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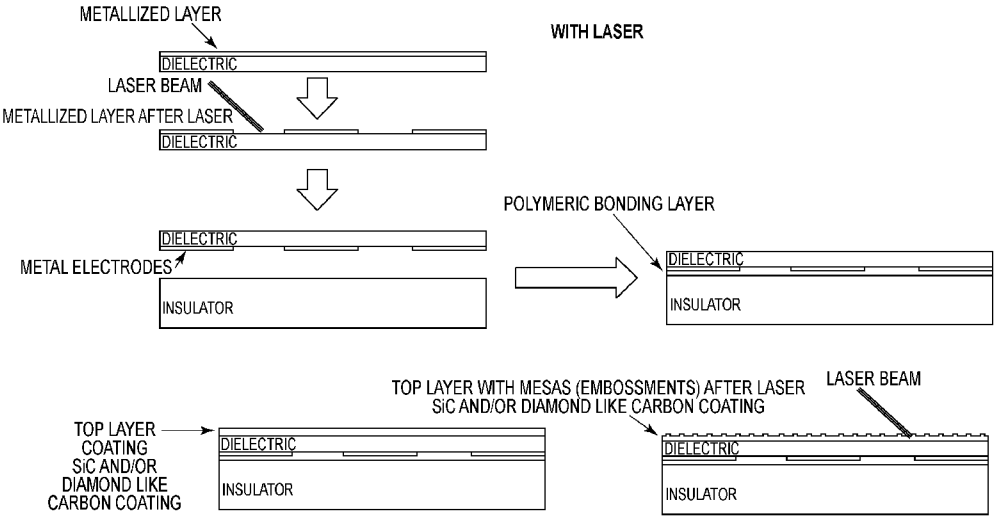

FIG. 2

(57) **Abstract:** Electrostatic chucks and methods for forming electrostatic chucks are provided. A method comprises obtaining a substrate comprising an etch resistant coating layer; ablating, with a laser, the etch resistant coating layer so as to remove at least a portion of the etch resistant coating layer so as to provide one or more exposed portions of the substrate; and forming an electrostatic chuck, wherein, when measuring an electrical resistance across the one or more exposed portions of the substrate between two metallized portions, the electrostatic chuck exhibits an electrical isolation of 300 GΩ or more. An electrostatic chuck comprises a substrate having at least one etch resistant coating layer comprising a laser ablated pattern, wherein the laser ablated pattern comprises one or more exposed portions of the substate spanning distances of at least 0.5 mm.

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LASER ABLATION APPLICATIONS FOR ELECTROSTATIC CHUCKS

CROSS-REFERENCE TO RELATED APPLICATION

[001] This application claims the benefit of and priority to U.S. Provisional Application No. 63/547,495 filed on November 6, 2023, which is incorporated herein by reference in its entirety for all purposes.

FIELD

[002] This disclosure relates to electrostatic chucks. More particularly, this disclosure relates to methods of forming electrostatic chucks using laser ablation and electrostatic chucks having laser ablated patterns.

BACKGROUND

[003] Current electrostatic chuck metallization and embossing processes use photolithography which involves multiple masking and etching steps utilizing a variety of chemicals leading to higher costs and longer lead times. Controllable and affordable methods for producing and embossing electrostatic chucks is an ongoing challenge.

SUMMARY

[004] This disclosure relates to methods of forming electrostatic chucks using laser ablation and electrostatic chucks having laser ablated patterns.

[005] Some embodiments relate to methods of forming electrostatic chucks. In some embodiments, the methods comprise obtaining a substrate comprising an etch resistant coating layer; ablating, with a laser, the etch resistant coating layer so as to remove at least a portion of the etch resistant coating layer so as to provide one or more exposed portions of the substrate; and forming an electrostatic chuck, wherein, when measuring an electrical resistance across the one or more exposed portions of the substrate between two metallized portions, the electrostatic chuck exhibits an electrical isolation of 300 GΩ or more.

[006] Some embodiments relate to the methods of forming electrostatic chucks. In some embodiments, the methods comprise obtaining a substrate comprising a

metallized layer; ablating, with a laser, the metallized layer so as to remove at least a portion of the metallized layer so as to provide one or more exposed portions of the substate; and forming an electrostatic chuck, wherein, when measuring an electrical resistance across the one or more exposed portions of the substrate between two metallized portions, the electrostatic chuck exhibits an electrical isolation of 300 GΩ or more.

[007] Some embodiments relate to electrostatic chucks. In some embodiments, the electrostatic chucks comprise a substrate having at least one etch resistant coating layer comprising a laser ablated pattern, wherein the laser ablated pattern comprises one or more exposed portions of the substate spanning distances of at least 0.5 mm.

DRAWINGS

[008] Some embodiments of the disclosure are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the embodiments shown are by way of example and for purposes of illustrative discussion of embodiments of the disclosure. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the disclosure may be practiced.

[009] FIG. 1 is a flowchart of a method of forming an electrostatic chuck, according to some embodiments.

[0010] FIG. 2 is a schematic diagram of a method of forming an electrostatic chuck, according to some embodiments.

[0011] FIG. 3 includes tables summarizing test results obtained from the evaluation of laser-ablated samples provided in accordance with some embodiments.

[0012] While the disclosure is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit aspects of the disclosure to the particular illustrative embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure.

DETAILED DESCRIPTION

[0013] Among those benefits and improvements that have been disclosed, other objects and advantages of this disclosure will become apparent from the following description taken in conjunction with the accompanying figures. The detailed description and the drawings, which are not necessarily to scale, depict illustrative embodiments and are not intended to limit the scope of the disclosure. The illustrative embodiments depicted are intended only as exemplary. Selected features of any illustrative embodiment may be incorporated into an additional embodiment unless clearly stated to the contrary.

[0014] Throughout the specification and claims, the following terms take the meanings explicitly associated herein, unless the context clearly dictates otherwise. The phrases “in one embodiment,” “in an embodiment,” and “in some embodiments” as used herein do not necessarily refer to the same embodiment(s), though it may. Furthermore, the phrases “in another embodiment” and “in some other embodiments” as used herein do not necessarily refer to a different embodiment, although it may. All embodiments of the disclosure are intended to be combinable without departing from the scope or spirit of the disclosure.

