US010692923B2

(12) **United States Patent**
Zhu et al.

(10) **Patent No.: US 10,692,923 B2**
(45) **Date of Patent: Jun. 23, 2020**

(54) **SYSTEMS AND METHODS FOR TRANSFER OF MICRO-DEVICES**

(71) Applicant: **Applied Materials, Inc.**, Santa Clara, CA (US)

(72) Inventors: **Mingwei Zhu**, San Jose, CA (US); **Sivapackia Ganapathiappan**, Los Altos, CA (US); **Boyi Fu**, San Jose, CA (US); **Hou T. Ng**, Campbell, CA (US); **Nag B. Patibandla**, Pleasanton, CA (US)

(73) Assignee: **Applied Materials, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/020,692**

(22) Filed: **Jun. 27, 2018**

(65) **Prior Publication Data**

US 2018/0315793 A1 Nov. 1, 2018

Related U.S. Application Data

(62) Division of application No. 15/270,763, filed on Sep. 20, 2016, now Pat. No. 10,032,827.

(Continued)

(51) **Int. Cl.**

H01L 21/66	(2006.01)
H01L 33/48	(2010.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H01L 27/156*** (2013.01); ***H01L 21/6835*** (2013.01); ***H01L 22/22*** (2013.01);

(Continued)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,791,474 B1	7/2014	Bibl et al.
10,032,827 B2	7/2018	Zhu et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CN	105144387	12/2015
JP	S56-017384	2/1981

(Continued)

OTHER PUBLICATIONS

'Terecircuits.com/photoprinting.shtml' [online]. "Terecircuits," 2015, [retrieved on Sep. 6, 2017]. Retrieved from the Internet: URL<terecircuits.com/photoprinting.shtml>, 2 pages.

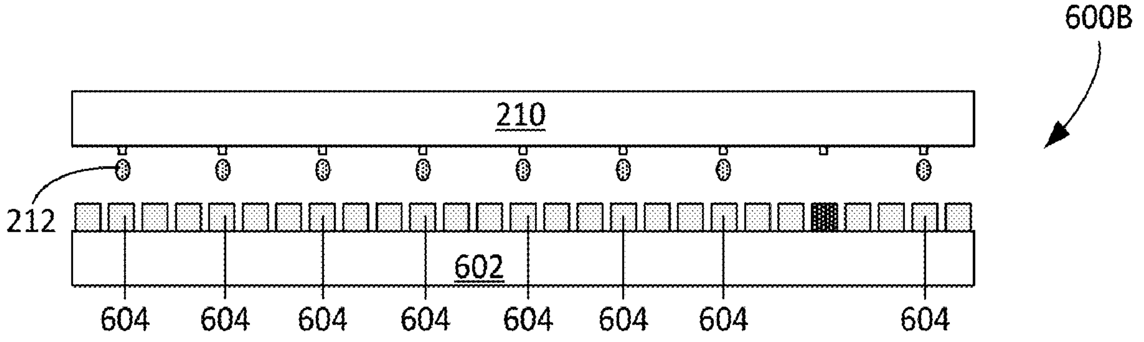
(Continued)

Primary Examiner — Charles D Garber
Assistant Examiner — Xiaoming Liu
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

An apparatus for positioning micro-devices on a substrate includes one or more supports to hold a donor substrate and a destination substrate, an adhesive dispenser to deliver adhesive on micro-devices on the donor substrate, a transfer device including a transfer surface to transfer the micro-devices from the donor substrate to the destination substrate, and a controller. The controller is configured to operate the adhesive dispenser to selectively dispense the adhesive onto selected micro-devices on the donor substrate based on a desired spacing of the selected micro-devices on the destination substrate. The controller is configured to operate the transfer device such that the transfer surface engages the adhesive on the donor substrate to cause the selected micro-devices to adhere to the transfer surface and the transfer surface then transfers the selected micro-devices from the donor substrate to the destination substrate.

16 Claims, 5 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/356,431, filed on Jun. 29, 2016.

(51) **Int. Cl.**

H01L 27/15	(2006.01)
H01L 33/00	(2010.01)
H01L 21/683	(2006.01)
H01L 23/00	(2006.01)
H01L 25/075	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 24/741*** (2013.01); ***H01L 24/83*** (2013.01); ***H01L 24/97*** (2013.01); ***H01L 33/0095*** (2013.01); ***H01L 33/48*** (2013.01); *H01L 22/20* (2013.01); *H01L 24/75* (2013.01); *H01L 25/0753* (2013.01); *H01L 2221/68368* (2013.01); *H01L 2224/7598* (2013.01); *H01L 2224/95136* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2002/0064032	A1	5/2002	Oohata	
2005/0087743	A1	4/2005	Ogihara et al.	
2006/0035164	A1	2/2006	Schaper	
2006/0154390	A1*	7/2006	Tran	B23K 26/40 438/22
2007/0103664	A1	5/2007	Chiu	
2008/0122119	A1*	5/2008	Kian	H01L 21/6835 257/783
2009/0056858	A1*	3/2009	Davila Casitas	B41F 16/00 156/184
2009/0090002	A1	4/2009	Motomuro	
2010/0259164	A1	10/2010	Oohata et al.	
2010/0326702	A1	12/2010	Dang	
2011/0076490	A1	3/2011	Higashibeppu et al.	
2013/0130440	A1	5/2013	Hu et al.	
2013/0273695	A1	10/2013	Menard et al.	
2013/0277785	A1*	10/2013	Chen	H01L 27/14632 257/432
2014/0191236	A1	7/2014	Nuzzo et al.	
2014/0267683	A1	9/2014	Bibl et al.	
2015/0294951	A1*	10/2015	Smits	C09J 5/06 438/119
2016/0124316	A1	5/2016	Markle et al.	
2016/0144608	A1	5/2016	Chang	
2016/0219684	A1	7/2016	Kaskey et al.	
2016/0282728	A1	9/2016	Johnston et al.	
2016/0336304	A1*	11/2016	Wu	H01L 21/6835
2017/0186730	A1	6/2017	Shen	
2017/0338199	A1	11/2017	Zou et al.	
2018/0006083	A1	1/2018	Zhu et al.	

FOREIGN PATENT DOCUMENTS

JP	S56-017385	2/1981
JP	H06-077317	10/1994
JP	2003-174041	6/2003
JP	2005-150703	6/2005
JP	2006-339464	12/2006
JP	2008-502151	1/2008
JP	2009-094181	4/2009
JP	2011-077235	4/2011
JP	2012-244012	12/2012
JP	2014-036060	2/2014
JP	2016-025151	2/2016
JP	2016-512347	4/2016

OTHER PUBLICATIONS

International Search Report and Written Opinion in International Application No. PCT/US2017/037742, dated Sep. 18, 2017, 10 pages.

International Preliminary Report on Patentability in International Application No. PCT/US2017/037742, dated Jan. 10, 2019, 7 pages.

Supplementary Partial European Search Report in European Application No. 17820906.0, dated Feb. 4, 2020, 19 pages.

JP Office Action in Japanese Application No. 2018-568689, dated Mar. 17, 2020, 56 pages (with English Translation).

