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Luo et al.

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(54) **METHODS, SYSTEMS, AND APPARATUS FOR INKJET PRINTING SELF-ASSEMBLED MONOLOAYER (SAM) STRUCTURES ON SUBSTRATES**

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Related U.S. Application Data

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(51) **Int. Cl.**

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B41J 2/01	(2006.01)
B41J 11/00	(2006.01)

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

CPC ***B41M 5/0047*** (2013.01); ***B41J 2/01*** (2013.01); ***B41J 11/00*** (2013.01)

(58) **Field of Classification Search**

CPC B41M 5/0047; B41J 2/01; B41J 11/00

See application file for complete search history.

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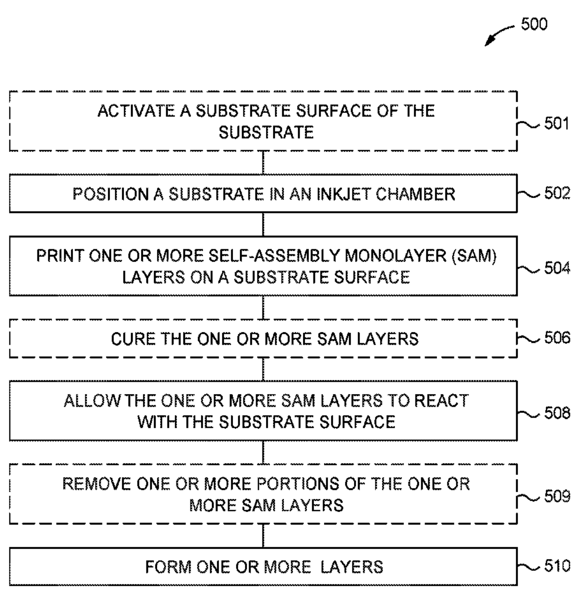
(57) **ABSTRACT**

Embodiments of the present disclosure relate to methods, systems, and apparatus for inkjet printing self-assembled monolayer (SAM) structures on substrates. In one embodiment, which can be combined with other embodiments, one or more SAM layers are printed on a substrate surface of a substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the inkjet chamber. The printing includes spraying one or more subsections of the substrate surface with an ink, the ink having a SAM composition. The SAM composition includes an active component, and a hydrophobic tail.

21 Claims, 8 Drawing Sheets



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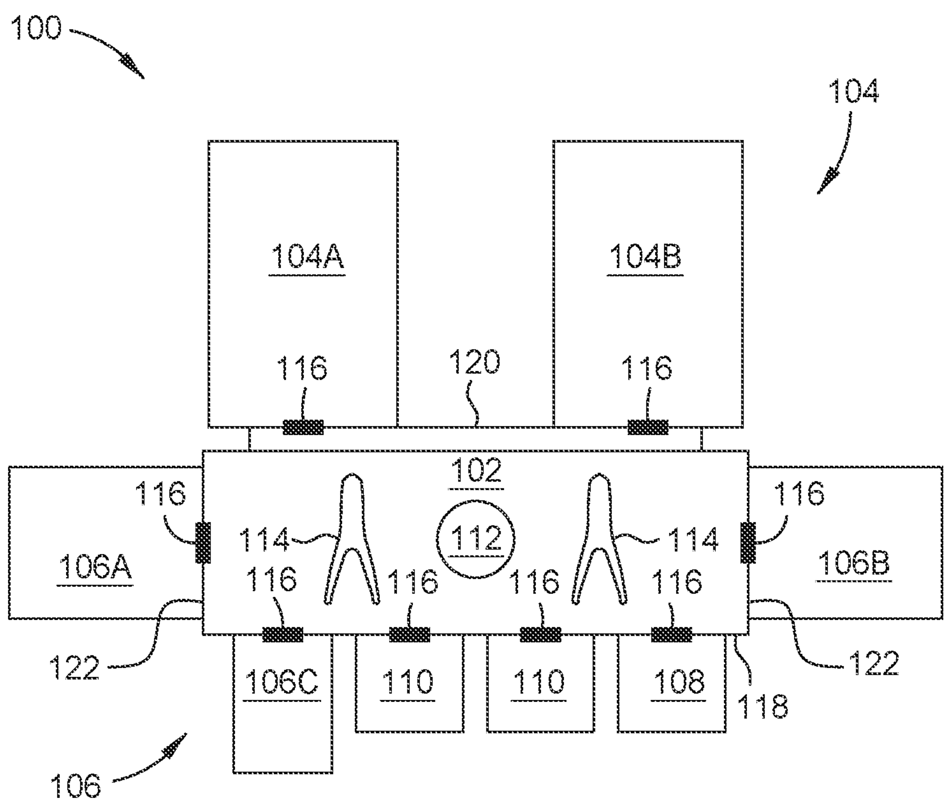
100
104
104A
104B
116
120
116
102
116
114
112
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106A
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106C
110
110
108
118
122
106