[0015] As used herein, the term “based on” is not exclusive and allows for being based on additional factors not described, unless the context clearly dictates otherwise.

[0016] As used in this specification and the appended claims, the singular forms “a”, “an”, and “the” include plural referents unless the content clearly dictates otherwise. As used in this specification and the appended claims, the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

[0017] The term “about” generally refers to a range of numbers that is considered equivalent to the recited value (e.g., having the same function or result). In many instances, the term “about” may include numbers that are rounded to the nearest significant figure.

[0018] Some embodiments relate to electrostatic chucks and methods of forming an electrostatic chuck. In some embodiments, the methods disclosed herein employ the use of laser ablation to form electrostatic chucks having complex and intricate metal electrode patterns, which heretofore have not been realized. For example, the methods disclosed herein may be employed to form precisely

patterned metal traces with improved patterns and geometry, as well as tight spacing and widths. As another example, the methods disclosed herein may be employed with respect to materials that are difficult to etch and/or cannot be etched, while also reducing fabrication time. As disclosed herein, these methods can be used to fabricate electrostatic chucks exhibiting improved performance and function, among other things.

[0019] FIG. 1 is a flowchart of a method 100 for forming an electrostatic chuck, according to some embodiments. In some embodiments, the method 100 for forming an electrostatic chuck may include one or more of the following steps: a step 102 of obtaining a substrate, a step 104 of ablating, with a laser, the substrate, and a step 106 of forming an electrostatic chuck. In some embodiments, when measuring an electrical resistance across the one or more exposed portions of the substrate between two metallized portions located within the same horizontal plane, the electrostatic chuck displays an electrical isolation of 300 GΩ or more.

[0020] According to some embodiments, the method 100 of forming an electrostatic chuck includes obtaining a substrate having an etch resistant coating layer disposed thereon (block 102). In some embodiments, the method further includes ablating the etch resistant coating layer with a laser (block 104). The step 104 of ablating the etch resistance coating layer includes removing at least a portion of the etch resistant coating layer so as to provide one or more exposed portions of the underlying substrate.

[0021] Some embodiments of this disclosure provide for a method of forming an electrostatic chuck including obtaining a substrate having a metallized layer disposed thereon (block 102). In some embodiments, the metallized layer is ablated with a laser (block 104). In some embodiments, ablating the metallized layer with a laser includes removing at least a portion of the metallized layer so as to provide one or more exposed portions of the underlying substate.

[0022] At step 102, in some embodiments, the method comprises obtaining a substrate including an etch resistant layer and/or a metallized layer. In some embodiments, the substrate includes at least one of a dielectric layer, a metallized layer, an etch resistant layer, a polymeric bonding layer, an insulator layer or any combination thereof. In some embodiments, the substrate includes a dielectric layer and an etch resistant layer located on the dielectric layer. In

some embodiments, the substrate includes a dielectric layer and a metallized layer located on the dielectric layer. In some embodiments, the etch resistant layer directly contacts the dielectric layer. In some embodiments, the metallized layer directly contacts the dielectric layer. In some embodiments, the substrate is bonded to an insulator layer. In some embodiments, the substrate is bonded to an insulator layer via a polymeric bonding layer. In some embodiments, the substrate is bonded to an insulator layer via an adhesive layer. In some embodiments, the dielectric layer is located between the metallized layer and the etch resistant layer. In some embodiments, when the substrate is bonded to an insulator layer, the metallized layer is located between the dielectric layer and the polymeric bonding layer.

[0023] In some embodiments, the substrate includes, but is not limited to, ceramic, alumina, zirconia, aluminum-nitride, aluminum-oxy-nitride, silicon-nitride, silicon-oxide, silicon-carbide, silicon-oxy-nitride, silicon-carbo-nitride, tungsten-carbide, molybdenum-disilicide, titanium-oxide, hafnium silicate, zirconium silicate, zirconium silicate, hafnium dioxide, strontium dioxide, scandium dioxide, zirconium dioxide, chromium oxide, yttrium oxide, iron oxide, barium oxide, barium titanate, tantalum oxide, or any combinations thereof. In some embodiments, the substrate includes ceramic. In some embodiments, the substrate includes alumina. In some embodiments, the substrate includes zirconia. In some embodiments, the substrate comprises aluminum-nitride. In some embodiments, the substrate includes aluminum-oxy-nitride. In some embodiments, the substrate includes silicon-nitride. In some embodiments, the substrate includes silicon-oxide. In some embodiments, the substrate includes silicon-carbide. In some embodiments, the substrate includes silicon-oxy-nitride. In some embodiments, the substrate includes silicon-carbo-nitride. In some embodiments, the substrate includes tungsten-carbide. In some embodiments, the substrate includes molybdenum-disilicide. In some embodiments, the substrate includes titanium-oxide. In some embodiments, the substrate includes hafnium silicate. In some embodiments, the substrate includes zirconium silicate. In some embodiments, the substrate includes zirconium silicate. In some embodiments, the substrate includes hafnium dioxide. In some embodiments, the substrate includes strontium dioxide. In some embodiments, the substrate includes scandium dioxide. In some embodiments, the substrate

includes zirconium dioxide. In some embodiments, the substrate includes chromium oxide. In some embodiments, the substrate includes yttrium oxide. In some embodiments, the substrate includes iron oxide. In some embodiments, the substrate includes barium oxide. In some embodiments, the substrate includes barium titanate. In some embodiments, the substrate includes tantalum oxide.

[0024] In some embodiments, the etch resistant layer includes, but is not limited to, at least one of silicon carbide, diamond, carbon, yttrium oxide, aluminum oxide, or any combinations thereof. In some embodiments, the etch resistant layer includes silicon carbide. In some embodiments, the etch resistant layer includes yttrium oxide. In some embodiments, the etch resistant layer includes aluminum oxide. In some embodiments, the etch resistant layer includes diamond.

