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(54) **TRANSFER METHOD OF EXPANDING PITCHES OF DEVICE AND AN APPARATUS FOR PERFORMING THE SAME**

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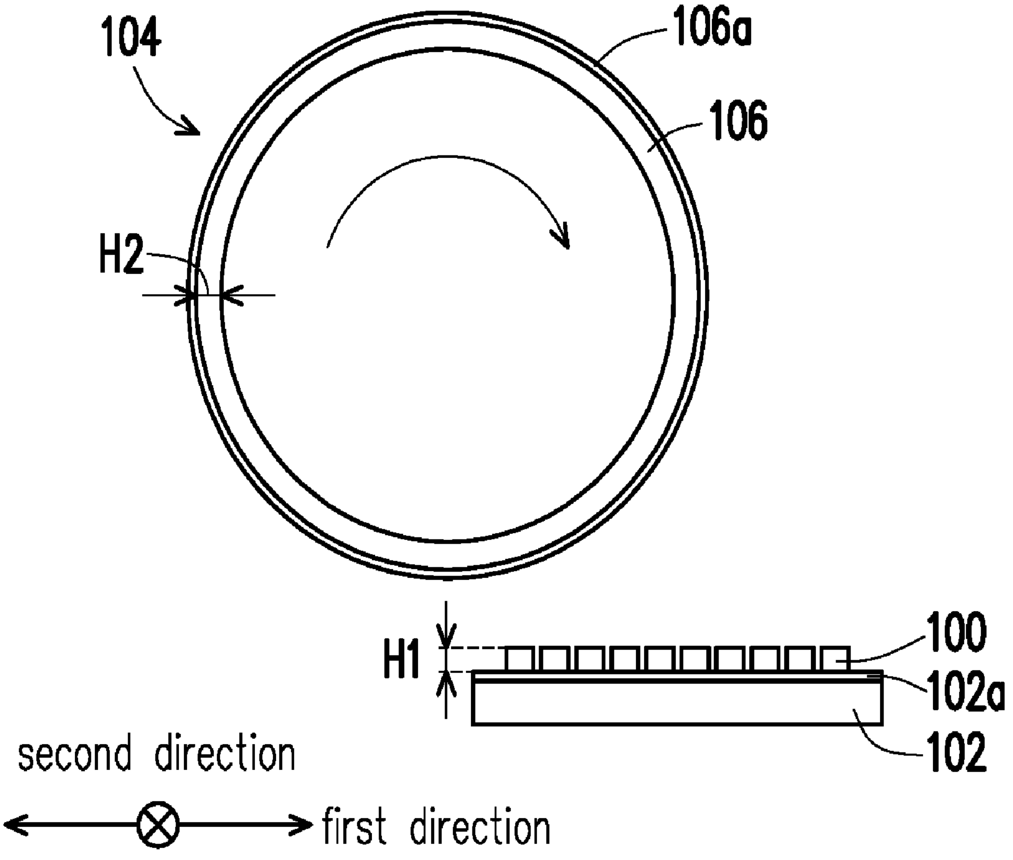
(57) **ABSTRACT**

A transfer method for expanding pitches of devices includes: providing a first substrate with micro devices having the pitches being a predetermined value in a first direction and a second direction; transferring the micro devices to a first roller by contacting it with the micro devices, wherein a pitch of contact line portions on the first roller is N times of the predetermined value; transferring the micro devices on the first roller to a second substrate; rotating the second substrate by 90 degrees; transferring the micro devices to a second roller by rolling the second roller to contact the micro devices; and then transferring the micro devices to a third substrate to expand the pitch of the micro devices in both the first and the second directions. The portions in contact with the micro devices all have adhesive layers with different adhesion operation windows.