FIG. 1

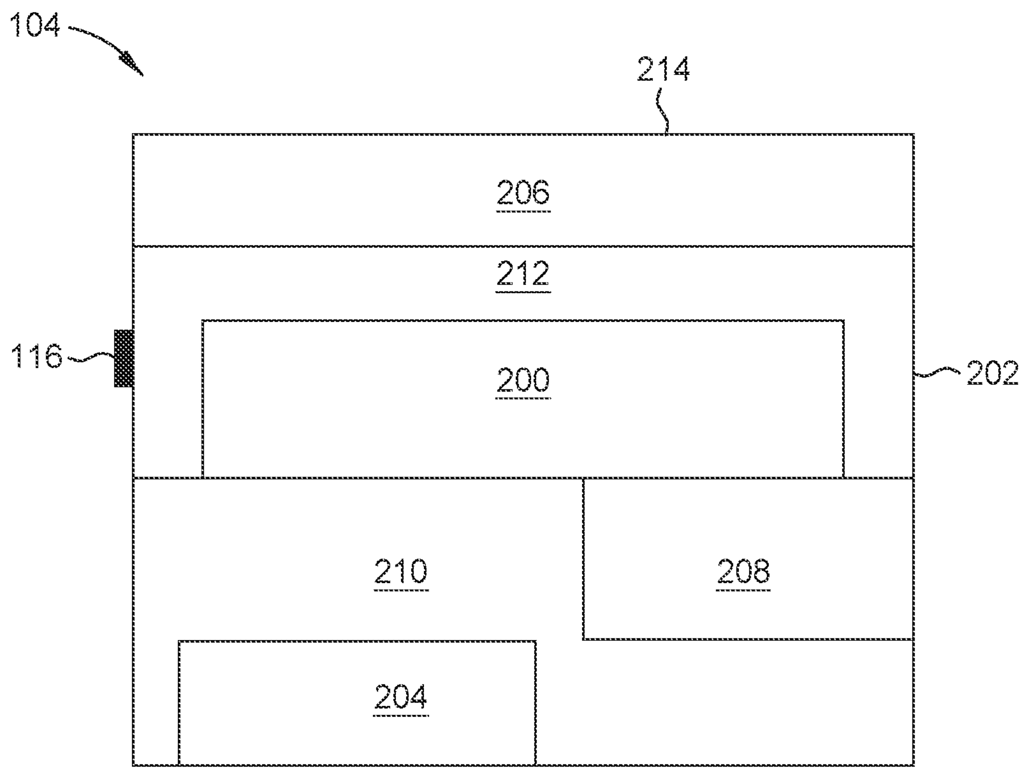


FIG. 2

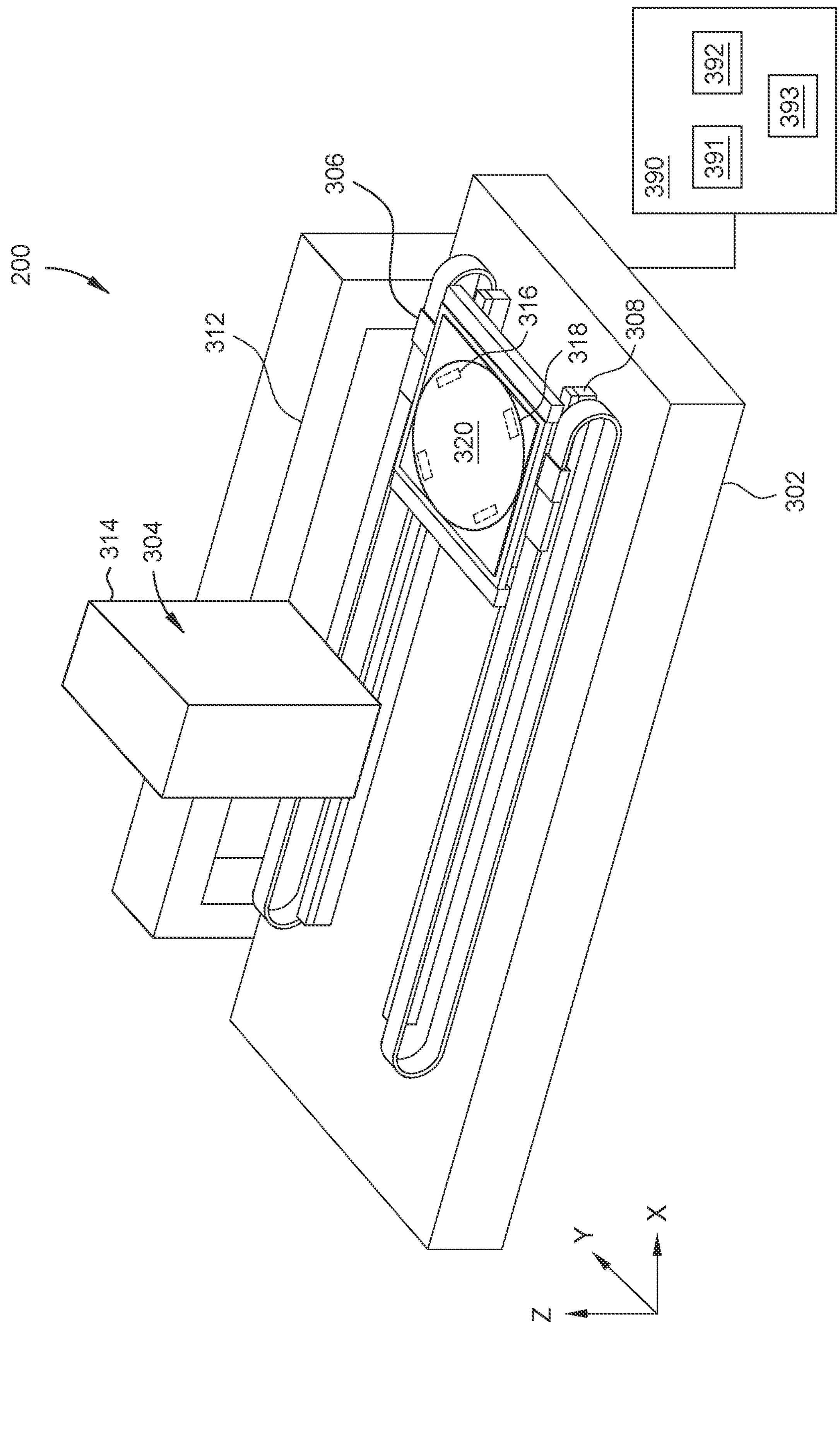
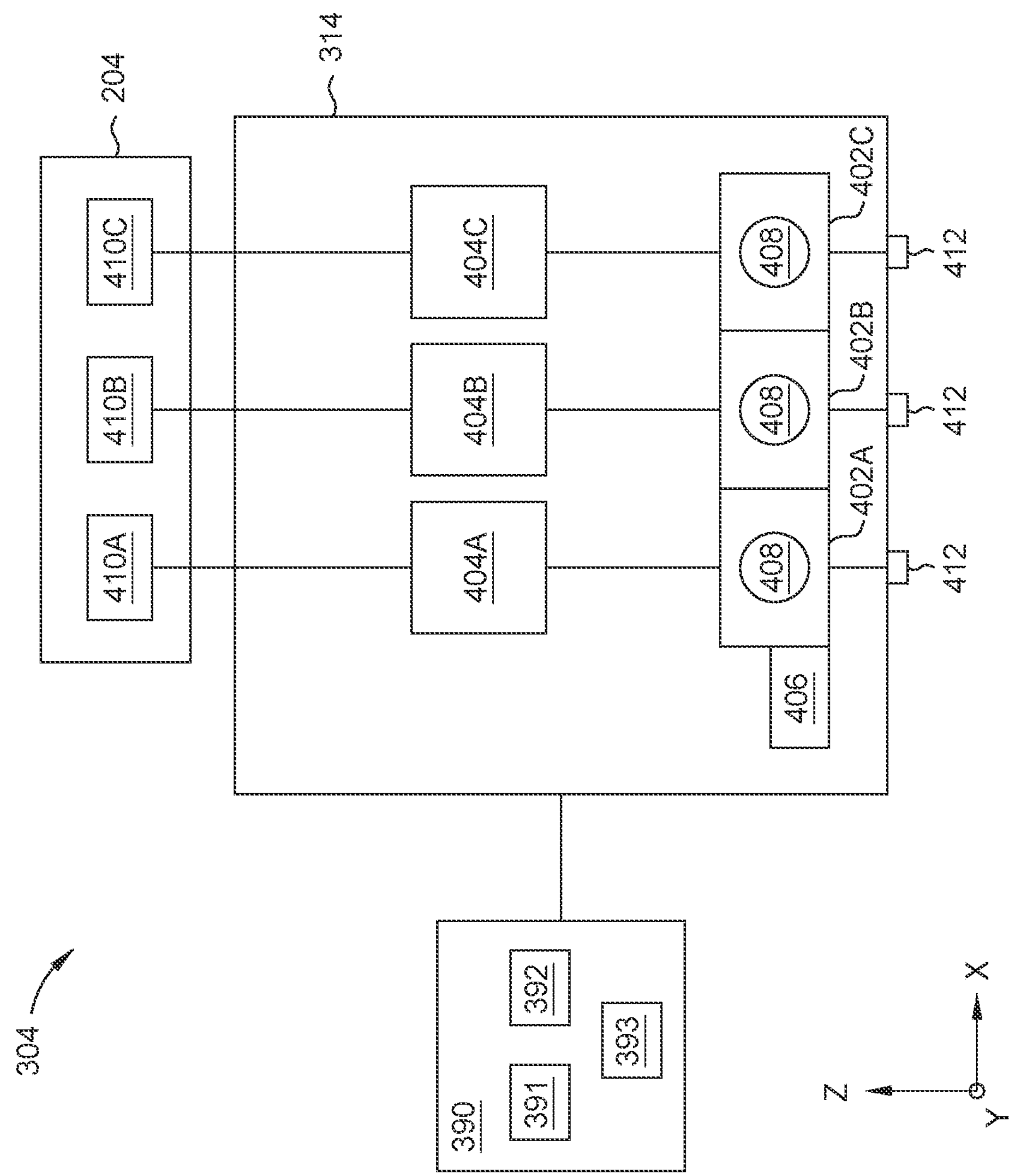


FIG. 3


304
204
314
410A
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412
390
391
392
393
X
Y
Z

FIG. 4

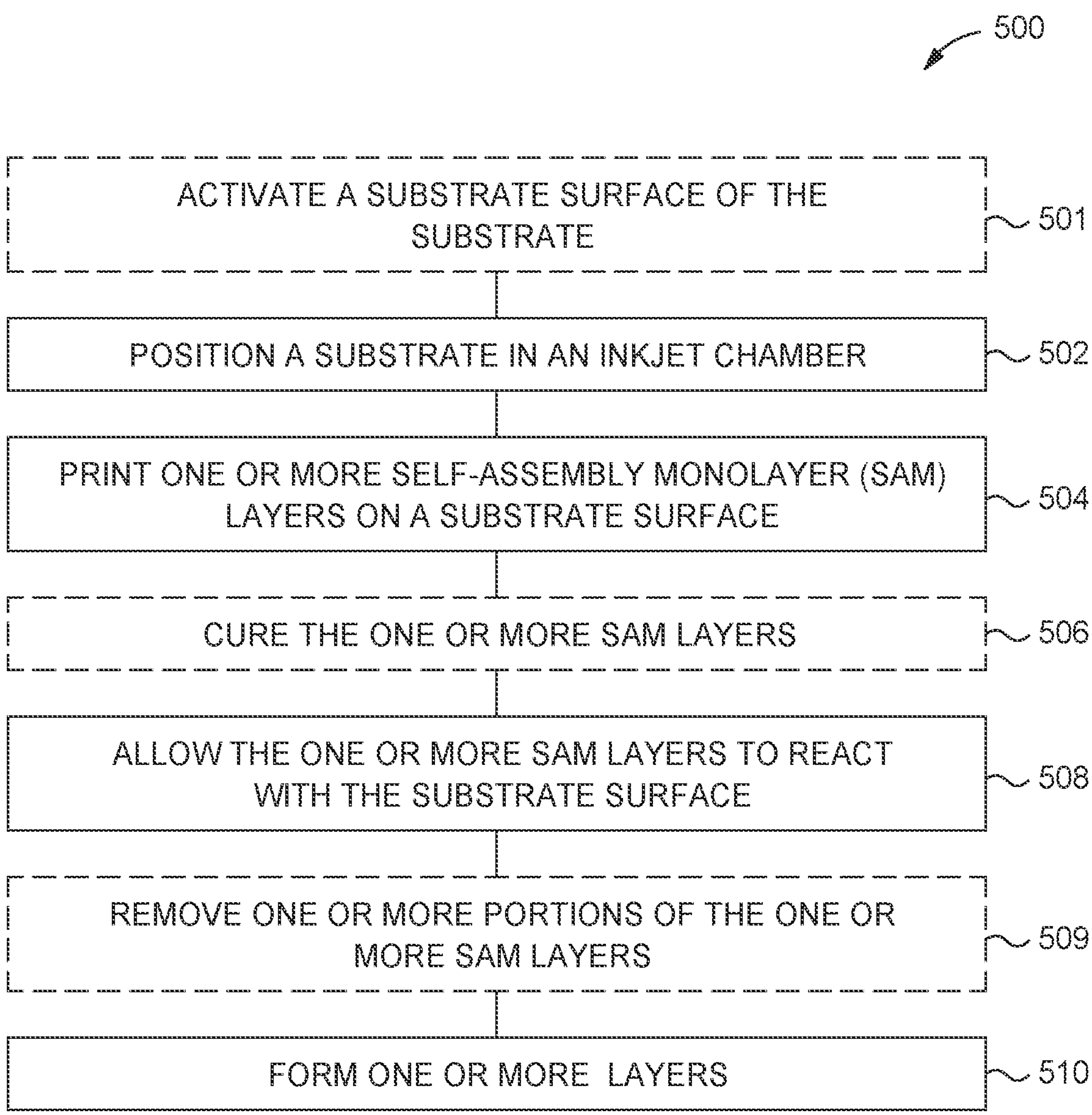
500
ACTIVATE A SUBSTRATE SURFACE OF THE SUBSTRATE
501
POSITION A SUBSTRATE IN AN INKJET CHAMBER
502
PRINT ONE OR MORE SELF-ASSEMBLY MONOLAYER (SAM) LAYERS ON A SUBSTRATE SURFACE
504
CURE THE ONE OR MORE SAM LAYERS
506
ALLOW THE ONE OR MORE SAM LAYERS TO REACT WITH THE SUBSTRATE SURFACE
508
REMOVE ONE OR MORE PORTIONS OF THE ONE OR MORE SAM LAYERS
509
FORM ONE OR MORE LAYERS
510

