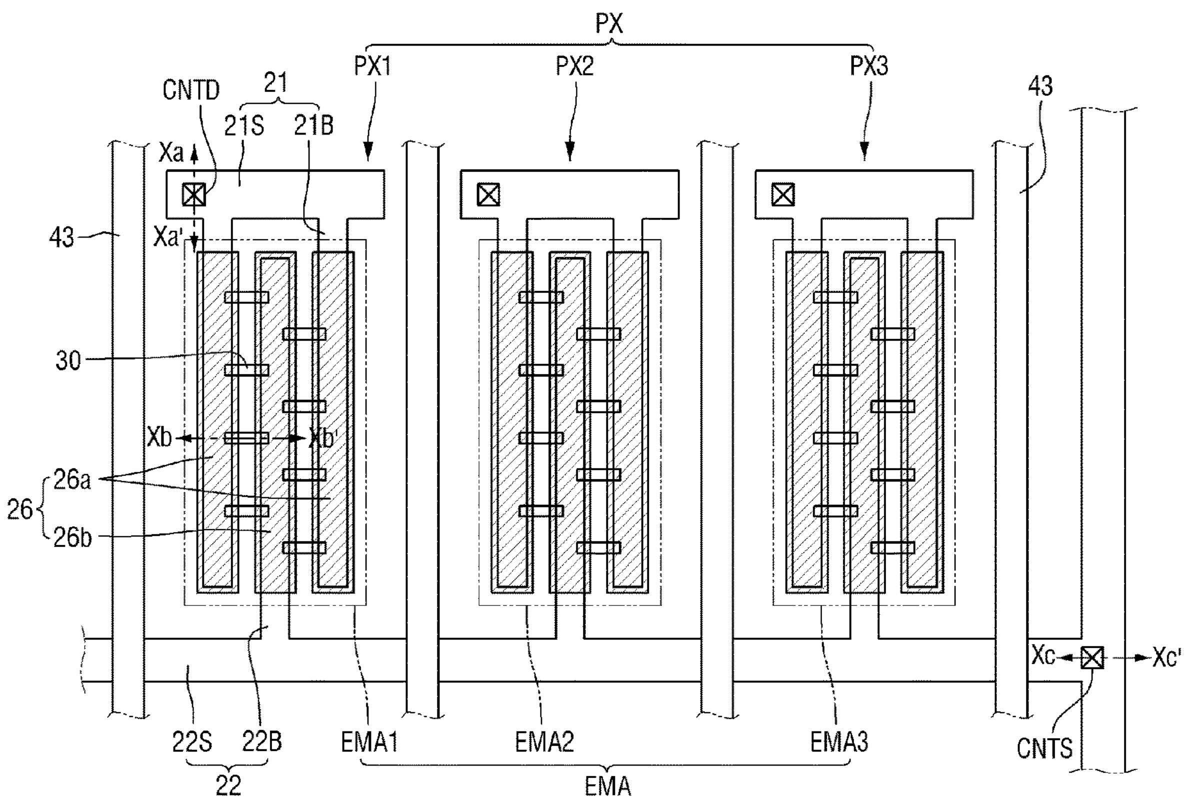


FIG. 15



PX
PX1
PX2
PX3
CNTD
21
21S
21B
43
Xa
Xa'
43
30
Xb
Xb'
26a
26
26b
22S
22B
22
EMA1
EMA2
EMA3
EMA
Xc
Xc'
CNTS

FIG. 16

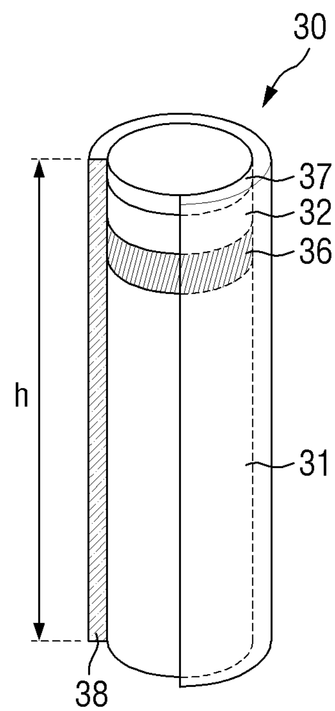


FIG. 17

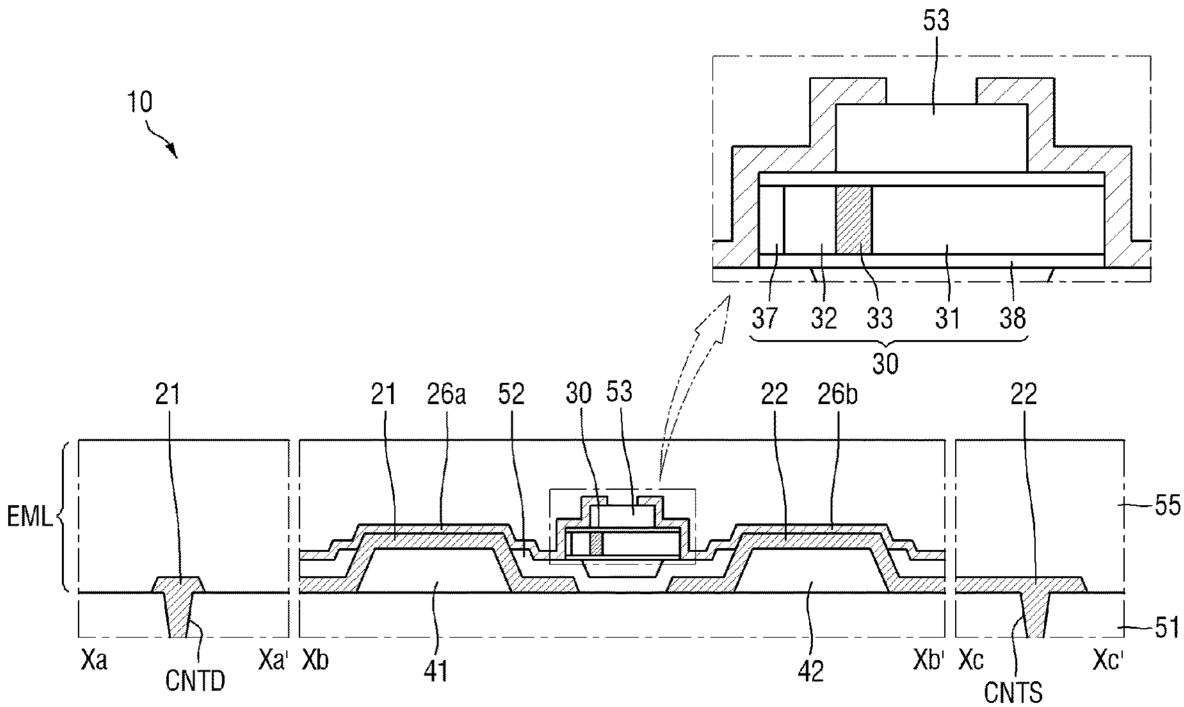

10
53
37
32
33
31
38
30
EML
21
21
26a
52
30
53
22
26b
22
55
51
Xa
CNTD
Xa'
Xb
41
42
Xb'
Xc
CNTS
Xc'

