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(54) Title: DEVICE AND METHOD FOR MASKLESS THIN FILM ETCHING

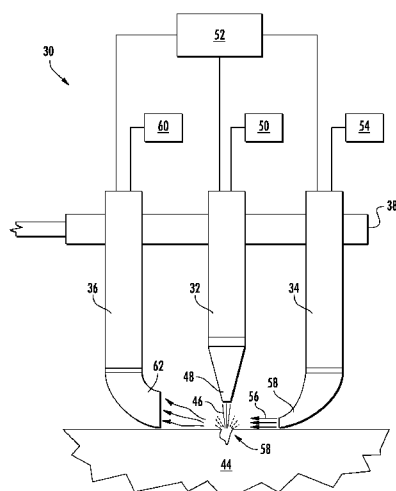


FIG. 2

(57) Abstract: A device for maskless thin film etching, including an ablation tool adapted to emit an ablative output for etching a surface, a gas jet associated with a source of carrier gas and adapted to emit a stream of the carrier gas at an area of the surface where the output of the ablation tool impinges, and a suction member associated with a vacuum source and adapted to collect ablated particulate from the area of the surface where the output of the ablation tool impinges, wherein the ablation tool, the gas jet, and the suction member are mounted adjacent one another.

DEVICE AND METHOD FOR MASKLESS THIN FILM ETCHING**Related Applications**

[0001] This Application claims priority to U.S. provisional patent application no. 62/322,415, filed April 14, 2016, entitled "Volume Change Accommodating TFE Materials" and incorporated by reference herein in its entirety.

Field

[0002] The present embodiments relate generally to the fabrication of thin film devices, and more particularly to maskless etching devices and techniques for the fabrication of thin film batteries.

Background

[0003] Solid state thin film batteries (TFBs) are known to exhibit several advantages over conventional battery technologies. These advantages include superior form factors, cycle life, power capability, and safety. An embodiment of a TFB may include a plurality of layers disposed in a stacked arrangement, such layers including a cathode current collector layer, a cathode layer, a solid state electrolyte, an anode layer, an anode current collector layer, and an encapsulation layer, for example. These layers are commonly formed by successive deposition of the layers on a substrate using a deposition tool. After certain layers are deposited, portions of the layers may be removed or "etched" before additional layers are deposited. In this manner a TFB having a predetermined layer profile or architecture may be achieved.

[0004] The etching of TFB layers has traditionally been accomplished using so-called "masked" etching techniques involving the use of a physical mask placed over a layer (or layers) to be etched. The mask covers certain portions of the layer and leaves other portions exposed.

The masked layer is subjected to a blanket ablation (e.g., via exposure to heat, solvent, ion bombardment, etc.), resulting in the exposed portions of the masked layer being removed while the covered portions are left intact.

[0005] More recently, so-called "maskless" etching techniques have been developed for selectively removing portions of TFB layers during manufacture. Maskless etching involves the use of a precision ablation tool (e.g., a laser) to etch discrete portions of a TFB layer (or layers) while leaving other portions of the layer intact. Despite being less expensive and facilitating higher throughput relative to masked etching, maskless etching is nonetheless associated with certain shortcomings. For example, a laser ablation tool can generate plasma and can create so-called "heat affected zones" (HAZs) immediately adjacent the ablation beam path, possibly damaging portions of an etched layer. A laser ablation tool can also disperse ablated particulate matter in the vicinity an ablation beam path. Either of these phenomena can facilitate the propagation of leakage currents in an affected layer, resulting in a defective or sub-standard TFB.

[0006] With respect to these and other considerations the present disclosure is provided.

Brief Summary

[0007] This Summary is provided to introduce a selection of concepts in a simplified form further described below in the Detailed Description. This Summary is not intended to identify key or essential features of the claimed subject matter, nor is this Summary intended as an aid in determining the scope of the claimed subject matter.

[0008] An exemplary embodiment of a device for maskless thin film etching in accordance with the present disclosure may include an ablation tool, a gas jet associated with a source of carrier gas and adapted to emit a stream of the carrier gas, and a suction member

associated with a vacuum source and adapted to collect gas and particulate. The ablation tool, the gas jet, and the suction member are mounted adjacent one another.

[0009] Another exemplary embodiment of a device for maskless thin film etching in accordance with the present disclosure may include an ablation tool adapted to emit an ablative output for etching a surface. The device may further include a gas jet associated with a source of carrier gas and adapted to emit a stream of the carrier gas at an area of the surface where the output of the ablation tool impinges. The device may further include a suction member associated with a vacuum source and adapted to collect ablated particulate from the area of the surface where the output of the ablation tool impinges. The ablation tool, the gas jet, and the suction member are mounted adjacent one another.