* cited by examiner

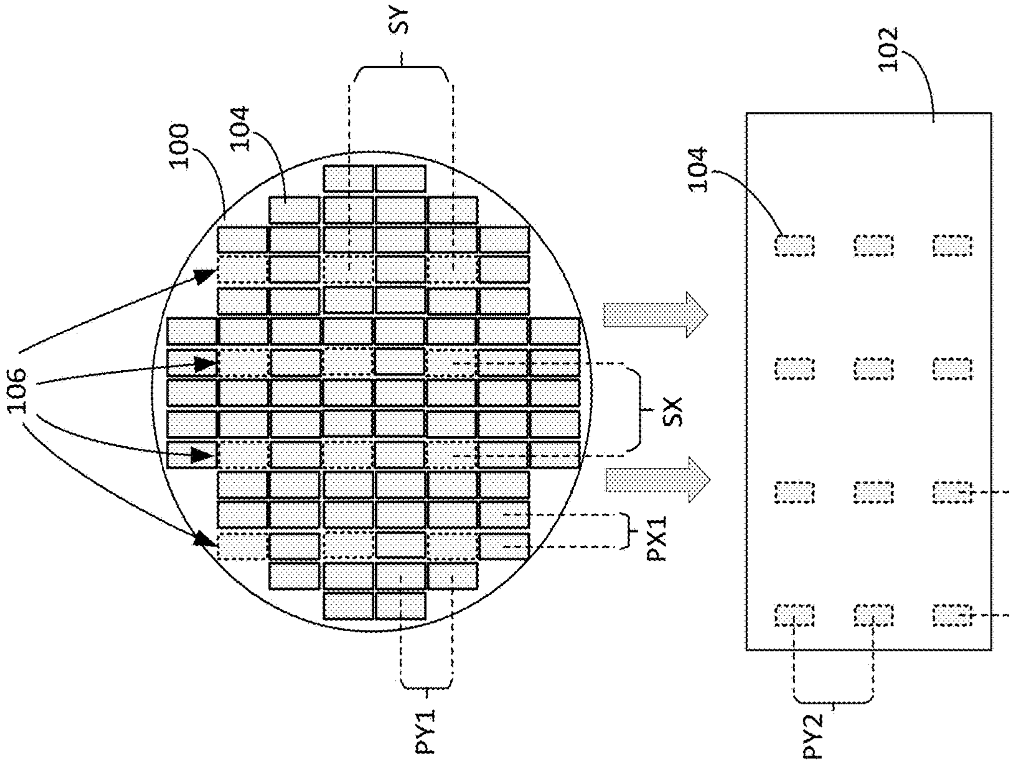


FIG. 1

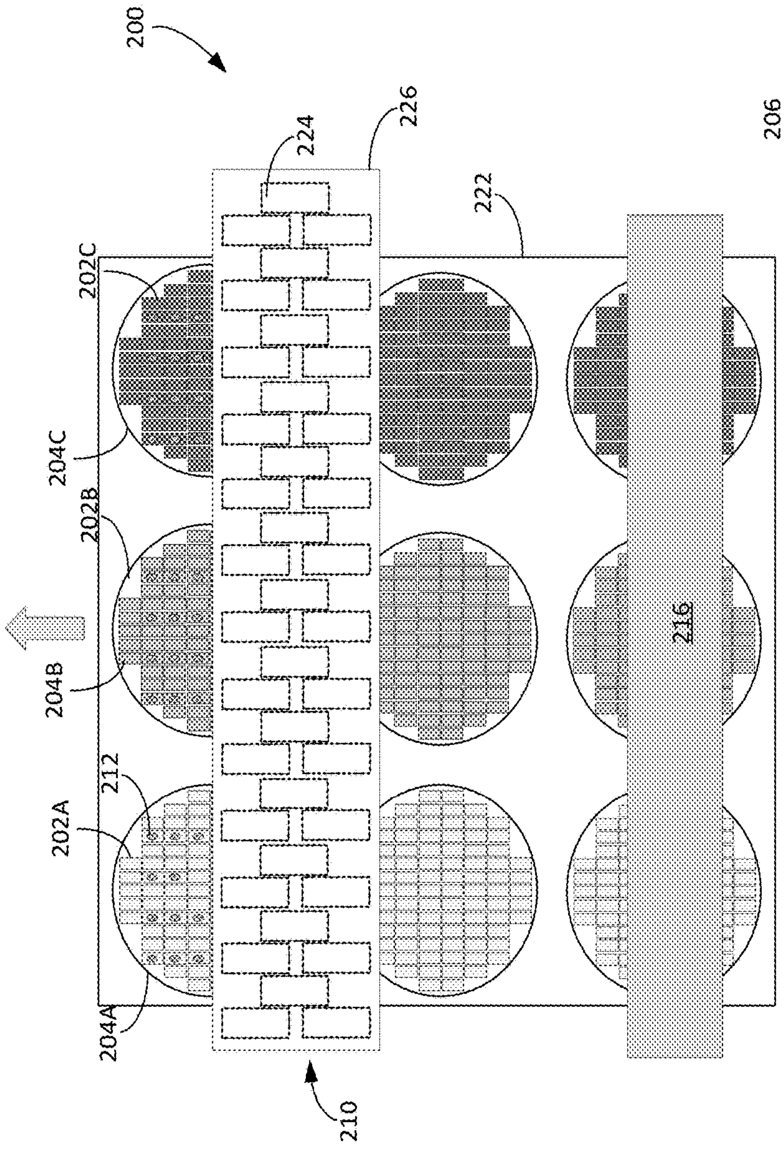

200
202C
204C
202B
204B
212
202A
204A
224
226
222
216
210

FIG. 2A

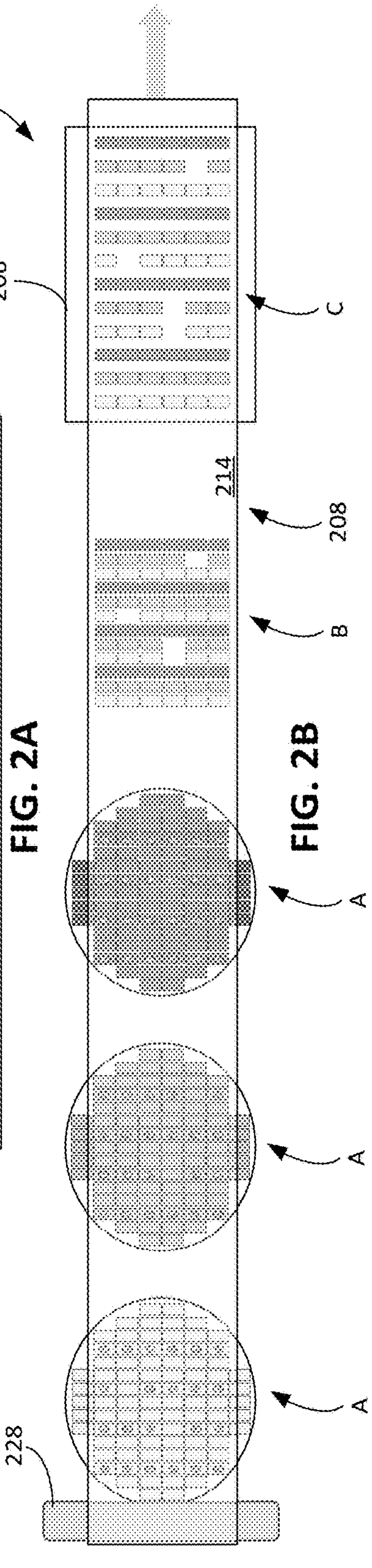

200
206
C
214
208
B
A
A
A
228

FIG. 2B

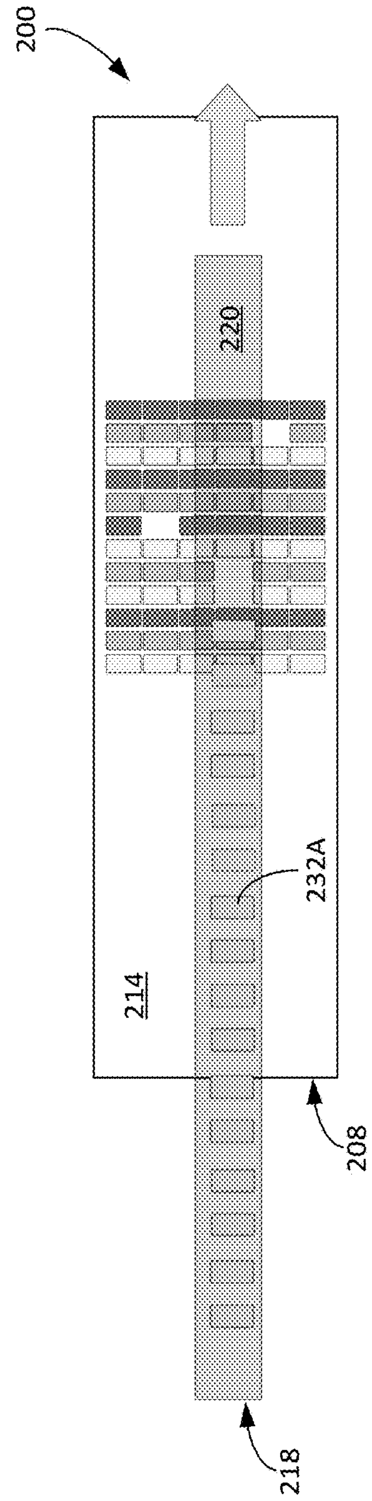

200
220
214
232A
208
218

FIG. 2C

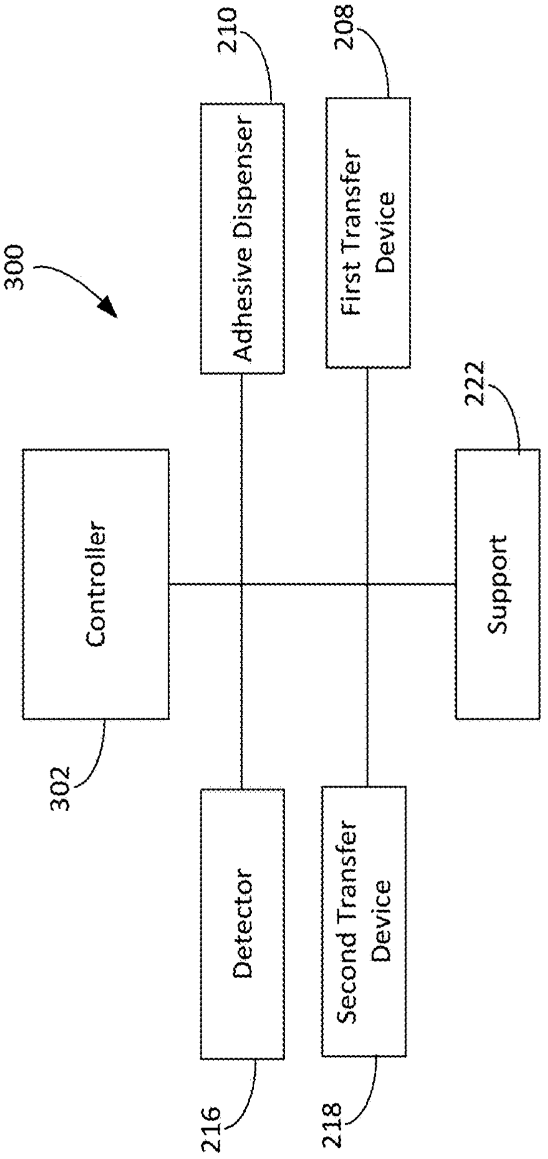

300
Adhesive Dispenser
210
First Transfer Device
208
Controller
302
Support
222
Detector
216
Second Transfer Device
218

FIG. 3

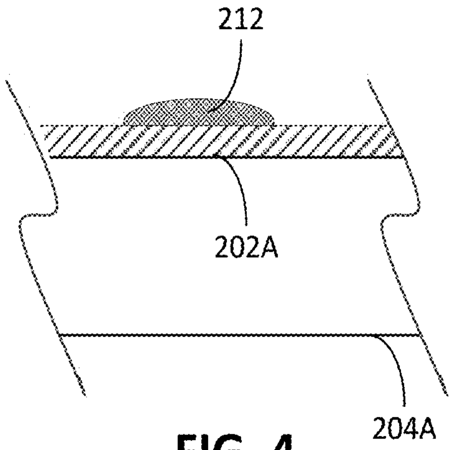


FIG. 4

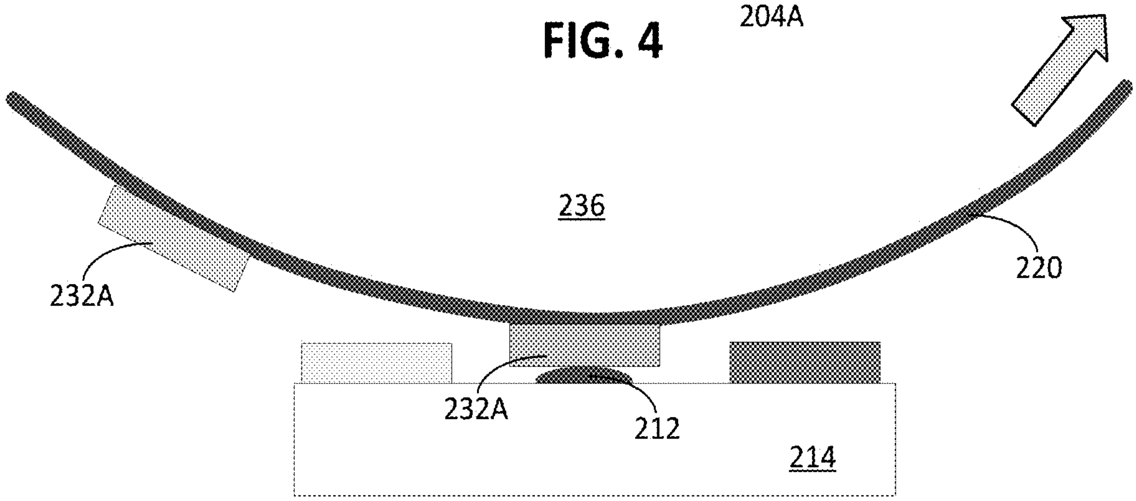


FIG. 5

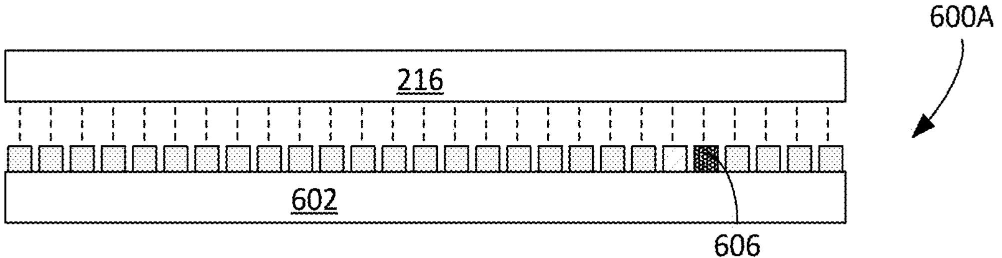


FIG. 6A

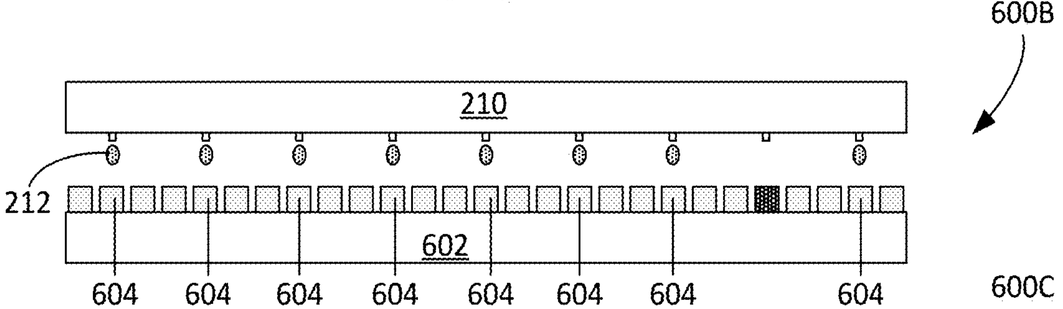


FIG. 6B

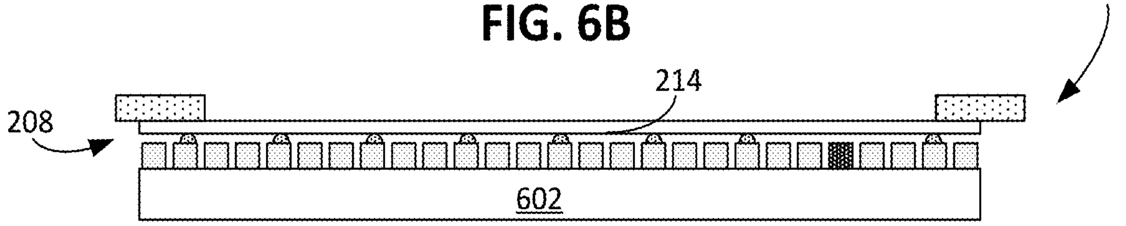


FIG. 6C

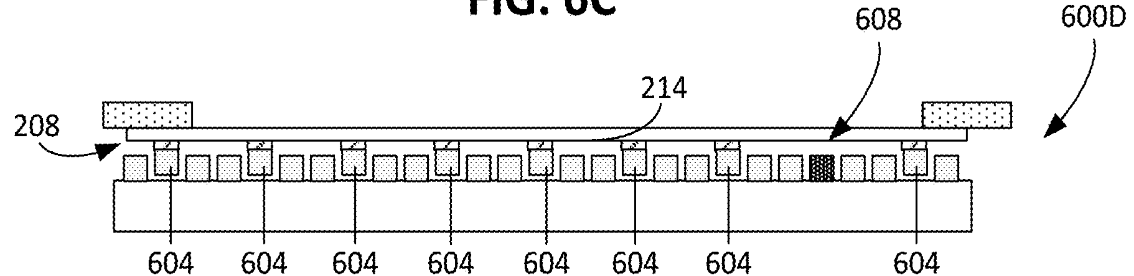


FIG. 6D

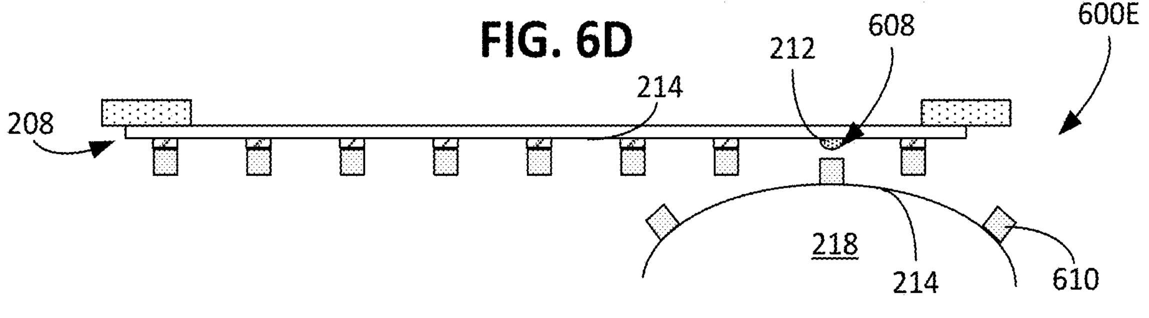


FIG. 6E

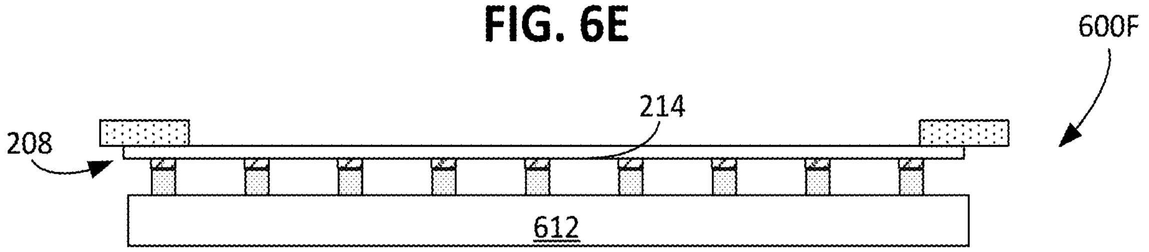


FIG.6F

SYSTEMS AND METHODS FOR TRANSFER OF MICRO-DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. application Ser. No. 15/270,763, filed Sep. 20, 2016, which claims priority to U.S. Provisional Application Ser. No. 62/356,431, filed Jun. 29, 2016, the disclosures of which are incorporated by reference.

TECHNICAL FIELD

This disclosure relates to the transfer of micro-devices from a donor substrate to a destination substrate.

BACKGROUND

A variety of products includes an array of individual devices on a substrate, with the devices addressable or controllable by circuitry on the substrate. For example, some display screens include an array of individually controllable pixels. In the case of light-emitting diode (LED) panels, these individual pixels can be independently controllable LEDs. The LED panels are commonly used for display screens, such as computers, touch panel devices, personal digital assistants (PDAs), cell phones, television monitors, and the like.