FIG. 18

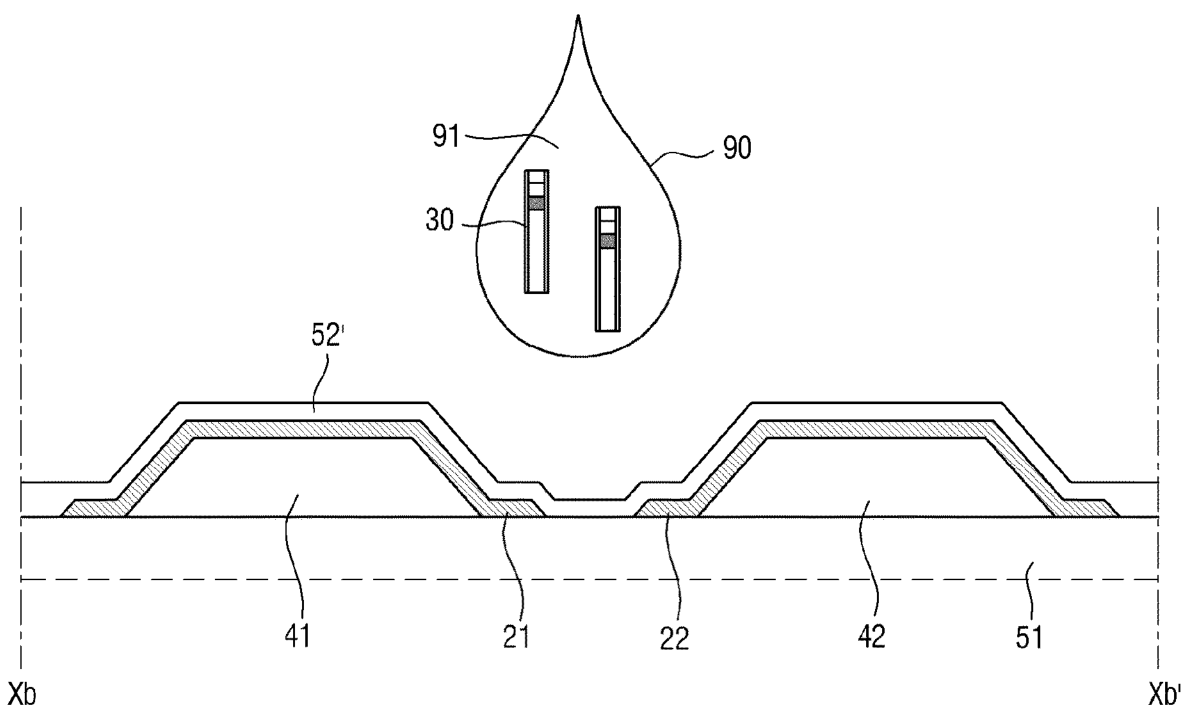


FIG. 19

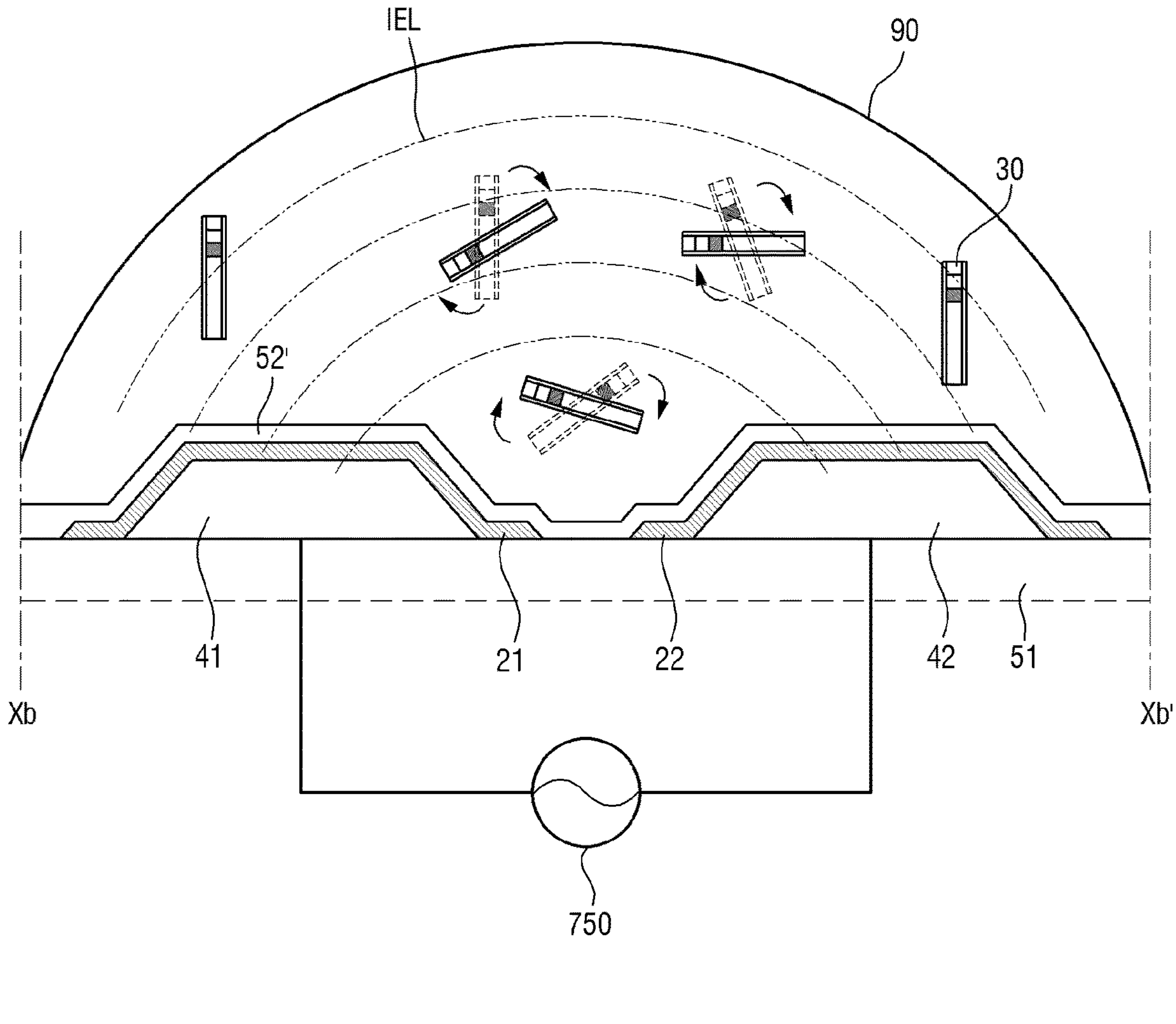


FIG. 20

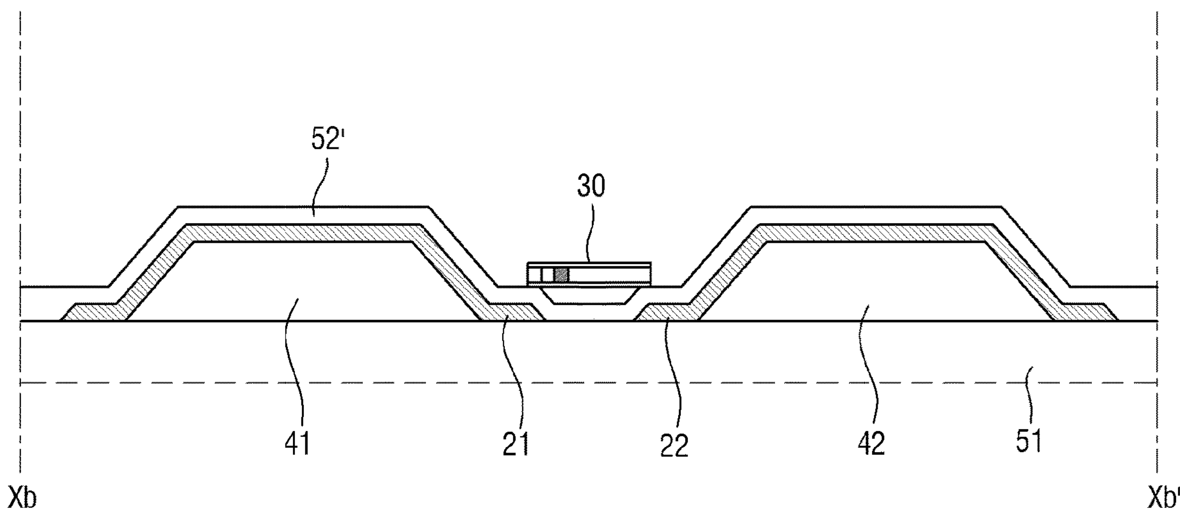
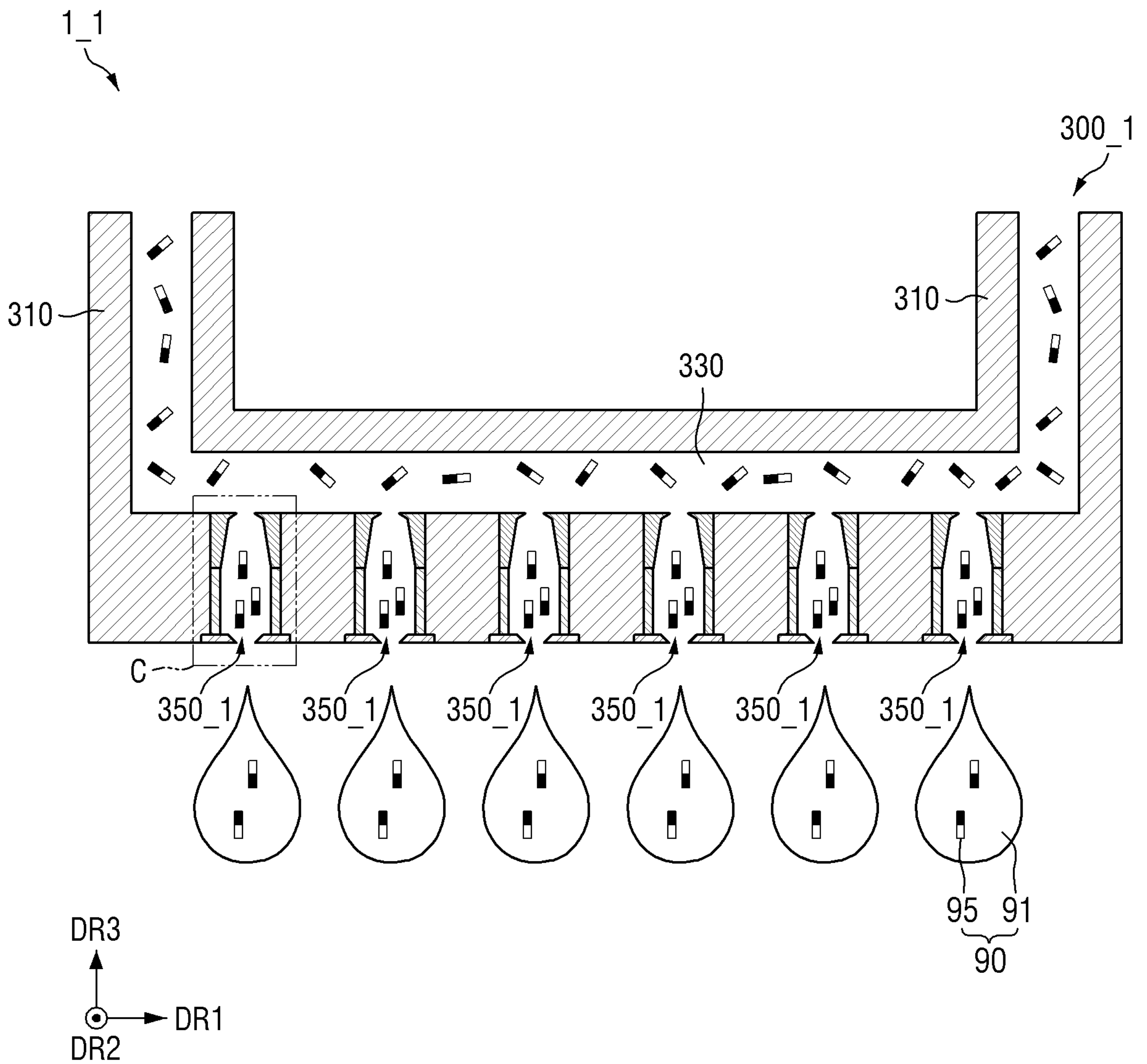
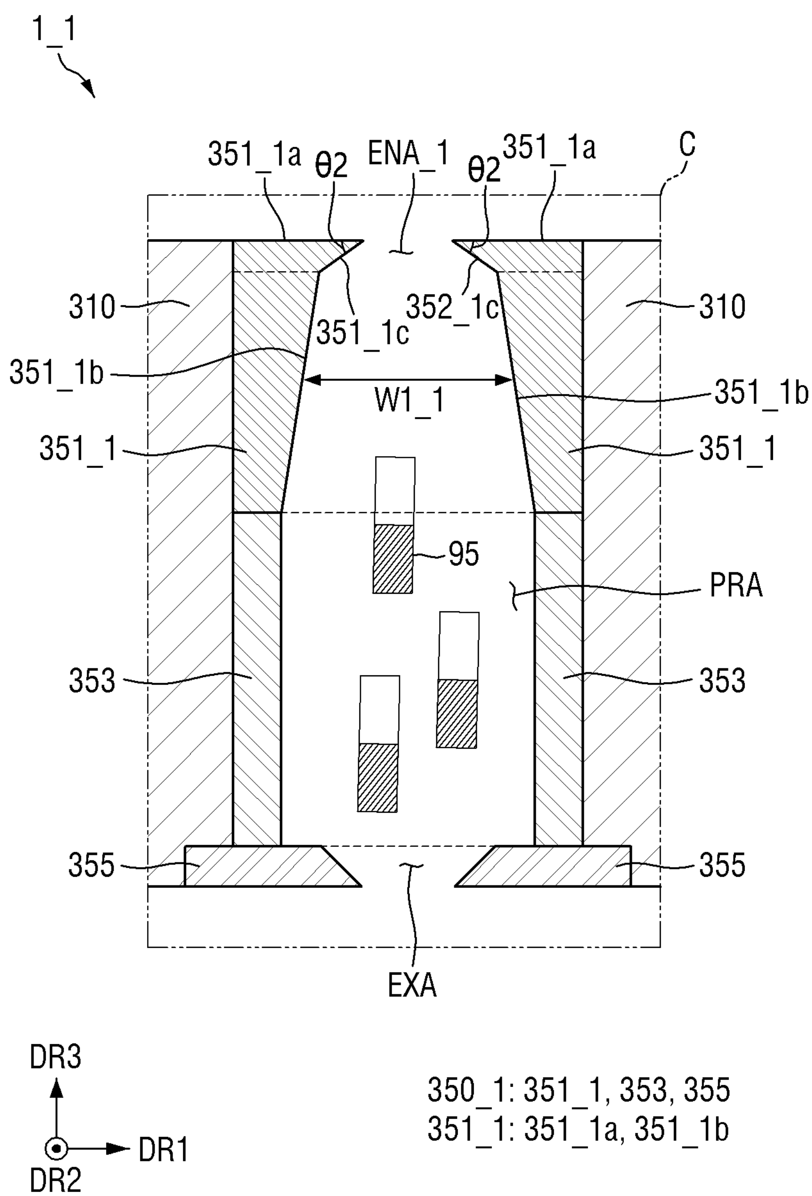


FIG. 21



1_1
300_1
310
310
330
C
350_1
350_1
350_1
350_1
350_1
350_1
95
91
90
DR3
DR1
DR2

FIG. 22


1_1
351_1a
θ2
ENA_1
θ2
351_1a
C
310
310
352_1c
351_1c
351_1b
W1_1
351_1b
351_1
351_1
95
PRA
353
353
355
355
EXA
DR3
DR1
DR2
350_1: 351_1, 353, 355
351_1: 351_1a, 351_1b

INKJET PRINTING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to and benefits of Korean Patent Application No. 10-2022-0060239 under 35 U.S.C. § 119, filed in the Korean Intellectual Property Office on May 17, 2022, the entire contents of which are incorporated herein by reference.

BACKGROUND

1. Technical Field

[0002] The disclosure relates to an inkjet printing apparatus capable of increasing lifetime of a head part.

2. Description of the Related Art

[0003] Display devices become more and more important as multimedia technology evolves. Accordingly, a variety of types of display devices such as organic light-emitting display (OLED) devices and liquid-crystal display (LCD) devices are currently used.

[0004] Display devices include a display panel such as an organic light-emitting display panel and a liquid-crystal display panel for displaying images. Among them, light-emitting display panel may include light-emitting elements. For example, light-emitting diodes (LEDs) may include an organic light-emitting diode (OLED) using an organic material as a fluorescent material, and an inorganic light-emitting diode using an inorganic material as a fluorescent material.

[0005] An inorganic light-emitting diode using an inorganic semiconductor as the fluorescent material has advantages in that it has durability in high-temperature environments and that it has a higher efficiency of blue light than organic light-emitting diodes.

[0006] It is to be understood that this background of the technology section is, in part, intended to provide useful background for understanding the technology. However, this background of the technology section may also include ideas, concepts, or recognitions that were not part of what was appreciated by those skilled in the pertinent art prior to a corresponding effective filing date of the subject matter disclosed herein.

SUMMARY

[0007] Embodiments provide an inkjet printing apparatus capable of increasing lifetime of a head.

[0008] 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.

[0009] According to an embodiment of the disclosure, an inkjet printing apparatus comprises a stage on which a substrate is seated; a nozzle part disposed above the stage and spraying an ink onto the substrate, the ink containing a solvent and solid substances; and a head part that supplies the ink to the nozzle part. The nozzle part includes an internal flow path extended in a first direction, through which the ink is supplied from the head part; and an inlet in which an entrance area is defined. The ink is introduced in a second direction intersecting the first direction from the internal flow path through the entrance area. The inlet includes an inclined surface adjacent to the entrance area and defining the entrance area; and a flat surface parallel to the first direction. An angle between the inclined surface and the flat surface is an acute angle.

[0010] In an embodiment, the nozzle part may further comprise a pressure part disposed adjacent to the inlet in the second direction and defining a pressure area that supplies a pressure to the ink introduced from the entrance area.

[0011] In an embodiment, the pressure part may comprise a piezoelectric element.

[0012] In an embodiment, the inkjet printing apparatus may further comprise an outlet adjacent to the pressure part in the second direction to define an exit area. The ink may be discharged from the exit area by the pressure applied in the pressure area.

[0013] In an embodiment, wherein a width of the entrance area may increase in the second direction.

[0014] In an embodiment, the entrance area may comprise an end adjacent to the internal flow path; and an opposite end adjacent to the pressure area. An area of the end of the entrance area may be smaller than an area of the opposite end of the entrance area.

[0015] In an embodiment, the ink may sequentially pass through the internal flow path, the entrance area, the pressure area, and the exit area.

[0016] In an embodiment, the nozzle part may further include a base in which the internal flow path and the inlet are located.

[0017] In an embodiment, the internal flow path may penetrate through the base.

[0018] In an embodiment, an edge of the internal flow path may be defined by the base and the flat surface of the inlet.

[0019] In an embodiment, the inclined surface may comprise a first inclined surface having an end in contact with the flat surface and an opposite end; and a second inclined surface in contact with the opposite end of the first inclined surface.

[0020] In an embodiment, the first inclined surface may be more inclined toward the entrance area than the second inclined surface.

[0021] According to an embodiment of the disclosure an inkjet printing apparatus comprises a stage on which a substrate is seated; a nozzle part disposed above the stage and spraying an ink onto the substrate, the ink containing a solvent and solid substances; and a head part that supplies the ink to the nozzle part. The nozzle part may include an internal flow path extended in a first direction, through which the ink is supplied from the head part; and an entrance area. The ink is introduced in a second direction intersecting the first direction from the internal flow path through the entrance area. A width of the entrance area increases in the second direction.

[0022] In an embodiment, the nozzle part may further include a pressure area disposed adjacent to the entrance area in the second direction and applying pressure to the ink introduced from the entrance area.

