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Luo et al.

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(54) **INKJET INKS FOR DEPOSITION AND REMOVAL IN A LASER DICING PROCESS**

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B23K 26/402 (2014.01)
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(58) **Field of Classification Search**
CPC G02B 5/1847; G02B 1/14; B23K 26/402; B23K 26/60
See application file for complete search history.

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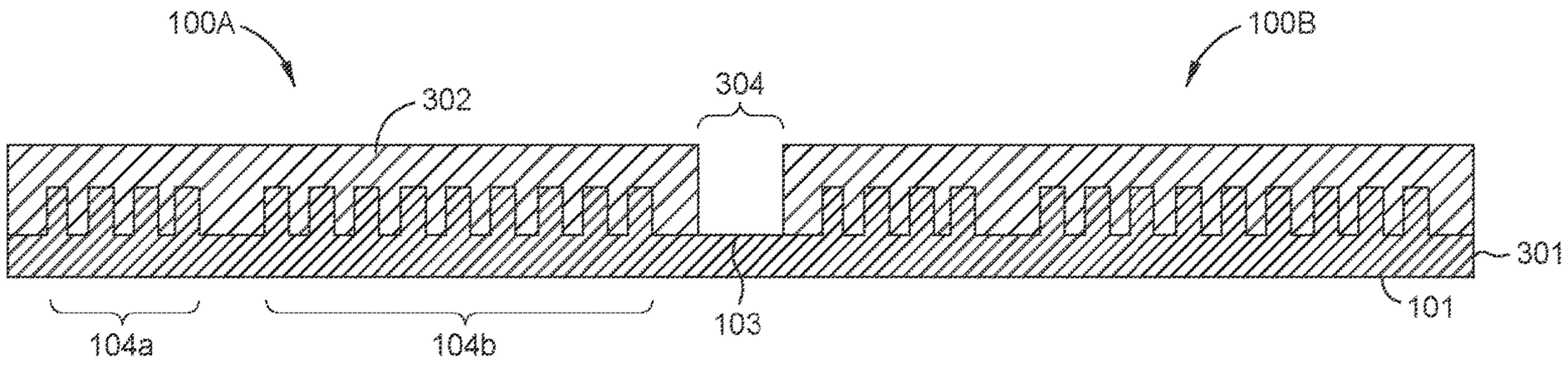
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(57) **ABSTRACT**

Methods of dicing optical devices from an optical device substrate are disclosed. The methods include disposing a protective coating only over the optical devices. The optical device substrate includes the optical devices disposed on the surface of the optical device substrate with areas therebetween. The areas of the optical device substrate are exposed by the protective coating. The protective coating includes a polymer, a solvent, and an additive. The methods further include curing the protective coating via a cure process so that the protective coating is water-soluble after the solvent is removed by the cure process, dicing the optical devices from the optical device substrate by projecting a laser beam to the areas between the optical devices, and exposing the
(Continued)



protective coating to water to remove the protective coating from the optical devices that are diced.

17 Claims, 4 Drawing Sheets

(51) **Int. Cl.**
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G02B 1/14 (2015.01)

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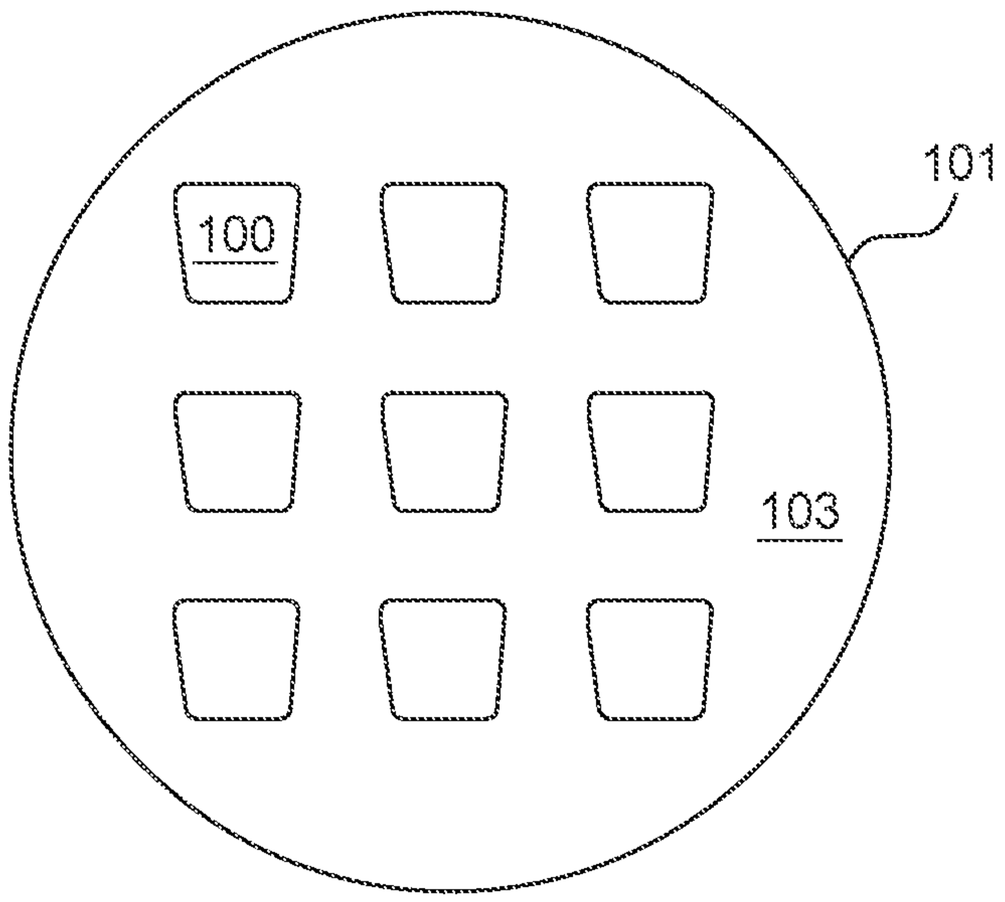