FIG. 5

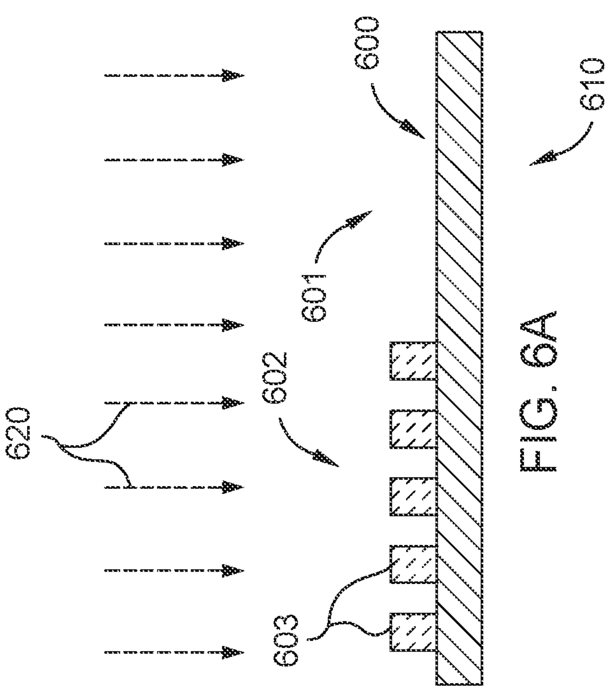

FIG. 6A

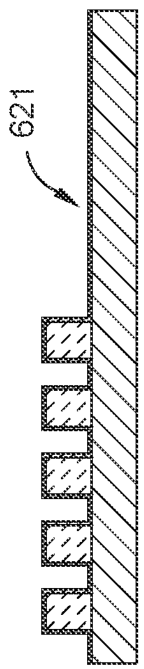

FIG. 6B

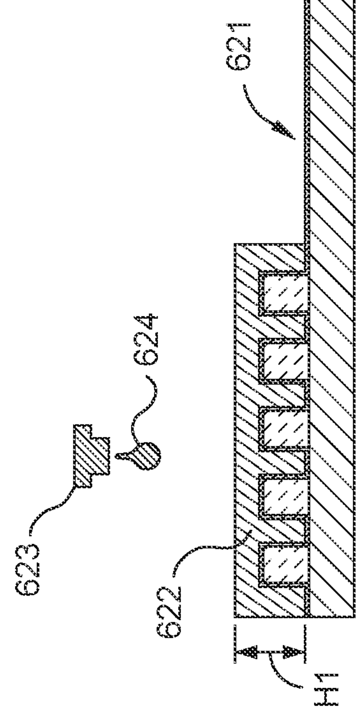

FIG. 6C

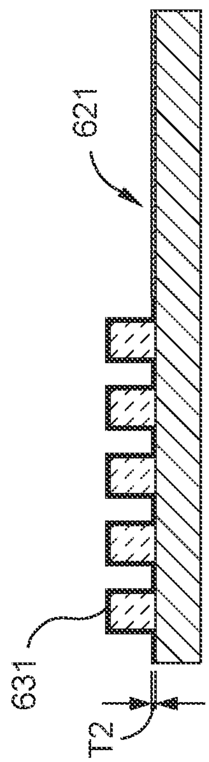

FIG. 6D

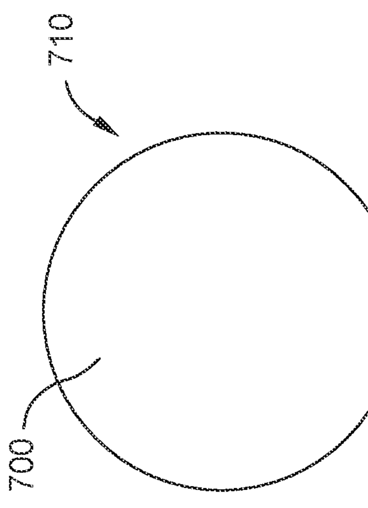

FIG. 7A

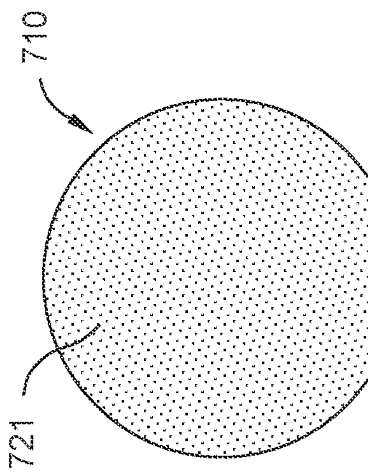

FIG. 7B

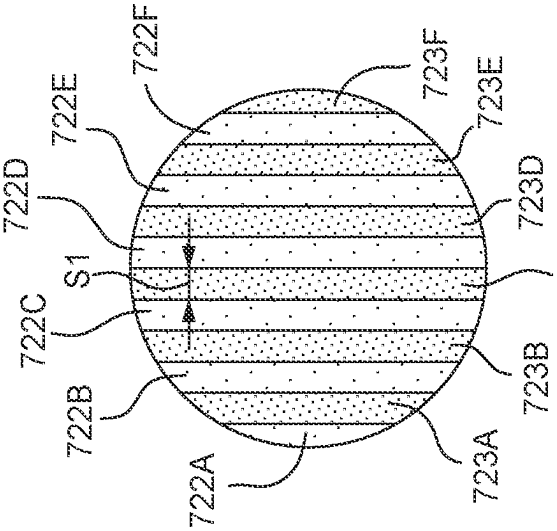

FIG. 7C

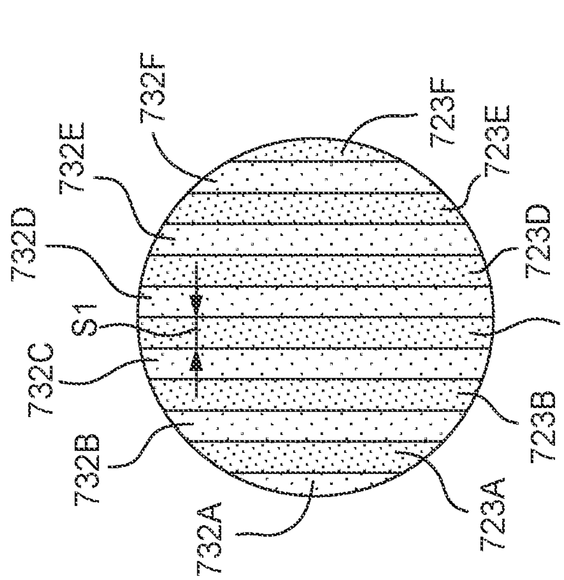

FIG. 7D

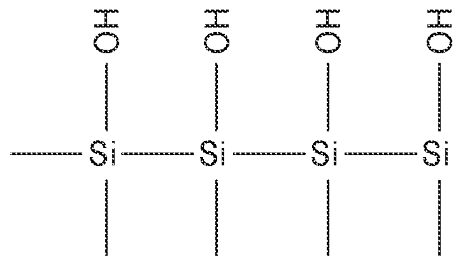

FIG. 8A

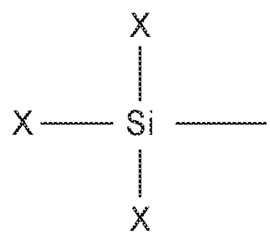

FIG. 8B

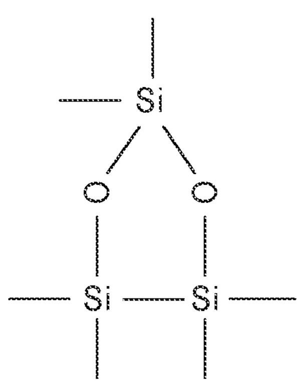

FIG. 8C

METHODS, SYSTEMS, AND APPARATUS FOR INKJET PRINTING SELF-ASSEMBLED MONOLOAYER (SAM) STRUCTURES ON SUBSTRATES

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. provisional patent application Ser. No. 63/339,279, filed May 6, 2022, which is herein incorporated by reference in its entirety.

BACKGROUND

Field

Embodiments of the present disclosure relate to methods, systems, and apparatus for inkjet printing self-assembled monolayer (SAM) structures on substrates.

Description of the Related Art

Surfaces energies and hydrophilicities of substrates can be used in processing operations. However, operations that seek to configure surface energies and/or hydrophilicities can be complex, expensive, and time-consuming. As an example, operations can involve several operations that would otherwise be unnecessary. Moreover, operations can fail to establish spatial control for surface energies and/or hydrophilicities.

Therefore, there is a need for improved methods, systems, and apparatus that facilitate spatial control in a manner that is simple, cost-effective, and time-efficient.

SUMMARY

Embodiments of the present disclosure relate to methods, systems, and apparatus for inkjet printing self-assembled monolayer (SAM) structures on substrates. In one embodiment, which can be combined with other embodiments, one or more SAM layers are printed on a substrate surface of a substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the inkjet chamber. The printing includes spraying one or more subsections of the substrate surface with an ink, the ink having a SAM composition. The SAM composition includes an active component, and a hydrophobic tail.

In one embodiment, which can be combined with other embodiments, a method of forming a self-assembled monolayer (SAM) structure includes positioning a substrate in an inkjet chamber, and printing one or more SAM layers on a substrate surface of the substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the inkjet chamber. The printing includes spraying one or more subsections of the substrate surface with an ink. The ink includes a SAM composition. The SAM composition includes an active component, and a hydrophobic tail. The method includes allowing the one or more SAM layers to react with the substrate surface.

In one embodiment, which can be combined with other embodiments, a non-transitory computer readable medium includes instructions that, when executed, cause a plurality of operations to be conducted. The plurality of operations includes activating a substrate surface of a substrate, and printing one or more SAM layers on the substrate surface of the substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the

inkjet chamber. The printing includes spraying one or more subsections of the substrate surface with an ink. The ink includes a SAM composition. The SAM composition includes an active component, and a hydrophobic tail. The plurality of operations includes curing the one or more SAM layers, and allowing the one or more SAM layers to react with the substrate surface.