In general, micro-devices can be fabricated using a sequence of microfabrication techniques, such as deposition, lithography and etching, to deposit and pattern a sequence of layers. One approach for fabricating a device that includes an array of individual micro-devices is to directly fabricate the individual micro-devices on the substrate which will form part of the product. This technique has been used, e.g., to fabricate the individual micro-devices on the substrate which will form part of the product. This technique has been used, e.g., to fabricate the TFT panel and color filter panels of an active matrix liquid crystal display (LCD). However, in LED panels are difficult to manufacture in curved or bendable display.

An alternative approach for fabricating a device that includes an array of individual micro-devices is to fabricate the micro-devices en masse on a separate substrate, and then transfer the micro-devices to the substrate which will form part of the product.

SUMMARY

In one aspect, an apparatus for positioning micro-devices on a substrate includes one or more supports to hold a donor substrate and a destination substrate, an adhesive dispenser to deliver adhesive on micro-devices on the donor substrate, a transfer device including a transfer surface to transfer the micro-devices from the donor substrate to the destination substrate, and a controller. The controller is configured to operate the adhesive dispenser to selectively dispense the adhesive onto selected micro-devices on the donor substrate based on a desired spacing of the selected micro-devices on the destination substrate. The controller is configured to operate the transfer device such that the transfer surface engages the adhesive on the donor substrate to cause the selected micro-devices to adhere to the transfer surface and the transfer surface then transfers the selected micro-devices from the donor substrate to the destination substrate.

In another aspect, a method of transferring micro-devices to a destination substrate includes selectively dispensing adhesive onto selected micro-devices on a donor substrate based on a desired spacing of the selected micro-devices on the destination substrate, and engaging the adhesive on the donor substrate with a transfer surface to cause the selected micro-devices to adhere to the transfer surface. The method also includes transferring each of the selected micro-devices from the donor substrate to the destination substrate using the transfer surface and in accordance to the desired spacing of the selected micro-devices on the destination substrate.

In some implementations, the controller is configured to operate the transfer device such that the transfer surface transfers first micro-devices to the destination substrate and then transfers second micro-devices to the destination substrate such that the second micro-devices adjacent to the first micro-devices. The first micro-devices and the second micro-devices, for example, both have the desired spacing on the destination substrate. In some cases, the controller is configured to operate the transfer device to transfer the first micro-devices from a first donor substrate and to transfer the second micro-devices from a second donor substrate.

In some implementations, the transfer device is a first transfer device. The apparatus further includes, for example, a second transfer device including a second transfer surface to transfer at least one additional micro-device to the transfer surface of the first transfer device or to the destination substrate. In some cases, the second transfer device is configured to transfer a single micro-device at a time to a receiving surface. The receiving surface is, for example, (i) the transfer surface of the first transfer device or (ii) a surface of the destination substrate. Alternatively or additionally, the controller is configured to operate the second transfer device such that the transfer surface of the second transfer device transfers the single micro-device from the donor substrate to a receiving surface to fill a gap between the selected micro-devices on the receiving surface with the single micro-device, thereby achieving a desired arrangement of the selected micro-devices on the receiving surface. Alternatively or additionally, the controller is configured to operate the adhesive dispenser to dispense adhesive on the receiving surface after the selected micro-devices are adhered to the receiving surface. The controller is, for example, configured to operate the second transfer device such that the transfer surface of the second transfer device engages the single micro-device with the second dispensed adhesive when the transfer surface of the second transfer device transfers the single micro-device to the receiving surface.

In some cases, the second transfer device is configured to transfer a plurality of micro-devices to the destination substrate. In some cases, the transfer surface is a planar surface. In some cases, the second transfer device includes a roller having the second transfer surface.

In some implementations, the apparatus further includes a sensor to detect one or more defective micro-devices on the donor substrate. The controller, for example, is configured to selectively dispense the adhesive such that the adhesive is not dispensed on the one or more failed micro-devices and the selected micro-devices does not include the one or more failed micro-devices.

In some cases, the sensor includes circuitry configured to optically excite the micro-devices on the donor substrate and an optical detector to detect light emitted by the micro-devices on the donor substrate.

In some cases, the transfer device is a first transfer device. The apparatus further includes, for example, a second transfer device including a second transfer surface to transfer a single micro-device at a time to the transfer surface of the first transfer device or transfer micro-devices to the destination substrate. The controller is, for example, configured to operate the first transfer device such that the transfer surface of the first transfer device engages the adhesive on the donor substrate to cause the selected micro-devices to adhere to the transfer surface of the first transfer device. The controller is, for example, configured to operate the second transfer device such that the second transfer surface of the second transfer device transfers one or more micro-devices to the transfer surface of the first transfer device based on a location of the one or more defective micro-devices.

In some implementations, the transfer surface includes a stretchable film to receive the selected micro-devices. In some cases, the apparatus further includes an actuator coupled to the stretching film. The controller is, for example, configured to cause the actuator to stretch the film such that the selected micro-devices to have the desired spacing when the transfer surface transfers the selected micro-devices to the destination substrate.

In some implementations, the transfer device includes a roller to receive the selected micro-devices from the donor substrate.

In some implementations, the transfer surface includes a planar surface to receive the selected micro-devices from the donor substrate.

In some implementations, the transfer device includes a heating element to heat the transfer surface when the transfer surface transfers the selected micro-devices to the destination substrate.

In some implementations, the apparatus includes an etching device to etch the donor substrate, thereby forming the micro-devices.

In some implementations, the apparatus further includes a photolithography module to form electrodes on the destination substrate. The controller is, for example, configured to operate the photolithography module to form the electrodes to electrically connect the selected micro-devices to the destination substrate.

In some implementations, the apparatus further includes a radiation emitter to emit a pattern of radiation to cure at the selectively dispensed adhesive before operating the transfer device.

In some implementations, the micro-devices include light emitting diodes. In some cases, the method further includes optically exciting the light emitting diodes on the donor substrate and detecting one or more defective micro-devices on the donor substrate. The method includes, for example, selectively dispensing the adhesive such that the adhesive is not dispensed on the one or more defective micro-devices and the selected micro-devices does not include the one or more defective micro-devices. Alternatively or additionally, the method further includes transferring one or more micro-devices to the transfer surface based on a location of the one or more failed micro-devices.

In some implementations, the micro-devices are first micro-devices. The method further includes, for example, transferring the first micro-devices to the destination substrate. The method includes, for example, transferring second micro-devices to the destination substrate such that the second micro-devices are adjacent to the first micro-devices. The first micro-devices and the second micro-devices, for example, both have the desired spacing on the destination substrate. The first micro-devices are, for example, configured to emit a first color light, and the second micro-devices are configured to emit a second color light. In some cases, a selected first micro-device and a selected second micro-device adjacent to one another define a display pixel for an LED display.

In some implementations, the method further includes stretching the transfer surface to cause the selected micro-devices to have the desired spacing when the transfer surface transfers the selected micro-devices to the destination substrate.

In some implementations, a spacing of the selected micro-devices on the donor substrate corresponds to the desired spacing of the selected micro-devices on the destination substrate.

Implementations can optionally provide (and are not limited to) one or more of the advantages described below and herein elsewhere. Because the destination substrate may be formed from a material incompatible with the fabrication processes, e.g., etching and deposition, to form the micro-devices, fabricating the micro-devices and then transferring the micro-devices to the destination substrate can enable manufacturing of cost-effective and high-performance display panels. Furthermore, the micro-devices on the donor substrate can be built at a higher spatial density than desired for the destination substrate, thereby increasing throughput and saving wafer space when building the micro-devices. A large number of micro-devices can be transferred in parallel from the donor substrate to the destination substrate. The transfer of the micro-devices to the destination substrate can be performed with high precision, thereby potentially increasing yield and decreasing manufacturing time and cost. Using the detector, defective micro-devices on the donor substrate can be identified and excluded such that only functioning micro-devices are used to form a micro-device product.

The details of one or more implementations of the subject matter described in this specification are set forth in the accompanying drawings and the description below. Other potential features, aspects, and advantages will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a donor substrate with micro-devices and a destination substrate with micro-devices.

FIGS. **2**A to **2**C schematically depict an example of a system to transfer micro-devices from a donor substrate to a destination substrate.

FIG. **3** is a block diagram of an example of a system to transfer micro-devices.

FIG. **4** is a side view of adhesive on a micro-device.

FIG. **5** is a side view of first and second transfer surfaces.

FIGS. **6**A to **6**F are side views of a system performing a process to transfer micro-devices from a donor substrate to a destination substrate.

Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

In order to continue to provide display devices and other devices at the prices demanded by consumers, new apparatuses, approaches, and systems are needed to precisely and cost-effectively provide micro-devices on substrates, such as large area substrates or flexible substrates.

As noted above, a process of fabricating a product having an array of individual micro-devices includes building the micro-devices en masse on a donor substrate and then transferring the micro-devices to a destination substrate forming part of the product. One reason to build the micro-devices on a first substrate is that the destination substrate may be a material that incompatible with the fabrication processes, e.g., etching and deposition, used to form the micro-devices. In other examples, the fabrication processes described herein can enable manufacturing of cost-effective and high-performance display panels. Another reason to build the micro-devices on first substrate is that the micro-devices can be fabricated at higher spatial density than used for the destination substrate, thereby increasing throughput and saving wafer real estate when building the micro-devices and consequently lowering cost. This approach, in some cases, suffers from low throughput requiring "pick-and-place" methods that can be slow, inaccurate, and costly. Therefore, there is a need to improve manufacturing processes and devices that include an array of micro-devices.