[0025] In some embodiments, the etch resistant layer is a coating. In some embodiments, the etch resistant layer is a deposited layer. In some embodiments, the etch resistant layer is deposited via one or more deposition processes. Examples of deposition processes include, without limitation, at least one of a chemical vapor deposition (CVD) process, a digital or pulsed chemical vapor deposition process, a plasma-enhanced cyclical chemical vapor deposition process (PECCVD), a flowable chemical vapor deposition process (FCVD), an atomic layer deposition (ALD) process, a thermal atomic layer deposition, a plasma-enhanced atomic layer deposition (PEALD) process, a metal organic chemical vapor deposition (MOCVD) process, a plasma-enhanced chemical vapor deposition (PECVD) process, or any combination thereof.

[0026] In some embodiments, the metallized layer includes, but is not limited to, aluminum, tungsten, nickel, stainless steel, silver, gold, tantalum, platinum, palladium, cobalt, titanium, copper, molybdenum, silicon, or any combinations thereof. In some embodiments, the metallized layer includes aluminum. In some embodiments, the metallized layer includes tungsten. In some embodiments, the metallized layer includes nickel. In some embodiments, the metallized layer includes stainless steel. In some embodiments, the metallized layer includes silver. In some embodiments, the metallized layer includes gold. In some embodiments, the metallized layer includes tantalum. In some embodiments, the metallized layer includes platinum. In some embodiments,

the metallized layer includes palladium. In some embodiments, the metallized layer includes cobalt. In some embodiments, the metallized layer includes titanium. In some embodiments, the metallized layer includes copper. In some embodiments, the metallized layer includes molybdenum. In some embodiments, the metallized layer includes silicon.

[0027] The etch resistant layer can have a thickness of 0.1 μm to 50 μm, or any range or subrange between 0.1 μm and 50 μm. In some embodiments, the etch resistant layer has a thickness of 0.1 μm to 45 μm, 0.1 μm to 40 μm, 0.1 μm to 35 μm, 0.1 μm to 30 μm, 0.1 μm to 25 μm, 0.1 μm to 20 μm, 0.1 μm to 15 μm, 0.1 μm to 10 μm, 0.1 μm to 9 μm , 0.1 μm to 8 μm, 0.1 μm to 7 μm, 0.1 μm to 6 μm, 0.1 μm to 5 μm, 0.1 μm to 4 μm, 0.1 μm to 3 μm, 0.1 μm to 2 μm, 0.1 μm to 1 μm, 5 μm to 50 μm, 10 μm to 50 μm, 15 μm to 50 μm, 20 μm to 50 μm, 25 μm to 50 μm, 30 μm to 50 μm, 35 μm to 50 μm, 40 μm to 50 μm, or 45 μm to 50 μm.

[0028] The metallized layer can have a thickness of 0.1 μm to 50 μm, or any range or subrange between 0.1 μm and 50 μm. In some embodiments, the metallized layer has a thickness of 0.1 μm to 45 μm, 0.1 μm to 40 μm, 0.1 μm to 35 μm, 0.1 μm to 30 μm, 0.1 μm to 25 μm, 0.1 μm to 20 μm, 0.1 μm to 15 μm, 0.1 μm to 10 μm, 0.1 μm to 9 μm , 0.1 μm to 8 μm, 0.1 μm to 7 μm, 0.1 μm to 6 μm, 0.1 μm to 5 μm, 0.1 μm to 4 μm, 0.1 μm to 3 μm, 0.1 μm to 2 μm, 0.1 μm to 1 μm, 5 μm to 50 μm, 10 μm to 50 μm, 15 μm to 50 μm, 20 μm to 50 μm, 25 μm to 50 μm, 30 μm to 50 μm, 35 μm to 50 μm, 40 μm to 50 μm, or 45 μm to 50 μm. In some embodiments, the metallized layer has a thickness of 0.7 μm to 1.5 μm, or any range or subrange between 0.7 μm to 1.5 μm. For example, in some embodiments, the metallized layer has a thickness of 0.8 μm to 1.5 μm, 0.9 μm to 1.5 μm, 1 μm to 1.5 μm, 1.1 μm to 1.5 μm, 1.2 μm to 1.5 μm, 1.3 μm to 1.5 μm, 1.4 μm to 1.5 μm, 0.7 μm to 1.4 μm, 0.7 μm to 1.3 μm, 0.7 μm to 1.2 μm, 0.7 μm to 1.1 μm, 0.7 μm to 1 μm, 0.7 μm to 0.9 μm, or 0.7 μm to 0.8 μm.

[0029] At step 104, in some embodiments, the method includes ablating, with a laser, the substrate having an etch resistant layer and/or a metallized layer. In some embodiments, the method includes ablating, with a laser, the etch resistant layer to remove at least a portion of the etch resistant layer and obtain one or more exposed portions of the substrate. In some embodiments, the method includes ablating, with a laser, the metallized layer to remove at least a portion

of the metallized layer and obtain one or more exposed portions of the substrate. In some embodiments, the ablating step 104 includes applying a laser to the substrate having the etch resistant layer and/or the metallized layer. In some embodiments, the ablating step 104 includes exposing the substrate having the etch resistant layer and/or the metallized layer to the laser. In some embodiments, the ablating step 104 includes removing at least a portion of the etch resistant layer and/or the metallized layer from substrate to expose a at least a portion of the underlying substrate. In some embodiments, the ablating step 104 includes setting parameters for a device producing the laser.

[0030] In some embodiments, the laser used in the ablating step 104 can include an ultra-violet nanosecond (UV ns) laser, an infra-red nanosecond (IR ns) laser, an infra-red picosecond (IR ps) laser, a green laser, or any combination thereof. In some embodiments, the laser includes an UV ns laser. In some embodiments, the laser includes an IR ns laser. In some embodiments, the laser includes an IR ps laser. In some embodiments, the laser includes a green laser.