[0023] In an embodiment, the nozzle part may further comprise an exit area disposed adjacent to the pressure area in the second direction. The ink may be discharged from the exit area by the pressure applied in the pressure area.

[0024] In an embodiment, the entrance area may comprise an end adjacent to the internal flow path; and an opposite end adjacent to the pressure area. An area of the end of the entrance area may be smaller than an area of the opposite end of the entrance area.

[0025] In an embodiment, the ink may sequentially pass through the internal flow path, the entrance area, the pressure area, and the exit area.

[0026] In an embodiment, the nozzle part may further comprise an inlet adjacent to the entrance area. The inlet may include an inclined surface defining the entrance area; and a flat surface parallel to the first direction. An angle between the inclined surface and the flat surface of the inlet may be an acute angle.

[0027] In an embodiment, the inclined surface may comprise a first inclined surface having an end in contact with the flat surface; and a second inclined surface in contact with an opposite end of the first inclined surface.

[0028] In an embodiment, the nozzle part may further comprise a pressure part adjacent to the pressure area. The pressure part may comprise a piezoelectric element.

[0029] According to an embodiment of the disclosure, reduction in lifetime of a head of an inkjet printing apparatus due to precipitation of solid particles may be prevented.

[0030] It should be noted that effects of the disclosure are not limited to those described above and other effects of the disclosure will be apparent to those skilled in the art from the following descriptions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] An additional appreciation according to the embodiments of the disclosure will become more apparent by describing in detail the embodiments thereof with reference to the attached drawings, wherein:

[0032] FIG. **1** is a schematic perspective view showing an inkjet printing apparatus according to an embodiment of the disclosure;

[0033] FIG. **2** is a schematic plan view of an inkjet head unit of the inkjet printing apparatus according to the embodiment of FIG. **1** as viewed from the third direction;

[0034] FIG. **3** is a view schematically showing the operation of the inkjet head unit of the inkjet printing apparatus according to the embodiment of FIG. **1**;

[0035] FIG. **4** is a view schematically showing the connection relationship between the ink storage unit and the inkjet head unit of the inkjet printing apparatus according to the embodiment of FIG. **1**;

[0036] FIG. **5** is a view schematically showing the inside of the inkjet head unit according to the embodiment of FIG. **1**;

[0037] FIG. **6** is a schematic cross-sectional view showing a cross section taken along line **X1**-**X1'** of FIG. **5**;

[0038] FIG. **7** is a schematic enlarged view of area A of FIG. **5**;

[0039] FIG. **8** is a view schematically showing a structure of an inside of an inkjet head unit of an inkjet printing apparatus according to Comparative Example;

[0040] FIG. **9** is a schematic cross-sectional view taken along line **X2**-**X2'** of FIG. **8**;

[0041] FIG. **10** is a schematic plan view of the probe device of the inkjet printing apparatus according to the embodiment of FIG. **1** as viewed from the third direction;

[0042] FIGS. **11** and **12** are diagrams schematically illustrating operations of the probe device of FIG. **10**;

[0043] FIG. **13** is a view schematically showing that an electric field is generated over a target substrate by the probe device of FIG. **10** to align the solid substances in the ink;

[0044] FIG. **14** is a plan view schematically showing a display device according to an embodiment of the disclosure;

[0045] FIG. **15** is a view schematically showing the layout of the structure of a pixel of the display device according to the embodiment of FIG. **14**;

[0046] FIG. **16** is a view schematically showing a light-emitting element of the display device according to the embodiment of FIG. **14**;

[0047] FIG. **17** is a schematic cross-sectional view taken along lines Xa-Xa', Xb-Xb', and Xc-Xc' of FIG. **15**;

[0048] FIGS. **18** to **20** are schematic views illustrating a method of fabricating the display device according to the embodiment of FIG. **14**;

[0049] FIG. **21** is a view schematically showing a structure of an inside of an inkjet head unit of an inkjet printing apparatus according to another embodiment; and

[0050] FIG. **22** is a schematic enlarged view of area C of FIG. **21**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0051] 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 disclosure. 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.

[0052] Unless otherwise specified, the illustrated embodiments are to be understood as providing features of the disclosure. 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 disclosure.

[0053] 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.

[0054] 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 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. Also, like reference numbers denote like elements.

[0055] Although the terms "first," "second," and the like may be used herein to describe various 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. Similarly, the second element could also be termed the first element.

[0056] 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 should be interpreted accordingly.

[0057] 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" and "an" 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.

[0058] 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.

[0059] 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 disclosure. 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 disclosure.

[0060] The terms "about" or "approximately" as used herein is inclusive of the stated value and means within an acceptable range of deviation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (i.e., the limitations of the measurement system). For example, "about" may mean within one or more standard deviations, or within ±30%, 20%, 10%, 5% of the stated value.

[0061] For the purposes of this disclosure, the phrase "at least one of A and B" may be construed as 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.

[0062] Unless otherwise defined or implied herein, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by those skilled in the art to which this disclosure pertains. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the disclosure, and should not be interpreted in an ideal or excessively formal sense unless clearly so defined herein.

[0063] Features of each of various embodiments of the disclosure may be partially or entirely combined with each other and may technically variously interwork with each other, and respective embodiments may be implemented independently of each other or may be implemented together in association with each other.

[0064] Hereinafter, embodiments of the disclosure will be described with reference to the accompanying drawings.

[0065] FIG. **1** is a schematic perspective view showing an inkjet printing apparatus according to an embodiment of the disclosure. FIG. **2** is a schematic plan view of an inkjet head part of the inkjet printing apparatus according to the embodiment of FIG. **1** as viewed from the third direction. FIG. **3** is a view schematically showing the operation of the inkjet head part of the inkjet printing apparatus according to the embodiment of FIG. **1**.

[0066] In FIG. **1**, a first direction DR**1**, a second direction DR**2**, and a third direction DR**3** may be defined. The first direction DR**1** and the second direction DR**2** may be perpendicular to each other, the first direction DR**1** and the third direction DR**3** may be perpendicular to each other, and the second direction DR**2** and the third direction DR**3** may be perpendicular to each other. The first direction DR**1** may refer to a horizontal direction in the drawings, the second direction DR**2** may refer to a vertical direction in the drawings, and the third direction DR**3** may refer to an up-and-down direction (or a thickness direction) in the drawings. As used herein, a direction may refer to a direction indicated by an arrow as well as an opposite direction thereto, unless specifically stated otherwise. In case that two opposite directions are distinguished, one of the two directions may be referred to as "one side in the direction," and another direction of the two directions may be referred to as "an opposite side in the direction." In FIG. **1**, a side indicated by an arrow of a direction may be referred to as a side in the direction, and an opposite side may be referred to as an opposite side in the direction.

[0067] Referring to FIGS. **1** to **3**, an inkjet printing apparatus **1** according to an embodiment of the disclosure may include a stage STA, an inkjet head part **100**, a base frame **600**, an ink storage part **500**, a first connecting line IL**1**, and a second connecting line IL**2**. A target substrate SUB may be seated on the stage STA. Nozzle parts **300** may be disposed in the inkjet head part **100**. The first connecting line IL**1** may connect the inkjet head part **100** to the ink storage part **500**. The second connecting line IL**2** may connect the inkjet head part **100** to the ink storage part **500**. The inkjet printing apparatus **1** according to the embodiment of the disclosure may spray an ink **90** onto a target substrate SUB seated on the stage STA using the inkjet head part **100** and the nozzle parts **300**.

[0068] The stage STA may allow the target substrate SUB to be seated on the stage STA. The stage STA may be disposed on a first rail RL**1** extended in the second direction DR**2** and a second rail RL**2** extended in the second direction DR**2**. The stage STA may move in the second direction DR**2** by a separate moving mechanism on the first rail RL**1** and the second rail RL**2**. Accordingly, the target substrate SUB may also move in the second direction DR**2** along the stage STA. The stage STA and the target substrate SUB may move in the second direction DR**2** and pass through the inkjet head part **100** disposed above the stage STA and the target substrate SUB. Thus, the ink **90** may be sprayed onto an upper surface of the target substrate SUB. Although the stage STA moves in the second direction DR**2** in the drawings, the disclosure is not limited thereto. In some implementations, the inkjet head part **100** may move in the second direction DR**2**. In the following description, it is assumed that the stage STG moves in the second direction DR**2** through the first rail RL**1** and the second rail RL**2** for convenience of illustration.

[0069] The inkjet head part **100** may eject the ink **90** onto the target substrate SUB through the nozzle parts **300**. The nozzle parts **300** may be attached to a bottom surface of the inkjet head part **100**. The nozzle parts **300** may be disposed such that they are spaced apart from one another on the bottom surface of the inkjet head part **100** and may be arranged in a row or multiple of rows. Although the nozzle parts **300** are arranged in two rows, and the nozzle parts **300** in one of the rows may be staggered with respect to those in another one of the rows in the example shown in FIG. **2**, the disclosure is not limited thereto. For example, the nozzle parts **300** may be arranged in more than two rows and may be arranged such that they overlap one another (e.g., in a view or direction) instead of being staggered. In some embodiments, the inkjet head part **100** may have a rectangular shape. However, the disclosure is not limited thereto.

[0070] The inkjet head part **100** may be disposed such that it is spaced apart from the target substrate SUB seated on the stage STA in the third direction DR**3**, and eject the ink **90** onto the upper surface of the target substrate SUB in the third direction DR**3**. The inkjet head part **100** may be disposed on the base frame **600** and a position of the inkjet head part **100** may be adjusted by a configuration of the base frame **600**.

[0071] The base frame **600** may have the inkjet head part **100** in which the nozzle parts **300** are disposed and mounted thereon to move the inkjet head part **100**, and may define a movement path of the inkjet head part **100**. The base frame **600** may include a support **610** and a moving unit **630**.

[0072] The support **610** of the base frame **600** may include a first support part **611** and second support parts **612**. The first support part **611** may hold the inkjet head part **100** in which the nozzle parts **300** is disposed. In some embodiments, the first support part **611** may have a bar shape extended in the first direction DR**1**, but the disclosure is not limited thereto. The second support parts **612** may hold up the first support part **611** in the third direction DR**3**. The second support parts **612** may be connected (or extended) to ends (e.g., both ends) of the first support part **611** in the first direction DR**1**, respectively, and may be extended in the third direction DR**3**. Accordingly, the first support part **611** and the inkjet head part **100** in which the nozzle parts **300** is disposed may be spaced apart from the stage STA in the third direction DR**3**.

[0073] The second support part **612** connected (or extended) to a side of the first support part **611** in the first direction DR**1** and the second support part **612** connected (or extended) to an opposite side of the first support part **611** in the first direction DR**1** may be spaced apart from each other in the direction DR**1**. The stage STA and the substrate SUB may be disposed between the second support part **612** connected (or extended) to the side of the first support part **611** in the first direction DR**1** and the second support part **612** connected (or extended) to the opposite side of the first support part **611** in the first direction DR**1** which are spaced apart from each other.

[0074] The moving unit **630** of the base frame **600** may have two roles. For example, the moving unit **630** of the base frame **600** may have a role to have the inkjet head part **100** mounted thereon and a role to move the inkjet head part **100** in the first direction DR**1**. The moving unit **630** may include a moving part **631** and a fixing part **632**. The moving part **631** may be mounted on the first support part **611** and movable in the first direction DR**1**. The fixing part **632** may be disposed on the bottom surface of the moving part **631** and have the inkjet head part **100** disposed thereon. The moving part **631** may be disposed on the first support **611** to move in the first direction DR**1** on the first support **611**. The inkjet head part **100** in which the nozzle parts **300** is disposed may be fixed to the fixing part **632** and move in the first direction DR**1** together with the moving part **631**.

[0075] The ink storage part **500** may store the ink **90** to be supplied to the inkjet head part **100**. In some embodiments, the ink storage part **500** may be disposed on the side of the first support **611**, but the disclosure is not limited thereto. The ink storage part **500** may be connected (or extended) to the inkjet head part **100** via the first connecting line IL**1** and the second connecting line IL**2**. The ink **90** of the ink storage part **500** may be supplied to the inkjet head part **100** via the first connecting line IL**1**, and the remaining ink **90** after it is discharged from the inkjet head part **100** may be retrieved back to the ink storage part **500** via the second connecting line IL**2**. Detailed description of the above-described operation is described below.

[0076] The ink **90** may include a solvent **91**, and bipolar elements **95** which are solid substances contained in the solvent **91**. The ink **90** may be provided as a solution or colloidal state. Each of the bipolar elements **95** may include a first end having a first polarity and a second end having a second polarity. The bipolar elements **95** dispersed in the solvent **91** may be supplied to the inkjet head part **100** and may be discharged therefrom.

[0077] In some embodiments, the solvent **91** may include at least one of acetone, water, alcohol, toluene, propylene glycol (PG), and propylene glycol methyl acetate (PGMA). However, the disclosure is not limited thereto.

[0078] The inkjet printing apparatus **1** may further include a probe device **700**.

[0079] The probe device **700** may form an electric field IEL (e.g., refer to FIG. **12**) in the target substrate SUB. The probe device **700** may be disposed on the stage STA. The probe device **700** may include a sub-stage **710** supporting the target substrate SUB. For example, the target substrate SUB may be seated on the sub-stage **710** of the probe device **700** disposed on the stage STA.

[0080] After the bipolar elements **95** of the ink **90** are sprayed onto the target substrate SUB with orientations (e.g., particular or selectable orientations), the bipolar elements **95** may be aligned in a direction on the target substrate SUB by the electric field IEL generated by the probe device **700**. Detailed description thereon is provided below in conjunction with FIGS. **10** to **13**.