In one embodiment, which can be combined with other embodiments, a system for processing substrates includes an inkjet chamber configured to conduct a printing operation, a stage positioned in the inkjet chamber, and an inkjet printer head positioned in the inkjet chamber. The system includes an activation chamber configured to conduct an activation operation, and a curing chamber configured to conduct a curing operation. The system also includes a controller communicatively coupled to the stage, the inkjet printer head, the activation chamber, and the curing chamber. The controller includes instructions that, when executed, cause a plurality of operations to be conducted. The plurality of operations includes printing one or more SAM layers on a substrate surface of a substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the inkjet chamber. The printing includes the inkjet printer head spraying one or more subsections of the substrate surface with an ink. The ink includes a SAM composition. The SAM composition includes an active component, and a hydrophobic tail. The plurality of operations includes allowing the one or more SAM layers to react with the substrate surface.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments of the present disclosure and are therefore not to be considered limiting of scope, as the disclosure may admit to other equally effective embodiments.

FIG. **1** is a schematic partial top view of an inkjet printing platform, according to one or more embodiments.

FIG. **2** is a schematic partial side-view of an inkjet chamber, according to one or more embodiments.

FIG. **3** is a schematic partial perspective view of an inkjet printer, according to one or more embodiments.

FIG. **4** is a schematic partial side-view of a processing apparatus, according to one or more embodiments.

FIG. **5** is a schematic flowchart of a method of forming a self-assembled monolayer (SAM) structure, according to one or more embodiments.

FIGS. **6**A-**6**D are schematic operation flow side views of a portion of the method shown in FIG. **5**, according to one or more embodiments.

FIGS. **7**A-**7**D are schematic operation flow top views of a portion of the method shown in FIG. **5**, according to one or more embodiments.

FIG. **8**A is a schematic diagram view of a bond structure of the activated surface shown in FIG. **7**B, according to one or more embodiments.

FIG. **8**B is a schematic diagram view of a bond structure of the ink shown in FIG. **6**C, according to one or more embodiments.

FIG. **8**C is a schematic diagram view of a bond structure of the reacted surfaces shown in FIG. **7**D, according to one or more embodiments.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

Embodiments of the present disclosure relate to methods, systems, and apparatus for inkjet printing self-assembled monolayer (SAM) structures on substrates. In one embodiment, which can be combined with other embodiments, one or more SAM layers are printed on a substrate surface of a substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the inkjet chamber. The printing includes spraying one or more subsections of the substrate surface with an ink, the ink having an SAM composition. The SAM composition includes an active component, and a hydrophobic tail.

Unless specified otherwise, the chemicals referred to herein can have any number of atoms for the elements included (e.g., stoichiometric or non-stoichiometric).

FIG. **1** is a schematic partial top view of an inkjet printing platform **100**, according to one or more embodiments. The present disclosure contemplates that inkjet printing platforms other than the inkjet printing platform **100** can be used. As an example, inkjet printing platforms can omit certain features shown in FIG. **1** and/or can include certain features not shown in FIG. **1**.

The inkjet printing platform **100** is part of a system for processing substrates. The inkjet printing platform **100** includes a transfer chamber **102**, one or more inkjet chambers **104** (e.g., two inkjet chambers **104**A, **104**B are shown), a plurality of auxiliary modules **106** (e.g., three auxiliary modules **106**A-**106**C are shown), a substrate flipper **108**, and load ports **110**. The transfer chamber **102** includes a pre-aligner **112** and two transfer robots **114** disposed therein. The transfer robots **114** are operable to transfer one or more substrates from the load ports **110** and between the plurality of auxiliary modules **106**, the substrate flipper **108**, the pre-aligner **112**, and the inkjet chambers **104**. The inkjet printing platform **100** is operable to process a substrate to form an optical film and/or an optical device. In one embodiment, which can be combined with other embodiments, the substrate is an optical device substrate. The processing of the substrate may include an inkjet printing operation. The substrate is any suitable substrate on which an optical device or optical device film may be formed. In embodiment, which can be combined with other embodiments, the substrate includes, but is not limited to, silicon (Si), silicon nitride (SiN), silicon dioxide (SiO_2), fused silica, quartz, silicon carbide (SiC), germanium (Ge), silicon germanium (SiGe), indium phosphide (InP), gallium arsenide (GaAs), gallium oxide (GaO), diamond, lithium niobate ($LiNbO_3$), gallium nitride (GaN), sapphire, tantalum oxide (Ta_2O_5), titanium dioxide (TiO_2), or any combination(s) thereof. The substrate may have a diameter in a range from about 100 mm to about 750 mm. In one embodiment, which can be combined with other embodiments, the substrate has a surface area of about 1,000 cm^2 or more. In embodiment, which can be combined with other embodiments, the surface area of the substrates may be about 2,000 cm^2 or more, such as about 4,000 cm^2 or more.

The inkjet printing operation conducted in the inkjet printing platform **100** assists in the fabrication of at least one optical device or an optical film. It is to be understood that the at least one optical device described herein is an exemplary optical device and other optical devices may be used with or modified to accomplish aspects of the present disclosure. In one embodiment, which can be combined with other embodiments, the optical device is a waveguide combiner. The waveguide combiner may be utilized for virtual, augmented, or mixed reality. In one embodiment, which can be combined with other embodiments, the optical device is a micro-lens array. In one embodiment, which can be combined with other embodiments, the optical device is utilized for prescription glasses. In one embodiment, which can be combined with other embodiments, the optical device is a flat optical device, such as a metasurface.

Prior to printing, the substrates are removed from the at least one load port **110** by one of the transfer robots **114** and transferred to the transfer chamber **102**. The load ports **110** are formed in a first portion **118** of the transfer chamber **102**. Upon completion of printing in the inkjet printing platform **100**, the printed substrates may be returned to the respective load ports **110** from which the substrates were initially removed. The load ports **110** are configured to automatically load and unload the substrates. The substrates can be accessed by the transfer robots **114** through a slit valve **116** formed between the load ports **110** and the transfer chamber **102**. The transfer robots **114** are configured to handle edges of a backside surface of the substrate to avoid backside surface contamination.

Prior to printing, the transfer robot **114** places the substrate on the pre-aligner **112**. The pre-aligner **112** may be positioned in the transfer chamber **102**. The pre-aligner **112** is operable to at least one of: read an identification of a substrate and/or detect an orientation of the substrate. The pre-aligner **112** is configured to align the substrate in a desired rotational orientation and/or a desired lateral orientation within the inkjet printing platform **100** based on the identification and the orientation of the substrate. In one embodiment, which can be combined with other embodiments, the pre-aligner **112** includes a heat source, such as lamps or infrared generating radiant heaters, adapted to heat the substrate to a desired temperature. The pre-aligner **112** can further be pressurized under a vacuum condition to ensure that any undesirable water or other contamination is removed from the surface of the substrate prior to processing.

The transfer robots **114** are operable to position the substrate in one of a plurality of auxiliary modules **106**. For example, as shown in FIG. **1**, the inkjet printing platform **100** includes a first auxiliary module **106**A, a second auxiliary module **106**B, and a third auxiliary module **106**C. The plurality of auxiliary modules **106** are coupled to at least one of side portions **122**, the first portion **118** or a second portion **120** of the transfer chamber **102**. For example, as shown in FIG. **1**, the first auxiliary module **106**A is coupled to the side portion **122**, the second auxiliary module **106**B is coupled to the first portion **118**, and the third auxiliary module **106**C is coupled to the first portion **118**. The plurality of auxiliary modules are coupled to the transfer chamber **102** via a plurality of slit valves **116**. The transfer robots **114** place the substrates into the auxiliary modules **106**A-**106**C via the slit valves **116**. The plurality of auxiliary modules **106** can be selectively isolated from the transfer chamber **102** by use of the slit valves **116** that are disposed between each of the plurality of auxiliary modules **106** and the transfer chamber **102**. The first auxiliary module **106**A is at least one of an activation module (such as a plasma module), film formation module, oxidation module, reaction module, lithography module, baking module, chilling module, ultraviolet (UV) curing module, thermal curing module, and/or imprinting module. The second auxiliary module **106**B is at least one of an activation module (such as a plasma module), film formation module, oxidation module, reaction module, lithography module, baking module, chilling module, ultraviolet (UV) curing module, thermal curing module, and/or imprinting module. The third auxiliary module **106**C is at least one of an activation module (such as a plasma module), film formation module, oxidation module, reaction module, lithography module, baking module, chilling module, ultraviolet (UV) curing module, thermal curing module, and/or imprinting module. The substrate may be transferred to one of the plurality of auxiliary modules **106** prior to the inkjet printing operation or after the inkjet printing operation performed in the inkjet chamber(s) **104**. Although the three auxiliary modules **106A-106**C are shown in FIG. **1**, the inkjet printing platform **100** is not limited in the number of auxiliary modules included. For example, one or more (such as one, or four or more) auxiliary modules **106** may be coupled to the transfer chamber **102**.

The transfer robots **114** are operable to position the substrate in one of the inkjet chambers **104**. For example, as shown in FIG. **1**, the inkjet printing platform **100** includes the first inkjet chamber **104**A and the second inkjet chamber **104**B. The inkjet chambers **104** may be coupled to the second portion **120** of the transfer chamber **102** opposing the third auxiliary module **106**C, the load ports **110**, and the substrate flipper **108**. The inkjet chambers **104** are operable to perform an inkjet printing operation on the substrate. The inkjet printing operation facilitates selective coating of the substrate with an inkjet material to avoid contamination in sensitive areas of the substrate. The thickness and/or height of the inkjet material on the substrate may be modulated with the inkjet printing operation to form a thickness profile and/or a height profile. Additionally, the inkjet printing operation can minimize material usage when forming the optical films or the substrates. In one embodiments, which can be combined with other embodiments, the inkjet printing operation, in combination with a subsequent film formation operation performed in one of the plurality of auxiliary modules **106**, may form a plurality of optical device structures on the substrate. The optical device structures may be nanostructures having sub-micron dimensions, e.g., nano-sized dimensions. In one embodiment, which can be combined with other embodiments, one or more of the plurality of auxiliary modules **106** is an activation module (such as an oxidation module) configured to conduct an activation operation on the substrates prior to the inkjet printing operation.