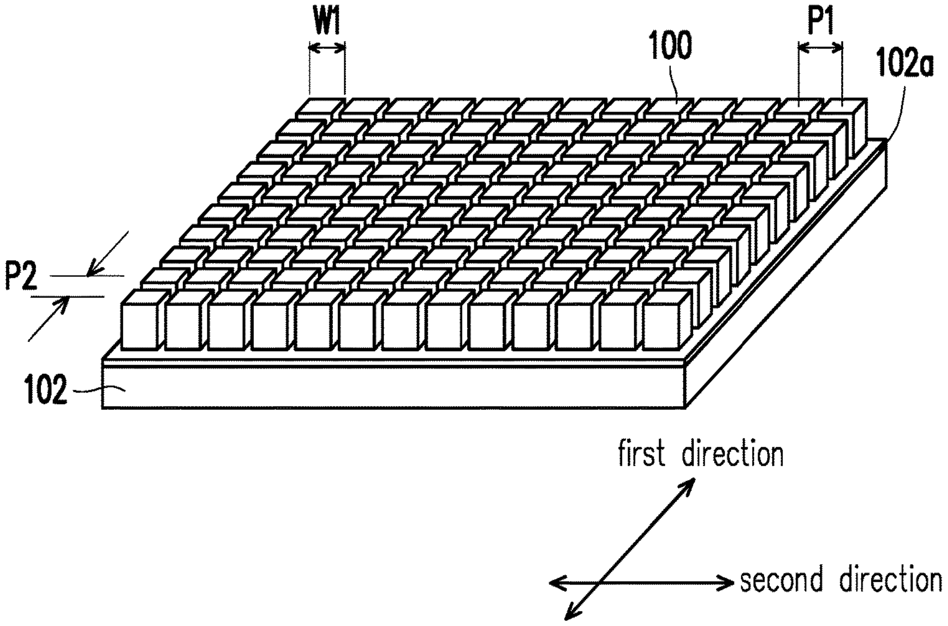

W1
100
P1
102a
P2
102
first direction
second direction

FIG. 1A

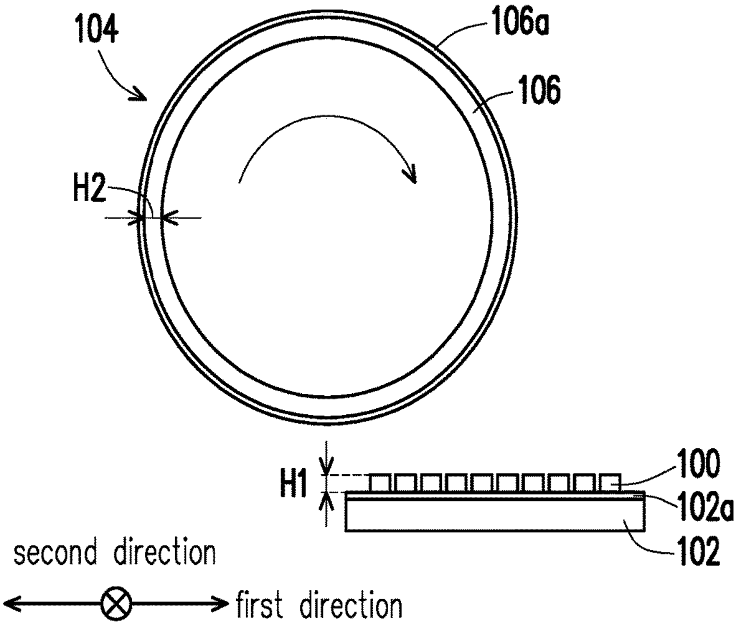

104
106a
106
H2
H1
100
102a
102
second direction
first direction

FIG. 1B

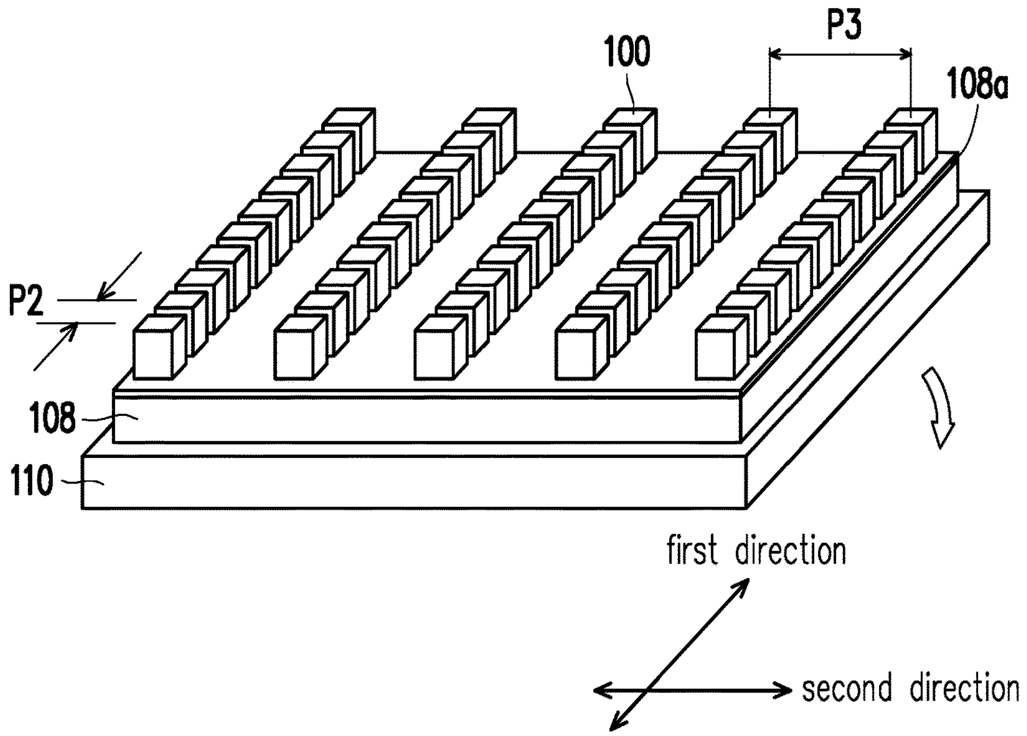

P3
100
108a
P2
108
110
first direction
second direction

FIG. 1C

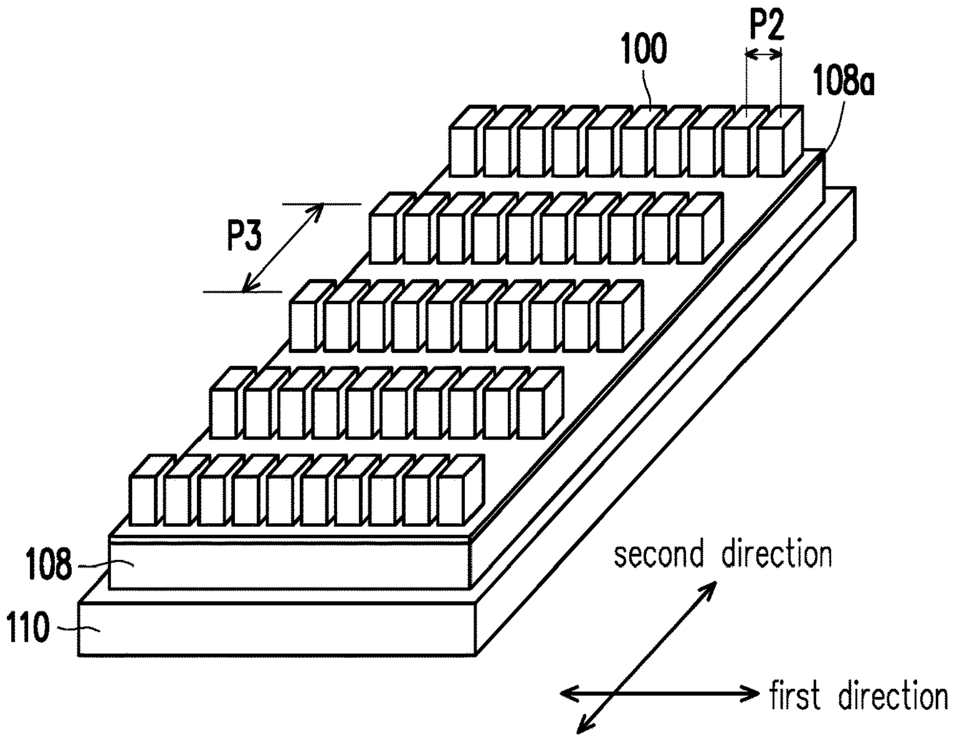

100
P2
108a
P3
108
110
second direction
first direction

FIG. 1D

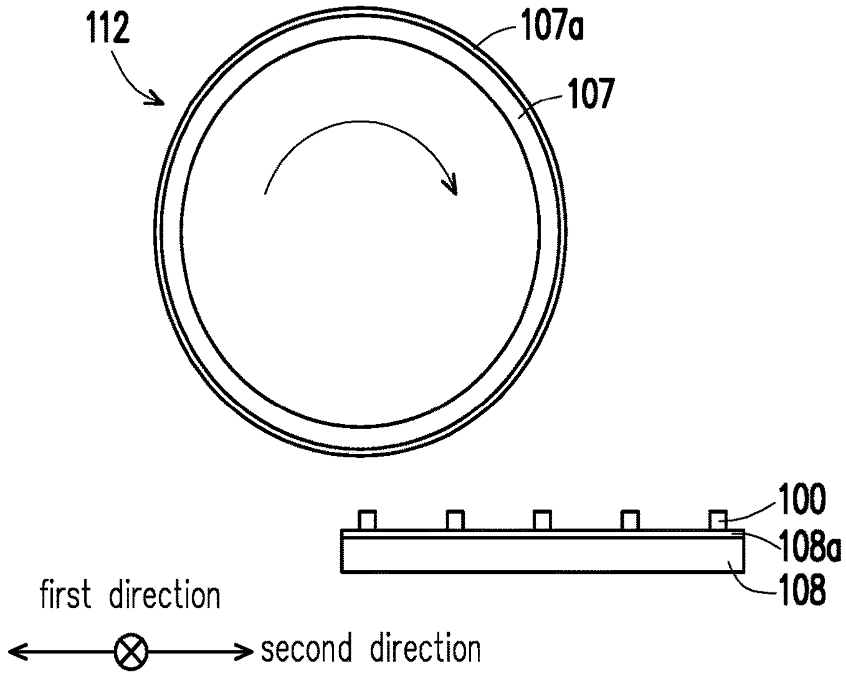

112
107a
107
100
108a
108
first direction
second direction

FIG. 1E

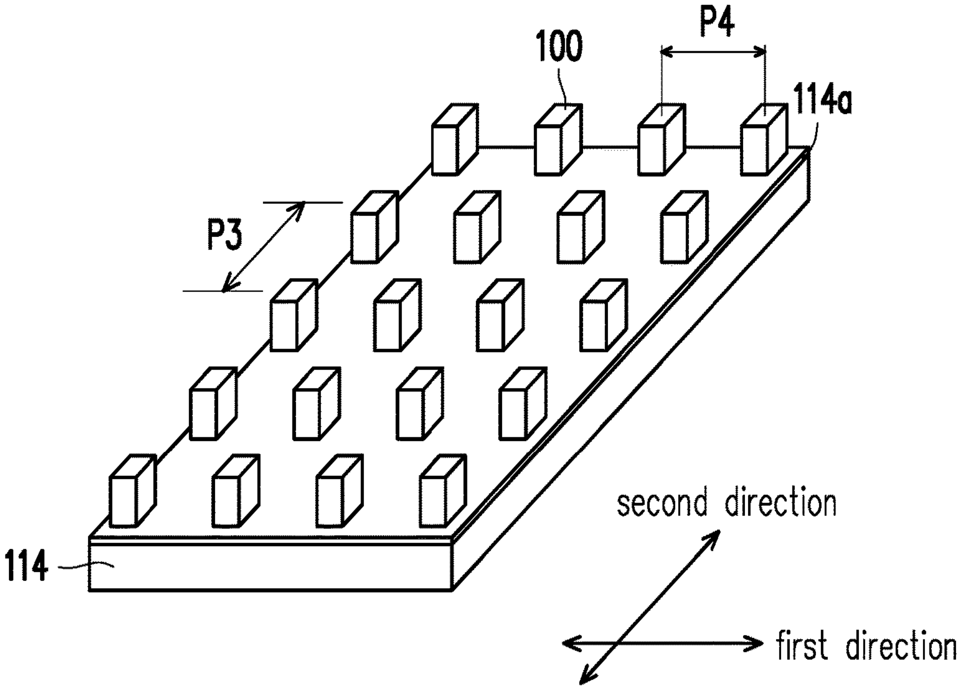

P4
100
114a
P3
114
second direction
first direction

FIG. 1F

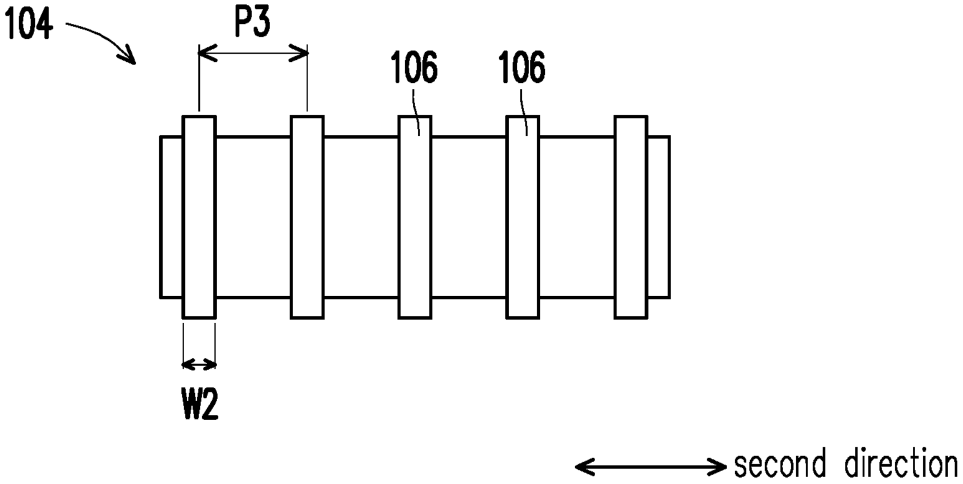

104
P3
106
106
W2
second direction

FIG. 2A

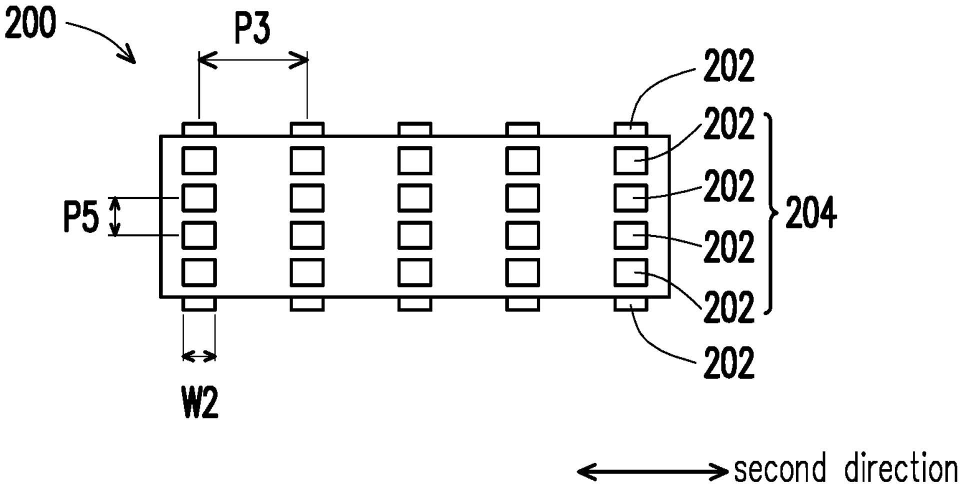

200
P3
202
202
202
202
202
202
204
P5
W2
second direction

FIG. 2B

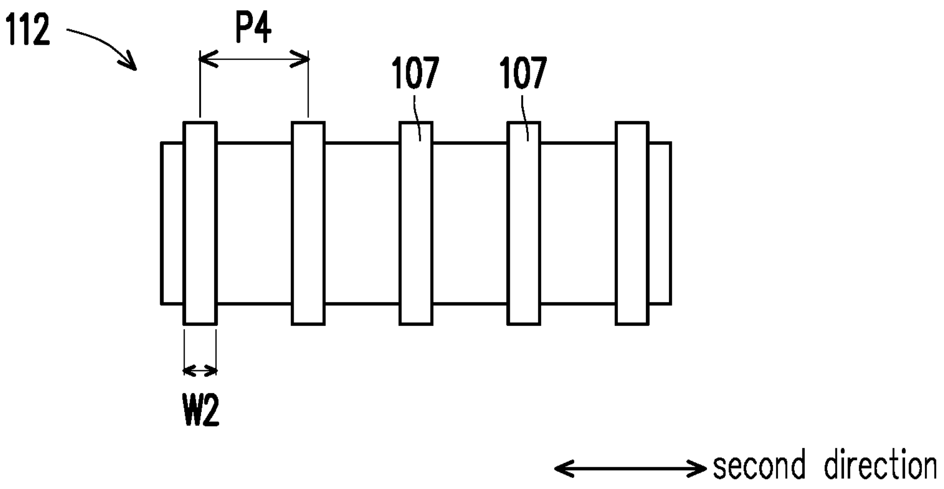


FIG. 2C

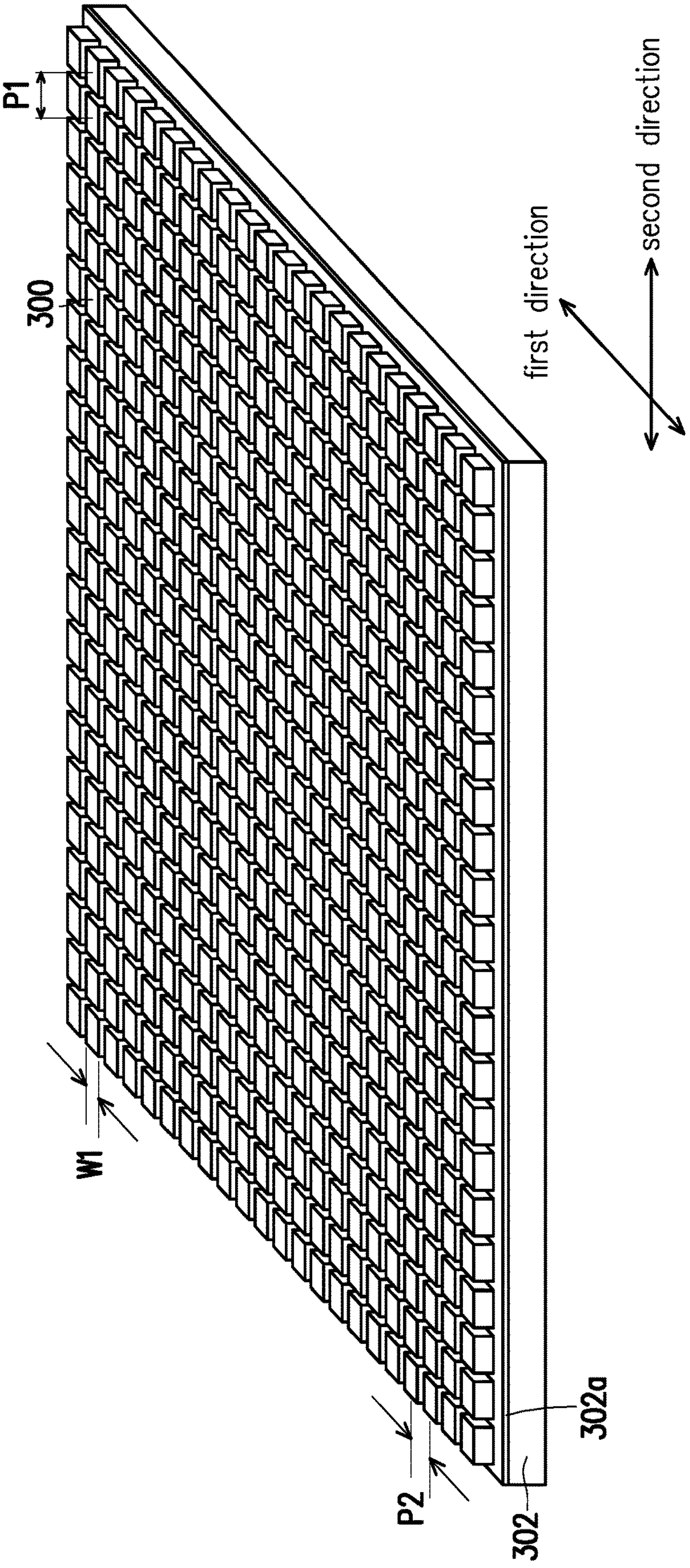


FIG. 3A

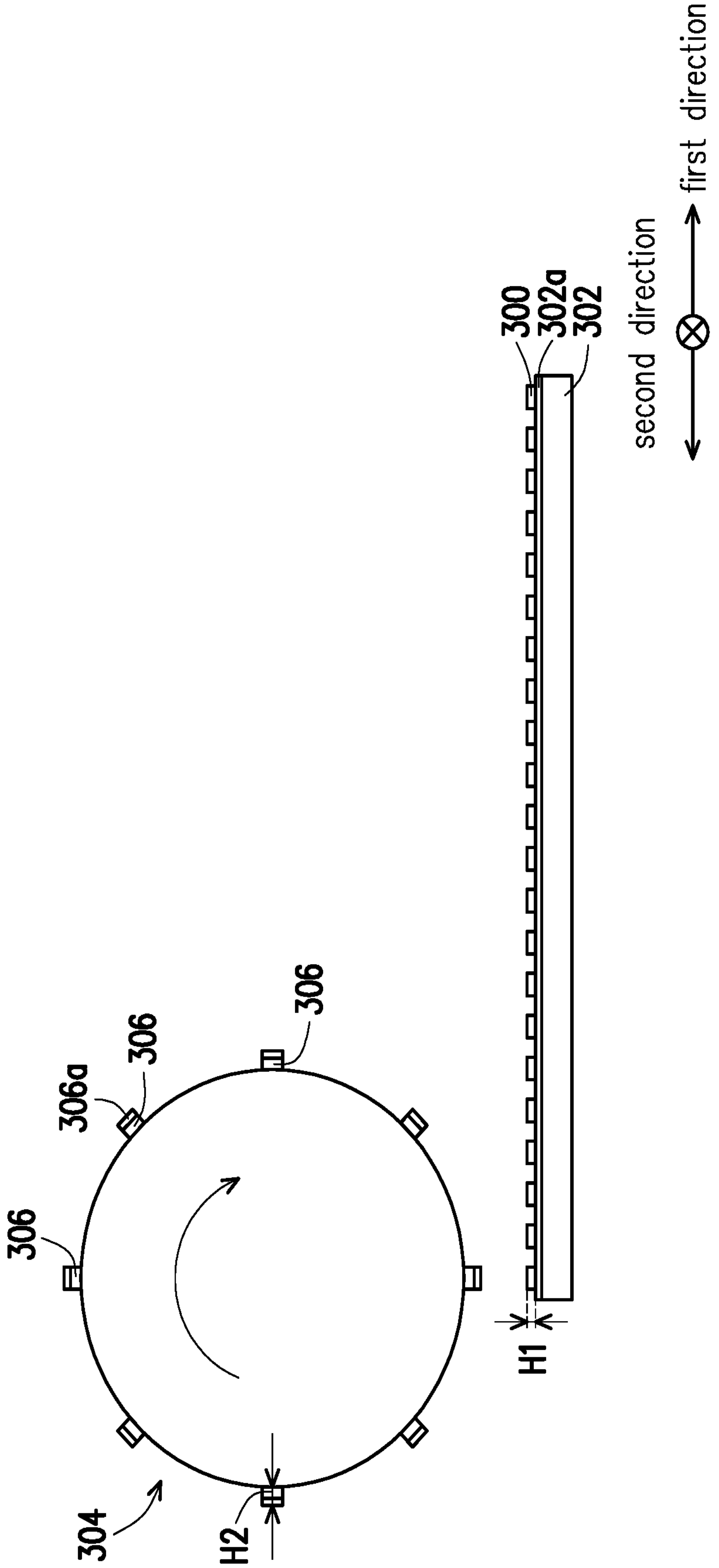

300
302a
302
second direction
first direction
306
306
306a
306
304
H2
H1

FIG. 3B

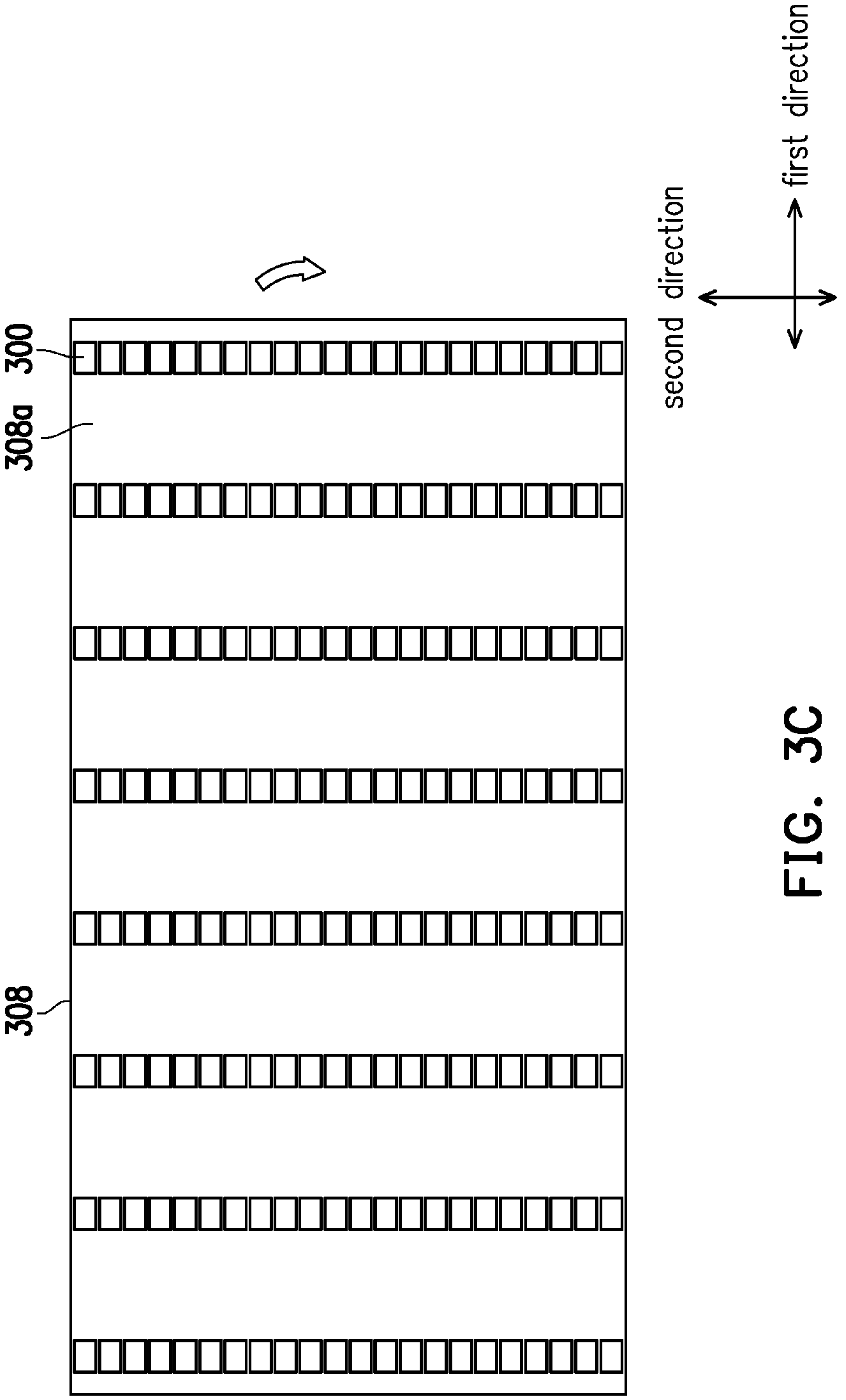


FIG. 3C

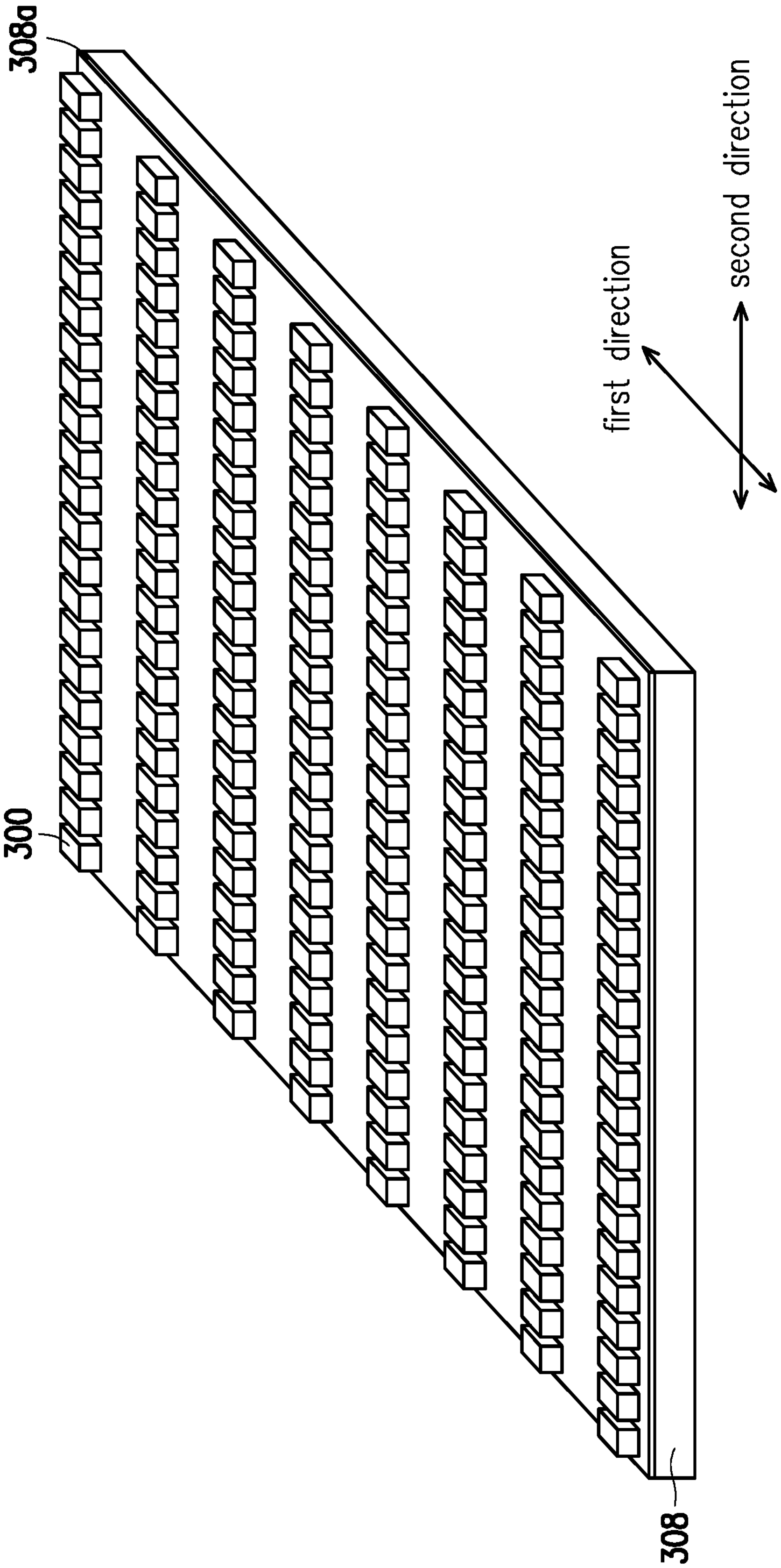


FIG. 3D

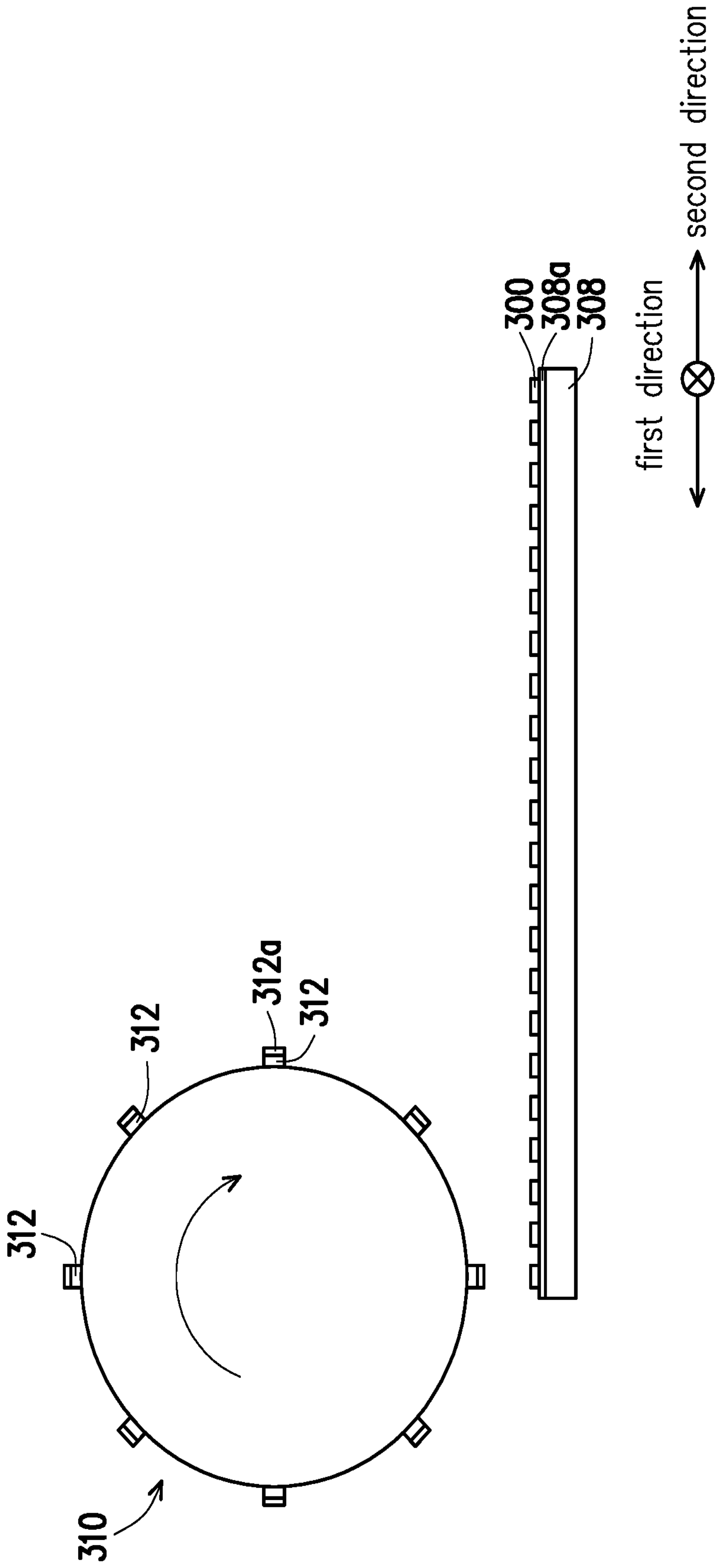

310
312
312
312a
312
300
308a
308
first direction
second direction

FIG. 3E

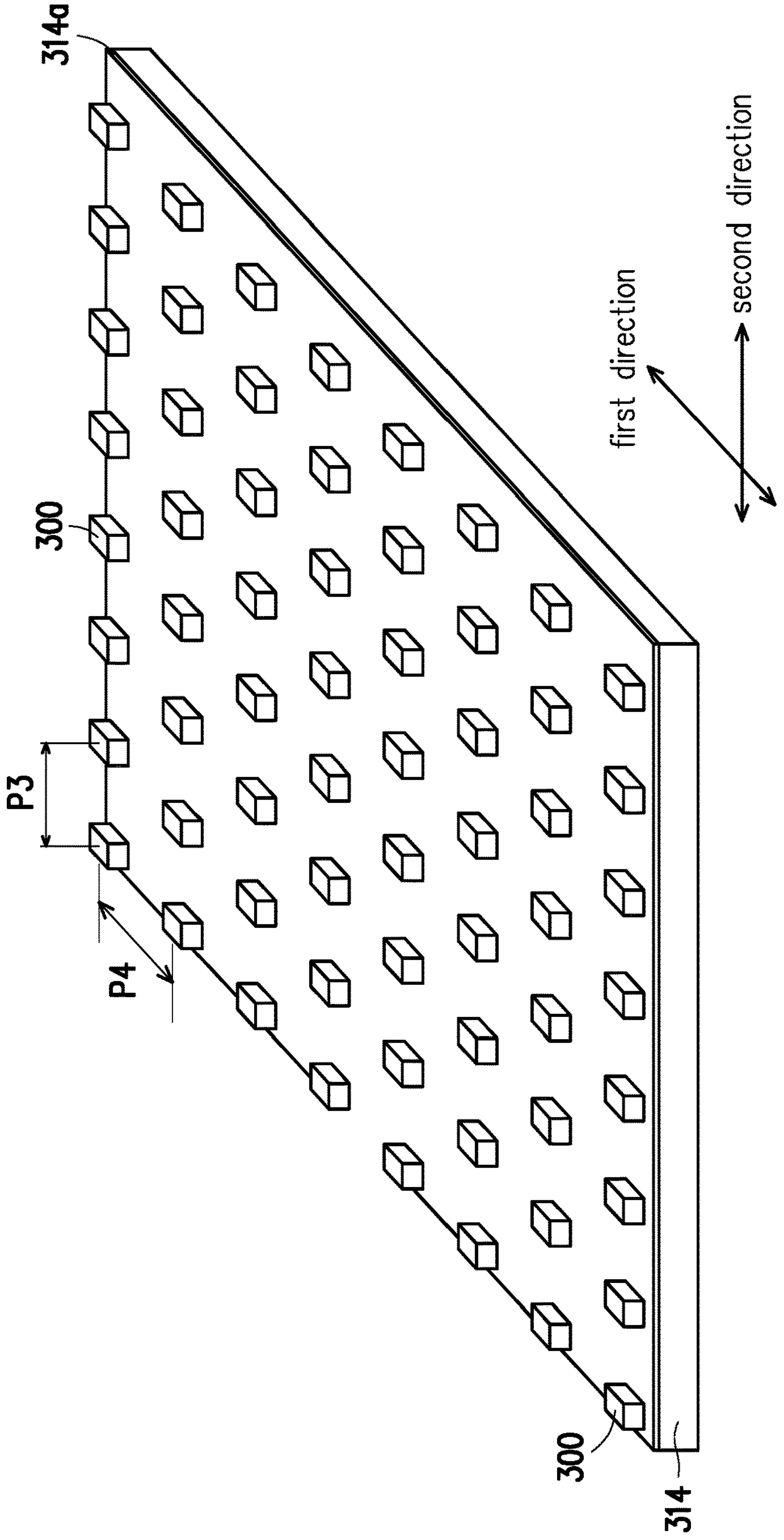


FIG. 3F

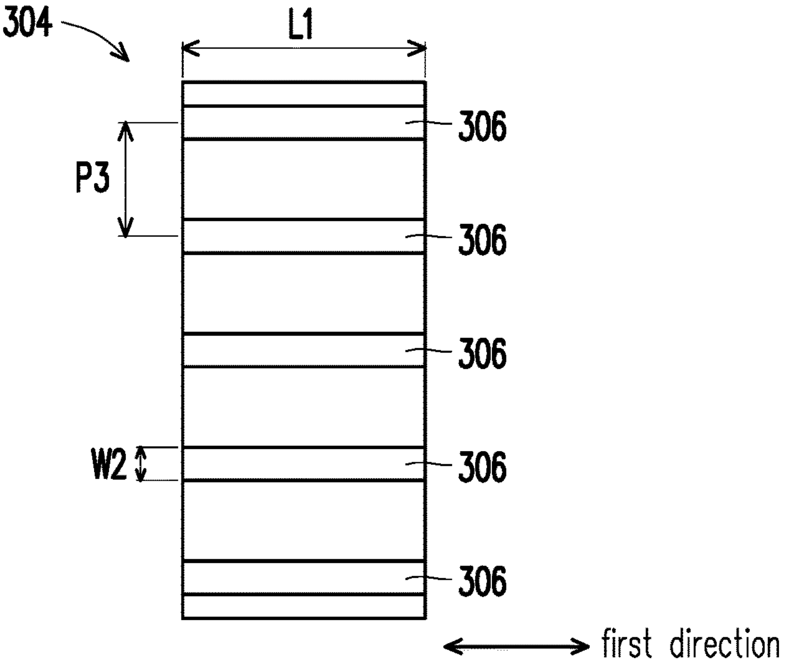

304
L1
306
306
306
306
306
P3
W2
first direction

FIG. 4A

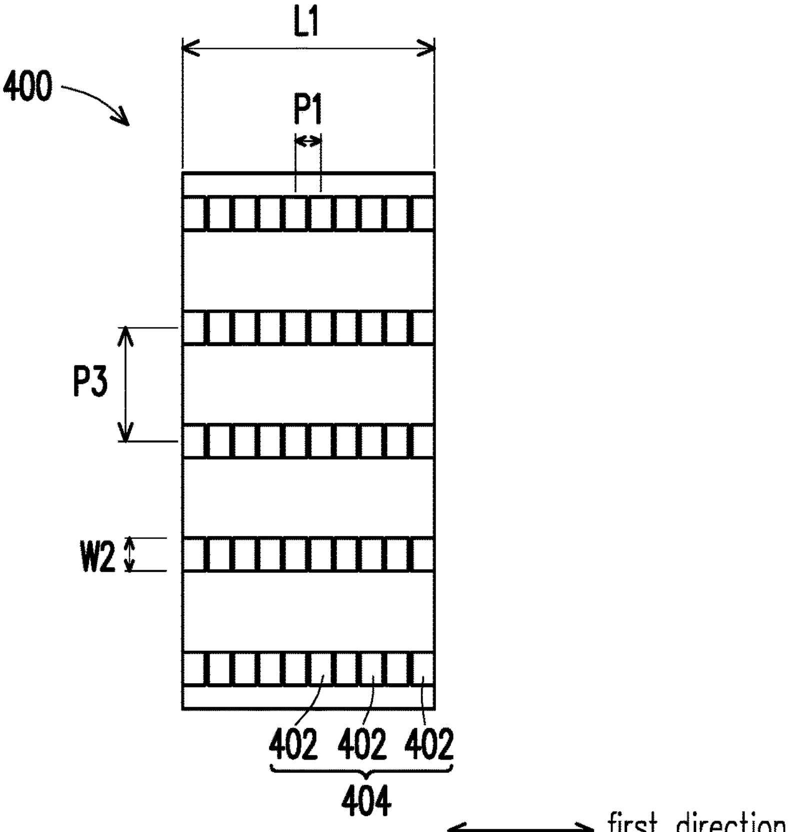

L1
400
P1
P3
W2
402
402
402
404
first direction

FIG. 4B

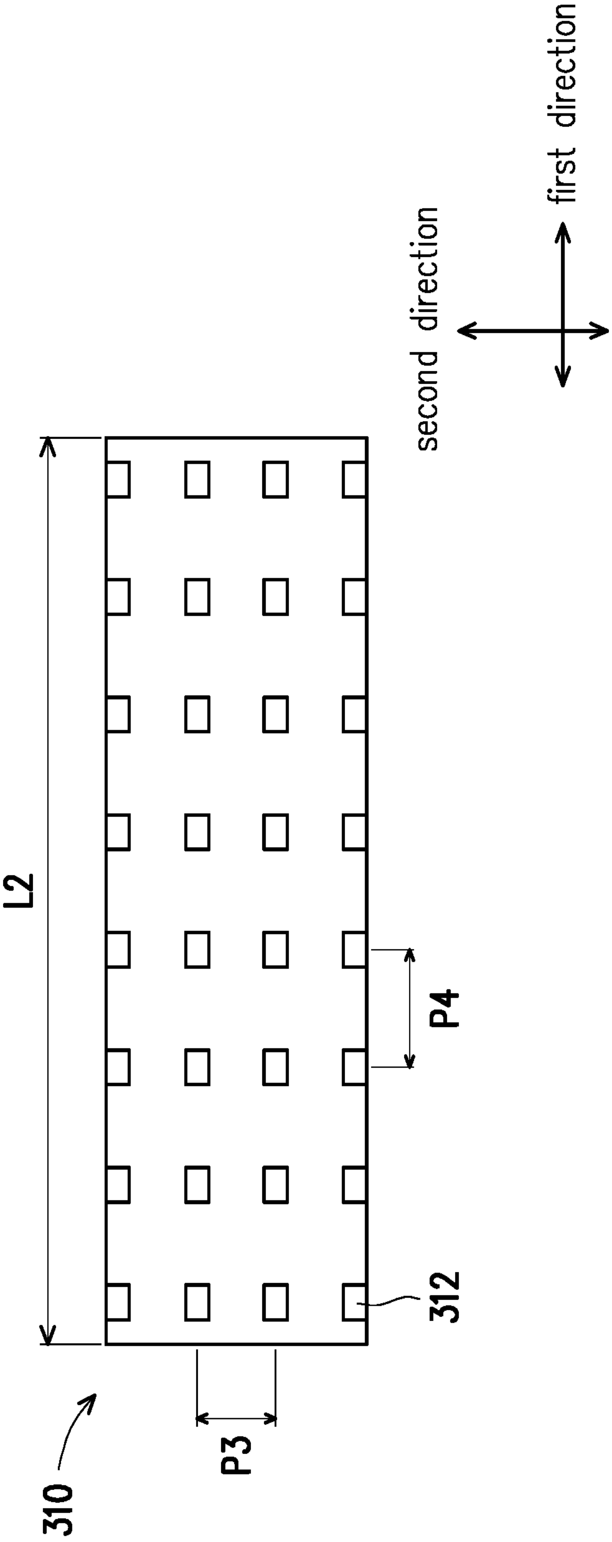


FIG. 4C