To transfer micro-devices from a donor substrate to a destination substrate, as described herein, a system can selectively dispense adhesive on a subset of micro-devices on the donor substrate to control a spacing of the subset of the micro-devices when they are transferred to the destination substrate. The subset of the micro-devices upon which the adhesive is dispensed is selected such that the spacing of the subset of the micro-devices, when transferred to the destination substrate, corresponds to a desired spacing.

FIG. **1** illustrates a donor substrate **100** and a destination substrate **102** each with an array of micro-devices **104**. The micro-devices **104** are small electronic devices, e.g., light-emitting diodes (LEDs), such as organic LEDs (OLEDs), micro-LEDs, and the like. The micro-devices **104** are micron-scale devices, e.g., with a maximum lateral dimension of about 100 microns. For example, the devices can have a lateral dimension of about 5-50 microns, such as 5-15 microns, 15 to 35 microns, 35 to 50 microns, and other appropriate lateral dimensions. The micro-devices **104** can be identical, i.e., same dimensions, circuit pattern and layer structure.

The micro-devices **104** can be fabricated directly on the donor substrate **100**, or the micro-devices **104** can be fabricated on another substrate, e.g., a device substrate, and then transferred to the donor substrate **100**. In some examples, the transfer of the micro-devices **104** from the device substrate to the donor substrate **100** does not alter the spacing between the micro-devices. For example, the micro-devices can be fabricated at relatively high density on the device substrate, and the device substrate can be removed or singulated so that each micro-device **104** is individually attached to the donor substrate. Although FIG. **1** illustrates the micro-devices **104** in a regular rectangular array with pitch PX**1** and PY**1** in the two perpendicular directions parallel to the face of the donor substrate **100**, other array configurations are possible, e.g., staggered rows.

The micro-devices **104** on the donor substrate **100** have a horizontal pitch PX**1** and a vertical pitch PY**1**. A subset **106** of the micro-devices **104** (the micro-devices **104** shown with dashed edges in FIG. **1**) have an initial configuration in which the micro-devices **104** have a first spacing SX and a second spacing SY in the two perpendicular directions parallel to the face of the destination substrate **102**. When the subset **106** of the micro-devices **104** is transferred to the destination substrate **102**, the subset **106** of the micro-devices **104** on the destination substrate **102** have a final configuration in which the micro-devices **104** have pitch PX2 and PY2 in the two perpendicular directions parallel to the face of the destination substrate **102**. The pitch PX2 and pitch PY**2**, for example, correspond to desired pitches for the micro-devices **104** on the micro-device product to be fabricated.

If the horizontal spacing SX and the vertical spacing SY are selected to correspond to the pitch PX**2** and the pitch PY**2**, respectively, the spacing between the micro-devices **104** in the subset **106** on the donor substrate **100** need not be additionally altered before the subset **106** is transferred to the destination substrate **102**. In such a case, the initial configuration matches the final configuration.

In some implementations, before being transferred to the destination substrate **102**, the subset **106** of the micro-devices **104** can be manipulated to increase or decrease the initial spacing SX and/or SY such that the final horizontal spacing and the final vertical spacing matches the desired pitch PX2 and PY2, respectively, on the destination substrate **102**. In such a case, the initial configuration may not match the final configuration but may be transformed to achieve the final configuration before the subset **106** of the micro-devices **104** is transferred to the destination substrate **102**. The spacing SX, SY for the initial configuration can be selected to reduce the magnitude of the alteration of the initial spacing SX, SY before the subset **106** having the final configuration is transferred to the destination substrate **102**.

FIGS. **2**A, **2**B, **2**C, and **3** illustrate an example of a transfer system **200** to transfer micro-devices **202**A from a donor substrate **204**A (FIGS. **2**A, **2**B) to a destination substrate **206** (FIG. **2**B) using a transfer device **208** (FIG. **2**B). The transfer system **200** further includes an adhesive dispenser **210**, as shown in FIG. **4**, that delivers adhesive **212** to the donor substrate **204**A, in particular, onto the micro-devices **202**A positioned on the donor substrate **204**A. The dispenser **210** is, for example, a printhead configured to dispense a pico to sub-picoliter of adhesive onto a micro-device. In some implementations, as shown in FIG. **4**, a droplet of the adhesive **212** is placed on a surface of the micro-device **202**A, e.g., an exposed outer surface. In some examples, a coating of the adhesive **212** is applied to the surface of the micro-device **202**A.

In an example of a control system **300** (FIG. **3**) for the transfer system **200**, a controller **302** controls operations of the transfer system **200** to transfer the micro-devices **202**A from the donor substrate **204**A to the destination substrate **206**. The controller **302** operates the adhesive dispenser **210**, e.g., to control selective delivery of the adhesive **212** to the micro-devices **202**A. The controller **302** also operates the transfer device **208**, e.g., to control transfer of the micro-devices **202**A from the donor substrate **204**A to the destination substrate **206** using a transfer surface **214** of the transfer device **208**.

In some implementations, the transfer system **200** includes a detector **216**. The controller **302** operates the detector **216**, if present, to detect failed micro-devices among the micro-devices **202**A on the donor substrate **204**A.

Furthermore, in some cases, the transfer system **200** includes a second transfer device **218** including a transfer surface **220**. The controller **302** operates the second transfer device **218**, if present, to transfer single micro-devices **202**A to a receiving surface, such as the transfer surface **214** or the destination substrate **206**.

The controller **302** operates the adhesive dispenser **210** to selectively dispense the adhesive **212** onto selected micro-devices **202**A on the donor substrate **204**A based on a desired spacing of the selected micro-devices **202**A on the destination substrate **206**. The controller **302** then operates the transfer device **208** such that the transfer surface **214** of the transfer device **208** engages the adhesive **212** on the donor substrate **204**A. The selected micro-devices **202**A adhere to the transfer surface **214** of the transfer device **208** such that the micro-devices **202**A are transferred from the donor substrate **204**A to the transfer surface **214**. The controller **302** then operates the transfer device **208** such that the transfer surface **214** transfers each of the selected micro-devices **202**A from the donor substrate **204**A to the destination substrate **206** in accordance to the desired spacing of the selected micro-devices **202**A on the destination substrate **206**.

The donor substrate **204**A and the adhesive dispenser **210** are movable relative to one another to control the location where adhesive **212** is dispensed. In some implementations, the donor substrate **204**A is supported on a support **222**. The support **222** is, for example, movable horizontally under the adhesive dispenser **210** to control the location where adhesive **212** is dispensed from the adhesive dispenser **210** on the donor substrate **204**A. As the support **222** is moved, the controller **302** controls the timing of ejection of the adhesive **212** from the adhesive dispenser **210** to control which of the micro-devices **202**A receives the adhesive **212**. In some cases, instead of the support **222** moving relative to the adhesive dispenser **210**, the support **222** remains stationary and the adhesive dispenser **210** is translated relative to the support **222** such that movement of the adhesive dispenser **210** controls the location where the adhesive **212** is dispensed.

The adhesive dispenser **210**, in some cases, dispenses the adhesive **212** on a single micro-device **202**A when the adhesive dispenser **210** is at a given position relative to the donor substrate **204**A. In some implementations, the adhesive dispenser **210** includes an array of printheads **224** supported on a gantry **226** above the donor substrate **204**A. In this case, the adhesive dispenser **210** can dispense the adhesive **212** onto multiple micro-devices simultaneously. The printheads **224** are selectively addressable, e.g., by the controller **302**, such that the adhesive **212** is selectively delivered to the micro-devices **202**A. The printheads **224** of the adhesive dispenser **210**, for example, span a width of the donor substrate **204**A such that the printheads **224** are capable of delivering adhesive **212** to any micro-devices **202**A in a row across the donor substrate **204**A.

The adhesive dispenser **210** and the donor substrate **204**A are movable relative to one another in one or both horizontal directions. For example, if the adhesive dispenser **210** dispenses the adhesive **212** to one micro-device **202**A at a time, relative movement in both directions may be sufficient to enable delivery of adhesive **212** to each of the micro-devices **202**A. In contrast, if the adhesive dispenser **210** dispenses the adhesive **212** to multiple micro-devices **202**A at a time, relative movement in a single direction may be sufficient to enable the adhesive **212** to be delivered to each of micro-devices **202**A. For example, if the adhesive dispenser **210** is supported by the gantry **226**, the gantry **226** can be movable above the donor substrate in one or both horizontal directions.

Referring to FIG. 2B, after the adhesive **212** is delivered to the selected micro-devices **202**A, the transfer device **208** is operated to transfer the micro-devices **202**A with the adhesive **212** to the transfer surface **214** of the transfer device **208**. The transfer surface **214** engages the adhesive **212** delivered to the micro-devices **202**A and then is operated to remove the micro-devices **202**A from the donor substrate **204**A. The adhesive **212** provides sufficient adhesive strength such that, for example, the transfer surface **214** can be lifted from the donor substrate **204**A with the micro-devices **202**A attached to the transfer surface **214**.

To cause the adhesive **212** to adhere to the transfer surface **214** and thereby cause the micro-devices **202** to attach to the transfer surface **214**, the transfer device **208** includes, for example, a rotatable roller **228**. The roller **228** is, for example, a pressure transfer roller that imparts a pressure on the transfer surface **214** when the transfer surface **214** is positioned against the adhesive **212** on the micro-devices **202**A. Alternatively or additionally, the roller **228** is a heated transfer roller that uses heat to cure the adhesive to increase the adhesion between the micro-devices **202**A and the transfer surface **214**. Instead of a roller, the transfer surface **214** could be a planar surface of a flat plate.