The first inkjet chamber **104**A and the second inkjet chamber **104**B are coupled to the transfer chamber **102** via a set of the plurality of slit valves **116**. The transfer robots **114** place the substrates into the first inkjet chamber **104**A and the second inkjet chamber **104**B through the slit valves **116**. The plurality of slit valves **116** provide an opening for a portion of the transfer robot **114** to enter into the inkjet chambers **104** to place the substrate on a stage (shown in FIG. **3**). The first inkjet chamber **104**A and the second inkjet chamber **104**B can be selectively isolated from the transfer chamber **102** by use of the slit valves **116** that are disposed between each of the first inkjet chamber **104**A and the transfer chamber **102**, as well as the second inkjet chamber **104**B and the transfer chamber **102**. The first inkjet chamber **104**A and the second inkjet chamber **104**B can further be pressurized under a vacuum condition when the slit valve **116** is closed to ensure that any undesirable water or other contamination is removed from the surface of the substrate during the inkjet printing operation. Each of the first inkjet chamber **104**A and the second inkjet chamber **104**B may be different than the other inkjet chamber. For example, the first inkjet chamber **104**A may be configured to deposit a different inkjet material than the second inkjet chamber **104**B. Although two inkjet chambers **104** are shown in FIG. **1**, the inkjet printing platform **100** is not limited in the number of inkjet chambers **104**. For example, one or more (such as one, or four or more) inkjet chambers **104** may be coupled to the transfer chamber **102**.

After the inkjet printing operation is performed in the at least one inkjet chamber **104**, the transfer robots **114** are operable to position the substrate in the substrate flipper **108**. The substrate flipper **108** may be coupled to the first portion **118** of the transfer chamber **102**. The substrate flipper **108** is coupled to the transfer chamber **102** via a slit valve **116**. The substrate flipper **108** flips the substrate such that a backside surface of the substrate is facing upwards. The substrate may be removed from the substrate flipper **108** and positioned in one of the plurality of auxiliary modules **106** and/or one of the inkjet chambers **104**. The substrate flipper **108** allows for double-side processing of the substrate. The capability of double-side processing allows the inkjet printing platform **100** to form functional optical films or optical devices on both surfaces of the substrate, which largely expands the design space and functionality of the substrate.

FIG. **2** is a schematic partial side-view of an inkjet chamber **104**, according to one or more embodiments. The present disclosure contemplates that inkjet chambers other than the inkjet chamber **104** can be used. As an example, inkjet chambers can omit certain features shown in FIG. **2** and/or can include certain features not shown in FIG. **2**.

The inkjet chamber **104** may correspond to the first inkjet chamber **104**A and/or the second inkjet chamber **104**B shown in FIG. **1**. The inkjet chamber **104** is included in the inkjet printing platform **100**. The inkjet chamber **104** includes an enclosure **202**. The enclosure **202** encloses an inkjet printer **200**, a fluid supply manifold **204**, a fan filter unit **206**, and an exhaust port **208** within the inkjet chamber **104**. The inkjet printer **200** and the fan filter unit **206** are disposed in a processing region **212** of the inkjet chamber. An inkjet printing operation is performed with the inkjet printer **200** within the processing region **212**. The exhaust port **208** and the fluid supply manifold **204** are disposed in a lower region **210** of the inkjet chamber **104**. The lower region **210** is disposed below the processing region **212**. The enclosure **202** includes a slit valve **116** therethrough such that a transfer robot **114** (shown in FIG. **1**) may position the substrate in the processing region **212**.

The fluid supply manifold **204** is disposed in the lower region **210**. The fluid supply manifold **204** may include a plurality of supply fluids. For example, the fluid supply manifold **204** may include maintenance fluids utilized for maintenance of the inkjet chamber **104**. The fluid supply manifold **204** may also include material sources, such as inkjet materials, utilized in the inkjet printing operation. The fluid supply manifold **204** may be fluidly coupled to the inkjet printer **200**.

The exhaust port **208** is disposed in the lower region **210**. The exhaust port **208** is fluidly coupled to the processing region **212**. The exhaust port **208** is operable to remove contaminants from the processing region **212** that are produced during processing. In one embodiment, which can be combined with other embodiments, contaminants such as volatile organic compounds (VOCs) generated by the inkjet material and/or maintenance materials are removed via the exhaust port **208**. The processing region **212** can be maintained at a negative pressure to facilitate avoiding the contaminants leaking outside of the inkjet chamber **104**.

The fan filter unit **206** is disposed in the processing region **212**. The fan filter unit **206** is coupled to a top surface **214** of the enclosure **202**. The fan filter unit **206** is operable to create a vertical flow of clean, dry air through the processing region **212**. The fan filter unit **206** can maintain the processing region **212** at a positive pressure to facilitate minimizing air and particle intake from outside the inkjet chamber **104**. The fan filter unit **206** and the exhaust port **208** can provide independent pressure control in the processing region **212**. The fan filter unit **206** and the exhaust port **208** can provide for control of the processing region **212**. The control of the processing region **212** facilitates ensuring process quality and consistency when processing the substrates.

FIG. **3** is a schematic partial perspective view of an inkjet printer **200**, according to one or more embodiments. The present disclosure contemplates that inkjet printers other than the inkjet printer **200** can be used. As an example, inkjet printers can omit certain features shown in FIG. **3** and/or can include certain features not shown in FIG. **3**.

The inkjet printer **200** is disposed in a processing region **212** (shown in FIG. **2**) of an inkjet chamber **104** (shown in FIG. **2**). The inkjet printer **200** includes a stage **306** and a processing apparatus **304**. The stage **306** is supported by a pair of tracks **308** disposed on a slab **302**. A substrate **320** is supported by the stage **306**. The stage **306** moves along the pair of tracks **308** in at least one of an X direction, a Y direction, and/or a Z direction, as indicated by the coordinate system shown in FIG. **3**. In one embodiment, which can be combined with other embodiments, the pair of tracks **308** is a pair of parallel magnetic channels. As shown, each track **308** of the pair of tracks **308** is linear. The pair of tracks **308** may have a non-linear shape. In one embodiment, which can be combined with other embodiments, an encoder is coupled to the stage **306** in order to provide information of the location of the stage **306** to a controller **390**. The controller **390** is generally designed to facilitate the control and automation of the inkjet printing operation described herein, along with other operations. The controller **390** may be communicatively coupled to the processing apparatus **304**, the stage **306**, and the encoder.

The processing apparatus **304** is coupled to a support **312**. The processing apparatus **304** is disposed over the pair of tracks **308**. The pair of tracks **308** and the stage **306** are operable to pass under the processing apparatus **304**. The processing apparatus **304** is supported over the slab **302** by the support **312**. The processing apparatus **304** includes a case **314**. The processing apparatus **304** is operable to distribute one or more inkjet materials onto the substrate **320**. The substrate **320** is positioned on the stage **306** via one of the transfer robots **114** (shown in FIG. **1**). The stage **306** may include vacuum slots **316** to retain the substrate **320**. The vacuum slots **316** are between 1 millimeter and 5 millimeters from an edge **318** of the substrate **320**. In one embodiment, which can be combined with other embodiments, the vacuum slots **316** are elevated from the surface of the stage **306**. The vacuum slots **316** retain the substrate **320** while minimizing contact to a backside surface of the substrate **320** and contamination of the substrate **320**.

The implementations described herein include the controller **390** configured to control various features to conduct the operations described herein. The controller **390** includes a central processing unit (CPU) **391**, a memory **392** containing instructions, and support circuits **393** for the CPU **391**. The controller **390** controls the various items directly, or via other computers and/or controllers. In embodiment, which can be combined with other embodiments, the controller **390** is communicatively coupled to dedicated controllers, and the controller **390** functions as a central controller.

The controller **390** is of any form of a general-purpose computer processor that is used in an industrial setting for controlling various substrate processing chambers and equipment, and sub-processors thereon or therein. The memory **392**, or non-transitory computer readable medium, is one or more of a readily available memory such as random access memory (RAM), dynamic random access memory (DRAM), static RAM (SRAM), and synchronous dynamic RAM (SDRAM (e.g., DDR1, DDR2, DDR3, DDR3L, LPDDR3, DDR4, LPDDR4, and the like)), read only memory (ROM), floppy disk, hard disk, flash drive, or any other form of digital storage, local or remote. The support circuits **393** are coupled to the CPU **391** for supporting the CPU **391** (a processor). The support circuits **393** include cache, power supplies, clock circuits, input/output circuitry and subsystems, and the like. Operational parameters (such as a reaction temperature) and operations are stored in the memory **392** as a software routine that is executed or invoked to turn the controller **390** into a specific purpose controller to control the operations of the various chambers/modules described herein. The controller **390** is configured to conduct any of the operations described herein. The instructions stored on the memory **192**, when executed, cause one or more of operations **502**-**510** of method **500** (described below) to be conducted.

The various operations described herein (such as the operations **502**-**510** of the method **500**) can be conducted automatically using the controller **390**, or can be conducted automatically or manually with certain operations conducted by a user.

The controller **390** is communicatively coupled to: an inkjet chamber configured to conduct a printing operation, a stage positioned in the inkjet chamber, an inkjet printer head positioned in the inkjet chamber, an activation chamber configured to conduct an activation operation, a curing chamber configured to conduct a curing operation, a reaction chamber configured to allow the reaction to occur at the reaction temperature, and/or a film formation chamber configured to conduct a film formation operation. The controller **390** can be disposed within the one or more inkjet chambers **104**A, **104**B or externally to the one or more inkjet chambers **104**A, **104**B.

FIG. **4** is a schematic side-view of a processing apparatus **304**, according to one or more embodiments. The present disclosure contemplates that processing apparatus other than the processing apparatus **304** can be used. As an example, processing apparatus **304** can omit certain features shown in FIG. **4** and/or can include certain features not shown in FIG. **4**.

The processing apparatus **304** may be disposed in an inkjet printer **200** (shown in FIG. **2**). The processing apparatus **304** is operable to distribute one or more inkjet materials onto the substrate **320** (shown in FIG. **3**). The processing apparatus **304** includes a plurality of printheads **402**A-**402**C, a plurality of ink recirculation modules **404**A-**404**C, at least one alignment camera **406**, and a plurality of alignment mechanisms **408**. The plurality of printheads **402**A-**402**C, the plurality of ink recirculation modules **404**A-**404**C, the at least one alignment camera **406**, and the plurality of alignment mechanisms **408** are disposed in a case **314** of the processing apparatus **304**.