FIG. 1A

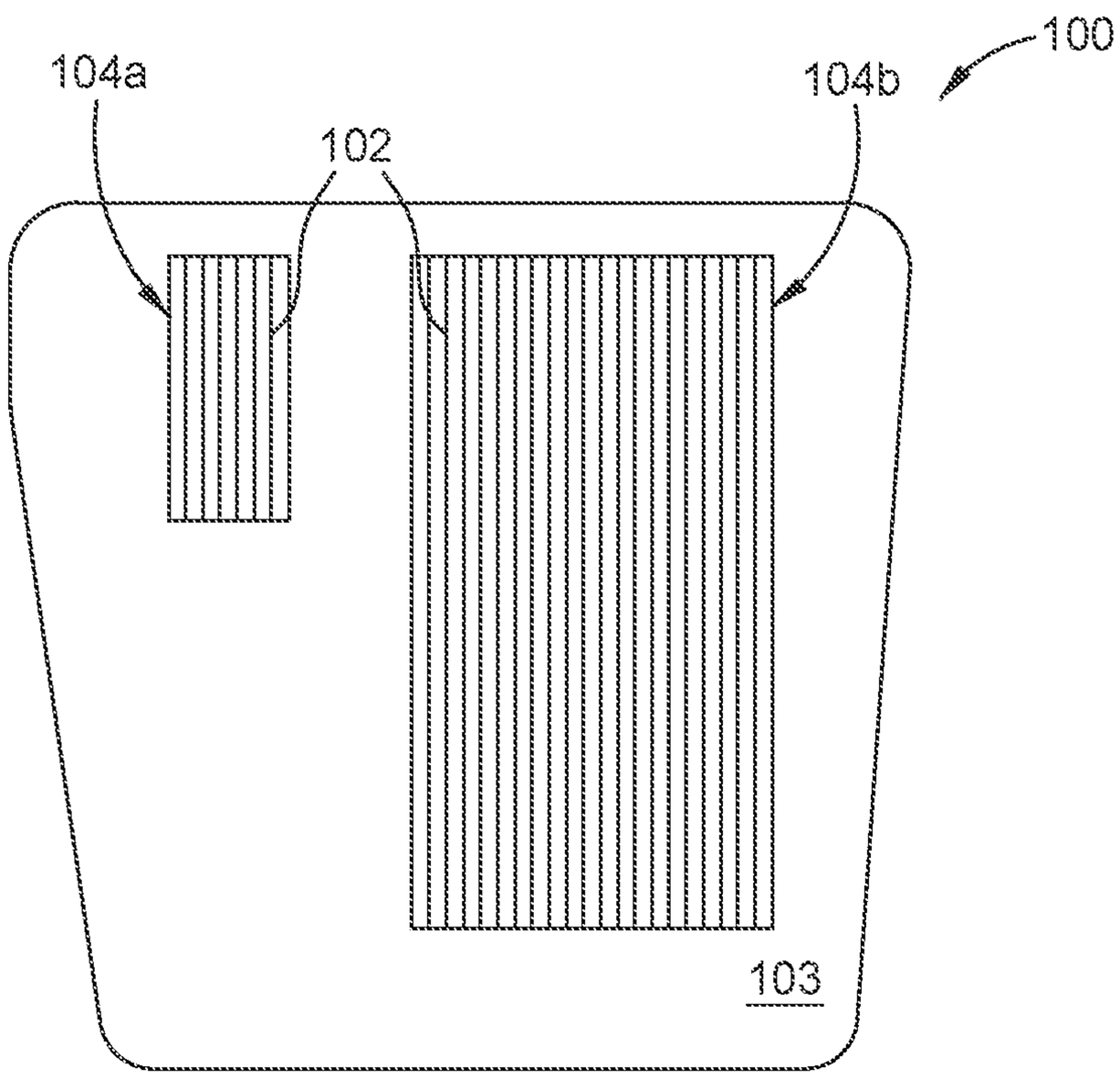


FIG. 1B

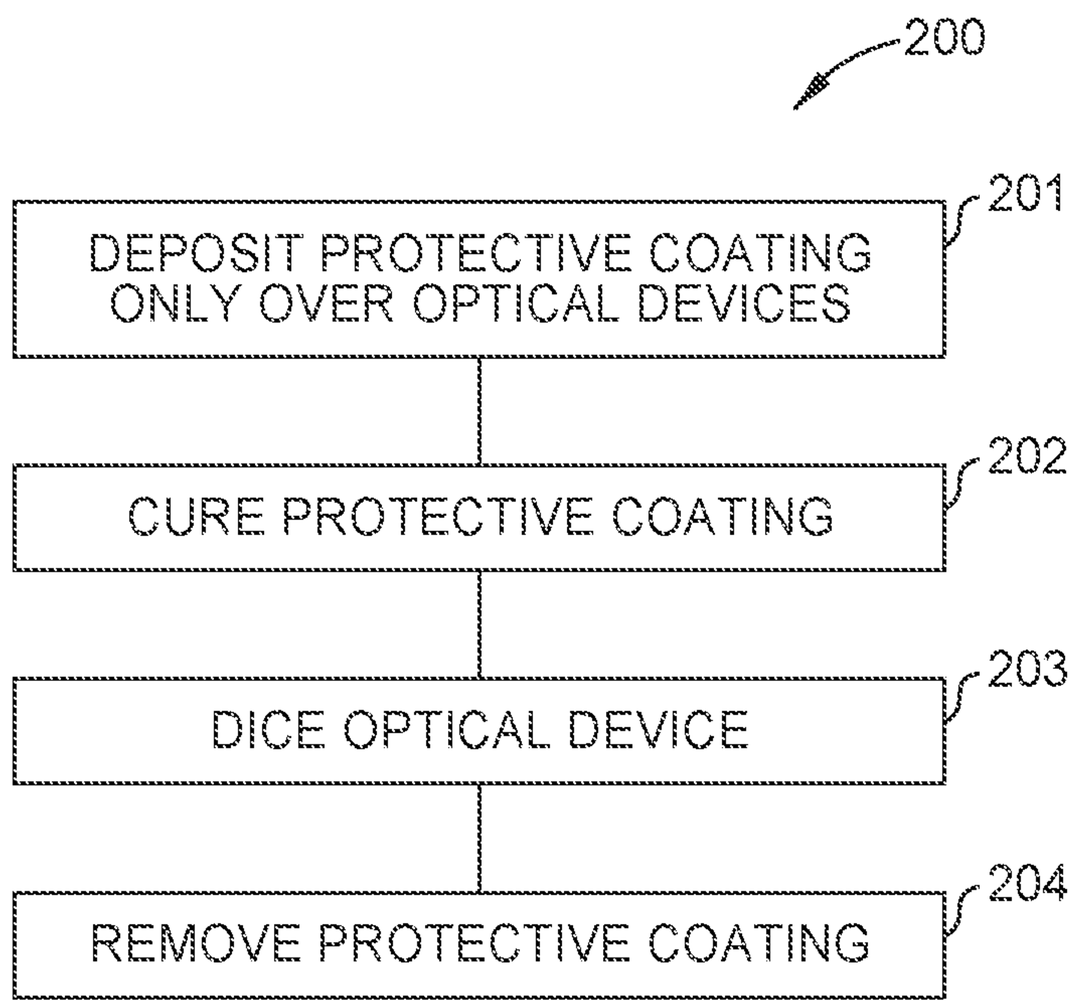

200
DEPOSIT PROTECTIVE COATING ONLY OVER OPTICAL DEVICES
201
CURE PROTECTIVE COATING
202
DICE OPTICAL DEVICE
203
REMOVE PROTECTIVE COATING
204