[0081] Hereinafter, an ink circulation system between the ink storage part **500** and the inkjet head part **100** of the inkjet printing apparatus **1** according to the embodiment of the disclosure is described below.

[0082] FIG. **4** is a view schematically showing the connection relationship between the ink storage part and the inkjet head part of the inkjet printing apparatus according to the embodiment of FIG. **1**.

[0083] Referring to FIG. **4**, the ink storage part **500** may supply the ink **90** to the inkjet head part **100**, and the inkjet head part **100** may discharge the supplied ink **90**. A part of the ink **90** supplied to the inkjet head part **100** may be discharged from the inkjet head part **100**, and the remainder (or the remaining part) of the ink **90** may be supplied back to the ink storage part **500**. For example, the ink **90** may circulate between the ink storage part **500** and the inkjet head part **100** via the first connecting line IL**1** and the second connecting line IL**2**.

[0084] In some embodiments, the ink storage part **500** may include a first ink storage **510**, a second ink storage **520**, a third ink storage **530**, a pressure pump **550**, a compressor **560**, and a flow meter **580**. For example, the second ink storage **520**, the pressure pump **550**, and the third ink storage **530** of the ink storage part **500** may be connected (or extended) to the inkjet head part **100**, and they may form a single circulation system.

[0085] The first ink storage **510** may prepare the produced ink **90**. The ink **90** containing the solvent **91** and the bipolar elements **95** may be prepared in the first ink storage **510**, and the ink **90** may be supplied to the circulation system.

[0086] The second ink storage **520** may be connected (or extended) to the first ink storage **510**, and the prepared ink **90** may be supplied. The second ink storage **520** may retrieve and store the remaining part of the ink **90** via the second connecting line IL**2** after the ink **90** is discharged from the inkjet head part **100**. The second ink storage **520** may be located between the third ink storage **530** and the inkjet head part **100**, and the first ink storage part **510**. The second ink storage **520** may be located between the third ink storage **530**, the inkjet head part **100**, and the first ink storage part **510**, the second ink storage **520** may control application of the ink **90** to the third ink storage **530** so that an appropriate amount of the ink **90** is supplied to the third ink storage **530** to facilitate the dispersion of the bipolar elements **95**. The ink **90** supplied to the second ink storage **520** may be supplied to the third ink storage **530** via the pressure pump **550**.

[0087] The pressure pump **550** may transfer power to a fluid so that the ink **90** can be circulated in the circulation system. The flow meter **580** may be disposed between the pressure pump **550** and the third ink storage **530**, and the flow meter **580** may measure a flow rate of the ink **90** supplied to the third ink storage **530**. The pressure pump **550** may adjust the flow rate of the ink **90** supplied to the third ink storage **530** according to the flow rate of the ink **90** measured by the flow meter **580**.

[0088] The compressor **560** may adjust a pressure in the third ink storage **530**. The compressor **560** may remove gas from an inside of the third ink storage **530** so that it is in a vacuum state. For example, the compressor **560** may introduce an outside inert gas, and the inside of the third ink storage **530** may have a pressure (e.g., a predetermined or selectable pressure). In an embodiment, the compressor **560** may be eliminated (or omitted).

[0089] The third ink storage **530** may supply the ink **90** to the inkjet head part **100** via the first connecting line ILL In some embodiments, the third ink storage **530** may include a stirrer, which may be used to disperse the bipolar elements **95** in the ink **90**. As the stirrer rotates, the ink **90** supplied to the third ink storage **530** may remain dispersed because the bipolar elements **95** do not sink. For example, the stirrer of the third ink storage **530** may prevent the bipolar elements **95** from sinking to a bottom of the third ink storage **530**. Thus, the number of the bipolar elements **95** may be reduced in the ink **90** discharged through the inkjet head part **100**. Accordingly, the third ink storage **530** may supply the ink **90** in which the bipolar elements **95** are evenly dispersed to the inkjet head part **100**, and the inkjet head part **100** may discharge the ink **90** containing a sufficient amount of the bipolar elements **95**.

[0090] A first valve VA**1** may be disposed on the first connecting line IL**1**, and a second valve VA**2** may be disposed on the second connecting line IL**2**. The first valve VA**1** may regulate (or control) the flow rate of the ink **90** supplied from the ink storage part **500** to the inkjet head part **100**, and the second valve VA**2** may regulate (or control) the flow rate of the ink **90** retrieved to the ink storage part **500** from the inkjet head part **100**.

[0091] Hereinafter, a process of discharging the ink **90** is described based on the structure of the nozzle parts **300**.

[0092] FIG. **5** is a view schematically showing the inside of the inkjet head part according to the embodiment of FIG. **1**. FIG. **6** is a schematic cross-sectional view showing a cross section taken along line X**1**-X**1**' of FIG. **5**. FIG. **7** is a schematic enlarged view of area A of FIG. **5**. FIG. **8** is a view schematically showing a structure of an inside of an inkjet head part of an inkjet printing apparatus according to Comparative Example. FIG. **9** is a schematic cross-sectional view taken along line X**2**-X**2**' of FIG. **8**.

[0093] Referring to FIGS. **5** to **7**, each of the nozzle parts **300** of the inkjet printing apparatus **1** according to the embodiment may include a base **310**, an internal flow path **330**, and injection holes **350**.

[0094] The base **310** of the nozzle part **300** may form a main body of the nozzle part **300**. The base **310** may be attached to the inkjet head part **100**.

[0095] The internal flow path **330** of the nozzle part **300** may be located inside the base **310** and may be connected (or extended) to an internal tube (not shown) of the inkjet head part **100**.

[0096] The internal flow path **330** may be a tube passing through the base **310** and may provide a channel through which the remaining part of the ink **90** (e.g., the remaining part of the ink **90** not introduced into the injection holes **350** of the nozzle part **300** after the ink has been supplied to the nozzle part **300** via the first connecting line IL**1** connected (or extended) to the ink storage part **500**) may be retrieved to the ink storage part **500** via the second connecting line IL**2** connected (or extended) to the ink storage part **500**.

[0097] In some embodiments, the internal flow path **330** may have a shape that generally extends in the first direction DR**1**, but the disclosure is not limited thereto. In the example shown in FIG. **5**, the internal flow path **330** may have a shape generally extended in the first direction DR**1**.

[0098] The injection holes **350** of the nozzle parts **300** may receive the ink **90** passing through the internal flow path **330** from the internal flow path **330** and discharge the ink **90**. As shown in FIGS. **5** and **6**, the injection holes **350** may be arranged on an opposite side of the internal flow path **330** in the third direction DR**3**, and the injection holes **350** may be spaced apart from one another in the first direction DR**1**. For example, each of the injection holes **350** may be connected (or extended) to the internal flow path **330**, and the injection holes **350** may be arranged and spaced apart from one another along the extension direction (i.e., the first direction DR**1**). Each of the injection holes **350** may be connected (or extended) to the internal flow path **330**. Each of the injection holes **350** may include an inlet **351**, a pressure part **353**, and an outlet **355**.

[0099] The inlet **351** of each of the injection holes **350** may define an entrance area ENA in which the ink **90** is supplied from the internal flow path **330**. The entrance area ENA may be connected (or extended) to the opposite side of the internal flow path **330** in the third direction DR**3**. The entrance area ENA may be a space passing through the inlet **351**. For example, the inlet **351** may have a shape surrounding the entrance area ENA, and the entrance area ENA may be defined as a space surrounded by the inlet **351**.

[0100] The entrance of the inlet **351** may be formed at an acute angle. For example, the inlet **351** may include a flat surface **351***a* as a surface arranged in the third direction DR**3**, and an inclined surface **351***b* as a surface surrounding the entrance area ENA. The flat surface **351***a* may intersect the inclined surface **351***b* at a first angle θ**1** that is an acute angle.

[0101] The flat surface **351***a* of the inlet **351** may be in direct contact with the internal flow path **330** and may be parallel to an extension direction of the internal flow path **330** (e.g., the first direction DR**1**). The flat surface **351***a* may have a flat surface in the extending direction of the internal flow path **330**. For example, as shown in FIG. **6**, the flat surface **351***a* may be flat without protruding toward the internal flow path **330** or being depressed (or recessed) in the third direction DR**3**. For example, an opposite edge of the internal flow path **300** in the third direction DR**3** may be defined by the base **310** and the flat surface **351***a* of the inlet **351**. Accordingly, the bipolar elements **95** dispersed in the ink **90** passing through the internal flow path **330** can flow without being accumulated.

[0102] The inclined surface **351***b* of the inlet **351** may be the surface surrounding the entrance area ENA and may have a shape inclined at a first angle θ**1** with respect to the flat surface **351***a*. For example, the inclined surface **351***b* may intersect the flat surface **351***a* at the first angle θ**1**. The first angle θ**1** may be an acute angle of less than 90°. As the inclined surface **351***b* is inclined at the first angle θ**1** that is an acute angle with respect to the flat surface **351***a*, the inclined surface **351***b* may not be exposed from the entrance area ENA in case that the entrance area ENA is viewed from the third direction DR**3** as shown in FIG. **6**. For example, an area of an end of the entrance area ENA in the third direction DR**3** may be smaller than an area of an opposite end of the entrance area ENA in the third direction DR**3**. Accordingly, in case that the bipolar elements **95** are introduced into the entrance area ENA, the bipolar elements **95** may not be accumulated on the inlet **351**. Thus, the lifetime of the nozzle parts **300** may be improved.

[0103] For example, referring to FIGS. **8** and **9**, an inkjet printing apparatus **1**' according to Comparative Example is different from the inkjet printing apparatus **1** according to the above-described embodiment at least in that an entrance of an inlet of each of injection holes **350**' is formed as an obtuse angle.

[0104] As the inlet of the injection hole **350**' of the inkjet printing apparatus **1**' according to Comparative Example is formed at an obtuse angle, an area of an end of an entrance area ENA' in the second direction DR**2** may be larger than an area of an opposite end in the third direction DR**3**. Thus, an inclined surface of the inlet may be exposed as shown in FIG. **9**, unlike that of FIG. **6**. As a result, bipolar elements **95** may be introduced into the entrance area ENA' and may form a precipitate (e.g., region B) which may block the entrance area ENA'. Therefore, the lifetime of nozzle parts **300**' may be reduced.

[0105] In view of the above, by inclining the inclined surface **351***b* at the first angle θ**1** that is an acute angle with respect to the flat surface **351***a*, it is possible to prevent the lifetime of the nozzle parts **300** from being reduced.

[0106] Referring back to FIGS. **5** to **7**, since the inclined surface **351***b* is inclined at the first angle θ**1** that is an acute angle with respect to the flat surface **351***a*, a width W**1** of the entrance area ENA may gradually increase toward the opposite side in the third direction DR**3**. If the first angle θ**1** is 90°, an entrance area ENA may not be able to have sufficient volume compared to the entrance area ENA having the first angle θ1 of an acute angle. As a result, an inflow resistance of the entrance area ENA may become larger, and the ink **90** may not be readily introduced. In view of the above, by setting the first angle θ1 as an acute angle to ensure a sufficient volume of the entrance area ENA, it is possible to reduce the inflow resistance of the ink **90** into the inlet **351**.

[0107] The pressure part **353** of each of the injection holes **350** may define a pressure area PRA that applies pressure to the ink **90** introduced from the entrance area ENA. The pressure area PRA may be a space passing through the pressure part **353**. For example, the pressure part **353** may have a shape surrounding the pressure area PRA, and the pressure area PRA may be defined as the space surrounded by the pressure area **353**. The pressure part **353** may apply pressure to the ink **90** introduced from the inlet **351** and adjust the amount of ink **90** discharged.

[0108] The pressure part **353** may be disposed under the inlet **351**. Accordingly, the pressure area PRA may be disposed under the entrance area ENA. In some embodiments, the pressure part **353** may include a piezoelectric element. However, the disclosure is not limited thereto. In case that the pressure part **353** includes a piezoelectric element, a shape of the pressure part **353** may be deformed by an electrical signal applied to the pressure part **353** to apply pressure to the ink **90**. In case that the pressure part **353** includes a piezoelectric element, the pressure part **353** may include, for example, a ceramic material such as barium titanate ($BaTiO_3$) and ammonium dihydrogen phosphate ($NH_4H_2PO_4$) However, the disclosure is not limited thereto.

[0109] The outlet **355** of each of the injection holes **350** may define an exit area EXA from which the ink **90** is discharged by the pressure applied in the pressure area PRA. The exit area EXA may be a space passing through the outlet **355**. For example, the outlet **355** may have a shape surrounding the exit area EXA, and the exit area EXA may be defined as the space surrounded by the outlet **355**.

[0110] The outlet **355** may include a material whose shape is not deformed by an external force. The outlet **355** may include a material different from a material of the pressure part **353**. For example, in case that the pressure part **353** includes a piezoelectric element, the outlet **355** may include a material other than the piezoelectric element.

[0111] As described above, the ink **90** introduced into each of the injection holes **350** through the internal flow path **330** of the nozzle part **300** may sequentially pass through the entrance area ENA, the pressure area PRA, and the exit area EXA along the opposite side in the third direction DR**3**, and the bipolar elements **95** of the ink **90** may not be precipitated by virtue of the shape of the inlet **351**. Accordingly, the lifetime of the nozzle part **300** may be improved, and the inflow resistance of the ink **90** may be reduced. Thus, the ink **90** may readily move to the pressure area PRA.

[0112] Hereinafter, detailed description of a probe device of the inkjet printing apparatus **1** according to the embodiment is provided below.

[0113] FIG. **10** is a schematic plan view of the probe device of the inkjet printing apparatus according to the embodiment of FIG. **1** as viewed from the third direction. FIGS. **11** and **12** are views schematically illustrating operations of the probe device of FIG. **10**. FIG. **13** is a view schematically showing generation of an electric field over a target substrate by the probe device of FIG. **10** to align the solid substances in the ink.