The processing apparatus **304** may include one or more printheads **402**A-**402**C. For example, as shown in FIG. **4**, the processing apparatus **304** includes a first printhead **402**A, a second printhead **402**B, and a third printhead **402**C. Although only three of the plurality of printheads **402**A-**402**C are shown in FIG. **4**, the processing apparatus **304** is not limited in the number of printheads **402**A-**402**C included in the case **314**. For example, one or more printheads **402**A-**402**C may be included in the case **314**. In one embodiment, which can be combined with other embodiments, a first inkjet chamber **104**A (shown in FIG. **1**) includes three printheads **402**A-**402**C and a second inkjet chamber **104**B (shown in FIG. **1**) includes four printheads. In one embodiment, which can be combined with other embodiments, the first inkjet chamber **104**A (shown in FIG. **1**) and the second inkjet chamber **104**B (shown in FIG. **1**) include the same number of printheads **402**A-**402**C in the processing apparatus **304**.

A fluid supply manifold **204** disposed in the inkjet chamber **104** includes one or more inkjet material sources **410**A-**410**C. Each inkjet material source **410**A-**410**C is fluidly coupled to one of the plurality of printheads **402**A-**402**C. For example, a first inkjet material source **410**A is coupled to the first printhead **402**A, a second inkjet material source **410**B is coupled to the second printhead **402**B, and a third inkjet material source **410**C is coupled to the third printhead **402**C. In one embodiment, which can be combined with other embodiments, each inkjet material source **410**A-**410**C may be loaded with different inkjet materials. In one embodiment, which can be combined with other embodiments, the same inkjet material may be loaded into at least two inkjet material sources **410**A-**410**C. In one embodiment, which can be combined with other embodiments, each of the inkjet material sources **410**A-**410**C includes a different inkjet material. Including the same inkjet material in multiple inkjet material sources **410**A-**410**C facilitates improving throughput and the print resolution of the inkjet printing operation. Including multiple inkjet materials in each inkjet chamber **104** facilitates increasing the array of inkjet materials that may be deposited in the inkjet operation. For example, each inkjet material may have different material properties, such as viscosity, to tune the optical film or the optical device to be formed by the inkjet printing operation. The multiple inkjet materials further enables different materials to physically and/or chemically interact with each other on the substrate to create films and structures that require multiple inkjet materials, thus increasing the variety of optical films and optical devices formed.

As shown in FIG. **1**, the first inkjet chamber **104**A and the second inkjet chamber **104**B are coupled to the transfer chamber **102**. The first inkjet chamber **104**A and the second inkjet chamber **104**B each include a processing apparatus **304** with the one or more printheads **402**A-**402**C. The configuration of the inkjet printing platform **100** facilitates improving the possible spectrum of optical films and optical devices that are produced in the inkjet printing platform **100** with increased quality. The quality of the optical films, optical device structures, and/or optical devices improves because a wide array of inkjet materials are able to be deposited within the inkjet printing platform **100**. Therefore, the optical films, optical device structures, and/or optical devices to be formed remain in the environment of the inkjet printing platform **100** to avoid contamination. The possible spectrum of optical films and optical devices that are produced in the inkjet printing platform **100** is increased due to the first inkjet chamber **104**A including a first set of one or more printheads **402**A-**402**C configured to deposit an inkjet material with a first viscosity range and the second inkjet chamber **104**B including a second set of one or more printheads **402**A-**402**C configured to deposit an inkjet material with a second viscosity range. The first viscosity range is different from the second viscosity range. Examples of the inkjet materials include, but are not limited to, acrylate, oil, aqueous, and/or solvent based formulations.

In embodiment, which can be combined with other embodiments, the one or more printheads **402**A-**402**C in the first inkjet chamber **104**A are configured to deposit different inkjet materials than the one or more printheads **402**A-**402**C in the second inkjet chamber **104**B. For example, the first inkjet chamber **104**A can include thermal printheads and the second inkjet chamber **104**B can include piezo printheads. Each different type of printhead is operable to deposit inkjet materials of different physical and chemical properties. In such an example, the viscosity of the inkjet materials to be deposited in the first inkjet chamber **104**A is different than the viscosity of the inkjet material in the second inkjet chamber **104**B. In one embodiment, which can be combined with other embodiments, aqueous inks may be deposited in the first inkjet chamber **104**A and oil-based inks can be deposited in the second inkjet chamber **104**B. Further, as each of the processing apparatus **304** in the first inkjet chamber **104**A and the second inkjet chamber **104**B can deposit multiple different inkjet materials, the range of inkjet materials that may be deposited in the inkjet printing platform increases. Each printhead **402**A-**402**C can deposit a different inkjet material. For example, the first inkjet chamber **104**A may deposit two or more different aqueous inkjet materials and the second inkjet chamber **104**B may deposit two or more different oil-based inkjet materials.

Each of the one or more printheads **402**A-**402**C includes a nozzle **412**. Additionally, the nozzle **412** of each of the one or more printheads **402**A-**402**C may be different. For example, a nozzle size of the nozzles **412** of each of the one or more printheads **402**A-**402**C further allows for a range of inkjet materials to be deposited. The nozzle of each of the printheads **402**A-**402**C in the first inkjet chamber **104**A and the second inkjet chamber **104**B can be chosen specifically based on the physical and chemical properties of the inkjet materials to be deposited. Therefore, inkjet materials with different physical and chemical properties can be deposited in the first inkjet chamber **104**A and the second inkjet chamber **104**B, respectively. The nozzle sizes of the nozzles **412** can be the same.

The first inkjet chamber **104**A and the second inkjet chamber **104**B can be configured to deposit inkjet materials having physical and chemical properties that are not compatible within the same processing apparatus **304**. Further, the first inkjet chamber **104**A and the second inkjet chamber **104**B are in communication via the transfer chamber **102**. As such, the inkjet printing platform **100** is configured such that different inkjet materials may physically and/or chemically interact with each other on the substrate **320** to create optical films, optical device structures, and/or optical devices without leaving the environment of the inkjet printing platform. Therefore, the formation of optical films, optical device structures, and/or optical devices that otherwise are difficult to form with a homogeneous ink composition may be formed. The first inkjet chamber **104**A includes one or more printheads **402**A-**402**C configured to deposit an inkjet material with the first viscosity range and the second inkjet chamber **104**B includes one or more printheads **402**A-**402**C configured to deposit an inkjet material with the second viscosity range. The first viscosity range is different than the second viscosity range. For example, the first viscosity range is an aqueous inkjet material and the second viscosity range is an oil-based inkjet material.

Each of the plurality of printheads **402**A-**402**C are coupled to one of the alignment mechanisms **408**. The alignment mechanisms **408** align each of the plurality of printheads **402**A-**402**C to each other. The plurality of printheads **402**A-**402**C are aligned with a translational offset less than about 5 μm. The plurality of printheads **402**A-**402**C are aligned within a rotational offset less than about 5 arcmin. Each of the plurality of printheads **402**A-**402**C can be moved in at least the X direction, the Y direction, and/or the Z direction. In one embodiment, which can be combined with other embodiments, the alignment mechanisms **408** are knobs coupled to the plurality of printheads **402**A-**402**C. The knobs may be adjusted to align the plurality of printheads **402**A-**402**C.

The plurality of ink recirculation modules **404**A-**404**C are disposed in the case **314**. The plurality of ink recirculation modules **404**A-**404**C are disposed above the plurality of printheads **402**A-**402**C. Each ink recirculation module **404**A-**404**C is fluidly coupled to one of the plurality of printheads **402**A-**402**C. For example, a first ink recirculation module **404**A is coupled to the first printhead **402**A, a second ink recirculation module **404**B is coupled to the second printhead **402**B, and a third ink recirculation module **404**C is coupled to the third printhead **402**C. The plurality of ink recirculation modules **404**A-**404**C are operable to circulate the inkjet material such that the inkjet material continuously flows through the processing apparatus **304**. The continuous flow of the inkjet material improves the deposition of the inkjet material during the inkjet printing operation by reducing inkjet material settlement and clogging in the processing apparatus **304**.

The processing apparatus **304** further includes at least one alignment camera **406**. The alignment camera **406** is disposed in the case **314**. The alignment camera **406** is operable to align the substrate within the inkjet printer **200** (shown in FIG. **2**). A transfer robot **114** (shown in FIG. **1**) provides the substrate into the inkjet chamber **104** and positions the substrate on a stage **306** (shown in FIG. **3**). The at least one alignment camera **406** will derive the spatial coordinates of the substrate to ensure the substrate is aligned with respect to the processing apparatus **304** in the inkjet printer **200** (shown in FIG. **2**). The alignment camera **406**, in communication with the controller **390**, adjusts the stage **306** to align the substrate **320** relative to the nozzles **412**. The alignment camera **406** is operable to move in the Z direction to focus on the substrate. The substrate **320** may be aligned when the backside surface of the substrate is facing upward.

FIG. **5** is a schematic flowchart of a method **500** of forming a self-assembled monolayer (SAM) structure, according to one or more embodiments.

Optional operation **501** includes activating a substrate surface of the substrate. In one embodiment, which can be combined with other embodiments, the substrate surface is exposed to one or more of a plasma, ultraviolet (UV) light, and/or ozone (**03**) to activate the substrate surface **600**. In one embodiment, which can be combined with other embodiments, the substrate surface **600** is exposed to UV light and ozone. In embodiment, which can be combined with other embodiments, substrate surface is exposed to plasma, and the plasma is an oxygen plasma.

In one embodiment, which can be combined with other embodiments, the activation oxidizes the substrate surface **600**. In embodiment, which can be combined with other embodiments, the activation forms active silanol in the substrate surface. In embodiment, which can be combined with other embodiments, the substrate is activated in a chamber (such as an auxiliary chamber, for example a plasma chamber) that is different than the inkjet chamber referenced in operation **502**. The present disclosure also contemplates that the substrate can be activated in the inkjet chamber, and operation **501** can be conducted after operation **502**.