In some examples, the neutralizing system of the transfer device **208** includes a radiation emitter that emits radiation, e.g., ultraviolet (UV) light, to cure the adhesive. In some implementations, the adhesive is activated using the UV light. Alternatively or additionally, the adhesive is applied to a select set of micro-devices **202**A, e.g., in a predefined area, and then activated on desired micro-devices **202**A using a patterned array of UV light. The radiation emitter, for example, is activated when the transfer surface **214** is placed against the adhesive **212** such that the micro-devices **202**A become attached to the transfer surface **214** only after the radiation is emitted to cure the adhesive. In some examples, the radiation emitter is incorporated into the roller **228**, if present.

The system can be an illumination system to selectively direct light from the light source onto the back side of the body that provides the transfer surface **214**. Alternatively, the system can include individually controllable heaters embedded in the body that provides the transfer surface **214**.

When the transfer device **208** is operated to attach the micro-devices **202**A from the donor substrate **204**A to the transfer surface **214**, only selected micro-devices are attached to the transfer surface **214**. In particular, only the micro-devices **202**A upon which the adhesive **212** has been dispensed are attached. These selected micro-devices therefore correspond to the micro-devices from the donor substrate **204**A that are transferred to the destination substrate **206**.

The transfer device **208** also includes a system to selectively “neutralize” the adhesive layer **212**. In this context, “neutralize” includes either removing the adhesive layer entirely, e.g., by dissolving or melting, or modifying the physical property of the material so that it is no longer adhesive (also termed “denaturing”). The system can be an illumination system to selectively direct light, e.g., UV light from the light source onto the back side of the body that provides the transfer surface **214**. Alternatively, the system can include heaters embedded in the body that provides the transfer surface **214**. The neutralization system can act to neutralize all of the adhesive on the transfer surface **214**, or be operable to neutralize adhesive in selective areas.

After the transfer surface **214** receives the selected micro-devices, the transfer device **208** is operated to cause the transfer surface **214** to transfer the selected micro-devices to the destination substrate **206**. The adhesive **212** attaching the micro-devices **202**A to the transfer surface **214** is neutralized such that the micro-devices **202**A are transferrable from the transfer surface **214** to the destination substrate **206**. For example, the material forming the adhesive **212** can be is chemically altered to a non-adhesive form, thereby enabling the micro-devices **202**A to be easily removed from the transfer surface **214** and placed on the destination substrate **206**.

In this regard, selected micro-devices are thus transferred from the donor substrate **204**A, to the transfer surface **214**, and then from the transfer surface **214** to the destination substrate **206**. As described herein, the selected micro-devices on the donor substrate **204**A correspond to the ones with selectively dispensed adhesive.

These selected micro-devices on the donor substrate **204**A have an initial configuration A. For example, if the selected micro-devices are uniformly spaced, configuration A is defined by a spacing in a first horizontal direction, a spacing in a second horizontal direction, or combinations thereof. In some implementations, configuration A refers to the configuration of the micro-devices on the donor substrate **204**A upon which the adhesive **212** is selectively dispensed. When the transfer surface **214** receives the selected micro-devices, the selected micro-devices are in configuration B. In some implementations, configuration B refers to the configuration of the selected micro-devices on the transfer surface **214** after the transfer surface **214** receives the selected micro-devices and before the transfer surface **214** is transformed to alter the spacing of the selected micro-devices. When the transfer surface **214** transfers the selected micro-devices to the destination substrate **206**, the selected micro-devices are in configuration C on the destination substrate **206**. In some implementations, configuration C refers to the configuration of the selected micro-devices on the destination substrate **206** after the selected micro-devices are transferred from the transfer surface **214** to the destination substrate **206**. Configuration C may correspond to a desired configuration of the micro-devices for the micro-device product to be fabricated.

In some implementations, configuration B and configuration A are the same.

In some implementations, the spacing in configuration C differs from the spacing in configuration B on the transfer surface **214** and configuration A on the donor substrate **204**A. Configuration C, for example, may have a configuration having a spacing of micro-devices that cannot be attained from selecting micro-devices on the donor substrate **204**A. In this regard, configuration A selected for the micro-devices **202**A on the donor substrate **204**A can have a spacing that is less than the spacing in configuration C.

The transfer surface **214** receives the micro-devices **202**A in configuration B, which is substantially identical or similar to configuration A. The transfer device **208** is then operated to cause the micro-devices **202**A to be moved from configuration B into configuration C. In some implementations, the transfer surface **214** corresponds to a film that is stretchable to increase the spacing between the micro-devices **202**A received by the transfer surface **214**. The micro-devices **202**A are initially in configuration B on the transfer surface **214**. After the film is stretched, the micro-devices **202**A are transformed into configuration C on the transfer surface **214**. The transfer surface **214** then transfers the micro-devices **202**A to the destination substrate **206** such that the micro-devices **202**A are positioned on the destination substrate in configuration C. In some examples, the transfer surface **214** is stretchable by 5 to 20 times in one or both horizontal dimensions so that the micro-devices on the transfer surface **214** are spaced 5 to 20 times further apart than their original spacing in configuration B.

If the transfer surface **214** is stretched, in some implementations, the adhesive **212** engaging the micro-devices **202**A to the transfer surface **214** is also stretchable to ensure that the micro-devices **202**A remain engaged to the transfer surface **214** after the transfer surface **214** is stretched. The adhesive **212** is, for example, an ultraviolet light curable polymeric material. In some examples, the adhesive **212** is 3D inkjet printable. The adhesive **212** can be a stretchable, flexible elastic polymeric material. In some implementations, the adhesive **212** is elastic deformable such that it elastically elongates between 100% to 500% of its original length. The viscosity of the adhesive **212** is, for example, between 80 and 100 centipoise at 25° C., between 10 and 20 centipoise at 70° C. The modulus of elasticity of the adhesive **212** is, for example, between 5 and 25 MPa at 25° C. The tensile strength of the adhesive **212** is, for example between 1 and 5 MPa with an elastically deformed elongation of 100% to 500% at 25° C.

In some implementations, configuration A on the donor substrate **204**A may not have a uniform spacing between selected micro-devices. For example, failed or missing micro-devices **202**A on the donor substrate **204**A may prevent a configuration of selected micro-devices having uniform spacing. Configuration A is selected, for example, to maximize the number of selected micro-devices having uniform spacing.

If the transfer system **200** includes the detector **216**, the detector **216** detects failed micro-devices **202**A to prevent the failed micro-devices **202**A from being transferred from the donor substrate **204**A to the destination substrate **206**. In particular, if the detector **216** detects failed micro-devices **202**A, the controller **302** selectively operates the adhesive dispenser **210** such that the adhesive **212** is not selectively dispensed at locations corresponding to the locations of the failed micro-devices. As a result, when the controller **302** operates the transfer device **208** to transfer the micro-devices **202**A from the donor substrate **204**A to the transfer surface **214**, the failed micro-devices **202**A do not attach to the transfer surface **214**.

To check the functionality of the LEDs, the detector **216** includes, for example, a radiation emitter and a radiation detector. If the micro-devices **202**A are LEDs, for example, the LEDs can be excited to emit radiation when the LEDs are functioning properly. The radiation emitter emits radiation toward the micro-devices **202**A positioned on the donor substrate **204**A. The radiation excites the micro-devices **202**A that are properly functioning such that the micro-devices **202**A emit optical radiation detectable by the radiation detector. The radiation detector is, for example, a photodetector responsive to a wavelength of light emitted by the micro-devices when excited.

In this regard, signals from the detector **216** are usable, e.g., by the controller **302**, to determine whether a given micro-device **202**A is functioning properly. If the micro-device **202**A is not functioning properly, e.g., the micro-device **202**A is a failed micro-device, the controller **302** controls the adhesive dispenser **210** such that the adhesive **212** is not dispensed on the failed micro-device and the failed micro-device does not attach to the transfer surface **214**. In some examples, the radiation emitted by the detector has a wavelength of 405 nm or shorter to excite the micro-devices.

The presence of failed micro-devices by the detector **216**, in some cases, causes configuration A of the micro-devices **202**A to have a non-uniform spacing. In some implementations, because adhesive **212** was not dispensed on failed micro-devices **202**A on the donor substrate **204**A, when the transfer surface **214** receives the selected micro-devices in configuration A from the donor substrate **204**A, configuration A includes gaps **230** where micro-devices would have been positioned if the micro-devices in those positions on the donor substrate **204**A were functioning properly.

A uniform spacing between the micro-devices when the micro-devices are on the destination substrate **206** can be desirable. For example, assuming that the micro-devices are

LEDs, then gaps caused by absent or defective LEDs on a display panel are visually notable. In this regard, in some implementations, the transfer device **208** is a first transfer device, and, referring to FIG. **2**C, the transfer system **200** includes the second transfer device **218** to fill the gaps **230** with micro-devices that are functioning properly. The second transfer device **218** includes the transfer surface **220** with functioning micro-devices **232**A of the same type as micro-device **202**A. The micro-devices **232**A have been checked using a detector, e.g., a radiation emitter and a radiation detector, to determine that they are functioning properly.

Referring to FIG. **5**, the second transfer device **218** transfers a micro-device **232**A to a receiving substrate **234**. The second transfer device **218**, for example, transfers micro-devices **232**A one at a time to the receiving substrate. The second transfer device **218** is, for example, as shown in FIG. **5**, a rotatable roller **236** including the transfer surface **220** to carry the micro-devices **232**A. The receiving substrate **234** is, for example, the transfer surface **214**. For example, the donor substrate **204**A can include a set of selected micro-devices **202**A in configuration A. The transfer surface **214** of the first transfer device **208** receives the micro-devices **202**A, the micro-devices **202**A having configuration B, which is substantially identical to configuration A.