[0031] In some embodiments, the laser used in ablating step 104 is applied at a rate of 0.5 mm^2/s to 8.5 mm^2/s, or any range or subrange between 0.5 mm^2/s to 8.5 mm^2/s. For example, in some embodiments, the laser is applied at a rate of 0.5 mm^2/s to 8.5 mm^2/s, 1 mm^2/s to 8.5 mm^2/s, 1.5 mm^2/s to 8.5 mm^2/s, 2 mm^2/s to 8.5 mm^2/s, 2.5 mm^2/s to 8.5 mm^2/s, 3 mm^2/s to 8.5 mm^2/s, 3.5 mm^2/s to 8.5 mm^2/s, 4 mm^2/s to 8.5 mm^2/s, 4.5 mm^2/s to 8.5 mm^2/s, 5 mm^2/s to 8.5 mm^2/s, 5.5 mm^2/s to 8.5 mm^2/s, 6 mm^2/s to 8.5 mm^2/s, 6.5 mm^2/s to 8.5 mm^2/s, 7 mm^2/s to 8.5 mm^2/s, 7.5 mm^2/s to 8.5 mm^2/s, 8 mm^2/s to 8.5 mm^2/s, 0.5 mm^2/s to 8 mm^2/s, 0.5 mm^2/s to 7.5 mm^2/s, 0.5 mm^2/s to 7 mm^2/s, 0.5 mm^2/s to 6.5 mm^2/s, 0.5 mm^2/s to 6 mm^2/s, 0.5 mm^2/s to 5.5 mm^2/s, 0.5 mm^2/s to 5 mm^2/s, 0.5 mm^2/s to 4.5 mm^2/s, 0.5 mm^2/s to 4 mm^2/s, 0.5 mm^2/s to 3.5 mm^2/s, 0.5 mm^2/s to 3 mm^2/s, 0.5 mm^2/s to 2.5 mm^2/s, 0.5 mm^2/s to 2 mm^2/s, 0.5 mm^2/s to 1.5 mm^2/s, or 0.5 mm^2/s to 1 mm^2/s.

[0032] In some embodiments, the laser used in ablating step 104 is applied in cycles of 1 s to 1000 s, or any range or subrange between 1 s and 1000 s. For example, in some embodiments, the laser is applied in cycles of 48 s to 798 s, or any range or subrange of 48 c to 798 s. For example, in some embodiments, the laser is applied in cycles of 50 s to 798 s, 100 s to 798 s, 150 s to 798 s, 200 s to 798 s, 250 s to 798 s, 300 s to 798 s, 350 s to 798 s, 400 s to 798 s, 450 s

to 798 s, 500 s to 798 s, 550 s to 798 s, 600 s to 798 s, 650 s to 798 s, 700 s to 798 s, 750 s to 798 s, 48 s to 750 s, 48 s to 700 s, 48 s to 650 s, 48 s to 600 s, 48 s to 550 s, 48 s to 500 s, 48 s to 450 s, 48 s to 400 s, 48 s to 350 s, 48 s to 300 s, 48 s to 250 s, 48 s to 200 s 48 s to 150 s, 48 s to 100 s, or 48 s to 500 s.

[0033] In some embodiments, the distance across one or more exposed portions of the substrate spans a distance of at least 0.5 mm. For example, in some embodiments, distance across the one or more exposed portions of the substrate span distances of at least 1 mm, 1.5 mm, 2 mm, 2.5 mm, 3 mm, 3.5 mm, 4 mm, 4.5 mm, 5 mm, 5.5 mm, 6 mm, 6.5 mm, 7 mm, 7.5 mm, 8 mm, 8.5 mm, 9 mm, 9.5 mm, or 10 mm. In some embodiments, the one or more exposed portions of the substrate span a distance of 0.5 mm to 10 mm, or any range or subrange between 0.5 mm and 10 mm. In some embodiments, the one or more exposed portions of the substrate span a distance of 0.5 mm to 9 mm, 0.5 mm to 8 mm, 0.5 mm to 7 mm, 0.5 mm to 6 mm, 0.5 mm to 5 mm, 0.5 mm to 4 mm, 0.5 mm to 3 mm, 0.5 mm to 2 mm, 0.5 mm to 1 mm, 1 mm to 10 mm, 2 mm to 10 mm, 3 mm to 10 mm, 4 mm to 10 mm, 5 mm to 10 mm, 6 mm to 10 mm, 7 mm to 10 mm, 8 mm to 10 mm, or 9 mm to 10 mm.

[0034] At step 106, in some embodiments, the method includes forming an electrostatic chuck. In some embodiments, forming an electrostatic chuck includes contacting the substrate with an insulator layer. In some embodiments, forming an electrostatic chuck includes bonding the substrate to the insulator layer. In some embodiments, forming an electrostatic chuck includes adhering the substrate to the insulator layer. In some embodiments, the forming includes assembling one or more layers into an electrostatic chuck. In some embodiments, forming an electrostatic chuck comprising at least one of an ablated etch resistant layer, a dielectric layer, an ablated metallized layer, a bonding layer, an insulator layer, or any combination thereof. In some embodiments, the dielectric layer is located between the ablated etch resistant layer and the ablated metallized layer. In some embodiments, the ablated metallized layer is located between the dielectric layer and the bonding layer. In some embodiments, the bonding layer is located between the ablated metallized layer and the insulator layer. In some embodiments, the dielectric layer directly contacts the ablated etch resistant layer. In some embodiments,

the dielectric layer directly contacts the metallized layer. In some embodiments, the dielectric layer directly contacts the bonding layer. In some embodiments, the bonding layer directly contacts the metallized layer. In some embodiments, the bonding layer directly contacts the insulator layer.

[0035] In some embodiments, when measuring an electrical resistance across the one or more exposed portions of the substrate formed between two metallized portions by laser ablation, the electrostatic chuck displays an electrical isolation of 300 GΩ to 1 TΩ, or any range or subrange between 300 GΩ and 1 TΩ. In some embodiments, when measuring an electrical resistance across the one or more exposed portions of the substrate, the electrostatic chuck displays an electrical isolation of 300 GΩ or more. In some embodiments, the electrostatic chuck displays an electrical isolation of 400 GΩ or more. In some embodiments, the electrostatic chuck displays an electrical isolation of 500 GΩ or more. In some embodiments, the electrostatic chuck displays an electrical isolation of 600 GΩ or more. In some embodiments, the electrostatic chuck displays an electrical isolation of 700 GΩ or more. In some embodiments, the electrostatic chuck displays an electrical isolation of 800 GΩ or more. In some embodiments, the electrostatic chuck displays an electrical isolation of 900 GΩ or more. In some embodiments, the electrostatic chuck displays an electrical isolation of 1 TΩ or more.