[0114] Referring to FIGS. **10** to **13**, the probe device **700** may include a sub-stage **710**, a probe support **730**, a probe part **750**, and an aligner **780**.

[0115] The probe device **700** may be disposed on the stage STA and may move in the second direction DR**2** together with the stage STA. The probe device **700** having the target substrate SUB disposed thereon may move along the stage STA, and the ink **90** may be sprayed on the target substrate SUB. In case that the ink **90** is sprayed, the probe device **700** may generate an electric field IEL over the target substrate SUB.

[0116] The sub-stage **710** may provide a space in which the target substrate SUB is placed. The probe support **730**, the probe part **750**, and the aligner **780** may be disposed on the sub-stage **710**.

[0117] At least one aligner **780** may be disposed on the sub-stage **710**. The aligner **780** may be disposed on each of sides of the sub-stage **710**, and the target substrate SUB may be placed in an area surrounded by aligners **780**.

[0118] The probe support **730** and the probe part **750** may be disposed on the sub-stage **710**. The probe support **730** may provide a space in which the probe part **750** is disposed on the sub-stage **710**. For example, the probe support **730** may be disposed on at least one side on the sub-stage **710** and may be extended in the extending direction of the side on the sub-stage **710**. For example, as shown in the drawing, the probe support **730** may be extended in the second direction DR**2** on left and right sides of the sub-stage **710**.

[0119] The probe part **750** may be disposed on the probe support **730** and form an electric field IEL on the target substrate SUB prepared on the sub-stage **710**. The probe part **750** and the probe support **730** may be extended in the second direction DR**2**. The length of the probe part **750** may be greater than a length of the target substrate SUB.

[0120] The probe part **750** may include a probe driver **753**, a probe jig **751**, and a probe pad **758**. The probe driver **753** may be disposed on the probe support **730**. The probe jig **751** may be disposed on the probe driver **753** and transmit an electrical signal. The probe pad **758** may be connected (or extended) to the probe jig **751** and transmit the electrical signal to the target substrate SUB.

[0121] The probe driver **753** may be disposed on the probe support **730** and move the probe jig **751** and the probe pad **758** in the third direction DR**3**. The probe pad **753** may be connected to or separated from the target substrate SUB by the driving of the probe driver **758**.

[0122] As shown in FIG. **12**, the probe pad **758** may be connected to the target substrate SUB and form an electric field IEL over the target substrate SUB through an electrical signal transmitted from the probe jig **751**. For example, the probe pad **758** may be in contact with an electrode or a power pad of the target substrate SUB, and the electrical signal from the probe jig **751** may be transmitted to the electrode or the power pad of the target substrate SUB.

[0123] The probe jig **751** may be connected (or extended) to the probe pad **758** and may be connected (or extended) to a separate voltage application device. The probe jig **751** may transmit an electrical signal transmitted from the voltage application device to the probe pad **758** to form an electric field IEL on the target substrate SUB. The electrical signal transmitted to the probe jig **751** may be a voltage for forming the electric field IEL, for example, an AC voltage. In other embodiments, multiple probe jigs **751** may be disposed, and the number of the probe jigs **751** is not particularly limited herein.

[0124] In the ink **90** discharged from the nozzle parts **300** onto the target substrate SUB, the bipolar elements **95** each including the first end and the second end having the above-described polarities may be dispersed. In case that the bipolar elements **95** are placed in an electric field IEL, a dielectrophoretic force may be transmitted so that their positions or orientations may be changed. As shown in FIG. **12**, the bipolar elements **95** in the ink **90** sprayed onto the target substrate SUB may be seated on the target substrate SUB while their positions and orientations are changed by the electric field IEL generated by the probe device **700**.

[0125] The timing at which the probe device **700** generates the electric field IEL over the target substrate SUB may not be particularly limited herein. In the drawings, the probe part **750** may generate the electric field IEL while the ink **90** is discharged from the nozzle units **300** and reaches the target substrate SUB. Accordingly, after the bipolar elements **95** have been discharged from the nozzles, the bipolar elements **95** may receive the dielectrophoretic force by the electric field IEL until the bipolar elements **95** reach the target substrate SUB. In some embodiments, the probe part **750** may generate the electric field IEL after the ink **90** has been seated on the target substrate SUB.

[0126] Although not shown in the drawings, the inkjet printing apparatus **1** according to an embodiment of the disclosure may further include a heat treatment part in which a process of volatilizing the ink **90** sprayed onto the target substrate SUB is performed. The heat treatment part may irradiate heat to the ink **90** sprayed onto the target substrate SUB, so that the solvent **91** of the ink **90** may be volatilized and removed, whereas the bipolar elements **95** may be disposed (or remain) on the target substrate SUB. The process of removing the solvent **91** by the irradiation of the heat to the ink **90** may be performed by a heat treatment process. Detailed description of the same constituent elements is omitted.

[0127] Incidentally, the above-described bipolar elements **95** may be light-emitting elements **30** including semiconductor layers, and the inkjet printing apparatus **1** according to the embodiment of the disclosure may fabricate the display device **10** including the light-emitting elements **30**. Hereinafter, detailed description of the display device **10** including the light-emitting elements **30** is provided below.

[0128] FIG. **14** is a plan view schematically showing a display device according to an embodiment of the disclosure. FIG. **15** is a view schematically showing the layout of the structure of a pixel of the display device according to the embodiment of FIG. **14**. FIG. **16** is a view schematically showing a light-emitting element of the display device according to the embodiment of FIG. **14**. FIG. **17** is a schematic cross-sectional view taken along lines Xa-Xa', Xb-Xb', and Xc-Xc' of FIG. **15**. FIGS. **18** to **20** are schematic views illustrating a method of fabricating the display device according to the embodiment of FIG. **14**.

[0129] Referring to FIG. **14**, the display device **10** according to the embodiment may display a moving image or a still image. The display device **10** may refer to any electronic device that provides a display screen. For example, the display device **10** may include a television set, a laptop computer, a monitor, an electronic billboard, the Internet of Things devices, a mobile phone, a smart phone, a tablet personal computer (PC), an electronic watch, a smart watch, a watch phone, a head-mounted display device, a mobile communications terminal, an electronic notebook, an electronic book, a portable multimedia player (PMP), a navigation device, a game console, a digital camera, a camcorder, etc.

[0130] A shape of the display device **10** may be modified in various ways. For example, the display device **10** may have shapes such as a rectangle with longer lateral sides, a rectangle with longer vertical sides, a square, a quadrangle with rounded corners, other polygons, a circle, etc. The shape of a display area DA of the display device **10** may be similar to an overall shape of the display device **10**. FIG. **13** shows the display device **10** and the display area DA in a shape of a rectangle with longer horizontal sides.

[0131] The display device **10** may include the display area DA and a non-display area NDA. In the display area DA, images may be displayed. In the non-display area NDA, images may not be displayed. The display area DA may be referred to as an active area, while the non-display area NDA may also be referred to as an inactive area.

[0132] The display area DA may generally occupy a center of the display device **10**. The display area DA may include pixels PX. The pixels PX may be arranged in a matrix. Each of the pixels PX may have a rectangle shape or a square shape in a plan view. However, the disclosure is not limited thereto. Each of the pixels PX may have a diamond shape having sides inclined in a direction. Each of the pixels PX may include at least one light-emitting element **30** that emits light of a wavelength band (e.g., a particular or selectable wave length band) to represent a color.

[0133] Referring to FIG. **15**, each of the pixels PX may include a first sub-pixel PX**1**, a second sub-pixel PX**2**, and a third sub-pixel PX**3**. The first sub-pixel PX**1** may emit light of a first color, the second sub-pixel PX**2** may emit light of a second color, and the third sub-pixel PX**3** may emit light of a third color. The first color may be blue, the second color may be green, and the third color may be red, but the disclosure is not limited thereto. The sub-pixels PXn may emit light of a same color. Although the pixel PX includes three sub-pixels PXn in the example shown in FIG. **15**, the disclosure is not limited thereto. The pixel PX may include more than two sub-pixels PXn.

[0134] Each of the sub-pixels PXn of the display device **10** may include an area defined as an emission area EMA. The first sub-pixel PX**1** may include a first emission area EMA**1**, the second sub-pixel PX**2** may include a second emission area EMA**2**, and the third sub-pixel PX**3** may include a third emission area EMA**3**. The emission area EMA may be defined as an area in which the light-emitting element **30** included in the display device **10** is disposed and emits light of a wavelength band (e.g., a specific or selectable wavelength band).

[0135] Although not shown in the drawings, each of the sub-pixels PXn of the display device **10** may include a non-emission area defined as another area than the emission area EMA. In the non-emission area, the light-emitting elements **30** may not be disposed and the lights emitted from the light-emitting elements **30** may not reach, and thus no light may exit from the non-emission area.

[0136] Each of the sub-pixels PXn of the display device **10** may include electrodes **21** and **22**, light-emitting elements **30**, contact electrodes **26**, inner banks **41** and **42** (e.g., refer to FIG. **17**), an outer bank **43**, and at least one insulating layer **51**, **52**, **53** and **55** (e.g., refer to FIG. **17**).

[0137] The electrodes **21** and **22** may be electrically connected to the light-emitting elements **30**, and a voltage (e.g., a predetermined or selectable voltage) may be applied to the electrodes **21** and **22**. Thus, the light-emitting element **30** may emit light of a specific wavelength band. At least a part of the electrodes **21** and **22** may be utilized to form an electric field within the sub-pixels PXn, and the light-emitting element **30** may be aligned.

[0138] The electrodes **21** and **22** may include the first electrode **21** and the second electrode **22**. In an embodiment, the first electrode **21** may be disconnected from a sub-pixel PXn to another sub-pixel PXn, while the second electrode **22** may be a common electrode connected across the sub-pixels PXn. One of the first electrode **21** and the second electrode **22** may be an anode electrode of the light-emitting element **30**, and another of the first electrode **21** and the second electrode **22** may be a cathode electrode of the light-emitting element **30**. However, the disclosure is not limited thereto.

[0139] The first electrode **21** and the second electrode **22** may include electrode stems **21**S and **22**S extended in the horizontal direction, respectively, and one or more electrode branches **21**B and **22**B branching off from the electrode stems **21**S and **22**S, respectively, and extended in the vertical direction intersecting the horizontal direction.

[0140] The first electrode **21** may include a first electrode stem **21**S and at least one first electrode branch **21**B. The first electrode stem **21**S may be extended in the horizontal direction. The at least one first electrode branch **21**B may branch off from the first electrode stem **21**S and be extended in the vertical direction.

[0141] In a pixel, ends (e.g., both ends) of the first electrode stem **21**S of the sub-pixel PXn may be terminated between the sub-pixels PXn. The ends (e.g., both ends) of the first electrode stem **21**S may be spaced apart from the adjacent sub-pixels PXn and located on substantially the same straight line as the first electrode stem **21**S of the adjacent pixel in the same row e.g., in the horizontal direction. Since the ends of the first electrode stem **21**S disposed in each of the sub-pixels PXn are spaced apart from those of the other sub-pixels PXn, different electric signals may be applied to the different first electrode branches **21**B, so that the first electrode branches **21**B can be driven individually.

[0142] The first electrode branches **21**B may branch off from at least a part of the first electrode stem **21**S and be extended in the vertical direction. The first electrode branches **21**B may be terminated such that they are spaced apart from the second electrode stem **22**S that is opposed to the first electrode stem **21**S.

[0143] The second electrode **22** may include a second electrode stem **22**S and a second electrode branch **22**B. The second electrode stem **22**S may be extended in the horizontal direction and spaced apart from the first electrode stem **21**S in the vertical direction, and a second electrode branch **22**B branching off from the second electrode stem **22**S and extended in the vertical direction. The opposite end of the second electrode stem **22**S may be electrically connected to the second electrode stem **22**S of another sub-pixel PXn adjacent to the pixel in the horizontal direction. For example, the second electrode stem **22**S may be extended in the horizontal direction to cross different sub-pixels PXn, unlike the first electrode stem **21**S. The second electrode stem **22**S may be extended across the sub-pixels PXn and electrically connected to a portion extending in a direction at an outer portion of the display area DA in which the pixels PX or the sub-pixels PXn are disposed, or in the non-display area NDA.

[0144] The second electrode branch **22**B may be spaced apart from and face the first electrode branch **21**B (e.g., face a side of the first electrode branch **21**B). The second electrode branch **22**B may be terminated while being spaced apart from the first electrode stem **21**S. The second electrode branch **22**B may be electrically connected to the second electrode stem **22**S, and an end of the second electrode branch **22**B may be spaced apart from the first electrode stem **21**S in the sub-pixel PXn.

[0145] The first electrode **21** and the second electrode **22** may be electrically connected to a circuit element layer of the display device **10** through contact holes. For example, the first electrode **21** and the second electrode **22** may be electrically connected to the circuit element layer of the display device **10** through a first electrode contact hole CNTD and a second electrode contact hole CNTS, respectively. In the drawing, the first electrode contact hole CNTD may be formed in every first electrode stem **21**S of each of the sub-pixels PXn, and the second electrode contact hole CNTS may be formed only in the single second electrode stem **22**S that crosses the sub-pixels PXn. However, the disclosure is not limited thereto. In some implementations, the second contact hole CT**2** may be formed in each of the sub-pixels PXn.

[0146] The outer bank **43** may be disposed at the boundary between the sub-pixels PXn, and the inner banks **41** and **42** may be disposed adjacent to the center of each of the sub-pixels PXn and under the electrodes **21** and **22**. Although the inner banks **41** and **42** (e.g., refer to FIG. **17**) are not shown in FIG. **15**, the first inner bank **41** and the second inner bank **42** may be disposed under the first electrode branch **21**B and the second electrode branch **22**B, respectively.