After the transfer surface **214** of the first transfer device **208** has received the micro-devices **202**A from the donor substrate **204**A in configuration B, the transfer surface **214** of the first transfer device **208** may include the gaps **230**, e.g., due to detection of failed micro-devices **202**A on the donor substrate **204**A. Adhesive **212** is dispensed on the transfer surface **214** of the first transfer device **208**. The second transfer device **218** then causes a functioning micro-device **232**A on the transfer surface **220** of the second transfer device **218** to engage with the adhesive **212** such that the functioning micro-device **232**A is transferred to the transfer surface **214** of the first transfer device **208**. In particular, the functioning micro-device **232**A is positioned on the transfer surface **214** of the first transfer device **208** to fill a gap **230**.

After each of the gaps **230** have been filled, the micro-devices on the transfer surface **214** of the first transfer device **208** have uniform spacing. If necessary, the micro-devices are manipulated to have desired configuration C. In this regard, if configuration B of the micro-devices on transfer surface **214** of the first transfer device **208** includes gaps, to transform the micro-devices to achieve configuration C, the process includes an operation to fill the gaps in configuration B and, in some cases, an operation to alter the spacing of configuration B between the micro-devices. Once the desired spacing has been achieved and the gaps have been filled, the micro-devices are transferred from the transfer surface **214** of the first transfer device **208** to the destination substrate **206** such that the micro-devices have configuration C on the destination substrate **206**.

In some implementations, instead of being a transfer surface of a transfer device, the receiving substrate **234** is the destination substrate **206**. The transfer surface **214** of the first transfer device **208**, for example, transfers the micro-devices to the destination substrate **206** having a desired spacing in accordance with the uniform spacing of desired configuration C. However, when initially positioned on the destination substrate **206**, the micro-devices **202** are not in configuration C due to the gaps between the micro-devices on the destination substrate **206**. After the gaps are filled by the micro-devices **232**A on the second transfer device **218**, the micro-devices are in configuration C on the destination substrate **206**, thus having the desired spacing and pattern defining configuration C. In some examples, to transfer a micro-device **232**A from the transfer surface **220** of the second transfer device **218**, the micro-device **232**A is released from the transfer surface **220** of the second transfer device **218**. The micro-device **232**A, for example, is attached to the transfer surface **220** by an adhesive that is denatured or removed when the micro-device **232**A is positioned at or over the gap to be filled on the destination substrate.

While FIGS. **2**A through **2**C have been described with respect to a single donor substrate **204**A having a single type of micro-device **202**A, alternatively or additionally, a transfer system includes additional donor substrates with additional types of micro-devices. As shown in FIG. **2**A, the transfer system **200** includes a donor substrate **204**B with micro-devices **202**B and a donor substrate **204**C with micro-devices **202**C. If the micro-devices **202**A, **202**B, **202**C are LEDs, the micro-devices **202**A, **202**B, **202**C, for example, each emit a different color light, e.g., red, green, blue, or the like.

The adhesive dispenser **210** dispenses adhesive on each of the donor substrates **204**A, **204**B, **204**C, in particular, on selected micro-devices **202**A, **202**B, **202**C on each of the donor substrate **204**A, **204**B, **204**C. The transfer device **208** uses the transfer surface **214** to pick up the selected micro-devices **202**A, **202**B, **202**C from each of the donor substrates **204**A, **204**B, **204**C. Adhesive **212** is dispensed on the micro-devices **202**A, **202**B, **202**C such that the selected micro-devices **202**A, **202**B, **202**C of each type are in configuration A. In this regard, when received by the transfer surface **214** of the transfer device **208**, the selected micro-devices **202**A, **202**B, **202**C are each in configuration A.

The selected micro-devices **202**A, **202**B, **202**C, altogether, are in configuration B. Configuration B, for example, is further defined by an ordering of the micro-devices **202**A, **202**B, **202**C and spacing between adjacent types of micro-devices **202**A, **202**B, **202**C. With respect to the ordering of the micro-devices **202**A, **202**B, **202**C, in the example shown in FIG. **2**B, going left to right, micro-devices **202**A are followed by micro-devices **202**B, which are in turn followed by micro-devices **202**C. In some implementations, the intra-type spacing between a specific type of micro-device, i.e., between micro-devices **202**A, between micro-devices **202**B, or between micro-devices **202**C, differs from the inter-type spacing between two types of micro-devices, i.e., between a micro-device **202**A and a micro-device **202**B, between a micro-device **202**B and a micro-device **202**C, or between a micro-device **202**A and a micro-device **202**C. Configuration B is defined, in some cases, by inter-type spacing, intra-type spacing, or both.

As described herein, the transfer surface **214** is transformable to increase or decrease intra-type spacing of the micro-devices **202**A, **202**B, **202**C on the transfer surface **214**. The transfer surface **214** is alternatively or additionally transformable to increase the inter-type spacing of the micro-devices **202**A, **202**B, **202**C on the transfer surface **214**. The transfer surface **214** is transformed to attain the desired inter-type and/or the desired intra-type spacing for configuration C of the micro-devices **202**A, **202**B, **202**C on the destination substrate **206**.

In some implementations, the second transfer device **218**, if present, includes functioning micro-devices of each type of the micro-devices **202**A, **202**B, **202**C on the transfer surface **220**. To fill a gap in configuration B, adhesive **212** is placed on the receiving substrate **234**, e.g., the transfer surface **214** of the first transfer device **208**, and then the appropriate type of functioning micro-device is engaged to the adhesive **212**. To fill a gap to achieve configuration C on the destination substrate **206**, the appropriate type of the functioning micro-device is released onto the destination substrate **206**. In some implementations, the system **200** includes multiple second transfer devices, each having a single type of functioning micro-devices. For example, if the system **200** includes three types of micro-devices, the system **200** can include three second transfer devices each having one of the micro-device types.

FIGS. **6**A to **6**F depict sequential operations **600**A to **600**F, respectively, in which the system performs operations including dispensing the powder, fusing the powder, and reclaiming powder that was not fused. Before beginning the operations **600**A to **600**F, the controller (e.g., the controller **302**) of the system can receive electronic data, e.g., computer-aided drafting data, indicative of the array of the micro-devices to be formed. As is described herein, the system uses the controller to control individual sub-systems or components of the system to execute the operations.

In some implementations, as shown in FIG. **6**A, at operation **600**A, the controller operates the detector **216** to detect failed micro-devices on a donor substrate **602**. At operation **600**B shown in FIG. **6**B, the controller operates the adhesive dispenser **210** to dispense the adhesive **212** onto selected micro-devices **604**. In some cases, the system does not detect failed micro-devices and thus, at operation **600**B, dispenses the adhesive **212** onto selected micro-devices **604** without operating a detector to detect failed micro-devices. In some implementations, if the detector **216** is present and detects a failed micro-device **606**, the controller receives a signal indicative of the failed micro-device **606** and controls the adhesive dispenser **210** such that the adhesive dispenser **210** does not dispense adhesive **212** onto the failed micro-device **606**. In some implementations, the controller operates the detector **216** to detect the failed micro-devices within a row of micro-devices, and then the controller operates the adhesive dispenser **210** to dispense the adhesive **212** on the functioning micro-devices in the row of the micro-devices. The controller repeats the detection operation **600**A and dispensing operation **600**B until the adhesive **212** is delivered to the desired number of micro-devices.

At operation **600**C as shown in FIG. **6**C, the controller operates the transfer device **208** to move the transfer surface **214** to engage with the selectively dispensed adhesive **212**. At operation **600**D as shown in FIG. **6**D, the controller operates the transfer device **208** to move the transfer surface **214** relative to the donor substrate **602**, thereby removing the selected micro-devices **604** from the donor substrate **602**. For example, the transfer surface **214** can be lifted away from the donor substrate **602**, e.g., normal to the surface of the donor substrate.

In some implementations, if there is a gap between micro-devices on the transfer surface **214**, for example, due to detection of a failed micro-device on the donor substrate **204**A, the controller operates the second transfer device **218** to fill the gap with a functioning micro-device **610**. For example, at operation **600**E shown in FIG. **6**E, the system causes adhesive **212** to be dispensed at a gap **608** on the transfer surface **214**. The gap **608**, for example, corresponds to a location of where the failed micro-device **606** would have been if the failed micro-device **606** had not failed. To transfer a functioning micro-device **610** on the transfer surface **220** of the second transfer device **218** to the transfer surface **214** of the first transfer device **208**, the controller operates the second transfer device **218** to engage the functioning micro-device **610** with the adhesive **212**.

After operation **600**E if there is a gap **608** or after operation **600**D if there are no gaps, at operation **600**F, the controller operates the transfer device **208** to transfer the micro-devices **604** from the transfer surface **214** to a destination substrate **612**. In particular, the transfer surface **214** can be lowered until the micro-devices **604** abut the destination substrate **612**, the adhesive can be neutralized, and the transfer surface **214** can be lifted away.

The examples described herein with respect to FIGS. **1** to **6**F illustrate some implementations of methods and systems within the scope of the present disclosure. Other implementations are possible. For example, in some implementations, the transfer system **200** includes an etching device to etch a micro-device wafer on a donor substrate into multiple micro-devices. The etching device etches the micro-device wafer into, for example, lateral micro-devices or vertical micro-devices. The etching device uses, for example, a laser scribing or dry etching method to separate the micro-device wafer into micro-devices.