TRANSFER METHOD OF EXPANDING PITCHES OF DEVICE AND AN APPARATUS FOR PERFORMING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority benefit of U.S. provisional application Ser. No. 62/542,250, filed on Aug. 7, 2017. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

TECHNICAL FIELD

[0002] The disclosure relates to a transfer method for expanding pitches of devices and an apparatus for performing the transfer method.

BACKGROUND

[0003] The micro LED display is one of the most discussed techniques among the next-generation display techniques. Particularly, it has the greatest potential in applications such as display for hand-held device, TV wall large-size indoor displays, AR/VR display devices, etc.

[0004] However, to be put to mass production, further development in the manufacturing process of the micro LED display is still required. For example, since micro devices (R/G/B) of the micro LED display have a small thickness and a small pitch, the conventional method of individual bonding cannot be adopted. Moreover, in addition to the requirement for position precision, the process of assembling the micro devices should also meet the speed requirement. However, due to the limitation of mass production, there is currently no perfect solution for rapidly and massively performing operations of pitch expansion and picking/placing of devices. Even though electrostatic picking/placing techniques have been developed, such techniques require complex and rapid high-precision mechanisms, and their overall costs for mass production cannot meet the expectation of the market.

SUMMARY

[0005] A transfer method for expanding pitches of devices of the disclosure includes the following steps. A first substrate with a plurality of micro devices is provided, wherein a pitch of the micro devices on the first substrate in a first direction and a second direction is a predetermined value, and a first adhesive layer is provided between the first substrate and the micro devices. Then, the micro devices are transferred to a first roller by rolling the first roller to contact the micro devices on the first substrate, wherein the first roller includes a plurality of contact line portions, a pitch of the contact line portions is N times of the predetermined value, and a second adhesive layer is provided on surfaces of the contact line portions. Next, the micro devices on the first roller are transferred to a second substrate, wherein a third adhesive layer is provided on a surface of the second substrate. The second substrate is rotated by 90 degrees. Afterwards, the micro devices are transferred to a second roller by rolling the second roller to contact the micro devices on the second substrate, wherein a fourth adhesive layer is provided on a surface of the second roller. Next, the micro devices on the second roller are transferred to a third substrate, wherein a fifth adhesive layer is provided on a surface of the third substrate.

[0006] A transfer apparatus for expanding pitches of devices of the disclosure is configured to transfer and expand a pitch of a plurality of micro devices located on a substrate, wherein a pitch of the micro devices in a first direction and a second direction is a predetermined value. The apparatus includes a first roller, a temporary substrate, a moving apparatus, and a second roller. The first roller includes a plurality of contact line portions, and a pitch of the contact line portions is N times of the predetermined value. The first roller is configured to roll to contact the micro devices on the substrate to transfer the micro devices to the contact line portions. The temporary substrate is configured to carry the micro devices transferred from the contact line portions. The moving apparatus is configured to rotate the temporary substrate with the micro devices by 90 degrees. The second roller is configured to roll to contact the micro devices on the temporary substrate to transfer the micro devices to the second roller.

[0007] In light of the above, the method of the disclosure adopts two-step roller transfer and rotates the temporary substrate by 90 degrees to rapidly and massively perform pitch expansion and transfer of the micro devices in a simple and low-cost manner. Therefore, the method is applicable to mass production.

[0008] Several exemplary embodiments accompanied with figures are described in detail below to further describe the disclosure in details.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings are included to provide a further understanding of the disclosure and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the disclosure and, together with the description, serve to explain the principles of the disclosure.

[0010] FIG. **1**A to FIG. **1**F are schematic diagrams illustrating a transfer process for expanding pitches of devices according to a first embodiment of the disclosure.

[0011] FIG. **2**A is a schematic diagram illustrating a roller used in the first embodiment.