FIG. 2

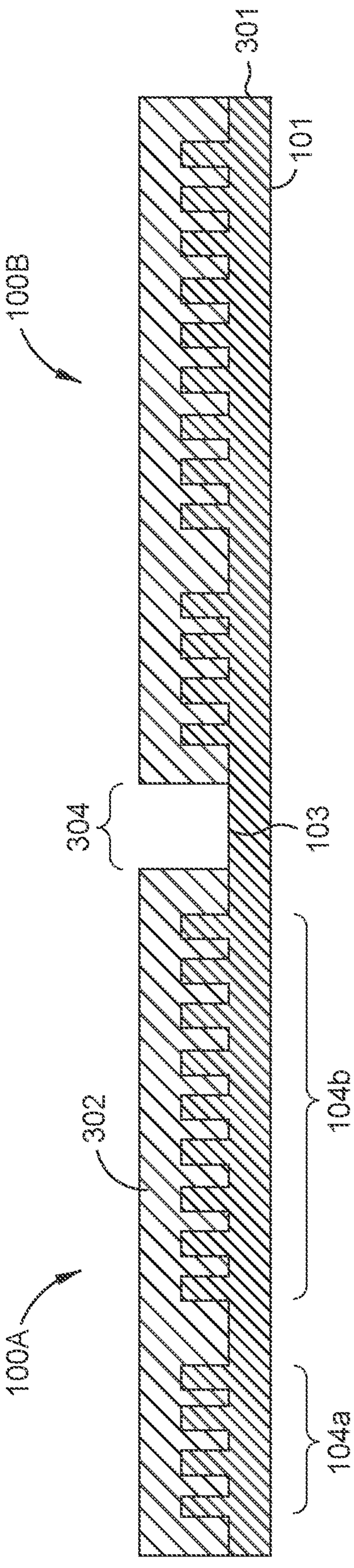

301
101
100B
304
103
302
104b
100A
104a

FIG. 3A

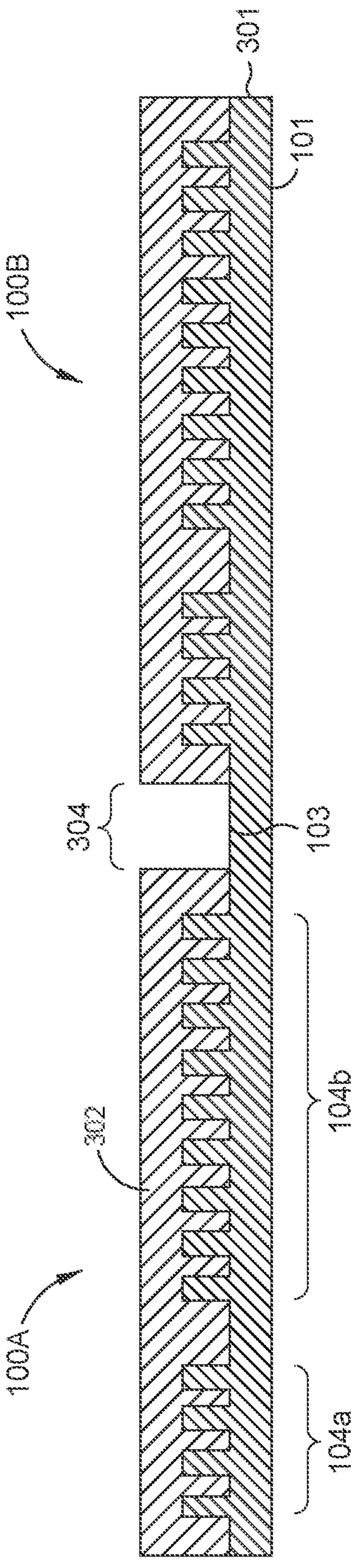

301
101
100B
304
103
302
104b
100A
104a

FIG. 3B

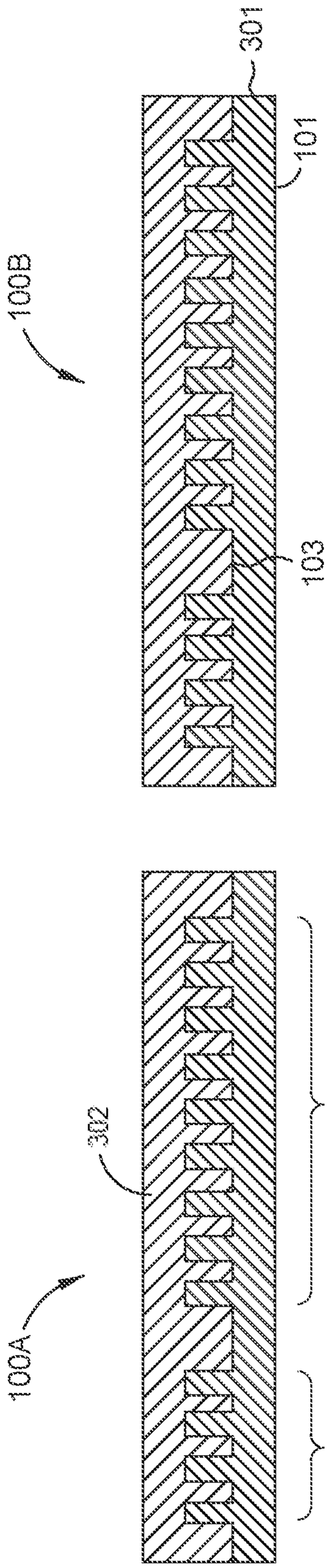

100B
301
101
103
100A
302
104a
104b

FIG. 3C

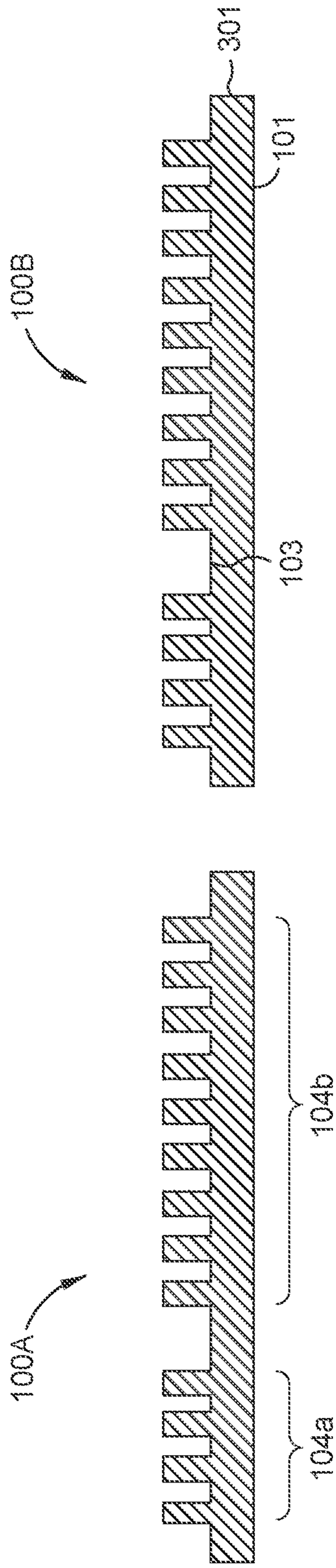

100B
301
101
103
100A
104a
104b

FIG. 3D

INKJET INKS FOR DEPOSITION AND REMOVAL IN A LASER DICING PROCESS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. Provisional Patent Application No. 63/268,504, filed Feb. 25, 2022, which is herein incorporated by reference in its entirety.

BACKGROUND

Field

Embodiments of the present disclosure generally relate to optical devices. Specifically, embodiments of the present disclosure relate to methods of laser dicing optical devices with a protective coating, and a protective coating for laser dicing optical devices.

Description of the Related Art

Virtual reality (VR) is generally considered to be a computer generated simulated environment in which a user has an apparent physical presence. A VR experience can be generated in 3D and viewed with a head-mounted display (HMD), such as glasses or other wearable display devices that have near-eye display panels as lenses to display a VR environment that replaces an actual environment.

Augmented reality (AR), however, enables an experience in which a user can still see through the display lenses of the glasses or other HMD device to view the surrounding environment, yet also see images of virtual objects that are generated for display and appear as part of the environment. AR can include any type of input, such as audio and haptic inputs, as well as virtual images, graphics, and video that enhances or augments the environment that the user experiences. In order to achieve an AR experience, a virtual image is overlaid on an ambient environment, with the overlaying performed by optical devices.

Multiple optical devices are fabricated on a substrate and then diced prior to use on VR and AR devices. Accordingly, there is a need for a method of laser dicing optical devices with a protective coating, and a protective coating for laser dicing optical devices.

SUMMARY

A method of dicing optical devices from an optical device substrate is provided. The method includes disposing a protective coating only over the optical devices. The optical device substrate includes the optical devices disposed on the surface of the optical device substrate with areas therebetween. The areas of the optical device substrate are exposed by the protective coating. The protective coating includes a polymer, a solvent, and an additive. The method further includes curing the protective coating via a cure process so that the protective coating is water-soluble after the solvent is removed by the cure process, dicing the optical devices from the optical device substrate by projecting a laser beam to the areas between the optical devices, and exposing the protective coating to water to remove the protective coating from the optical devices that are diced.