[0036] In some embodiments, a surface roughness on the one or more exposed portions of the substrate is less than 1 μm (e.g., 0.01 μm to 1 μm, or any range or subrange between 0.01 μm and 1 μm), or less than 0.75 micrometers. For example, in some embodiments, the expected surface roughness of the one or more exposed portions of the substrate is less than 0.7 μm, less than 0.65 μm, less than 0.6 μm, less than 0.55 μm, less than 0.51 μm, or less than 0.5 μm. In some embodiments,

[0037] In some embodiments, the one or more exposed portions of the substrate provide for a plurality of embossments.

[0038] In some embodiments, the one or more exposed portions of the substate provide for a plurality of electrodes. In some embodiments, the plurality of electrodes includes separate electrically conducting pathways. In some embodiments, the plurality of electrodes includes at least two electrodes. In some embodiments, the plurality of electrodes includes at least three electrodes.

In some embodiments, the plurality of electrodes includes at least four electrodes. In some embodiments, the plurality of electrodes includes at least five electrodes. In some embodiments, the plurality of electrodes includes at least six electrodes.

[0039] In some embodiments, the plurality of electrodes forms a pattern. In some embodiments, the pattern can be a pattern in which each of the plurality of electrodes extends from a starting point to an ending point. In some embodiments, the pattern is a pattern such that none of the plurality of electrodes contact or cross one another. In some embodiments, the pattern can be based on a shape of the surface substrate, such as a circular, square, or rectangular shape. In some embodiments, the plurality of electrodes forms a spiral pattern.

[0040] Some embodiments of this disclosure provide for an electrostatic chuck. In some embodiments, the electrostatic chuck includes a substrate having at least one etch resistant coating layer as disclosed herein. In some embodiments, the at least one etch resistant coating layer includes a laser ablated pattern. In some embodiments, the laser ablated pattern includes one or more exposed portions of the substate spanning distances of at least 0.5 mm. For example, in some embodiments, the one or more exposed portions of the substrate in the laser ablated pattern span distances of at least 1 mm, 1.5 mm, 2 mm, 2.5 mm, 3 mm, 3.5 mm, 4 mm, 4.5 mm, 5 mm, 5.5 mm, 6 mm, 6.5 mm, 7 mm, 7.5 mm, 8 mm, 8.5 mm, 9 mm, 9.5 mm, or 10 mm. It will be appreciated that the electrostatic chucks may comprise any of the electrostatic chucks disclosed herein, including those formed according to the methods disclosed herein, without departing from the scope of this disclosure.

[0041] FIG. 2 is a schematic diagram of a method of forming an electrostatic chuck, according to some embodiments. As shown in FIG. 2, the metallized layer is located on the dielectric layer prior to laser-ablating the metallized layer. After laser-ablating the metallized layer, the laser-ablated metallized layer is bonded to an insulator layer via a polymeric bonding layer. An etch resistant layer is formed on an opposing surface of the dielectric layer and subsequently laser ablated to form embossments, wherein the opposing surface of the dielectric layer is the surface opposite the surface on which the laser-ablated metallized layer is located.

EXAMPLE

[0042] As an alternative to photolithography and/or etching, a metallized layer was removed by laser ablation. The metallized layer was located on an alumina substrate. A portion of the metallized layer was removed by laser ablation sufficient to expose at least a portion of the alumina substrate. The metallized layer comprised a titanium coating. UV nanosecond, IR nanosecond, and IR picosecond lasers were employed. Various attributes of the laser ablated samples were evaluated and compare (e.g. step height, surfacer roughness, electrical isolation, trace and resistance). The results are provided in FIG. 3 which includes two tables summarizing the test results of laser-ablated samples provided in accordance with some embodiments of the disclosure. In sum, samples ablated using the IR nanosecond and UV nanosecond lasers both passed electrical testing. The samples ablated using IR picosecond fast and slow exhibited favorable surface roughness values.

ASPECTS

[0043] Various Aspects are described below. It is to be understood that any one or more of the features recited in the following Aspect(s) can be combined with any one or more other Aspect(s).

Aspect 1. A method, comprising:

obtaining a substrate comprising an etch resistant coating layer;

ablating, with a laser, the etch resistant coating layer so as to remove at least a portion of the etch resistant coating layer so as to provide one or more exposed portions of the substrate; and

forming an electrostatic chuck,

wherein, when measuring an electrical resistance across the one or more exposed portions of the substrate, the electrostatic chuck displays an electrical isolation of 300 GΩ or more.

Aspect 2. The method according to Aspect 1, wherein the etch resistant coating layer comprises silicon, carbide, yttrium oxide, aluminum oxide, or any combinations thereof.

Aspect 3. The method according to any one of Aspects 1-2, wherein the substrate comprises ceramic, alumina, zirconia, aluminum-nitride, aluminum-oxy-nitride, silicon-nitride, silicon-oxide, silicon-carbide, silicon-oxy-nitride, silicon-carbo-nitride, tungsten-carbide, molybdenum-disilicide, titanium-oxide, hafnium silicate, zirconium silicate, zirconium silicate, hafnium dioxide, strontium dioxide, scandium dioxide, zirconium dioxide, chromium oxide, yttrium oxide, iron oxide, barium oxide, barium titanate, tantalum oxide, or any combinations thereof.

Aspect 4. The method according to any one of Aspects 1-3, wherein the laser comprises ultra-violet nanosecond (UV ns) lasers, infra-red nanosecond (IR ns) lasers, infra-red picosecond (IR ps) lasers, green lasers, or any combinations thereof.

Aspect 5. The method according to any one of Aspects 1-4, wherein the laser is applied at a rate of 0.5 mm^2/s to 8.5 mm^2/s.