Operation **502** includes positioning a substrate in an inkjet chamber. The substrate can be positioned on a stage. The positioning can include causing relative movement between the stage and a processing apparatus that includes one or more inkjet nozzles. The relative movement can be cause by moving one or both of the stage and/or the processing apparatus. The positioning can align the substrate relative to the one or more inkjet nozzles.

Operation **504** includes printing one or more SAM layers on a substrate surface of the substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the inkjet chamber. In one embodiment, which can be combined with other embodiments, the one or more SAM layers include a plurality of SAM layers printed in a spatial manner such that a first SAM layer is spaced from a second SAM layer. The printing includes spraying one or more subsections of the substrate surface with an ink that includes a SAM composition. The SAM composition includes an active component and a hydrophobic tail. The spatial manner leaves a portion of the substrate surface exposed to a processing region of the inkjet chamber. The processing region can be at least part of an internal volume of the inkjet chamber. In embodiment, which can be combined with other embodiments, the exposing of operation **501** occurs prior to the printing of operation **504**.

The active component includes one or more of silane, thiol (—SH), amine (—NH_2), acid (—COOH), and/or alcohol (—OH). In one embodiment, which can be combined with other embodiments, the silane includes one or more of —$SiCl_3$, —$SiBr_3$, —$SiMe_2Cl$, —$SiMe_2Br$, —$Si(OMe)_3$, —$Si(OEt)_3$, —SiH_3, and/or —$SiMe_2H$. In one embodiment, which can be combined with other embodiments, the silane includes one or more of trichlorosilane (HCl_3Si), trimethoxysilane ($(CH_3O)_3SiH$), triethoxysilane ($HSi(OC_2H_5)_3$), and/or dichloromethylsilane (CH_3SiHCl_2). Other materials are contemplated for the silane. The hydrophobic tail includes one or more of: one or more C1-C20 Alkanes, a copolymer, polyethylene glycol (PEG), polydimethylsiloxane (PDMS), polypropylene glycol (PPG), polyacrylate, one or more polymethacrylates, polystyrene, and/or one or more derivatives thereof. In one embodiment, which can be combined with other embodiments, the one or more C1-C20 Alkanes are perfluorinated or partially fluorinated, or non-fluorinated. The back bond of the Alkanes can be linear or branched. Other organic functionalities can be included for the hydrophobic tail, such as one or more of an ether, an ester, an amide, a ketone, a vinyl, an alkynyl, a carbonate, and/or a urethane.

In one embodiment, which can be combined with other embodiments, the SAM composition includes one or more of a polymer and/or an oligomer, in addition to the active component and the hydrophobic tail. The polymer includes one or more of a copolymer, perfluoropolyether (PFPE), polyethylene glycol (PEG), polydimethylsiloxane (PDMS), polypropylene glycol (PPG), polyacrylate, one or more polymethacrylates, polystyrene, and/or one or more derivatives thereof.

In one embodiment, which can be combined with other embodiments, the SAM composition includes one or more of a solvent and/or an additive, in addition to the active component and the hydrophobic tail. The solvent includes one or more of an organic alkane, an alkene, alcohol, an ester, an ether, a carbonate, and/or a fluorinated solvent. The additive includes one or more of: one or more amphiphilic materials, one or more copolymers, and/or one or more charged molecules. The fluorinated solvent includes one or more of 3M™ Fluorinert™ electronic liquid FC-40, 3M™ Novec™ 7200 engineered fluid, an AsahiKlin™ AE-3000 series solvent, AMOLEA™ AT2, NEXT 3000, and/or EnSolv® NEXT. Other fluorinated solvent(s) are contemplated for the solvent.

Optional operation **506** includes curing the one or more SAM layers prior to the allowing of the one or more SAM layers to react with the substrate surface (of operation **508**). The curing includes ultraviolet (UV) curing and/or thermal curing. In one embodiment, which can be combined with other embodiments, the curing cures the polymer of the one or more SAM layers. In embodiment, which can be combined with other embodiments, the curing occurs after all of the one or more SAM layers are printed. In embodiment, which can be combined with other embodiments, the one or more SAM layers are cured in a chamber (such as an auxiliary chamber, for example a curing chamber) that is different than the inkjet chamber referenced in operation **502** after transferring the substrate out of the inkjet chamber. The present disclosure also contemplates that the substrate can be cured in the inkjet chamber.

Operation **508** includes allowing the one or more SAM layers to react with the substrate surface. The SAM composition of the one or more SAM layers reacts with the silanol of the substrate surface to form siloxane. The one or more SAM layers are allowed to react with the substrate surface at a reaction temperature and for a reaction time. The reaction temperature is within a range of an ambient temperature (such as room temperature) to 200 degrees Celsius. The reaction time is within a range of 1 second to 10 minutes. The polymer has a glass transition temperature (Tg) that is less than the reaction temperature. In embodiment, which can be combined with other embodiments, the one or more SAM layers react with the substrate surface in a chamber (such as an auxiliary chamber, for example a reaction chamber) that is different than the inkjet chamber referenced in operation **502** after transferring the substrate out of the inkjet chamber. The present disclosure also contemplates that the reaction can occur in the inkjet chamber.

The present disclosure contemplates that the activating the substrate surface, the reaction, and/or the curing can take place in the inkjet chambers **104**A, **104**B, the auxiliary modules **106**A-**106**C, and/or one or more chambers not shown in FIG. **1**.

Optional operation **509** includes removing one or more portions of the one or more SAM layers after the allowing of the one or more SAM layers to react with the substrate surface. In one embodiment, which can be combined with other embodiments, the one or more portions are stripped away using a solvent. In embodiment, which can be combined with other embodiments, the solvent is organic or water. The removed one or more portions are upper sections of the one or more SAM layers that include a polymer matrix.

The present disclosure contemplates that the removal of the one or more portions can take place in the inkjet chambers **104**A, **104**B, the auxiliary modules **106**A-**106**C, and/or one or more chambers not shown in FIG. **1**.

Operation **510** includes forming one or more layers over the portion of the substrate surface that is left exposed in operation **504**. In one embodiment, which can be combined with other embodiments, the one or more layers are device function layers. In one embodiment, which can be combined with other embodiments, the one or more layers are deposited using atomic layer deposition (ALD), such as area-selective ALD (AS-ALD). The present disclosure contemplates that other formation operations may be used, such as one or more of: epitaxial deposition, multi-beam-epitaxy (MBE), ion-beam-assisted-deposition (IBAD), physical vapor deposition (PVD), chemical vapor deposition (CVD, such as plasma-enhanced CVD or flowable CVD), nanoimprinting lithography, photolithography patterning, a liquid material pour casting process, a spin-on glass, a spin-on coating process, a liquid spray coating process, a dry powder coating process, a screen printing process, and/or a doctor blading process. In one embodiment, which can be combined with other embodiments, the one or more layers include one or more of silicon (Si), phosphorus (P), germanium (Ge), silicon oxide, silicon nitride, silicon oxynitride, metal, metal oxide, metal nitride, metal oxynitride, metal silicide, metal silicate, and/or metal carbide. In embodiment, which can be combined with other embodiments, the metal includes one or more of titanium (Ti), tantalum (Ta), tungsten (W), aluminum (Al), chromium (Cr), and/or hafnium (Hf). Other metals are contemplated.

In one embodiment, which can be combined with other embodiments, the one or more layers are deposited using ALD, and the one or more layers include one or more of metal oxide, metal nitrile, conducting metal, and/or noble metal. The metal oxide includes one or more of aluminum oxide (Al_2O_3), silicon dioxide (SiO_2), hafnium oxide (HfO_2), tantalum pentoxide (Ta_2O_5), titanium dioxide (TiO_2), zirconium dioxide (ZrO_2). The metal nitrile includes one or more silicon nitride (Si_3N_4), titanium nitride (TiN), tantalum nitride (TaN), and/or aluminum nitride (AlN). The conducting metal includes one or more of copper (Cu) and/or tungsten (W). The noble metal includes one or more of iridium (Ir), ruthenium (Ru), and/or palladium (Pd). Other materials are contemplated for the metal oxide, the metal nitrile, the conducting metal, and/or the noble metal.

The present disclosure contemplates that the formation of the one or more layers can take place in the auxiliary modules **106**A-**106**C and/or one or more chambers not shown in FIG. **1**.

The present disclosure contemplates that the operations of the method **500** can be conducted at least partially simultaneously with each other. As an example, the positioning of operation **502** can be conducted at least partially simultaneously with the printing of operation **504**. As an example, the curing of operation **506** can be conducted at least partially simultaneously with the reaction of operation **508**.

FIGS. **6**A-**6**D are schematic operation flow side views of a portion of the method **500** shown in FIG. **5**, according to one or more embodiments.

FIG. **6**A shows a substrate **610** having a substrate surface **600**. The substrate surface **600** includes a planar portion **601** and a non-planar portion **602**. The non-planar portion **602** includes a plurality of nanostructures **603**, such as gratings. During the activation operation of operation **501**, the substrate surface **600** is exposed to a material **620**. The material **620** includes one or more of a plasma, UV light, and/or ozone.

FIG. 6B shows the substrate surface **600** activated into an activated surface **621**. In one embodiment, which can be combined with other embodiments, the substrate surface **600** is exposed to one or more of a plasma, ultraviolet (UV) light, and/or ozone (O_3) to activate the substrate surface **600**. In one embodiment, which can be combined with other embodiments, the substrate surface **600** is exposed to UV light and ozone. In one embodiment, which can be combined with other embodiments, the activation of the substrate surface **600** oxidizes the substrate surface **600**. The activation of the substrate surface **600** generates active silanol in the active surface **621**.