[0012] FIG. **2**B is a schematic diagram illustrating another roller used in the first embodiment.

[0013] FIG. **2**C is a schematic diagram illustrating yet another roller used in the first embodiment.

[0014] FIG. **3**A to FIG. **3**F are schematic diagrams illustrating a transfer process for expanding pitches of devices according to a second embodiment of the disclosure.

[0015] FIG. **4**A is a schematic diagram illustrating a first roller used in the second embodiment.

[0016] FIG. **4**B is a schematic diagram illustrating another first roller used in the second embodiment.

[0017] FIG. **4**C is a schematic diagram illustrating a second roller used in the second embodiment.

DETAILED DESCRIPTION

[0018] A description accompanied with drawings is provided in the following to sufficiently explain embodiments of the disclosure. However, the disclosure may still be implemented in many other different forms and should not be construed as limited to the embodiments described hereinafter. In the drawings, for clarity, the components and their relative proportions may not be illustrated based on their actual sizes.

[0019] FIG. **1**A to FIG. **1**F are schematic diagrams illustrating a transfer process for expanding pitches of devices according to a first embodiment of the disclosure.

[0020] Referring to FIG. **1**A, the transfer method for expanding pitches of devices of the present embodiment is applicable to various manufacturing processes for expanding pitches of devices (e.g., a micro device (R/G/B) assembly process of a micro LED display), but the disclosure is not limited thereto. Any manufacturing process that requires precise positioning and rapid and mass operations of pitch expansion and picking/placing of devices may use the method described in the present embodiment. In the present embodiment, a first substrate **102** with a plurality of micro devices **100** is first provided. The material of the first substrate **102** is, for example, a non-deformable inorganic material to reduce variations in the position of the micro devices **100** on the first substrate **102** resulting from variations in the environmental temperature or humidity. Moreover, a pitch P**1** and a pitch P**2** of the micro devices **100** on the first substrate **102** in a second direction and a first direction are predetermined values. Herein, the "pitch" refers to a distance between central points of two adjacent micro devices **100** in one single direction. Since a gap must be present between the micro devices **100**, the pitches P**1** and P**2** are generally slightly larger than a width W**1** of the micro device **100**. In addition, in the example of the micro devices of the micro LED display, a method of providing the micro devices **100** may be as follows. A plurality of micro devices of the same color are first simultaneously manufactured on a whole semiconductor substrate. Then, the micro devices are separated by laser cutting or dry etching, for example. Next, the micro devices are transferred onto the first substrate **102**, and before the transfer, an adhesive layer **102***a* is coated on the surface of the first substrate **102** to increase the adhesion force between the first substrate **102** and the micro devices **100**. Specifically, the adhesive layer **102***a* is a pressure-sensitive adhesive such as a UV release film. Therefore, after the pressure-sensitive adhesive is subjected to a light or heat stimulus, cross-linking reaction occurs or gas is generated such that the adhesive force of the pressure-sensitive adhesive is reduced. For example, the adhesive force of the UV release film before de-adhesion is greater than the adhesive force after de-adhesion.

[0021] Next, referring to FIG. **1**B, by rolling a first roller **104** to contact the micro devices **100** on the first substrate **102**, the micro devices **100** are transferred to the first roller **104**. Specifically, the first roller **104** includes contact line portions **106** radially arranged thereon. An adhesive layer **106***a* is coated on the surfaces of the contact line portions, and the adhesive layer **106***a* is a pressure-sensitive adhesive. In the present embodiment, the adhesion force of the adhesive layer **106***a* is greater than the adhesion force of the adhesive layer **102***a* after being subjected to a light or heat stimulus, and the adhesion force may be an adhesive force, an electrostatic force, a pressure, or a Van der Waals force. For example, the adhesive layer **106***a* may use another adhesive material having a viscosity operation window different from that of the adhesive layer **102***a* to pick up the micro devices **100** on the first substrate **102** by adhesion. One example is a pressure-sensitive adhesive (PSA) having an adhesive force between the adhesive forces of the UV release film before light irradiation (before transfer) and after light irradiation. In an embodiment, a rolling speed of the first roller **104** matches a speed at which the first substrate **102** is moved in an extension direction (i.e., the first direction) of the contact line portions **106**, such that mass production can be performed.

[0022] Moreover, since FIG. **1**B is a side view in the first direction, only one contact line portion **106** is shown, and the contact line portion **106** is a continuous line. However, in a side view (see FIG. **2**A) in the second direction, a plurality of contact line portions **106** are observed, and a pitch P**3** of the contact line portions **106** is N times of P**1**, namely, N times of the predetermined value (N is a positive real number larger than or equal to 1). A width W**2** of the contact line portion **106** may be equal to or greater than the width W**1** of the micro device **100** to enhance the strength by which the contact line portions **106** pick up or adhere to the micro devices **100**. In addition, a height H**2** of the contact line portion **106** may be, for example, equal to or greater than a height H**1** of the micro device **100** to enhance the operation quality at the time when the contact line portions **106** pick up or adhere to the micro devices **100**.

[0023] Other modifications may be further made to the first roller **104**. For example, in a roller **200** shown in FIG. **2**B, a contact line portion **204** is formed of a plurality of first protrusions **202**. A pitch P**5** of the first protrusions **202** is equal to the pitch P**2** (i.e., the predetermined value) of the micro devices **100**. In other words, when the roller **200** rolls in the first direction and contacts the micro devices **100**, each of the micro devices **100** adheres to one of the first protrusions **202**.

[0024] After the micro devices **100** are transferred to (the contact line portions **106** of) the first roller **104**, referring to FIG. **1**C, the micro devices **100** of the first roller **104** are transferred to a second substrate **108** (a temporary substrate). An adhesive layer **108***a* is coated on the surface of the second substrate **108**. Specifically, the adhesive layer **108***a* is a pressure-sensitive adhesive, and the material of the second substrate **108** is selected, for example, to match the coefficient of thermal expansion (CTE) of the first substrate **102**. In the present embodiment, the adhesion force of the adhesive layer **108***a* is greater than the adhesion force of the adhesive layer **106***a*, and the adhesion force may be an adhesive force, an electrostatic force, a pressure, or a Van der Waals force. For example, the adhesive layer **108***a* may use another adhesive material having a viscosity operation window different from that of the adhesive layer **106***a* to pick up the micro devices **100** on the contact line portions **106** by adhesion. One example is a UV release film, which has an adhesive force before UV light irradiation greater than the adhesive force of the pressure-sensitive adhesive. In FIG. **1**C, the pitch P**2** in the first direction of the micro devices **100** transferred onto the second substrate **108** is the predetermined value, and the pitch P**3** in the second direction is N times of P**1**. Therefore, in this stage, expansion of the pitch of the micro devices **100** by N times in the second direction is completed.

[0025] Next, the second substrate **108** is rotated by 90 degrees by using a moving apparatus **110** to obtain the result shown in FIG. **1**D. The moving apparatus **110** is not specifically limited herein. Any apparatus capable of rotating the second substrate **108** by 90 degrees is applicable to the disclosure. Therefore, in addition to the plate-shaped apparatus shown in FIG. **1**C, a robotic arm, a rotating robot, a linear robot, or a combination of these apparatuses may also be used to complete the operation of rotating the second substrate **108** by 90 degrees.

[0026] Then, referring to FIG. **1**E, in the present embodiment, a second roller **112** is used to again roll and contact the micro devices **100** on the second substrate **108**, wherein the second roller **112** includes contact line portions **107** radially arranged thereon, an adhesive layer **107***a* is coated on the surfaces of the contact line portions **107**, and the adhesive layer **107***a* is a pressure-sensitive adhesive. In a side view (see FIG. **2**C) in the second direction, a plurality of contact line portions **107** are observed, and a pitch P4 of the contact line portions **107** is M times of P**2**, namely, M times of the predetermined value (M is a positive real number larger than or equal to 1). Since the second roller **112** rolls in the second direction, only the micro devices **100** having the pitch P4 will be transferred to the contact line portions **107** in the first direction. Similar to the first roller **104**, the rolling direction of the second roller **112** is not changed in the whole process of the present embodiment. The directions labeled in the drawings represent the arrangement directions of the micro devices **100**. Therefore, what is changed is the arrangement direction of the micro devices **100**.

[0027] In the present embodiment, the adhesion force of the adhesive layer **107***a* is greater than the adhesion force of the adhesive layer **108***a* after being subjected to a light or heat stimulus, and the adhesion force may be an adhesive force, an electrostatic force, a pressure, or a Van der Waals force. For example, the adhesive layer **107***a* may use another adhesive material having a viscosity operation window different from that of the adhesive material of the adhesive layer **108***a* to pick up the micro devices **100** on the second substrate **108** by adhesion. For example, if the adhesive layer **108***a* is a UV release film, the adhesive layer **107***a* may be a pressure-sensitive adhesive having an adhesive force between the adhesive forces of the UV release film before light irradiation (before transfer) and after light irradiation. Through light irradiation to the UV release film, the adhesiveness of the adhesive layer **108***a* is reduced.

[0028] After the micro devices **100** are transferred to (the contact line portions **107** of) the second roller **112**, referring to FIG. **1**F, the micro devices **100** on the second roller **112** are transferred to a third substrate **114**. An adhesive layer **114***a* is coated on the surface of the third substrate **114**. The third substrate **114** may be a temporary substrate or a product substrate. If the third substrate **114** is a temporary substrate, the material is selected, for example, to match the coefficient of thermal expansion (CTE) of the first substrate **102**. For example, the first substrate **102** and the third substrate **114** may be formed of the same material. Alternatively, the third substrate **114** is a product substrate having circuits and electrodes. In the present embodiment, the adhesion force of the adhesive layer **114***a* is greater than the adhesion force of the adhesive layer **107***a*, and the adhesion force may be an adhesive force, an electrostatic force, a pressure, or a Van der Waals force. For example, when the third substrate **114** is a product substrate having circuits and electrodes, the adhesive layer **114***a* may be an anisotropic conductive film (ACF) or an anisotropic conductive paste (e.g. self-assembly anisotropic conductive paste, SAP) to simultaneously achieve adhesion, electrical conduction, and self-assembly positioning. On the other hand, if the third substrate **114** is a temporary substrate, the UV release film may be used, and transfer to another product substrate may be performed in a subsequent process. For example, the micro devices **100** on the third substrate **114** may be first attached to a glass substrate, and a UV light is irradiated from the backside of the third substrate **114** to reduce the adhesiveness of the UV release film. Then, the third substrate **114** is peeled off.

[0029] In summary of the process of the first embodiment, the apparatus for implementing the first embodiment at least includes the first substrate **102**, the first roller **104**, the second substrate **108** (i.e., the temporary substrate), the second roller **112**, and the moving apparatus **110**. Table 1 below shows material selections of the components in the exemplary solution where the transfer of the micro devices is controlled by the adhesive force. However, the disclosure is not limited thereto.