Aspect 6. The method according to any one of Aspects 1-5, wherein the laser is applied in cycles of 48 s to 798 s.

Aspect 7. The method according to any one of Aspects 1-6, wherein the one or more exposed portions of the substrate span distances of at least 0.5 mm.

Aspect 8. The method according to any one of Aspects 1-7, wherein the one or more exposed portions of the substrate provide for a plurality of embossments.

Aspect 9. A method, comprising:

obtaining a substrate comprising a metallized layer;

ablating, with a laser, the metallized layer so as to remove at least a portion of the metallized layer so as to provide one or more exposed portions of the substate; and

forming an electrostatic chuck,

wherein, when measuring an electrical resistance across the one or more exposed portions of the substrate, the electrostatic chuck displays an electrical isolation of 300 GΩ or more.

Aspect 10. The method according to Aspect 9, wherein the metallized layer comprises aluminum, tungsten, nickel, stainless steel, silver, gold, tantalum, platinum, palladium, cobalt, titanium, copper, molybdenum, silicon, or any combinations thereof.

Aspect 11. The method according to any one of Aspects 9-10, wherein the metallized layer has a thickness of 0.7 micrometers to 1.5 micrometers.

Aspect 12. The method according to any one of Aspects 9-11, wherein the one or more exposed portions of the substate span distances of at least 0.5 mm.

Aspect 13. The method according to any one of Aspects 9-12, wherein the one or more exposed portions of the substate provide for a plurality of electrodes having separate electrically conducting pathways.

Aspect 14. An electrostatic chuck, comprising:

a substrate having at least one etch resistant coating layer comprising a laser ablated pattern;

wherein the laser ablated pattern comprises one or more exposed portions of the substate spanning distances of at least 0.5 mm.

Aspect 15. The electrostatic chuck according to Aspect 14, wherein the at least one etch resistant coating layer comprises a metallized layer.

Aspect 16. The electrostatic chuck according to any one of Aspects 14-15, wherein the one or more exposed portions of the substate provide for a plurality of electrodes having separate electrically conducting pathways.

Aspect 17. The electrostatic chuck according to Aspect 16, wherein the one or more exposed portions of the substate provide for a plurality of embossments.

[0044] It is to be understood that changes may be made in detail, especially in matters of the construction materials employed and the shape, size, and arrangement

of parts without departing from the scope of this disclosure. This Specification and the embodiments described are examples, with the true scope and spirit of the disclosure being indicated by the claims that follow.

CLAIMS

What is claimed is:

1. A method, comprising:

   obtaining a substrate comprising an etch resistant coating layer;

   ablating, with a laser, the etch resistant coating layer to remove at least a portion of the etch resistant coating layer and obtain one or more exposed portions of the substrate; and

   forming an electrostatic chuck,

      wherein, when measuring an electrical resistance across an exposed portion of the substrate between two metallized portions, the electrostatic chuck exhibits an electrical isolation of 300 GΩ or more.

2. The method of claim 1, wherein the etch resistant coating layer comprises silicon, carbide, yttrium oxide, aluminum oxide, or any combinations thereof.

3. The method of claim 1, wherein the substrate comprises ceramic, alumina, zirconia, aluminum-nitride, aluminum-oxy-nitride, silicon-nitride, silicon-oxide, silicon-carbide, silicon-oxy-nitride, silicon-carbo-nitride, tungsten-carbide, molybdenum-disilicide, titanium-oxide, hafnium silicate, zirconium silicate, zirconium silicate, hafnium dioxide, strontium dioxide, scandium dioxide, zirconium dioxide, chromium oxide, yttrium oxide, iron oxide, barium oxide, barium titanate, tantalum oxide, or any combinations thereof.

4. The method of claim 1, wherein the laser comprises ultra-violet nanosecond (UV ns) lasers, infra-red nanosecond (IR ns) lasers, infra-red picosecond (IR ps) lasers, green lasers, or any combinations thereof.

5. The method of claim 1, wherein the laser is applied at a rate of 0.5 mm^2/s to 8.5 mm^2/s.

6. The method of claim 1, wherein the laser is applied in cycles of 48 s to 798 s.

7. The method of claim 1, wherein the one or more exposed portions of the substrate span distances of at least 0.5 mm.

8. The method of claim 1, wherein the one or more exposed portions of the substrate provide for a plurality of embossments.

9. A method, comprising:

obtaining a substrate comprising a metallized layer;

ablating, with a laser, the metallized layer so as to remove at least a portion of the metallized layer so as to provide one or more exposed portions of the substate; and

forming an electrostatic chuck,

wherein, when measuring an electrical resistance across an exposed portion of the substrate between two metallized portions, the electrostatic chuck exhibits an electrical isolation of 300 GΩ or more.

10. The method of claim 9, wherein the metallized layer comprises aluminum, tungsten, nickel, stainless steel, silver, gold, tantalum, platinum, palladium, cobalt, titanium, copper, molybdenum, silicon, or any combinations thereof.

11. The method of claim 9, wherein the metallized layer has a thickness of 0.7 micrometers to 1.5 micrometers.

12. The method of claim 9, wherein the one or more exposed portions of the substate span distances of at least 0.5 mm.

13. The method of claim 9, wherein the one or more exposed portions of the substate provide for a plurality of electrodes having separate electrically conducting pathways.

14. An electrostatic chuck, comprising:

a substrate having at least one etch resistant coating layer comprising a laser ablated pattern comprising one or more exposed portions of the substate spanning distances of at least 0.5 mm, wherein when measuring an electrical

resistance across an exposed portion of the substrate between two metallized portions, the electrostatic chuck exhibits an electrical isolation of 300 GΩ or more.

15. The electrostatic chuck of claim 14, wherein the at least one etch resistant coating layer comprises a metallized layer.

16. The electrostatic chuck of claim 14, wherein the one or more exposed portions of the substate provide for a plurality of electrodes having separate electrically conducting pathways.

17. The electrostatic chuck of claim 14, wherein the one or more exposed portions of the substate provide for a plurality of embossments.