A method of dicing optical devices from an optical device substrate is provided. The method includes disposing a protective coating by inkjet deposition or screen printing deposition only over the optical devices. The optical devices have a plurality of optical device structures disposed thereon. The optical device substrate includes the optical devices disposed on the surface of the optical device substrate with areas therebetween. The areas of the optical device substrate are exposed by the protective coating. The protective coating includes a polymer, a solvent, and an additive. The method further includes curing the protective coating via a cure process so that the protective coating is water-soluble after the solvent is removed by the cure process, dicing the optical devices from the optical device substrate by projecting a laser beam to the areas between the optical devices, and exposing the protective coating to water to remove the protective coating from the optical devices that are diced.

A method of dicing optical devices from an optical device substrate is provided. The method includes disposing a protective coating by inkjet deposition or screen printing deposition only over the optical devices. The optical devices have a plurality of optical device structures disposed thereon. The optical device substrate includes the optical devices disposed on the surface of the optical device substrate with areas therebetween. The areas of the optical device substrate are exposed by the protective coating. The protective coating includes a polymer. The polymer includes at least one of a polyvinylpyrrolidone (PVP) containing material, a polypropylene containing material, polyvinyl acetate (PVA) containing material, or a combination thereof, a solvent, and an additive. The method further includes curing the protective coating via a cure process so that the protective coating is water-soluble after the solvent is removed by the cure process, dicing the optical devices from the optical device substrate by projecting a laser beam to the areas between the optical devices, and exposing the protective coating to water to remove the protective coating from the optical devices that are diced.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the 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 typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

FIG. **1**A is a perspective, frontal view of an optical device substrate according to embodiments described herein.

FIG. **1**B is a perspective, frontal view of an optical device according to embodiments described herein.