TABLE 1

Component	Material	Requirement
first substrate	non-deformable inorganic material, e.g., glass, silicon wafer, quartz	reducing variations in position of micro devices thereon resulting from variations in environmental temperature or humidity
adhesive layer between first substrate and micro devices	UV release film manufactured by Nan Ya Plastics Corporation; glass adhesive force before de-adhesion may be adjusted to be 500 gf/25 mm to 2500 gf/25 mm, and glass adhesive force after de-adhesion may be reduced to 30 gf/25 mm or below	adhesive force before de-adhesion being greater than adhesive force after de-adhesion
first roller	e.g., stainless steel, anodic aluminum oxide	dimensionally stable material matching coefficient of thermal expansion (CTE) of first substrate
contact line portions	polydimethylsiloxane (PDMS) (adhesive force: 50 gf/25 mm to 100 gf/25 mm)	elastomer
adhesive layer on contact line portions	pressure-sensitive adhesive (adhesive force: 100 gf/25 mm to 200 gf/25 mm)	adhesive force being between adhesive forces of UV release film before light irradiation and after light irradiation

TABLE 1-continued

Component	Material	Requirement
second substrate	glass, silicon wafer, quartz	transparent, dimensionally stable
adhesive layer on second substrate	UV release film above	adhesive force before de-adhesion being greater than adhesive force of adhesive material on contact line portions
second roller	e.g., stainless steel, anodic aluminum oxide	dimensionally stable material matching coefficient of thermal expansion (CTE) of second substrate
contact line portions	PDMS	elastomer
adhesive layer on contact line portions	pressure-sensitive adhesive	adhesive force being between adhesive forces of UV release film before light irradiation and after light irradiation
third substrate	product substrate	transparent, flexible, dimensionally stable
	glass	transparent, dimensionally stable
adhesive layer on third substrate	UV release film above	adhesive force before de-adhesion being greater than adhesive force of adhesive material on contact line portions
	anisotropic conductive film (ACF) (peel strength at about 500 gf/25 mm) or Epowell AP series anisotropic conductive paste (SAP) (peel strength at about 4800 gf/25 mm) manufactured by Sekisui Chemical Co., Ltd.	conductive adhesive for adhesion, electrical conduction, and self-assembly positioning

[0030] FIG. **3**A to FIG. **3**F are schematic diagrams illustrating a transfer process for expanding pitches of devices according to a second embodiment of the disclosure.

[0031] Referring to FIG. **3**A, the transfer method for expanding pitches of devices of the present embodiment is similarly applicable to various manufacturing processes for expanding pitches of devices (e.g., a micro device (R/G/B) assembly process of a micro LED display), but the disclosure is not limited thereto. Any manufacturing process that requires precise positioning and rapid and mass operations of pitch expansion and picking/placing of devices may use the method described in the present embodiment. In the present embodiment, a first substrate **302** with a plurality of micro devices **300** is first provided. An adhesive layer **302***a* is coated on the surface of the first substrate **302**. The material of the first substrate **302** is, for example, a non-deformable inorganic material to reduce variations in the position of the micro devices **300** on the first substrate **302** resulting from variations in the environmental temperature or humidity. Moreover, a pitch P**1** and a pitch P**2** of the micro devices **300** on the first substrate **302** in a first direction and a second direction are predetermined values. In addition, compared to the micro devices of the first embodiment, a thickness of the micro devices **300** is smaller, so the transfer process is more difficult. Reference may be made to the description of the first embodiment for the preparation of the micro devices **300**, which shall not be repeatedly described here.

[0032] Next, referring to FIG. **3**B, by rolling a first roller **304** to contact the micro devices **300** on the first substrate **302**, the micro devices **300** are transferred to the first roller **304**. Specifically, the first roller **304** includes contact line portions **306** axially arranged thereon. An adhesive layer **306***a* is coated on the surfaces of the contact line portions **306**. As FIG. **3**B is a side view in the first direction, referring to FIG. **4**A, which is a side view in the second direction, FIG. **4**A shows a plurality of contact line portions **306**, and each of the contact line portions **306** is a continuous line. A pitch P**3** of the contact line portions **306** is N times of P**2**, namely, N times of the predetermined value (N is a positive real number larger than or equal to 1). A width W**2** of the contact line portion **306** may be equal to or greater than a width W**1** of the micro device **300** to enhance the strength by which the contact line portions **306** pick up or adhere to the micro devices **300**. In addition, a height H**2** of the contact line portion **306** may be equal to or greater than a height H**1** of the micro device **300** to enhance the operation quality at the time when the contact line portions **306** pick up or adhere to the micro devices **300**. Furthermore, a width L**1** of the first roller **304** may be smaller than the width of the first substrate **302**, and transfer of the micro devices **300** may be completed by repetitive picking/placing.

[0033] Other modifications may be further made to the first roller **304**. For example, in a roller **400** shown in FIG. **4**B, a contact line portion **404** is formed of a plurality of first protrusions **402**. A pitch of the first protrusions **402** is equal to the pitch P**1** (i.e., the predetermined value) of the micro devices **300**. In other words, when the roller **400** rolls in the first direction and contacts the micro devices **300**, each of the micro devices **300** adheres to one of the first protrusions **402**.

[0034] Referring to FIG. 3B, the adhesion force of the adhesive layer **306***a* is greater than the adhesion force of the adhesive layer **302***a* after being subjected to a light or heat stimulus, and the adhesion force may be an adhesive force, an electrostatic force, a pressure, or a Van der Waals force. For example, the adhesive layer **306***a* may use another adhesive material (e.g., a pressure-sensitive adhesive) having a viscosity operation window different from that of the adhesive layer **302***a* to pick up the micro devices **300** on the first substrate **302** by adhesion. In the second embodiment, a rolling speed of the first roller **304** matches a speed at which the first substrate **302** is moved in the first direction such that application to a production line is possible.

[0035] After the micro devices **300** are transferred to (the contact line portions **306** of) the first roller **304**, referring to FIG. 3C, the micro devices **300** of the first roller **304** are transferred to a second substrate **308** (a temporary substrate). An adhesive layer **308***a* is coated on the surface of the second substrate **308**. The material of the second substrate **308** is selected, for example, to match the coefficient of thermal expansion (CTE) of the first substrate **302**. In the present embodiment, the adhesion force of the adhesive layer **308***a* is greater than the adhesion force of the adhesive layer **306***a*, and the adhesion force may be an adhesive force, an electrostatic force, a pressure, or a Van der Waals force. For example, another adhesive material having a viscosity operation window different from that of the adhesive layer **306***a* may be used on the second substrate **308** as the adhesive layer **308***a* to pick up the micro devices **300** on the contact line portions **306** by adhesion. One example is a UV release film, which has an adhesive force before UV light irradiation greater than the adhesive force of the pressure-sensitive adhesive. In FIG. 3C, the pitch P1 in the second direction of the micro devices **300** transferred onto the second substrate **308** is the predetermined value, and the pitch P3 in the first direction is N times of the predetermined value, P2. Therefore, in this stage, expansion of the pitch of the micro devices **300** by N times in the first direction is completed.

[0036] Next, the second substrate **308** is rotated by 90 degrees to obtain the result shown in FIG. 3D. Moreover, rotation of the second substrate **308** by 90 degrees may be performed by using a moving apparatus such as a carrier and a robotic arm (for example, using a combination of a rotating robot and a linear robot) and is not specifically limited herein.

[0037] Then, referring to FIG. 3E, by rolling a second roller **310** to contact the micro devices **300** on the second substrate **308**, the micro devices **300** are transferred to the second roller **310**. The second roller **310** includes a plurality of second protrusions **312**. An adhesive layer **312***a* is coated on the surfaces of the second protrusions **312**. In the side view (see FIG. 4C) in the first direction, it is observed that the pitch P3 of the second protrusions **312** in the second direction is N times of P2, and the pitch P4 of the second protrusions **312** in the first direction is M times of P1, wherein M is a positive real number larger than or equal to 1, and M may be a value equal to N. Furthermore, a width L2 of the second roller **310** may be determined by the total length of the second substrate **308** in the first direction, or the same as L1 to transfer of the micro devices **300** by repetitive picking/placing. Since the pitches between the second protrusions **312** of the second roller **310** itself has been expanded by N times and M times in both the first direction and the second direction, only the micro devices **300** having the pitch **P3** will be transferred onto the second protrusions **312**.

[0038] In the present embodiment, the adhesion force of the adhesive layer **312***a* is greater than the adhesion force of the adhesive layer **308***a* after being subjected to a light or heat stimulus, and the adhesion force may be an adhesive force, an electrostatic force, a pressure, or a Van der Waals force. For example, the adhesive layer **312***a* may use another adhesive material having a viscosity operation window different from that of the adhesive material of the adhesive layer **308***a* to pick up the micro devices **300** on the second substrate **308** by adhesion. One example is a pressure-sensitive adhesive having an adhesive force between the adhesive forces of the UV release film before light irradiation (before transfer) and after light irradiation. Through light irradiation to the UV release film, the adhesiveness of the adhesive layer **308***a* is reduced.

[0039] After the micro devices **300** are transferred to (the second protrusions **312** of) the second roller **310**, referring to FIG. 3F, the micro devices **300** on the second roller **310** are transferred to a third substrate **314**, which may be a temporary substrate or a product substrate. An adhesive layer **314***a* is coated on the surface of the third substrate **314**. If the third substrate **314** is a temporary substrate, the material is selected, for example, to match the coefficient of thermal expansion (CTE) of the first substrate **302**. For example, the first substrate **302** and the third substrate **314** may be formed of the same material. Alternatively, the third substrate **314** is a product substrate having circuits and electrodes. In the present embodiment, the adhesion force of the adhesive layer **314***a* is greater than the adhesion force of the adhesive layer **312***a*, and the adhesion force may be an adhesive force, an electrostatic force, a pressure, or a Van der Waals force. For example, when the third substrate **314** is a product substrate having circuits and electrodes, the adhesive layer **314***a* may use an ACF or an SAP as the adhesive material to simultaneously achieve adhesion, electrical conduction, and self-assembly positioning. On the other hand, if the third substrate **314** is a temporary substrate, the UV release film may be used, and transfer to another product substrate may be performed in a subsequent process. For example, the micro devices **300** on the third substrate **314** may be first attached to a glass substrate, and a UV light is irradiated from the backside of the third substrate **314** to reduce the adhesiveness of the UV release film. Then, the third substrate **314** is peeled off.

[0040] In summary of the process of the second embodiment, the apparatus for implementing the second embodiment at least includes the first substrate **302**, the first roller **304**, the second substrate **308** (i.e., the temporary substrate), the moving apparatus (not shown), and the second roller **310**. Table 2 below shows material selections of the components in the exemplary solution where the transfer of the micro devices is controlled by the adhesive force. However, the disclosure is not limited thereto.