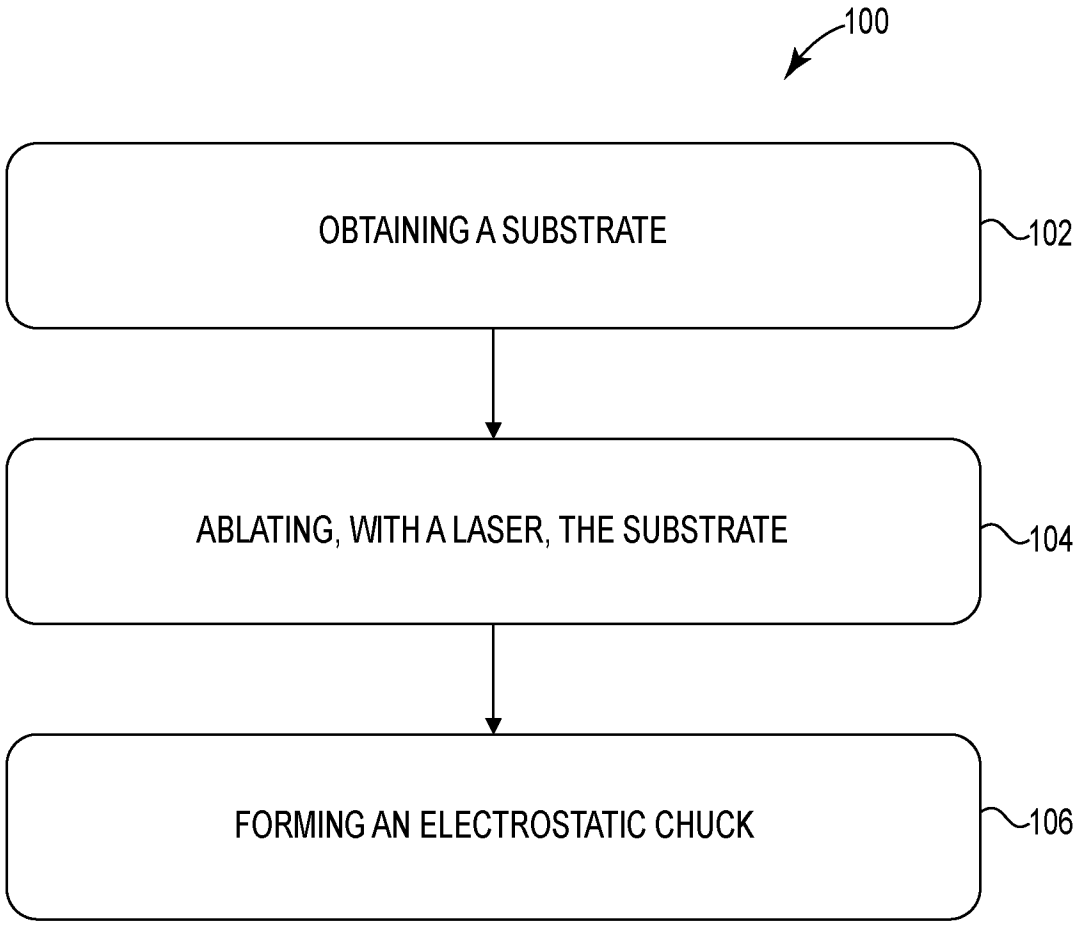
100
OBTAINING A SUBSTRATE
102
ABLATING, WITH A LASER, THE SUBSTRATE
104
FORMING AN ELECTROSTATIC CHUCK
106

FIG. 1

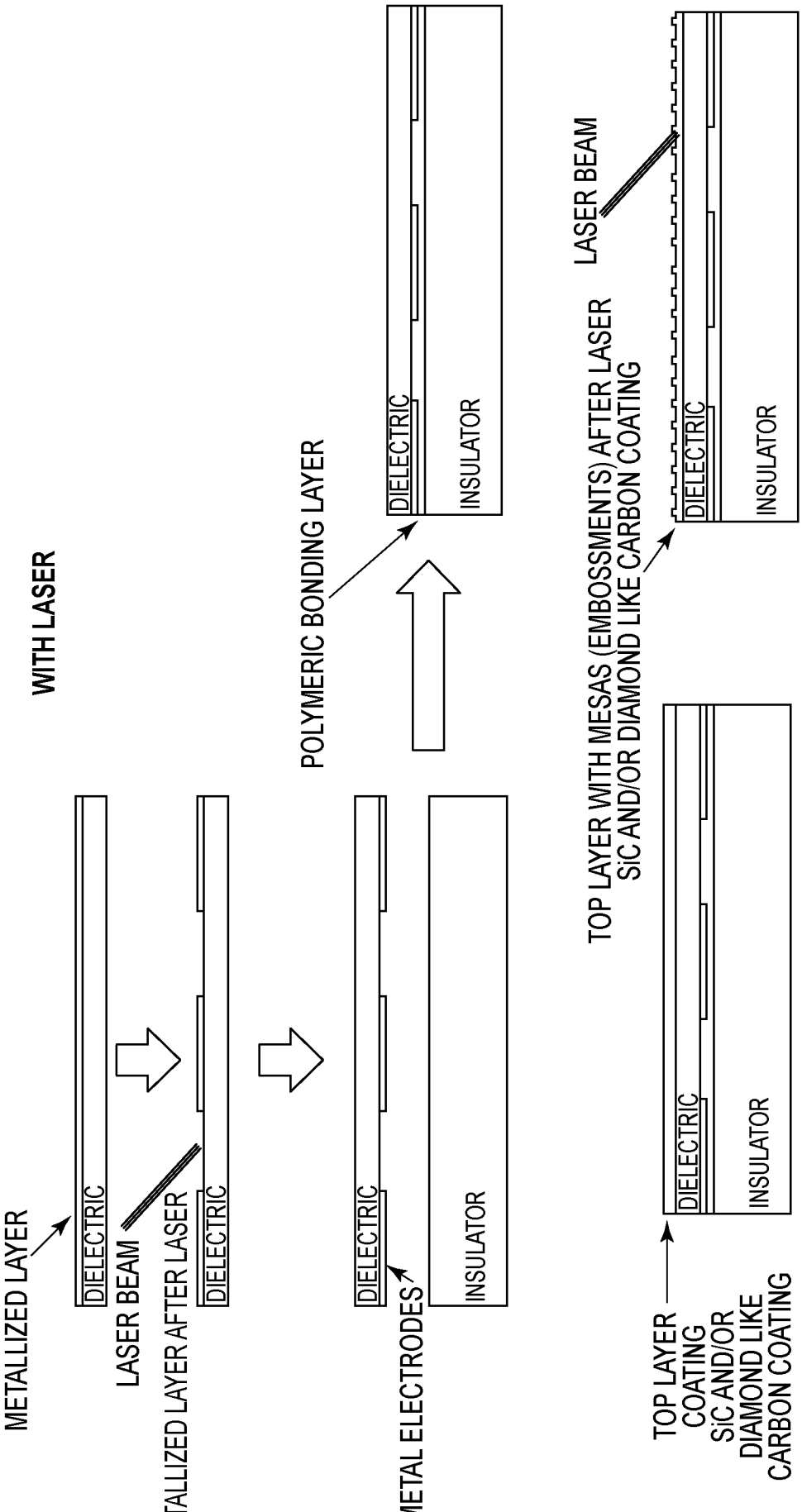
WITH LASER
METALLIZED LAYER
DIELECTRIC
LASER BEAM
METALLIZED LAYER AFTER LASER
DIELECTRIC
METAL ELECTRODES
DIELECTRIC
INSULATOR
POLYMERIC BONDING LAYER
DIELECTRIC
INSULATOR
TOP LAYER WITH MESAS (EMBOSSMENTS) AFTER LASER
SiC AND/OR DIAMOND LIKE CARBON COATING
LASER BEAM
DIELECTRIC
INSULATOR
TOP LAYER
COATING
SiC AND/OR
DIAMOND LIKE
CARBON COATING
DIELECTRIC
INSULATOR