[0147] The outer bank **43** may be disposed at the boundary between the sub-pixels PXn (e.g., adjacent ones of the sub-pixels PXn). The ends of the first electrode stems **21**S may be terminated at the external bank **43**, and the ends of the first electrode stems **21**S may be spaced apart from one another. For example, the ends of the first electrode stems **21**S may be spaced apart from the external bank **43**. The outer bank **43** may be extended in the vertical direction and may be disposed at the boundaries of the sub-pixels PXn arranged in the horizontal direction. However, the disclosure is not limited thereto. The outer bank **43** may be extended in the horizontal direction and may be disposed at the boundaries of the sub-pixels PXn arranged in the vertical direction as well. The outer bank **43** and the inner banks **41** and **42** may include a same material, and may be formed together via a single process.

[0148] The light-emitting element **30** may be disposed between the first electrode **21** and the second electrode **22**. An end of the light-emitting element **30** may be electrically connected to the first electrode **21**, and another end thereof may be electrically connected to the second electrode **22**. The light-emitting elements **30** may be electrically connected to the first electrode **21** and the second electrode **22** through contact electrodes **26**. Detailed description of the contact electrodes **26** is provided below.

[0149] The light-emitting elements **30** may be spaced apart from one another and may be substantially parallel to one another. A spacing (or a distance) between the light-emitting elements **30** is not limited thereto. In some implementations, some of the light-emitting elements **30** may be disposed close to each other to form a group, and some other of the light-emitting elements **30** may disposed close to each other to form another group that is spaced apart from the group. In other embodiments, the light-emitting elements **30** may be arranged such that they are orientated in a direction with irregular densities. In the embodiment, the light-emitting elements **30** may have a shape extended in a direction. The direction in which the electrodes (e.g., the first electrode branch **21**B and the second electrode branch **22**B) are extended may be substantially perpendicular to the direction in which the light-emitting elements **30** are extended. However, the disclosure is not limited thereto. The light-emitting elements **30** may be oriented obliquely to the direction in which the first electrode branch **21**B and the second electrode branch **22**B are extended, rather than being perpendicular to it.

[0150] The light-emitting element **30** may be a light-emitting diode. For example, the light-emitting element **30** may have a size in micrometers or nanometers and may be an inorganic light-emitting diode made of an inorganic material. The electric field IEL (e.g., refer to FIG. **12**) may be formed in the direction between the two electrodes (e.g., the first electrode **21** and the second electrode **22**), and polarities may be created therebetween. Thus, inorganic light-emitting diodes may be aligned between the two electrodes facing each other. The light-emitting elements **30** may be aligned between two electrodes by an electric field formed over the two electrodes.

[0151] The light-emitting element **30** according to an embodiment may have a shape extended in a direction. The light-emitting element **30** may have a shape of a rod, wire, tube, etc. In an embodiment, the light-emitting element **30** may have a cylindrical or rod-like shape. The shape of the light-emitting element **30** is not limited thereto. The light-emitting element **30** may have various shapes including a polygonal column shape such as a cube, a cuboid, a hexagonal column, etc. In other embodiments, the light-emitting element **30** may have a shape that is extended in a direction with partially inclined outer surfaces. The semiconductors included in the light-emitting element **30** may have a structure sequentially arranged or stacked each other along the direction. Detailed description of the semiconductors included in the light-emitting element **30** is provided below.

[0152] The light-emitting element **30** may include a semiconductor layer doped with impurities of a conductive type (e.g., p-type or n-type). An electric signal applied from an external source may be transmitted, and the semiconductor layers may emit light of a wavelength band (e.g., a certain or selectable wavelength band).

[0153] In some embodiments, the light-emitting element **30** according to an embodiment may have a shape extended in a direction. The light-emitting element **30** may have a shape such as nanorods, nanowires and nanotubes. In an embodiment, the light-emitting element **30** may have a cylindrical or rod-like shape. However, the shape of the light-emitting element **30** is not limited thereto and may have various shapes such as a cube, a cuboid and a hexagonal column.

[0154] As shown in FIG. **16**, the light-emitting element **30** may include a first semiconductor layer **31**, a second semiconductor layer **32**, an active layer **36**, an electrode layer **37**, and an insulating film **38**.

[0155] The first semiconductor layer **31** may be an n-type semiconductor. For example, when the light-emitting element **30** emits light of a blue wavelength band, the first semiconductor layer **31** may include a semiconductor material having the following chemical formula: $Al_xGa_yIn_{1-x-y}N$ ($0 \le x \le 1, 0 \le y \le 1, 0 \le x+y \le 1$). For example, the semiconductor material of the first semiconductor layer **31** may be at least one of n-type doped AlGaInN, GaN, AlGaN, InGaN, AlN, and InN. The first semiconductor layer **31** may be doped with an n-type dopant, and the n-type dopant may be Si, Ge, Sn, etc. However, the disclosure is not limited thereto. According to an embodiment of the disclosure, the first semiconductor layer **31** may be n-GaN doped with n-type Si. A length of the first semiconductor layer **31** may be in a range of about 1.5 μm to about 5 μm. However, the disclosure is not limited thereto.

[0156] The second semiconductor layer **32** may be disposed on the active layer **36**. Detailed description of the active layer **36** is provided below. The second semiconductor layer **32** may be a p-type semiconductor. For example, when the light-emitting element **30** emits light of a blue or green wavelength band, the second semiconductor layer **32** may include a semiconductor material having the following chemical formula: $Al_xGa_yIn_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$). For example, the semiconductor material of the second semiconductor layer **32** may be at least one of p-type doped AlGaInN, GaN, AlGaN, InGaN, AlN, and InN. The second semiconductor layer **32** may be doped with a p-type dopant, and the p-type dopant may be at least one of Mg, Zn, Ca, Se, and Ba. However, the disclosure is not limited thereto. According to an embodiment of the disclosure, the second semiconductor layer **32** may be p-GaN doped with p-type Mg. A length of the second semiconductor layer **32** may be in a range of about 0.05 μm to about 0.10 μm. However, the disclosure is not limited thereto.

[0157] Although each of the first semiconductor layer **31** and the second semiconductor layer **32** is implemented as a signal layer in the drawings, the disclosure is not limited thereto. According to some embodiments of the disclosure, depending on the material of the active layer **36**, the first semiconductor layer **31** and the second semiconductor layer **32** may further include a larger number of layers (e.g., a clad layer, a tensile strain barrier reducing (TSBR) layer, or the like).

[0158] The active layer **36** may be disposed between the first semiconductor layer **31** and the second semiconductor layer **32**. The active layer **36** may include a material having a single or multiple quantum well structure. When the active layer **36** includes a material having the multiple quantum well structure, the structure of the active layer **36** may include quantum layers and well layers alternately stacked one another. Electron-hole pairs may be combined in the active layer **36** in response to an electrical signal applied through the first semiconductor layer **31** and the second semiconductor layer **32**, and the active layer **36** may emit light. For example, when the active layer **36** emits light of the blue wavelength band, the active layer **36** may include a material such as AlGaN and AlGaInN. For example, when the active layer **36** has a multi-quantum well structure in which quantum layers and well layers are alternately stacked one another, the quantum layers may include AlGaN or AlGaInN, and the well layers may include a material such as GaN and AlGaN. According to an embodiment of the disclosure, the active layer **36** may include AlGaInN as the quantum layer and AlInN as the well layer, and the active layer **36** may emit blue light having a center wavelength band in a range of about 450 nm to about 495 nm.

[0159] However, the disclosure is not limited thereto. The active layer **36** may have a structure in which a semiconductor material having a large band gap energy and a semiconductor material having a small band gap energy are alternately stacked on one another, and may include other Group III to Group V semiconductor materials depending on the wavelength range of the emitted light. Accordingly, the light emitted from the active layer **36** is not limited to the light of the blue wavelength band. The emissive layer **36** may emit light of red or green wavelength band in some implementations. A length of the active layer **36** may be in a range of about 0.05 μm to about 0.10 μm. However, the disclosure is not limited thereto.

[0160] The light emitted from the active layer **36** may exit not only through outer surfaces of the light-emitting element **30** in a longitudinal direction but also through side surfaces (e.g., both side surfaces) of the light-emitting element **30**. The direction in which the light emitted from the active layer **36** propagates is not limited to one direction, and the light may be emitted from the active layer **36** in various directions.

[0161] The electrode layer **37** may be an ohmic contact electrode. However, the disclosure is not limited thereto. The electrode layer **37** may be Schottky contact electrodes. The light-emitting element **30** may include at least one electrode layer **37**. Although the light-emitting element **30** includes the electrode layer **37** in the example shown in FIG. **28**, the disclosure is not limited thereto. In some implementations, the light-emitting element **30** may include a larger number of electrode layers **37**. In other embodiments, the electrode layer **37** may be omitted. The following description on the light-emitting element **30** may be equally applied even if the number of electrode layers **37** is different or the electrode layer **37** may further include other structures.

[0162] The electrode layer **37** may reduce a resistance (e.g., electrical resistance) between the light-emitting element **30** and the electrodes or the contact electrodes when the light-emitting element **30** is electrically connected to the electrodes (e.g., the first electrode **21** and the second electrode **22** of FIG. **15**) or the contact electrodes **26** (e.g., refer to FIG. **15**) in the display device **10** according to the embodiment of the disclosure. The electrode layer **37** may include a metal having electrical conductivity. For example, the electrode layer **37** may include at least one of aluminum (Al), titanium (Ti), indium (In), gold (Au), silver (Ag), indium tin oxide (ITO), indium zinc oxide (IZO), and indium tin-zinc oxide (ITZO). The electrode layer **37** may include a semiconductor material doped with n-type or p-type impurities. The electrode layer **37** may include a same material or may include different materials. However, the disclosure is not limited thereto.

[0163] The insulating film **38** may be adjacent to (e.g., surround) the outer surfaces of the semiconductor layers (e.g., the first semiconductor layer **31**, the second semiconductor layer **32**, and the active layer **36**) and electrode layers described above. According to an embodiment of the disclosure, the insulating film **38** may be adjacent to (e.g., surround) at least the outer surface of the active layer **36**, and may be extended in a direction in which the light-emitting element **30** is extended. The insulating film **38** may protect the above-described elements. For example, the insulating film **38** may be adjacent to (e.g., surround) the side surfaces of the elements (e.g., the semiconductor layers and the electrode layer), and the ends (e.g., both ends) of the light-emitting element **30** in the longitudinal direction may be exposed.

[0164] Although the insulating film **38** is extended in the longitudinal direction of the light-emitting element **30** to cover from the first semiconductor layer **31** to the side surface of the electrode layer **37** (e.g., to cover the side surfaces or the outer surfaces of the first semiconductor layer **31**, the active layer **36**, the second semiconductor layer **32**, and the electrode layer **37**) in the example shown in the drawing, the disclosure is not limited thereto. The insulating film **38** may cover only the outer surface of a part of the semiconductor layer, including the active layer **36**, or may cover only a part of the outer surface of the electrode layer **37** to partially expose the outer surface of the electrode layer **37**. A part of the upper surface of the insulating film **38** may be rounded which is adjacent to at least one end of the light-emitting element **30** in a cross-sectional view.

[0165] A thickness of the insulating film **38** may be in a range of about 10 nm to about 1.0 μm. For example, the thickness of the insulating film **38** may be about 40 nm. However, the disclosure is not limited thereto.

[0166] The insulating film **38** may include materials having an insulating property such as silicon oxide (SiOx), silicon nitride (SiNx), silicon oxynitride (SiOxNy), aluminum nitride (AlN), and aluminum oxide (Al_2O_3). Accordingly, it is possible to prevent an electrical short-circuit that may occur in case that the active layer **36** comes in contact with an electrode through which an electric signal is transmitted to the light-emitting element **30**. Since the insulating film **38** may protect the outer surface of the light-emitting element **30** including the active layer **36**, it is possible to prevent a decrease in luminous efficiency.

[0167] In some embodiments, the outer surface of the insulating film **38** may be subjected to a surface treatment. The light-emitting elements **30** may be dispersed in an ink **90** and the ink **90** may be sprayed onto the electrodes (e.g., the first electrode **21** and the second electrode **22**). Thus, the light-emitting elements **30** may be aligned on the electrodes during the process of fabricating the display device **10**. In doing so, a surface treatment may be applied to the insulating film **38** so that it becomes hydrophobic or hydrophilic in order to keep the light-emitting elements **30** dispersed in the ink **90** from being aggregated with one another.

[0168] A length h of the light-emitting element **30** may be in a range of about 1 μm to about 10 μm or from about 2 μm to about 6 μm. For example, the length h of the light-emitting element **30** may be in a range of about 3 μm to about 5 μm. A diameter of the light-emitting elements **30** may be in a range of about 30 nm to about 700 nm, and an aspect ratio of the light-emitting elements **30** may be in a range of about 1.2 to about 100. However, the disclosure is not limited thereto. The light-emitting elements **30** included in the display device **10** may have different diameters depending on compositional difference of the active layer **36**. For example, the diameter of the light-emitting elements **30** may be about 500 nm.