FIG. **2** is a flow diagram of a method for dicing optical devices according to embodiments described herein.

FIGS. **3**A-**3**D are schematic, cross-sectional views of a portion of an optical device substrate during a method for dicing optical devices according to embodiments described herein.

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 generally relate to optical devices. Specifically, embodiments of the present

disclosure relate to a method of laser dicing optical devices with a protective coating, and a protective coating for laser dicing optical devices.

FIG. **1**A is a perspective, frontal view of an optical device substrate **101**. The optical device substrate **101** includes a plurality of optical devices **100** disposed on a surface **103** of the optical device substrate **101**. The optical devices **100** are waveguide combiners utilized for virtual, augmented, or mixed reality. The optical device substrate **101** can be any substrate used in the art, and can be either opaque or transparent to a chosen laser wavelength depending on the use of the optical device substrate **101**. Additionally, the optical device substrate **101** may be of varying shapes, thicknesses, and diameters. For example, the optical device substrate **101** may have a diameter of about 150 mm to about 300 mm. The optical device substrate **101** may have a circular, rectangular, or square shape. The optical device substrate **101** may have a thickness of between about 300 μm to about 1 mm. Although only nine optical devices **100** are shown on the optical device substrate **101**, any number of optical devices **100** may be disposed on the surface **103**.

FIG. **1**B is a perspective, frontal view of an optical device **100**. It is to be understood that the optical devices **100** described herein are exemplary optical devices and other optical devices may be used with or modified to accomplish aspects of the present disclosure. The optical device **100** includes a plurality of optical device structures **102** disposed on the surface **103** of the optical device substrate **101**. The optical device structures **102** may be nanostructures having sub-micron dimensions, e.g., nano-sized dimensions. Regions of the optical device structures **102** correspond to one or more gratings, such as a first grating **104***a* and a second grating **104***b*. In some embodiments, which can be combined with other embodiments described herein, the optical device **100** includes at least the first grating **104***a* corresponding to an input coupling grating and the second grating **104***b* corresponding to an output coupling grating. The optical device structures **102** may have other shapes including, but not limited to, circular, triangular, elliptical, regular polygonal, irregular polygonal, and/or irregular shaped cross-sections.

After fabrication of the optical devices **100** on the optical device substrate **101**, it is desirable to dice the optical device substrate **101** into individual optical devices. For example, as shown in FIG. **3**D further described herein, a first optical device **100**A and a second optical device **1006** are diced from the substrate into individual optical devices. In order to improve the quality of the optical devices **100** after dicing, contamination during the dicing process must be reduced. The method **200** described herein provides for dicing of the optical devices **100** with reduced contamination via the use of a water-soluble protective coating that is selectively deposited over the optical devices **100** prior to dicing.

FIG. **2** is a flow a flow diagram of a method **200** for dicing optical devices **100** from the optical device substrate **101**. FIGS. **3**A-**3**D are schematic, cross-sectional views of a portion **301** of the optical device substrate **101** during the method **200**. The portion **301** of the optical device substrate **101** corresponds to the first optical device **100**A and the second optical device **100**B to be diced from the optical device substrate **101**.

At operation **201**, a protective coating **302** is deposited only over the optical devices **100**. Portions of the surface **103** of the optical device substrate **101** without the optical devices **100** are not coated with the protective coating **302**. As shown in FIG. **3**A, the protective coating **302** is deposited only on the first optical device **100**A and the second optical device **1006**. The protective coating **302** is deposited by inkjet deposition or screen printing deposition. Inkjet deposition or screen printing deposition provides for selective deposition of the protective coating **302** only on the optical devices **100**. The protective coating **302** may reflect, refract, or diffract a laser beam during a laser dicing process. The reflection, refraction, or diffraction of the laser beam may lead to undesired laser dosage or other results causing areas **304** of the optical device substrate **101** without the optical devices **100** to not be completely removed. Deposition of the protective coating **302** only on the optical devices **100** allows the areas **304** of the optical device substrate **101** exposed by the protective coating **302** to be completely removed after a laser dicing process. Prior to curing, the protective coating **302** for inkjet printing has a viscosity of 0.5 centipoise (cP) to 200 cP at 25° C. Prior to curing, the protective coating **302** for screen printing has a viscosity of 1000 centipoise (cP) to 100000 cP at 25° C. Prior to curing, the protective coating **302** has a surface tension from 15 millinewton per meter (mN/m) to 90 mN/m.

The protective coating **302** includes a polymer, a solvent, and an additive. In some embodiments, the protective coating **302** further includes a photo curable material. The polymer includes at least one of a polyvinylpyrrolidone (PVP) containing material, a polypropylene containing material, a polyvinyl acetate (PVA) containing material, or a combination thereof. The PVP containing material includes at least one of a PVP polymer, a PVP copolymer, a PVP block copolymer, or a combination thereof. The polymer is hydrophilic and water-soluble. The hydrophilic and water-soluble polymer allows for the protective coating **302** to be soluble in water after the protective coating **302** is cured by UV radiation, thermal baking, or a combination thereof. Thermal baking is conducted at a temperature of 25° C. to 300° C. or less. The water may be deionized water or distilled water.