TABLE 2

Component	Material	Requirement
first substrate	non-deformable inorganic material, e.g., glass, silicon wafer, quartz	reducing variations in position of the micro devices thereon resulting from variations in environmental temperature or humidity
adhesive layer between first substrate and micro devices	UV release film manufactured by Nan Ya Plastics Corporation, glass adhesive force before de-adhesion may be adjusted to be 500 gf/25 mm to 2500 gf/25 mm, and glass adhesive force after de-adhesion may be reduced to 30 gf/25 mm or below	adhesive force before de-adhesion being greater than adhesive force after de-adhesion
first roller	e.g., stainless steel, anodic aluminum oxide	dimensionally stable material matching coefficient of thermal expansion (CTE) of first substrate
contact line portions	polydimethylsiloxane (PDMS) (adhesive force: 50 gf/25 mm to 100 gf/25 mm)	elastomer
adhesive layer on contact line portions	oil-borne or water-borne acrylic pressure-sensitive adhesive	adhesive force being between adhesive forces of UV release film before light irradiation and after light irradiation
second substrate	glass, quartz	transparent, dimensionally stable
adhesive layer on second substrate	UV release film above	adhesive force being between adhesive forces of UV release film before light irradiation and after light irradiation
second roller	e.g., stainless steel, anodic aluminum oxide	dimensionally stable material matching coefficient of thermal expansion (CTE) of second substrate
second protrusions	PDMS	elastomer
adhesive layer on second protrusions	oil-borne or water-borne acrylic pressure-sensitive adhesive above	adhesive force being between adhesive forces of UV release film before light irradiation and after light irradiation
third substrate	glass, quartz	transparent, flexible, dimensionally stable
	glass	transparent, dimensionally stable
adhesive layer on third substrate	UV release film above	adhesive force before de-adhesion being greater than adhesive force after de-adhesion
	anisotropic conductive film (ACF) (peel strength at about 500 gf/cm) or Epowell AP series anisotropic conductive paste (SAP) (peel strength at about 4800 gf/cm) manufactured by Sekisui Chemical Co., Ltd.	conductive adhesive having adhesive force

[0041] In summary of the above, the disclosure adopts the transfer technique of two-step rollers with the flat substrate to achieve pitch expansion and transfer of the micro devices in a simple and low-cost manner, which avoids the heavy time consumption of the picking/placing technique using linear motion combination.

[0042] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed embodiments without departing from the scope or spirit of the disclosure. In view of the foregoing, it is intended that the disclosure covers modifications and variations provided that they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A transfer method for expanding pitches of devices, comprising:

providing a first substrate with a plurality of micro devices, wherein a pitch of the micro devices on the first substrate in a first direction and a second direction is both a predetermined value, and a first adhesive layer is provided between the first substrate and the micro devices;

transferring the micro devices to a first roller by rolling the first roller to contact the micro devices on the first substrate, wherein the first roller comprises a plurality of contact line portions, a pitch of the contact line portions is N times of the predetermined value, and a second adhesive layer is provided on surfaces of the contact line portions;

transferring the micro devices on the first roller to a second substrate, wherein a third adhesive layer is provided on a surface of the second substrate;

rotating the second substrate by 90 degrees;

transferring the micro devices to a second roller by rolling the second roller to contact the micro devices on the second substrate, wherein a fourth adhesive layer is provided on a surface of the second roller; and

transferring the micro devices on the second roller to a third substrate, wherein a fifth adhesive layer is provided on a surface of the third substrate.

2. The transfer method for expanding pitches of devices according to claim **1**, wherein a width of the contact line portion is equal to or greater than a width of the micro device.

3. The transfer method for expanding pitches of devices according to claim **1**, wherein a height of the contact line portion is equal to or greater than a height of the micro device.

4. The transfer method for expanding pitches of devices according to claim **1**, wherein a rolling speed of the first roller matches a speed at which the first substrate is moved in an extension direction of the contact line portions.

5. The transfer method for expanding pitches of devices according to claim **1**, wherein each of the contact line portions is formed of a plurality of first protrusions or is a continuous line.

6. The transfer method for expanding pitches of devices according to claim **5**, wherein a pitch of the first protrusions is equal to the predetermined value.

7. The transfer method for expanding pitches of devices according to claim **6**, wherein the contact line portions are radially arranged on the first roller.

8. The transfer method for expanding pitches of devices according to claim **1**, wherein the first roller and the second roller are different rollers.

9. The transfer method for expanding pitches of devices according to claim **8**, wherein the contact line portions are axially arranged on the first roller.

10. The transfer method for expanding pitches of devices according to claim **8**, wherein a width of the second roller is the N times of a width of the first roller, the second roller comprises a plurality of second protrusions, and a pitch of the second protrusions in the first direction is M times of the predetermined value, and a pitch of the second protrusions in the second direction is N times of the predetermined value.

11. The transfer method for expanding pitches of devices according to claim **1**, wherein an adhesion force of the second adhesive layer is greater than an adhesion force of the first adhesive layer.

12. The transfer method for expanding pitches of devices according to claim **1**, wherein an adhesion force of the third adhesive layer is greater than an adhesion force of the second adhesive layer.

13. The transfer method for expanding pitches of devices according to claim **1**, wherein an adhesion force of the fourth adhesive layer is greater than an adhesion force of the third adhesive layer.

14. The transfer method for expanding pitches of devices according to claim **1**, wherein an adhesion force of the fifth adhesive layer is greater than an adhesion force of the fourth adhesive layer.

15. The transfer method for expanding pitches of devices according to claim **1**, wherein the first adhesive layer, the second adhesive layer, the third adhesive layer, the fourth adhesive layer, and the fifth adhesive layer each independently comprise a pressure-sensitive adhesive, a conductive solder paste, or an anisotropic conductive film, wherein the pressure-sensitive adhesive is a pressure-sensitive adhesive in which cross-linking reaction occurs or gas is generated to reduce an adhesive force after the pressure-sensitive adhesive is subjected to a light or heat stimulus.

16. The transfer method for expanding pitches of devices according to claim **1**, wherein the third substrate comprises a temporary substrate or a product substrate.

17. The transfer method for expanding pitches of devices according to claim **1**, wherein the first substrate and the third substrate are formed of the same material.

18. A transfer apparatus for expanding pitches of devices configured to transfer and expand a pitch of a plurality of micro devices located on a substrate, wherein the pitch of the micro devices in a first direction and a second direction is both a predetermined value, the apparatus comprising:

a first roller comprising a plurality of contact line portions, wherein a pitch of the contact line portions is N times of the predetermined value, and the first roller is configured to roll to contact the micro devices on the substrate for transferring the micro devices to the contact line portions;

a temporary substrate configured to carry the micro devices transferred from the contact line portions;

a moving apparatus configured to rotate the temporary substrate with the micro devices by 90 degrees; and

a second roller configured to roll to contact the micro devices on the temporary substrate for transferring the micro devices to the second roller.

19. The transfer apparatus for expanding pitches of devices according to claim **18**, wherein a width of the contact line portion is equal to or greater than a width of the micro device.

20. The transfer apparatus for expanding pitches of devices according to claim **18**, wherein a height of the contact line portion is equal to or greater than a height of the micro device.

21. The transfer apparatus for expanding pitches of devices according to claim **18**, wherein a rolling speed of the first roller matches a speed at which the substrate is moved in an extension direction of the contact line portions.

22. The transfer apparatus for expanding pitches of devices according to claim **18**, wherein each of the contact line portions is formed of a plurality of protrusions or is a continuous line.

23. The transfer apparatus for expanding pitches of devices according to claim **22**, wherein a pitch of the first protrusions is equal to the predetermined value.

24. The transfer apparatus for expanding pitches of devices according to claim **18**, wherein the first roller and the second roller are the same roller.

25. The transfer apparatus for expanding pitches of devices according to claim **24**, wherein the contact line portions are radially arranged on the first roller.

26. The transfer apparatus for expanding pitches of devices according to claim **18**, wherein the first roller and the second roller are different rollers.

27. The transfer apparatus for expanding pitches of devices according to claim **26**, wherein the contact line portions are axially arranged on the first roller.

28. The transfer apparatus for expanding pitches of devices according to claim **26**, wherein a width of the second roller is the N times of a width of the first roller, the second roller comprises a plurality of second protrusions, a pitch of the second protrusions in the first direction is M times of the predetermined value, and a pitch of the second protrusions in the second direction is N times of the predetermined value.

29. The transfer apparatus for expanding pitches of devices according to claim **18**, further comprising:

a first adhesive layer disposed between the substrate and the micro devices;

a second adhesive layer disposed on surfaces of the contact line portions;

a third adhesive layer disposed on a surface of the temporary substrate; and

a fourth adhesive layer disposed on a surface of the second roller.

30. The transfer apparatus for expanding pitches of devices according to claim **29**, wherein an adhesion force of the second adhesive layer is greater than an adhesion force of the first adhesive layer.

31. The transfer apparatus for expanding pitches of devices according to claim **29**, wherein an adhesion force of the third adhesive layer is greater than an adhesion force of the second adhesive layer.

32. The transfer apparatus for expanding pitches of devices according to claim **29**, wherein an adhesion force of the fourth adhesive layer is greater than an adhesion force of the third adhesive layer.

33. The transfer apparatus for expanding pitches of devices according to claim **30**, wherein the adhesion force comprises an adhesive force, an electrostatic force, a pressure, or a Van der Waals force.

34. The transfer apparatus for expanding pitches of devices according to claim **31**, wherein the adhesion force comprises an adhesive force, an electrostatic force, a pressure, or a Van der Waals force.

35. The transfer apparatus for expanding pitches of devices according to claim **32**, wherein the adhesion force comprises an adhesive force, an electrostatic force, a pressure, or a Van der Waals force.

36. The transfer apparatus for expanding pitches of devices according to claim **29**, wherein the first adhesive layer, the second adhesive layer, the third adhesive layer, and the fourth adhesive layer each independently comprise a pressure-sensitive adhesive, a conductive solder paste, or an anisotropic conductive film, wherein the pressure-sensitive adhesive is a pressure-sensitive adhesive in which crosslinking reaction occurs or gas is generated to reduce an adhesive force after the pressure-sensitive adhesive is subjected to a light or heat stimulus.

* * * * *

专利名称(译)	扩展设备间距的转移方法和用于执行该设备的设备		
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摘要(译)

一种用于扩展器件间距的转移方法，包括：为第一基板提供在第一方向和第二方向上具有预定值的间距的微器件;通过使微型器件与微型器件接触，将微型器件转移到第一辊子，其中第一辊子上的接触线部分的间距是预定值的N倍;将第一辊上的微型器件转移到第二基板上;将第二基板旋转90度;通过滚动第二辊将微型器件转移到第二辊上以接触微型器件;然后将微器件转移到第三衬底，以在第一和第二方向上扩展微器件的间距。与微型器件接触的部分都具有带有不同粘附操作窗口的粘合剂层。