[0169] The light-emitting elements **30** according to an embodiment of the disclosure may include an active layer **36** including different materials to emit light of different wavelength bands to the outside. In the display device **10**, the light-emitting elements **30** of the first sub-pixel PX**1** may emit a first light having a central wavelength band of a first wavelength, the light-emitting elements **30** of the second sub-pixel PX**2** may emit a second light having a central wavelength band of a second wavelength, and the light-emitting elements **30** of the third sub-pixel PX**3** may emit a third light having a central wavelength band of a third wavelength. Accordingly, the first light may be output from the first sub-pixel PX**1**, the second light may be output from the second sub-pixel PX**2**, and the third light may be output from the third sub-pixel PX**3**. In some embodiments, the first light may be blue light having a central wavelength band in a range of about 450 nm to about 495 nm, the second light may be green light having a central wavelength band in a range of about 495 nm to about 570 nm, and the third light may be red light having a central wavelength band in a range of about 620 nm to about 750 nm. However, the disclosure is not limited thereto.

[0170] Although FIG. **17** shows only the cross-section of the first sub-pixel PX**1**, the description may be equally applied to other pixels PX or sub-pixels PXn. FIG. **17** shows the cross-section passing through a first end to a second end of a light-emitting element **30** disposed in a first sub-pixel PX**1**.

[0171] For example, although not shown in FIG. **17**, the display device **10** may further include a circuit element layer positioned under each of the electrodes **21** and **22**. The circuit element layer may include semiconductor layers and conductive patterns, and may include at least one transistor and a power supply line. Detailed description of the elements in the circuit element layer is provided below.

[0172] Referring to FIGS. **15** and **17**, the display device **10** may include a first insulating layer **51**, electrodes **21** and **22** disposed on the first insulating layer **51**, light-emitting elements **30**, etc. A circuit element layer (not shown) may be further disposed under the first insulating layer **51**. The first insulating layer **51** may include an organic insulating material to provide a flat surface.

[0173] Inner banks **41** and **42**, an outer bank **43**, electrodes **21** and **22**, and the light-emitting element **30** may be disposed on the first insulating layer **51**.

[0174] In the processes of fabricating the display device **10**, in case that the ink **90** in which the light-emitting elements **30** are dispersed is sprayed using the above-described inkjet printing apparatus **1** of FIG. **1**, the outer bank **43** may prevent the ink **90** from flowing over the boundaries of the sub-pixels PXn (e.g., the boundaries between adjacent ones of the sub-pixels PXn). The outer bank **43** may separate the different sub-pixels PXn from one another so that the ink **90** of the different sub-pixels PXn in which the light-emitting elements **30** are dispersed may not be mixed with each other. However, the disclosure is not limited thereto.

[0175] The inner banks **41** and **42** may include a first inner bank **41** and a second inner bank **42** disposed adjacent to the center of each of the sub-pixels PXn.

[0176] The first inner bank **41** and the second inner bank **42** may be spaced apart from each other. The first electrode **21** may be disposed on the first inner bank **41**, and the second electrode **22** may be disposed on the second inner bank **42**. Referring to FIGS. **15** and **17**, the first electrode branch **21**B may be disposed on the first inner bank **41** and the second electrode branch **22**B may be disposed on the second inner bank **42**.

[0177] The first inner bank **41** and the second inner bank **42** may be disposed in each of the sub-pixels PXn, and the first inner bank **41** and the second inner bank **42** may be extended in the vertical direction. However, the disclosure is not limited thereto. The first inner bank **41** and the second inner bank **42** may be disposed in each of the sub-pixels PXn and form a pattern on a front surface of the display device **1**. The inner banks **41** and **42** and the outer banks **43** may include polyimide (PI). However, the disclosure is not limited thereto.

[0178] The first inner bank **41** and the second inner bank **42** may have a structure that at least partially protrudes from the first insulating layer **51**. The first inner bank **41** and the second inner bank **42** may protrude upwardly from the plane on which the light-emitting elements **30** are disposed, and at least a part of the protruding portions of the first inner bank **41** and the second inner bank **42** may have an inclination. Since the inner banks **41** and **42** have inclined sides that protrude from the first insulating layer **51**, the light emitted from the light-emitting elements **30** may be reflected off the inclined sides of the inner banks **41** and **42**. As will be described below, if the electrodes **21** and **22** disposed on the inner banks **41** and **42**, respectively, may include a material having high reflectivity, and the light emitted from the light-emitting elements **30** may be reflected off the electrodes **21** and **22** so that the light may travel toward an upper side of the first insulating layer **51**.

[0179] The outer bank **43** may be disposed at the boundary of each of the sub-pixels PXn and form a grid pattern, and the inner banks **41** and **42** may be disposed within each of the sub-pixels PXn and extended in a direction.

[0180] The electrodes **21** and **22** may be disposed on the first insulating layer **51** and the inner banks **41** and **42**. As described above, the electrodes **21** and **22** may include electrode stems **21**S and **22**S and electrode branches **21**B and **22**B, respectively.

[0181] The first electrode **21** and the second electrode **22** may be partially disposed on the first insulating layer **51** and may be partially disposed on the first inner bank **41** and the second inner bank **42**. As described above, the first electrode stem **21**S of the first electrode **21** and the second electrode stem **22**S of the second electrode **22** may be extended in the horizontal direction. The first inner bank **41** and the second inner bank **42** may be extended in the vertical direction and may also be disposed in adjacent sub-pixels PXn in the vertical direction.

[0182] The first electrode contact hole CNTD may penetrate through the first insulating layer **51** and expose a part of the circuit element layer. The first electrode contact hole CNTD may be formed in the first electrode stem **21**S of the first electrode **21**. The first electrode **21** may be electrically connected to a transistor of the circuit element layer through the first electrode contact hole CNTD. An electric signal may be transmitted from the transistor to the first electrode **21**.

[0183] The second electrode stem **22**S of the second electrode **22** may be extended in a direction and may be disposed in the non-emission area in which the light-emitting elements **30** are not disposed. The second electrode contact hole CNTS may penetrate through the first insulating layer **51** and expose the part of the circuit element layer. The second electrode contact hole CNTS may be formed in the second electrode stem **22**S. The second electrode **22** may be electrically connected to a power electrode via the second electrode contact hole CNTS. An electric signal may be transmitted from the power electrode to the second electrode **22**.

[0184] Parts of the first electrode **21** and the second electrode **22** (e.g., the first electrode branch **21**B and the second electrode branch **22**B) may be disposed in the first inner bank **41** and the second inner bank **42**, respectively. The light-emitting elements **30** may be disposed in a region between the first electrode **21** and the second electrode **22**. For example, the light-emitting elements **30** may be disposed in a space in which the first electrode branch **21**B and the second electrode branch **22**B are spaced apart from and face each other.

[0185] Each of the electrodes **21** and **22** may include a transparent conductive material. For example, each of the electrode layers **21** and **22** may include a material such as indium tin oxide (ITO), indium zinc oxide (IZO), and indium tin zinc oxide (ITZO). However, the disclosure is not limited thereto. In some embodiments, each of the electrodes **21** and **22** may include a conductive material having a high reflectivity. For example, each of the electrodes **21** and **22** may include a metal such as silver (Ag), copper (Cu), and aluminum (Al) as the material having a high reflectivity. Light incident on each of the electrodes **21** and **22** may be reflected and exit toward an upper side of each of the sub-pixels PXn.

[0186] Each of the electrodes **21** and **22** may have a structure in which one or more layers of a transparent conductive material and a metal layer having high reflectivity are stacked each other. In other embodiments, each of the electrodes **21** and **22** may be made up of a single layer including at least one of the transparent conductive material and the metal. In an embodiment, each of the electrodes **21** and **22** may have a stack structure of ITO/silver (Ag)/ITO/IZO. In other embodiments, each of the electrodes **21** and **22** may be an alloy including at least one of aluminum (Al), nickel (Ni), and lanthanum (La). However, the disclosure is not limited thereto.

[0187] The second insulating layer **52** may be disposed on the first insulating layer **51**, the first electrode **21**, and the second electrode **22**. The second insulating layer **52** may be disposed to partially cover the first electrode **21** and the second electrode **22**. The second insulating layer **52** may cover the upper surface (e.g., most of the upper surface) of each of the first electrode **21** and the second electrode **22**. The second insulating layer **52** may expose a part of each of the first electrode **21** and the second electrode **22**. The second insulating layer **52** may be disposed to expose a part of the upper surfaces of the first electrode **21** and the second electrode **22**. For example, the second insulating layer **52** may expose a part of the upper surface of the first electrode branch **21**B disposed on the first inner bank **41** and the upper surface of the second electrode branch **22**B disposed on the inner bank **42**. For example, the second insulating layer **52** may be formed substantially entirely on the first insulating layer **51**, and may include an opening partially exposing the first electrode **21** and the second electrode **22**.

[0188] In an embodiment, the second insulating layer **52** may have a step (e.g., a step difference, thickness difference, or height difference) so that a part of the upper surface of the second insulating layer **52** is recessed between the first electrode **21** and the second electrode **22**. In some embodiments, the second insulating layer **52** may include an inorganic insulating material, and a part of the upper surface of the second insulating layer **52** disposed to cover the first electrode **21** and the second electrode **22** may be recessed due to the step of the elements disposed under the second insulating layer **52**. The light-emitting elements **30** may be disposed on the second insulating layer **52** between the first electrode **21** and the second electrode **22** and form an empty space with the recessed upper surface of the second insulating layer **52**. The light-emitting elements **30** may be partially spaced apart from the upper surface of the second insulating layer **52**, and the space may be filled with a material of the third insulating layer **53**. Detailed description of the third insulating layer **53** is provided below. However, the disclosure is not limited thereto. The second insulating layer **52** may form a flat upper surface, and the light-emitting element **30** may be disposed on the second insulating layer **53**.

[0189] The second insulating layer **52** may protect the first electrode **21** and the second electrode **22** and electrically insulate from one other. The second insulating layer **52** may prevent the light-emitting element **30** disposed thereon from being brought into contact with other elements and damaged. However, the shape and structure of the second insulating layer **52** are not limited thereto.

[0190] The light-emitting elements **30** may be disposed on the second insulating layer **52** between the electrodes **21** and **22**. For example, at least one light-emitting element **30** may be disposed on the second insulating layer **52** disposed between the electrode branches **21**B and **22**B. However, the disclosure is not limited thereto. Although not shown in the drawings, at least some of the light-emitting elements **30** may be disposed in each of the sub-pixels PXn. For example, the at least some of the light-emitting elements **30** may be disposed in other regions out of a region between the electrode branches **21**B and **22**B. The light-emitting elements **30** may be disposed on ends of the first electrode branch **21**B and the second electrode branch **22**B facing each other. The light-emitting elements **30** may be electrically connected to the electrodes **21** and **22** through the contact electrodes **26**.

[0191] In each of the light-emitting elements **30**, multiple layers may be disposed in a direction parallel to the first insulating layer **51**. A light-emitting element **30** of the display device **10** according to an embodiment may have a shape extended in a direction and may have a structure in which multiple semiconductor layers are sequentially disposed in the direction. As described above, in the light-emitting element **30**, the first semiconductor layer **31**, the active layer **36**, the second semiconductor layer **32**, and the electrode layer **37** may be sequentially disposed in the direction, and the outer surfaces thereof may be surrounded by the insulating film **38**. The light-emitting elements **30** of the display device **10** may be arranged such that they are extended in parallel to the first insulating layer **51**. The semiconductor layers included in the light-emitting elements **30** may be disposed sequentially in the direction parallel to the upper surface of the first insulating layer **51**. However, the disclosure is not limited thereto. In some embodiments, in case that the light-emitting elements **30** have a different structure, layers of the light-emitting elements **30** may be disposed in the direction perpendicular to the first insulating layer **51**.

[0192] The end of each of the light-emitting elements **30** may be in contact with a first contact electrode **26***a*, and the another end thereof may be in contact with a second contact electrode **26***b*. According to an embodiment of the disclosure, no insulating film is formed on an end surface of the light-emitting element **30** on a side in the extension direction, and the end surface of the light-emitting element **30** may be exposed. Thus, the exposed end surface of the light-emitting element **30** may be in contact with the first contact electrode **26***a* and the second contact electrode **26***b*. Detailed description of the first contact electrode **26***a* and the second contact electrode **26***b* is provided below. However, the disclosure is not limited thereto. In some implementations, the insulating film **38** of the light-emitting element **30** may be removed at least partially, and the end surfaces (e.g., both end surfaces) of the light-emitting element **30** may be partially exposed.

[0193] The third insulating layer **53** may be partially disposed on the light-emitting elements **30** disposed between the first electrode **21** and the second electrode **22**. The third insulating layer **53** may be disposed to partially surround the outer surface of the light-emitting elements **30**. The third insulating layer **53** may protect the light-emitting elements **30** and fix the light-emitting elements **30** during the process of fabricating the display device **10**. According to an embodiment of the disclosure, a part of the material of the third insulating layer **53** may be disposed between a lower surface of the light-emitting element **30** and the second insulating layer **52**. As described above, the third insulating layer **53** may be formed to fill the space between the second insulating layer **52** and the light-emitting elements **30** formed during the process of fabricating the display device **10**. Accordingly, the third insulating layer **53** may be formed to surround the outer surface of the light-emitting element **30**. However, the disclosure is not limited thereto.

[0194] The third insulating layer **53** may be extended in the vertical direction between the first electrode branch **21**B and the second electrode branch **22**B in a plan view. For example, the third insulating layer **53** may have an island shape or a linear shape on the first insulating layer **51** in a plan view. According to an embodiment of the disclosure, the third insulating layer **53** may be disposed on the light-emitting elements **30**.

[0195] The first contact electrode **26***a* and the second contact electrode **26***b* may be disposed on the electrodes **21** and **22**, respectively, and the third insulating layer **53**. For example, the first contact electrode **26***a* may be disposed on the first electrode **21** and the third insulating layer **53**, and the second contact electrode **26***b* may be disposed on the second electrode **22** and the third insulating layer **53**. The first contact electrode **26***a* and the second contact electrode **26***b* may be disposed on the third insulating layer **53**, and the first contact electrode **26***a* and the second contact electrode **26***b* may be spaced apart from each other. The third insulating layer **53** may electrically insulate the first contact electrode **26***a* from the second contact electrode **26***b*, and the first contact electrode **26***a* and the second contact electrode **26***b* may not be in direct contact with each other.