The photo curable material includes one or more monomers, cross-linkers, oligomers, photo initiators, or combinations thereof. The photo curable material cross-links into a water-soluble polymer network when the protective coating **302** is cured. A water-soluble polymer network allows for the protective coating **302** to be soluble in water. In some embodiments, the protective coating **302** is cured via a UV cure process or thermal baking process. The monomers include water-soluble acrylates, such as methacrylates, epoxies, or combinations thereof. The cross-linkers include water-soluble multi-functional acrylates, such as multi-functional acrylates, methacrylates, epoxies, or combinations thereof. The oligomers include water-soluble acrylates, methacrylates, epoxies, or combinations thereof. The additive includes one or more surfactants or one or more polymers.

The solvent includes an organic solvent and water. The organic solvent includes an ester, an ether, and an alcohol. The ester, the ether, and the alcohol have a boiling point less than or equal to 300° C. at 1 atm. The organic solvent includes di(propylene glycol) methyl ether (DPGME), Dipropylene glycol n-butyl ether (DPGBE), Tri(propylene glycol) methyl ether (TPGME), dipropylene glycol mono-n-propylether (DPGPE), dipropylene glycol dimethyl ether (DPGDME), tripropylene glycol (mono) n-butyl ether (TPGBE), propylene glycol butyl ether (PGBE), (2-(2-methoxyethoxy)ethanol (DEGME), 2-(2-ethoxyethoxy) ethanol (DEGEE), triethylene glycol monomethyl ether (TEGME), propylene glycol methyl ether (PGME), propylene glycol propyl ethe (PGPE), propylene glycol methyl ether acetate (PGMEA), dipropylene glycol monomethyl

ether acetate (DPGMEA), ethanol, methanol, isopropanol, 1-butanol, 2-butanol, 1-pentanol, 2-pentanol, 3-pentanol, 1-hexanol, 2-hexanol, 3-hexanol, butyl acetate, butyl lactate, or combinations thereof. The solvent includes 0% to 80% water. The solvent allows for the protective coating **302** to be selectively deposited as an inkjet ink or screen printing ink. Upon curing the solvent is removed from the protective coating **302**.

At operation **202**, as shown in FIG. **3**B, the protective coating **302** is cured. The protective coating **302** is cured via a bake process or UV cure process. Upon curing the solvent is removed from the protective coating **302**. In some embodiments, the protective coating **302** is cured via a bake process. In other embodiments, the protective coating **302** is cured via a UV cure process. At operation **203**, the optical devices **100** are diced. The areas **304** of the substrate the optical device substrate **101** exposed by the protective coating **302** are removed via a dicing process. The dicing process is a laser dicing process. During the laser dicing process a laser beam is projected to the areas **304**. The areas **304** of the optical device substrate **101** exposed by the protective coating **302** are completely removed after the laser dicing process due to the deposition of the protective coating **302** only on the optical devices **100**. As shown in FIG. **3**C, the first optical device **100**A and the second optical device **100**B are diced from the portion **301** of optical device substrate **101** and the area **304** is removed.

At operation **204**, the protective coating **302** is removed from the optical devices **100**. As shown in FIG. **3**D, the protective coating **302** is removed from the first optical device **100**A and the second optical device **1008**. The protective coating **302** is removed by exposure to water. The water may be deionized water or distilled water. As the protective coating **302** is water-soluble, removal of the protective coating **302** with water provides for aqueous waste. Organic waste generated from insoluble coatings, such as organic coatings, may contaminate the optical devices **100**.

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, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method of dicing waveguides from an optical device substrate, comprising:

disposing a protective coating over the waveguides, each waveguide having an input coupling grating comprising first optical device structures and an output coupling grating comprising second optical device structures, the optical device substrate comprising the waveguides disposed on a surface of the optical device substrate with areas therebetween, wherein the protective coating is selectively disposed to cover the waveguides while leaving areas between the waveguides exposed for laser dicing, the protective coating comprising:

a polymer;

a solvent, and

an additive;

curing the protective coating via a cure process so that the protective coating is water-soluble after the solvent is removed by the cure process;

dicing the waveguides from the optical device substrate by projecting a laser beam to the areas between the waveguides such that the exposed areas are removed while the waveguides covered by the protective coating are protected during the laser dicing; and

exposing the protective coating to water to remove the protective coating from the waveguides that are diced.

2. The method of claim **1**, wherein the solvent comprises an organic solvent and water.

3. The method of claim **2**, wherein the organic solvent includes an ester, an ether, and an alcohol.

4. The method of claim **3**, wherein the ester, the ether, and the alcohol have a boiling point less than or equal to 300° C. at 1 atm.