In some implementations, a predefined number of rows of micro-devices are transferred from the donor substrate to the transfer surface during a single transfer operation of micro-devices from the donor substrate to the transfer surface. The transfer surface picks up, for example, 5 to 20 rows of micro-devices from the donor substrate and then transfers these rows to the destination substrate. The transfer surface continues to transfer the predefined number of rows of the micro-devices from the donor substrate to the destination substrate until the desired number of rows have been transferred.

In some implementations, the micro-devices are fabricated into a lateral device in which both p-type and n-type contacts are fabricated on the same side. Photolithography and dry etching are applied to define a mesa structure and to expose an n-type device layer. Transparent conductive oxides layer, e.g., indium tin oxide, is deposited on the p-type device surface to improve current spreading. N-type and p-type ohmic contacts are formed afterwards through photolithography and deposition. A dielectric layer is deposited on the lateral device surface and sidewall to reduce surface leakage current and improve device reliability performance.

In some implementations, the micro-devices are fabricated into a vertical device where the p-type and n-type contacts are made on opposite sides. A reflective mirror can be fabricated on the p-side of the vertical device to improve light extraction. After metallization, the micro-devices are wafer-bonded to a conducting carrier wafer. The destination substrate can then be removed through laser or chemical lift-off method before electrodes are fabricated on the n-type layer.

In some implementations, products may need multiple micro-devices **202**A, **202**B, **202**C of different types in each cell of the product to be formed. For example, for a color LED display may need three micro-LEDs, one for each of red, blue and green. Each micro-LED can provide a sub-pixel. A variety of patterns are possible for the sub-pixels. For example, the different colored sub-pixels can simply be arranged in a single row or column. Alternatively, for example, the sub-pixels within a cell can be arranged in a quincunx pattern with two sub-pixels each of two colors, e.g., red and green, and a single sub-pixel of the third color, e.g., blue (this pattern is also known as a PenTile matrix). The transfer techniques can be used to form displays with more than three color sub-pixels, e.g., a display with red, green, blue and yellow micro-LEDs.

The different color LEDs can be LEDs with phosphor layers that emit differently colored light, or they can be LEDs with different colored filter layers, or they can be LEDs that emit white light but also include an overlaying phosphor material that absorbs the white light and re-emits differently colored light (this material can be quantum dots).

The different micro-devices, e.g., the different color micro-LEDs, can be fabricated on different donor substrates at higher spatial density than needed for the destination substrate. The transfer process can then be performed for each donor substrate. That is, the micro-devices from each particular donor substrate can be transferred to its own transfer substrate. For example, there can be a transfer substrate with blue micro-LEDs, a transfer substrate with red micro-LEDs, and a transfer substrate with green micro-LEDs. For each transfer substrate, a micro-device can be transferred for each cell to the destination substrate.

In some implementations, the destination substrate **206** is a flexible substrate. For example, the destination substrate **206** can be a flexible circuit and micro-devices **110** can be micro-LEDs, thus providing a flexible display screen. Alternatively or in addition, the destination substrate **206** can a stretchable substrate. The destination substrate is, for example, the backplane of a flat-panel display.

In some implementations, both the n-type and p-type contacts and interconnecting circuitry are pre-fabricated on the destination substrate so that transferred micro-devices are electrically connected after they are placed on the destination substrate. In another example, only one type of contact is pre-fabricated on the destination substrate. A shadow mask or photolithography method can be used to fabricate the other type of contact.

The controller can be implemented in digital electronic circuitry, or in computer software, firmware, or hardware, or in combinations of them. The controller can include one or more computer program products, i.e., one or more computer programs tangibly embodied in an information carrier, e.g., in a non-transitory machine readable storage medium or in a propagated signal, for execution by, or to control the operation of, data processing apparatus, e.g., a programmable processor, a computer, or multiple processors or computers. A computer program (also known as a program, software, software application, or code) can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a standalone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

The processes and logic flows described in this specification can be performed by one or more programmable processors executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows can also be performed by, and apparatus can also be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit).

A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made. Accordingly, other implementations are within the scope of the claims.

What is claimed is:

1. A method of transferring micro-devices to a destination substrate, comprising:

selectively dispensing adhesive onto selected micro-devices on a donor substrate based on a desired spacing of the selected micro-devices on the destination substrate such that droplets of adhesive are ejected onto less than all of the micro-devices on the donor substrate, wherein selectively dispensing adhesive comprises ejecting droplets of adhesive onto the micro-devices;

engaging the adhesive on the donor substrate with a transfer surface to cause the selected micro-devices to adhere to the transfer surface; and

transferring each of the selected micro-devices from the donor substrate to the destination substrate using the transfer surface and in accordance to the desired spacing of the selected micro-devices on the destination substrate, wherein transferring the selected micro-devices includes:

withdrawing the transfer surface from the donor substrate such that the selected micro-devices detach from the donor substrate and remain adhered by the adhesive to the transfer surface,

lowering the transfer surface toward the destination substrate so that the selected micro-devices engage the destination substrate, and

withdrawing the transfer surface from the destination substrate with the selected micro-devices remaining on the destination substrate.

2. The method of claim **1**, wherein the micro-devices comprise light emitting diodes.

3. The method of claim **2**, further comprising:

optically exciting the light emitting diodes on the donor substrate and detecting one or more defective micro-devices on the donor substrate; and

selectively dispensing the adhesive such that the adhesive is not dispensed on the one or more defective micro-devices and the selected micro-devices does not comprise the one or more defective micro-devices.

4. The method of claim **3**, further comprising transferring one or more micro-devices to the transfer surface based on a location of the one or more defective micro-devices.

5. The method of claim **1**, wherein the micro-devices are first micro-devices, and the method further comprises

transferring the first micro-devices to the destination substrate; and

transferring second micro-devices to the destination substrate such that the second micro-devices are adjacent to the first micro-devices, the first micro-devices and the second micro-devices both having the desired spacing on the destination substrate,

wherein the first micro-devices are configured to emit a first color light, and the second micro-devices are configured to emit a second color light.

6. The method of claim **5**, wherein a selected first micro-device and a selected second micro-device adjacent to one another define a display pixel for an LED display.

7. The method of claim **1**, further comprising stretching the transfer surface to cause the selected micro-devices to have the desired spacing when the transfer surface transfers the selected micro-devices to the destination substrate.

8. The method of claim **1**, wherein a spacing of the selected micro-devices on the donor substrate corresponds to the desired spacing of the selected micro-devices on the destination substrate.

9. The method of claim **1**, comprising neutralizing the adhesive before withdrawing the transfer surface from the destination substrate.

10. The method of claim **9**, wherein neutralizing the adhesive comprises denaturing the adhesive.

11. The method of claim **10**, wherein denaturing the adhesive comprises illuminating the adhesive.

12. The method of claim **10**, wherein denaturing the adhesive comprises heating the adhesive.

13. The method of claim **9**, wherein neutralizing the adhesive comprises removing the adhesive.

14. The method of claim **13**, wherein removing the adhesive comprises dissolving or melting the adhesive.

15. The method of claim **1**, wherein the transfer surface comprises a roller to receive the selected micro-devices from the donor substrate.

16. The method of claim **1**, wherein the transfer surface comprises a planar surface to receive the selected micro-devices from the donor substrate.

* * * * *

专利名称(译)	微型设备转移的系统和方法		
公开(公告)号	US10692923	公开(公告)日	2020-06-23
申请号	US16/020692	申请日	2018-06-27
[标]申请(专利权)人(译)	应用材料股份有限公司		
申请(专利权)人(译)	APPLIED MATERIALS , INC.		
当前申请(专利权)人(译)	APPLIED MATERIALS , INC.		
[标]发明人	ZHU MINGWEI GANAPATHIAPPAN SIVAPACKIA FU BOYI NG HOU T PATIBANDLA NAG B		
发明人	ZHU, MINGWEI GANAPATHIAPPAN, SIVAPACKIA FU, BOYI NG, HOU T. PATIBANDLA, NAG B.		
IPC分类号	H01L21/66 H01L21/683 H01L27/15 H01L33/48 H01L33/00 H01L23/00 H01L25/075		
CPC分类号	H01L22/22 H01L33/48 H01L27/156 H01L24/741 H01L21/6835 H01L24/83 H01L24/97 H01L33/0095 H01L2221/68368 H01L25/0753 H01L2224/7598 H01L24/75 H01L2224/95136 H01L22/20 H01L2221/68322 H01L2221/68354 H01L2221/68381 H01L21/67721		
代理机构(译)	FISH & RICHARDSON P.C.		
助理审查员(译)	刘 , XIAOMING		
优先权	62/356431 2016-06-29 US		
其他公开文献	US20180315793A1		
外部链接	Espacenet		

摘要(译)

一种用于将微器件定位在衬底上的设备，包括一个或多个支撑施主衬底和目标衬底的支撑件，一种粘合剂分配器，用于在施主衬底上的微器件上传递粘合剂，一种传递设备，其包括传递表面，用于传递给体衬底。从施主衬底到目的衬底的微型器件，以及控制器。 控制器被配置为基于目标基板上所选微型装置的期望间隔，来操作粘合剂分配器以选择性地将粘合剂分配到施主基板上的所选微型装置上。 控制器被配置为操作转移装置，使得转移表面与施主衬底上的粘合剂接合，以使所选的微型器件粘附至转移表面，然后转移表面将所选的微型器件从施主衬底转移至施主衬底。 目标基材。