[0196] The first contact electrode **26***a* may be in contact with an exposed partial region of the first electrode **21** on the first inner bank **41**, and the second contact electrode **26***b* may be in contact with an exposed partial region of the second electrode **22** on the second inner bank **42**. The first contact electrode **26***a* and the second contact electrode **26***b* may transmit electrical signals transmitted from the respective electrodes **21** and **22** to the light-emitting elements **30**.

[0197] The contact electrodes **26** may include a conductive material. For example, the connection electrodes CNE may include ITO, IZO, ITZO, aluminum (Al), etc. However, the disclosure is not limited thereto.

[0198] A passivation layer **55** may be disposed on the contact electrode **26** and the third insulating layer **53**. The passivation layer **55** may protect the elements (e.g., the light-emitting elements **30**) disposed on the first insulating layer **51** from external environments.

[0199] Each of the second insulating layer **52**, the third insulating layer **53**, and the passivation layer **55** may include an inorganic insulating material or an organic insulating material. According to an embodiment of the disclosure, the second insulating layer **52**, the third insulating layer **53**, and the passivation layer **55** may include an inorganic insulating material such as silicon oxide (SiOx), silicon nitride (SiNx), silicon oxynitride (SiOxNy), aluminum oxide (Al_2O_3), and aluminum nitride (AlN). The second insulating layer **52**, the third insulating layer **53**, and the passivation layer **55** may include, as an organic insulating material, an acrylic resin, an epoxy resin, a phenol resin, a polyamide resin, a polyimide resin, an unsaturated polyester resin, a polyphenylene resin, a polyphenylene sulfide resin, benzocyclobutene, a cardo resin, a siloxane resin, a silsesquioxane resin, polymethyl methacrylate, polycarbonate, a polymethyl methacrylate-polycarbonate synthetic resin, etc. However, the disclosure is not limited thereto.

[0200] Referring to FIGS. **18** to **20**, the display device **10** according to an embodiment may be fabricated using the inkjet printing apparatus **1** described above with reference to FIG. **1**. The inkjet printing apparatus **1** may eject the ink **90** in which the light-emitting elements **30** are dispersed, and the light-emitting elements **30** may be disposed between the first electrode **21** and the second electrode **22** of the display device **10**.

[0201] Initially, as shown in FIG. **18**, a first insulating layer **51**, a first inner bank **41** and a second inner bank **42** spaced apart from each other on the first insulating layer **51**, a first electrode **21** and a second electrode **22** disposed on the inner bank **41** and the second inner bank **42**, respectively, and a second insulating material layer **52'** covering the first electrode **21** and the second electrode **22** are prepared. The second insulating material layer **52'** may be partially patterned in a subsequent process to form the second insulating layer **52** of the display device **10**. The above elements may be formed by patterning a metal, an inorganic material, an organic material, etc. via mask processes.

[0202] The ink **90** in which the light-emitting elements **30** are dispersed may be sprayed onto the first electrode **21** and the second electrode **22**. The light-emitting elements **30** may be a kind of the bipolar elements **95**. The injection of the ink **90** in which the light-emitting elements **30** are dispersed may be carried out by using the above-described inkjet printing apparatus **1** and a method of printing the bipolar elements **95**. As shown in the drawing, the inkjet printing apparatus **1** according to the embodiment may discharge the ink **90** in which a uniform number of light-emitting elements

30 are dispersed. Description of the discharging of the ink **90** has been described above; and, therefore, the repetitive descriptions will be omitted.

[0203] Subsequently, as shown in FIG. **19**, an electric signal may be applied to the first electrode **21** and the second electrode **22** and generate an electric field IEL in the ink **90** in which the light-emitting elements **30** are dispersed. The light-emitting elements **30** may be seated between the first electrode **21** and the second electrode **22** as the dielectrophoretic force is transmitted by the electric field IEL and the orientations and positions are changed.

[0204] Subsequently, as shown in FIG. **20**, the solvent **91** of the ink **90** may be removed. The light-emitting elements **30** may be disposed between the first electrode **21** and the second electrode **22** via the above-described processes. Subsequently, although not shown in the drawings, the second insulating material layer **52'** may be patterned to form the second insulating layer **52**, and a third insulating layer **53**, a first contact electrode **26*a*** and a second contact electrode **26*b***, and a passivation layer **55** (e.g., refer to FIG. **17**) may be formed, so that a display device can be fabricated.

[0205] The shape and material of the light-emitting elements **30** are not limited to those described with reference to FIG. **16**. In some embodiments, the light-emitting elements **30** may include a greater number of layers or may have different shapes.

[0206] Hereinafter, a modification of the inkjet printing apparatus **1** according to the embodiment is described below. In the following description, the same or similar elements will be denoted by the same or similar reference numerals, and repetitive descriptions will be omitted or briefly described.

[0207] FIG. **21** is a view schematically showing a structure of an inside of an inkjet head part of an inkjet printing apparatus according to another embodiment. FIG. **22** is a schematic enlarged view of area C of FIG. **21**.

[0208] In the example shown in FIGS. **21** and **22**, in an inkjet printing apparatus **1_1** according to this embodiment, an entrance of an inlet **351_1** of each of injection holes **350_1** may have a shape with multiple angles. For example, according to this embodiment, the inlet **351_1** may have multiple inclined surfaces **351_1*b*** and **351_1*c***.

[0209] According to this embodiment, the inlet **351_1** may include a flat surface **351_1*a*** as a surface in the third direction DR**3**, and a first inclined surface **351_1*b*** and a second inclined surface **351_1*c*** as surfaces surrounding an entrance area ENA_**1**. The second inclined surface **351_*c*** may be more inclined toward the entrance area ENA_**1** than the first inclined surface **351_*b***. The flat surface **351_1*a*** of the inlet **351_1** according to the embodiment is substantially identical to the flat surface **351*a*** of the inlet **351** of the inkjet printing apparatus **1** according to the above-described embodiment; and, therefore, the repetitive descriptions will be omitted.

[0210] The flat surface **351_1*a*** may intersect the second inclined surface **351_1*c*** at a second angle θ2 that is an acute angle. The first inclined surface **351_1*b*** and the second inclined surface **351_1*c*** may intersect each other. The first inclined surface **351_1*b*** and the second inclined surface **351_1*c*** may be inclined at different angles. For example, an end of the second inclined surface **351_1*c*** may be in contact with the flat surface **351_1*a***, and another end of the second inclined surface **351_1*c*** may be in contact with the first inclined surface **351_1*b***. The first inclined surface **351_1*b*** may form an acute angle with the direction parallel to the flat surface **351_1*a***. For example, the first inclined surface **351_1*b*** may form an acute angle with an imaginary surface parallel to the first direction DR**1**.

[0211] As the second inclined surface **351_1*c*** is inclined at the second angle θ2 that is an acute angle with respect to the flat surface **351_1*a***, and the first inclined surface **351_1*b*** is in contact with the opposite end of the second inclined surface **351_1*c***, i.e., it is inclined at an acute angle with an imaginary surface parallel to the first direction DR**1**, the first inclined surface **351_1*b*** and the second inclined surface **351_1*c*** may not be exposed from the entrance area ENA_**1** when the entrance area ENA_**1** is viewed in the third direction DR**3**. For example, an area of an end of the entrance area ENA_**1** in the third direction DR**3** may be smaller than an area of an opposite end of the entrance area ENA in the third direction DR**3**. Accordingly, in case that the bipolar elements **95** are introduced into the entrance area ENA_**1**, the bipolar elements **95** may not be accumulated on the inlet **351_1**, so that the lifetime of the nozzle parts **300** may be improved.

[0212] Since the first inclined surface **351_1*b*** and the second inclined surface **351_1*c*** are inclined at different angles, the width W**1_1** of the entrance area ENA_**1** may increase toward the opposite side in the third direction DR**3**, and a rate of change of the width W**1_1** of the entrance area ENA_**1** in the third direction DR**3** may vary from a point where the first inclined surface **351_1*b*** and the second inclined surface **351_1*c*** come into contact with each other. This is due to the process of forming the inlet **351_1** in which the entrance area ENA_**1** is defined. For example, the inlet **351_1** in which the entrance area ENA_**1** is not formed may be processed and form the entrance area ENA_**1**. The process of processing the inlet **351_1** to form the entrance area ENA_**1** may be carried out, for example, by dry etching or wet etching.

[0213] For example, the process of processing the inlet **351_1** to form the entrance area ENA_**1** may include forming the first inclined surface **351_1*b*** (e.g., primary processing) and forming the second inclined surface **351_1*c*** (e.g., secondary processing). When the second inclined surface **351_1*c*** is formed after the first inclined surface **351_1*b*** is formed, the thickness of the inlet **351_1** to be processed to form the second inclined surface **351_1*c*** may be reduced. Thus, the entrance area ENA_**1** may be readily formed.

[0214] The above description is an example of technical features of the disclosure, and those skilled in the art to which the disclosure pertains will be able to make various modifications and variations. Thus, the embodiments of the disclosure described above may be implemented separately or in combination with each other.

[0215] Therefore, the embodiments disclosed in the disclosure are not intended to limit the technical spirit of the disclosure, but to describe the technical spirit of the disclosure, and the scope of the technical spirit of the disclosure is not limited by these embodiments. The protection scope of the disclosure should be interpreted by the following claims, and it should be interpreted that all technical spirits within the equivalent scope are included in the scope of the disclosure.

What is claimed is:

1. An inkjet printing apparatus comprising:

a stage on which a substrate is seated;

a nozzle part disposed above the stage and spraying an ink onto the substrate, the ink containing a solvent and solid substances; and

a head part that supplies the ink to the nozzle part, wherein

the nozzle part includes:

an internal flow path extended in a first direction, through which the ink is supplied from the head part; and

an inlet in which an entrance area is defined,

the ink is introduced in a second direction intersecting the first direction from the internal flow path through the entrance area,

the inlet includes:

an inclined surface adjacent to the entrance area and defining the entrance area; and

a flat surface parallel to the first direction, and

an angle between the inclined surface and the flat surface is an acute angle.

2. The apparatus of claim 1, wherein the nozzle part further comprises:

a pressure part disposed adjacent to the inlet in the second direction and defining a pressure area that supplies a pressure to the ink introduced from the entrance area.

3. The apparatus of claim 2, wherein the pressure part comprises a piezoelectric element.

4. The apparatus of claim 3, further comprising:

an outlet adjacent to the pressure part in the second direction to define an exit area,

wherein the ink is discharged from the exit area by the pressure applied in the pressure area.

5. The apparatus of claim 4, wherein a width of the entrance area increases in the second direction.

6. The apparatus of claim 5, wherein

the entrance area comprises:

an end adjacent to the internal flow path; and

an opposite end adjacent to the pressure area, and

an area of the end of the entrance area is smaller than an area of the opposite end of the entrance area.

7. The apparatus of claim 6, wherein the ink sequentially passes through the internal flow path, the entrance area, the pressure area, and the exit area.

8. The apparatus of claim 1, wherein the nozzle part further comprises a base in which the internal flow path and the inlet are located.

9. The apparatus of claim 8, wherein the internal flow path penetrates through the base.

10. The apparatus of claim 9, wherein an edge of the internal flow path is defined by the base and the flat surface of the inlet.

11. The apparatus of claim 1, wherein the inclined surface comprises:

a first inclined surface having:

an end in contact with the flat surface; and

an opposite end; and

a second inclined surface in contact with the opposite end of the first inclined surface.

12. The apparatus of claim 11, wherein the first inclined surface is more inclined toward the entrance area than the second inclined surface.

13. An inkjet printing apparatus comprising:

a stage on which a substrate is seated;

a nozzle part disposed above the stage and spraying an ink onto the substrate, the ink containing a solvent and solid substances; and

a head part that supplies the ink to the nozzle part, wherein

the nozzle part includes:

an internal flow path extended in a first direction, through which the ink is supplied from the head part; and

an entrance area,

the ink is introduced in a second direction intersecting the first direction from the internal flow path through the entrance area, and

a width of the entrance area increases in the second direction.

14. The apparatus of claim 13, wherein the nozzle part further comprises:

a pressure area disposed adjacent to the entrance area in the second direction and applying pressure to the ink introduced from the entrance area.

15. The apparatus of claim 14, wherein

the nozzle part further comprises an exit area disposed adjacent to the pressure area in the second direction, and

the ink is discharged from the exit area by the pressure applied in the pressure area.

16. The apparatus of claim 15, wherein

the entrance area comprises:

an end adjacent to the internal flow path; and

an opposite end adjacent to the pressure area, and

an area of the end of the entrance area is smaller than an area of the opposite end of the entrance area.

17. The apparatus of claim 16, wherein the ink sequentially passes through the internal flow path, the entrance area, the pressure area, and the exit area.

18. The apparatus of claim 14, wherein

the nozzle part further comprises an inlet adjacent to the entrance area,

the inlet includes:

an inclined surface defining the entrance area; and

a flat surface parallel to the first direction, and

an angle between the inclined surface and the flat surface of the inlet is an acute angle.

19. The apparatus of claim 18, wherein the inclined surface comprises:

a first inclined surface having an end in contact with the flat surface; and

a second inclined surface in contact with an opposite end of the first inclined surface.

20. The apparatus of claim 18, wherein

the nozzle part further comprises a pressure part adjacent to the pressure area, and

the pressure part comprises a piezoelectric element.

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