5. The method of claim **3**, wherein the organic solvent comprises di(propylene glycol) methyl ether (DPGME), dipropylene glycol n-butyl ether (DPGBE), Tri(propylene glycol) methyl ether (TPGME), dipropylene glycol mono-n-propylether (DPGPE), dipropylene glycol dimethyl ether (DPGDME), tripropylene glycol (mono) n-butyl ether (TPGBE), propylene glycol butyl ether (PGBE), (2-(2-methoxyethoxy) ethanol (DEGME), 2-(2-ethoxyethoxy) ethanol (DEGEE), triethylene glycol monomethyl ether (TEGME), propylene glycol methyl ether (PGME), propylene glycol propyl ethe (PGPE), propylene glycol methyl ether acetate (PGMEA), dipropylene glycol monomethyl ether acetate (DPGMEA), ethanol, methanol, isopropanol, 1-butanol, 2-butanol, 1-pentanol, 2-pentanol, 3-pentanol, 1-hexanol, 2-hexanol, 3-hexanol, butyl acetate, butyl lactate, or combinations thereof.

6. The method of claim **1**, wherein the polymer comprises at least one of a polyvinylpyrrolidone (PVP) containing material, a polypropylene containing material, polyvinyl acetate (PVA) containing material, or a combination thereof.

7. The method of claim **6**, wherein the PVP containing material comprises at least one of a PVP polymer, a PVP copolymer, a PVP block copolymer, or a combination thereof.

8. The method of claim **1**, wherein the protective coating further comprises a photo curable material.

9. The method of claim **8**, wherein the photo curable material comprises one or more monomers, cross-linkers, oligomers, photo initiators, or combinations thereof.

10. The method of claim **1**, wherein the polymer is hydrophilic and water-soluble.

11. The method of claim **1**, wherein the protective coating is deposited by inkjet deposition or screen printing deposition only over the waveguides.

12. A method of dicing waveguides from an optical device substrate, comprising:

disposing a protective coating by inkjet deposition or screen printing deposition over the waveguides, each waveguide having an input coupling grating comprising first optical device structures and an output coupling grating comprising second optical device structures disposed thereon, the optical device substrate comprising the waveguides disposed on a surface of the optical device substrate with areas therebetween, wherein the inkjet deposition or screen printing deposition deposits the protective coating on the waveguides and leaves the areas between the waveguides exposed for laser dicing, the protective coating comprising:

a polymer, wherein the polymer is hydrophilic and water-soluble;

a solvent, and

an additive;

curing the protective coating via a cure process so that the protective coating is water-soluble after the solvent is removed by the cure process;

dicing the waveguides from the optical device substrate by projecting a laser beam to the areas between the waveguides such that the exposed areas are removed while the waveguides covered by the protective coating are protected during the laser dicing; and

exposing the protective coating to water to remove the protective coating from the waveguides that are diced.

13. The method of claim **12**, wherein the solvent comprises an organic solvent and water.

14. The method of claim **13**, wherein the organic solvent includes an ester, an ether, and an alcohol.

15. The method of claim **14**, wherein the ester, the ether, and the alcohol have a boiling point less than or equal to 300° C. at 1 atm.

16. The method of claim **13**, wherein the organic solvent comprises di(propylene glycol) methyl ether (DPGME), dipropylene glycol n-butyl ether (DPGBE), Tri(propylene glycol) methyl ether (TPGME), dipropylene glycol mono-n-propylether (DPGPE), dipropylene glycol dimethyl ether (DPGDME), tripropylene glycol (mono) n-butyl ether (TPGBE), propylene glycol butyl ether (PGBE), (2-(2-methoxyethoxy)ethanol (DEGME), 2-(2-ethoxyethoxy) ethanol (DEGEE), triethylene glycol monomethyl ether (TEGME), propylene glycol methyl ether (PGME), propylene glycol propyl ethe (PGPE), propylene glycol methyl ether acetate (PGMEA), dipropylene glycol monomethyl ether acetate (DPGMEA), ethanol, methanol, isopropanol, 1-butanol, 2-butanol, 1-pentanol, 2-pentanol, 3-pentanol, 1-hexanol.

17. A method of dicing waveguides from an optical device substrate, comprising:

disposing a protective coating by inkjet deposition or screen printing deposition over the waveguides, each waveguide having an input coupling grating comprising first optical device structures and an output coupling grating comprising second optical device structures disposed thereon, the optical device substrate comprising the waveguides disposed on a surface of the optical device substrate with areas therebetween, wherein the protective coating covers the waveguides and leaves the areas between the waveguides exposed for laser dicing, the protective coating comprising:

a polymer, the polymer comprising at least one of a polyvinylpyrrolidone (PVP) containing material, a polypropylene containing material, polyvinyl acetate (PVA) containing material, or a combination thereof;

a solvent, and

an additive;

curing the protective coating via a cure process so that the protective coating is water-soluble after the solvent is removed by the cure process;

dicing the waveguides from the optical device substrate by projecting a laser beam to the areas between the waveguides such that the exposed areas are removed while the waveguides covered by the protective coating are protected during the laser dicing; and

exposing the protective coating to water to remove the protective coating from the waveguides that are diced.

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