FIG. 2

AREA	Sa	Sz	Ra(X)	Ra(Y)	CYCLE	RATE
ORIGINAL	0.37 um	5.6 um	0.39 um	0.26 um		
UV ABLATION	0.66 um	8.5 um	0.66 um	0.52 um	798 s	0.5 mm^2/s
IR NS ABLATION	0.59 um	5.8 um	0.57 um	0.58 um	65 s	6.3 mm^2/s
IR PS FAST ABLATION	0.38 um	3.8 um	0.31 um	0.29 um	48 s	8.5 mm^2/s
IR PS SLOW ABLATION	0.31 um	4.2 um	0.21 um	0.19 um	96 s	4.3 mm^2/s

LOCATION	STEP HEIGHT (μm)	Ra SPEC: <0.51 um SURFACE ROUGHNESS (μm)	ELECTRICAL ISOLATION	ABLATED REGION TRACE RESISTANCE
UV NC LASER	5.71	0.757	328 GΩ	> E13 Ω
IR NC LASER	3.52	0.498	1.16 TΩ	> E13 Ω
IR PS FAST	1.29	0.408	552 MΩ	3 E12 Ω
IR PS SLOW	1.866	0.468	53.5 MΩ	2.37 E9 Ω

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/049138

A. CLASSIFICATION OF SUBJECT MATTER

B23Q 3/154(2006.01)i; **B23K 37/04**(2006.01)i; **H01L 21/683**(2006.01)i; **B23K 26/354**(2014.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B23Q 3/154(2006.01); C04B 41/88(2006.01); H01L 21/3065(2006.01); H01L 21/677(2006.01); H01L 21/683(2006.01); H01R 43/00(2006.01); H02N 13/00(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: electrostatic chuck, laser, substrate, etch resistant coating layer, metallized layer, electrical isolation, electrical resistance, embossments

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2019-021867 A (DISCO ABRASIVE SYSTEM LTD.) 07 February 2019 (2019-02-07) paragraphs [0016]-[0035] and figures 1, 2	1-17
A	JP 2019-179780 A (SUMITOMO OSAKA CEMENT CO., LTD.) 17 October 2019 (2019-10-17) paragraphs [0029], [0065]-[0068] and figure 2C	1-17
A	US 2016-0358803 A1 (APPLIED MATERIALS, INC.) 08 December 2016 (2016-12-08) paragraph [0037] and figure 1	1-17
A	JP 2016-072567 A (NGK SPARK PLUG CO., LTD.) 09 May 2016 (2016-05-09) paragraphs [0051]-[0072] and figures 3-9	1-17
A	US 2008-0151466 A1 (SIMPSON, MATTHEW A.) 26 June 2008 (2008-06-26) paragraphs [0029]-[0058] and figure 1	1-17

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 January 2025	**09 January 2025**

Name and mailing address of the ISA/KR	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2024/049138

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2019-021867 A	07 February 2019	CN 109285806 A	29 January 2019
		CN 109285806 B	19 December 2023
		JP 6935132 B2	15 September 2021
		KR 10-2019-0010445 A	30 January 2019
		KR 10-2533799 B1	17 May 2023
		TW 201917815 A	01 May 2019
		TW I766037 B	01 June 2022
JP 2019-179780 A	17 October 2019	None	
US 2016-0358803 A1	08 December 2016	CN 107636820 A	26 January 2018
		CN 107636820 B	07 January 2022
		JP 2018-518055 A	05 July 2018
		KR 10-2018-0005742 A	16 January 2018
		KR 10-2547845 B1	23 June 2023
		TW 201643986 A	16 December 2016
		TW I669772 B	21 August 2019
		US 10332773 B2	25 June 2019
		WO 2016-195945 A1	08 December 2016
JP 2016-072567 A	09 May 2016	CN 105489541 A	13 April 2016
		CN 105489541 B	17 May 2019
		JP 6463936 B2	06 February 2019
		KR 10-2016-0039536 A	11 April 2016
		TW 201617299 A	16 May 2016
		TW I574936 B	21 March 2017
		US 2016-0099163 A1	07 April 2016
US 2008-0151466 A1	26 June 2008	WO 2008-082977 A2	10 July 2008
		WO 2008-082977 A3	12 September 2008