FIG. 6C shows a SAM layer **622** printed onto the non-planar portion **602** of the activated surface **621**. As described herein, the SAM layer **622** can include materials such as one or more polymers and/or additives. The SAM layer **622** is printed to a height H1 that is up to 1.0 micron. The height H1 of the SAM layer **622** exceeds a height of the nanostructures **603** to facilitate a more complete coating of the nanostructures **603** with the SAM layer **602**. In embodiment, which can be combined with other embodiments (such as in the implementation shown in FIG. 6C), the SAM layer **622** is printed to the height H1, and the SAM layer **622** has a varying printed thickness due to the nanostructures. The SAM layer **622** is printed by one or more nozzles **623** spraying an ink **624** onto the activated surface **621**. The SAM layer **622** reacts with the silanol of the activated surface **621** to form a reacted surface **631** (shown in FIG. 6D) of the SAM layer **622**. The reacted surface **631** includes siloxane. In one embodiment, which can be combined with other embodiments, the ink **624** includes a polymer to facilitate reduced or eliminated vaporization and/or contamination of the SAM layer **622** throughout the method **500**. The reduced vaporization and contamination facilitate reduced material consumption and enhanced performance.

FIG. 6D shows the reacted surface **631**. Upper sections of the SAM layer **622** are removed, leaving the reacted surface **631**. The upper sections have excess SAM material. The reacted surface **631** has a thickness T2 within a range of 0.1 nm to 5.0 nm, such as 1.00 nm to 5.0 nm. In one embodiment, which can be combined with other embodiments, the thickness T2 is less than 2.0 nm. In a subsequent film formation operation, one or more layers can be formed over the exposed activated surface **621**. The reacted surface **631** having siloxane facilitates reduced or eliminated film formation over the non-planar portion **602**.

The reacted surface **631** has a surface energy (such as surface tension) that is lower than a surface energy of the activated surface **621**. The reacted surface **631** has a water contact angle that is higher than a water contact angle of the activated surface **621**. The reacted surface **631** is hydrophobic and the activated surface **621** is hydrophilic. The lower surface energy facilitates reduced or eliminated film formation over the non-planar portion **602**.

FIGS. 7A-7D are schematic operation flow top views of a portion of the method **500** shown in FIG. **5**, according to one or more embodiments.

FIG. 7A shows a bare silicon (Si) substrate **710** having a substrate surface **700**. The substrate **710** is planar.

FIG. 7B shows the substrate surface **700** activated into an activated surface **721**.

FIG. 7C shows a plurality of SAM layers **722**A-**722**F printed on the substrate surface (which is activated as the activated surface **721**) in a spatial manner. The SAM layers **722**A-**722**F are printed in a spatial manner such that a first SAM layer **722**C is spaced from a second SAM layer **722**D by a spacing **51**. FIG. 7C also shows exposed portions **723**A-**723**F of the activated surface **721**.

FIG. 7D shows the SAM layers **722**A-**722**F reacted into a plurality of reacted surfaces **732**A-**732**F.

FIG. **8**A is a schematic diagram view of a bond structure of the activated surface **721** shown in FIG. **7**B, according to one or more embodiments. The bond structure shown in FIG. **8**A shows silanol.

FIG. **8**B is a schematic diagram view of a bond structure of the ink **624** shown in FIG. 6C, according to one or more embodiments. In the bond structure, silicon "Si" is bonded with an element of functional group "X." In one embodiment, which can be combined with other embodiments, the element "X" includes one or more of chlorine (Cl), an alkoxy, hydroxide, (OH), and/or methoxy (OMe).

FIG. **8**C is a schematic diagram view of a bond structure of the reacted surfaces **732**A-**732**F shown in FIG. **7**D, according to one or more embodiments. The bond structure shown in FIG. **8**C shows siloxane. The present disclosure contemplates that the bottom Si atoms shown in FIG. **8**C can be bonded in a side-by-side configuration to the Si atoms shown in FIG. **8**A.

Benefits of the present disclosure include localized control and spatial control of deposition of SAM layer(s); simplicity and reduced complexity of operations; reduced costs; reduced consumption of materials; reduced or eliminated vaporization of SAM materials; reduced or eliminated contamination of SAM materials; and time-efficiency. The present disclosure facilitates localized patterning of SAM layer(s) in a manner that is relatively quick, simple, and cost-efficient.

It is contemplated that one or more aspects disclosed herein may be combined. As an example, one or more aspects, features, components, and/or properties of the inkjet printing platform **100**, the inkjet chamber **104**, the inkjet printer **200**, the processing apparatus **304**, the method **500**, the operation flow shown in FIGS. **6**A-**6**D, the operation flow shown in FIGS. **7**A-**7**D, and/or the bond structure(s) shown in FIGS. **8**A-**8**C may be combined. Moreover, it is contemplated that one or more aspects disclosed herein may include some or all of the aforementioned benefits.

While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof. The present disclosure also contemplates that one or more aspects of the embodiments described herein may be substituted in for one or more of the other aspects described. The scope of the disclosure is determined by the claims that follow.

What is claimed is:

1. A method of forming a self-assembled monolayer (SAM) structure, the method comprising:

positioning a substrate in an inkjet chamber;

printing one or more SAM layers on a substrate surface of the substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the inkjet chamber, the printing comprising:

spraying one or more subsections of the substrate surface with an ink, the ink comprising a SAM composition, and the SAM composition comprising:

an active component, and

a hydrophobic tail;

allowing the one or more SAM layers to react with the substrate surface; and

removing upper sections of the one or more SAM layers after the allowing of the one or more SAM layers to react with the substrate surface.

2. The method of claim **1**, wherein the one or more SAM layers include a plurality of SAM layers printed in a spatial manner such that a first SAM layer is spaced from a second SAM layer.

3. The method of claim **1**, further comprising forming one or more layers over the portion of the substrate surface.

4. The method of claim **1**, further comprising activating the substrate surface prior to the printing of the one or more SAM layers, and the activating comprises exposing the substrate surface to one or more of an oxygen plasma, UV light, or ozone.

5. The method of claim **1**, further comprising removing one or more portions of the one or more SAM layers after the allowing of the one or more SAM layers to react with the substrate surface.

6. The method of claim **1**, wherein the substrate surface comprises silanol, and the SAM composition reacts with the silanol to form siloxane.

7. The method of claim **1**, wherein the SAM composition further comprises one or more of a polymer or an oligomer.

8. The method of claim **7**, wherein the polymer includes one or more of a copolymer, perfluoropolyether (PFPE), polyethylene glycol (PEG), polydimethylsiloxane (PDMS), polypropylene glycol (PPG), polyacrylate, one or more polymethacrylates, polystyrene, or one or more derivatives thereof.

9. The method of claim **7**, wherein the one or more SAM layers are allowed to react with the substrate surface at a reaction temperature, and the polymer has a glass transition temperature (Tg) that is less than the reaction temperature.

10. The method of claim **7**, further comprising curing the one or more SAM layers to cure the polymer prior to the allowing of the one or more SAM layers to react with the substrate surface, the curing including one or more of ultraviolet (UV) curing or thermal curing.

11. The method of claim **7**, wherein the SAM composition further comprises one or more of a solvent or an additive, wherein:

the solvent includes one or more of an organic alkane, an alkene, alcohol, an ester, an ether, a carbonate, or a fluorinated solvent; or

the additive includes one or more of: one or more amphiphilic materials, one or more copolymers, or one or more charged molecules.

12. The method of claim **1**, wherein each of the upper sections includes a polymer matrix, and the removing of the upper sections comprises stripping the upper sections using a solvent that is organic or water.

13. The method of claim **1**, wherein the active component includes one or more of silane, thiol, amine, acid, or alcohol.

14. The method of claim **13**, wherein the hydrophobic tail includes one or more C1-C20 Alkanes having a back bond that is linear or branched, and the one or more C1-C20 Alkanes are perfluorinated, partially fluorinated, or non-fluorinated.

15. The method of claim **14**, wherein the hydrophobic tail includes one or more of an ether, an ester, an amide, a ketone, a vinyl, an alkynyl, a carbonate, or a urethane.

16. The method of claim **13**, wherein the hydrophobic tail includes one or more of a copolymer, polyethylene glycol (PEG), polydimethylsiloxane (PDMS), polypropylene glycol (PPG), polyacrylate, one or more polymethacrylates, polystyrene, or one or more derivatives thereof.

17. A system for processing substrates, comprising:

an inkjet chamber configured to conduct a printing operation;

a stage positioned in the inkjet chamber;

an inkjet printer head positioned in the inkjet chamber;

an activation chamber configured to conduct an activation operation;

a curing chamber configured to conduct a curing operation; and

a controller communicatively coupled to the stage, the inkjet printer head, the activation chamber, and the curing chamber, the controller comprising instructions that, when executed, cause a plurality of operations to be conducted, the plurality of operations comprising:

the operations of the method of claim **1**.

18. The system of claim **17**, further comprising:

a reaction chamber configured to allow the reaction to occur at a reaction temperature; and

a film formation chamber configured to conduct a film formation operation.

19. A non-transitory computer readable medium comprising instructions that, when executed, cause a plurality of operations to be conducted, the plurality of operations comprising:

activating a substrate surface of a substrate;

printing one or more SAM layers on the substrate surface of the substrate in a localized manner such that a portion of the substrate surface is left exposed, the printing comprising:

spraying one or more subsections of the substrate surface with an ink, the ink comprising a SAM composition, and the SAM composition comprising:

an active component, and

a hydrophobic tail;

curing the one or more SAM layers;

allowing the one or more SAM layers to react with the substrate surface; and

removing upper sections of the one or more SAM layers after the allowing of the one or more SAM layers to react with the substrate surface.

20. A method of forming a self-assembled monolayer (SAM) structure, the method comprising:

positioning a substrate in an inkjet chamber;

printing one or more SAM layers on a substrate surface of the substrate in a localized manner such that a portion of the substrate surface is left exposed to a processing region of the inkjet chamber, the printing comprising:

spraying one or more subsections of the substrate surface with an ink, the ink comprising a SAM composition, and the SAM composition comprising:

an active component,

a hydrophobic tail, and

a polymer; and

allowing the one or more SAM layers to react with the substrate surface, the one or more SAM layers allowed to react with the substrate surface at a reaction temperature, and the polymer has a glass transition temperature (Tg) that is less than the reaction temperature.

21. The method of claim **20**, wherein the SAM composition further comprises an oligomer.

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