[0010] An exemplary embodiment of a method for maskless thin film etching in accordance with the present disclosure may include positioning an ablation tool adjacent a surface to be etched. The method may further include positioning a gas jet adjacent the ablation tool, wherein the gas jet is associated with a source of carrier gas and is adapted to emit a stream of the carrier gas, and positioning a suction member adjacent the ablation tool, wherein the suction member associated with a vacuum source and is adapted to collect gas and particulate.

Brief Description of the Drawings

[0011] **FIG. 1** is a cross-sectional view illustrating an exemplary thin-film battery structure contemplated for fabrication by the disclosed device and method;

[0012] **FIG. 2** is a schematic illustration of an exemplary embodiment of an etching device in accordance with the present disclosure;

[0013] FIG. 3 is a flow diagram illustrating an exemplary method in accordance with the present disclosure.

Detailed Description

[0014] The present embodiments will now be described more fully hereinafter with reference to the accompanying drawings, where some embodiments are shown. The subject matter of the present disclosure may be embodied in many different forms and are not to be construed as limited to the embodiments set forth herein. These embodiments are provided so this disclosure will be thorough and complete, and will fully convey the scope of the subject matter to those skilled in the art. In the drawings, like numbers refer to like elements throughout.

[0015] The present disclosure relates to a device and method for masklessly etching layers of thin film batteries (TFBs) during manufacture. Particularly, the disclosed device and method are directed toward mitigating manufacturing defects associated with maskless ablation techniques, and specifically those defects stemming from plasma generation and re-deposition of ablated particulate in the vicinity of an ablated area of a TFB layer.

[0016] In general, the disclosed device and method may include an ablation tool (e.g., a laser) for etching discrete, predetermined portions of the layers of a TFB after the layers have been deposited on a substrate. The disclosed device and method further include a gas jet and a suction member disposed adjacent the ablation tool. The gas jet may be coupled to a gas source containing a pressurized carrier gas and may be configured to direct a stream of the pressurized carrier gas toward a point where the ablation tool impinges on an ablated surface (e.g., a surface of a layer of a TFB). The suction member may be coupled to a vacuum source and may be configured to draw gas and particulate away from the point where the ablation tool impinges on an ablated surface. Thus, the pressurized carrier gas emitted from the gas jet may provide a

medium for entraining ablated particulate generated by the ablation tool, and the suction member may evacuate the carrier gas and the entrained particulate from the ablation site. The ablated particulate is thus prevented from redepositing on the etched surface. In various embodiments, the carrier gas may be an inert gas selected for an ability to suppress plasma formation in the vicinity of the ablation site for mitigating the creation of heat affected zones (HAZs) in surrounding portions of the etched surface.

[0017] As will be appreciated, the disclosed device and method can be implemented in the manufacture of a variety of different TFB architectures. **FIG. 1** illustrates a cross-sectional view of a non-limiting, exemplary TFB 10 amenable to fabrication using the device and method described herein. The illustrated TFB 10 may include a stack of layers 12 fabricated on a substrate 14. The stack of layers 12 may include a cathode current collector (CCC) layer 16, a cathode layer 18, a solid state electrolyte layer 20, an anode/anode current collector (ACC) layer 24, and an encapsulation layer 26. In one non-limiting embodiment, the encapsulation layer 26 may be formed of a plurality of alternating polymer and dielectric layers 28, 29 for providing the encapsulation layer 26 with resiliency to accommodate thermal expansion and contraction of the TFB 10. The CCC may be formed of a metal layer (e.g., Au or Pt) or a plurality of metal layers (e.g., Ti and Au or Ti and Pt) capable of good adhesion to the substrate 14 and capable of withstanding high temperature annealing of the cathode layer 18. The cathode layer 18 may be formed of lithium cobalt oxide (LiCoO₂) or a similar material. The solid state electrolyte layer 20 may be formed of lithium phosphorus oxynitride (LiPON) or similar material. The ACC layer 24 may be formed of copper or similar material.

[0018] The device and method disclosed herein may be utilized to etch portions of the various layers 12 of the TFB 10 as the various layers 12 are deposited atop the substrate 14 (e.g.,

in between depositions) to achieve a predetermined TFB architecture. For example, the TFB 10 depicted in **FIG. 1** has a so-called "non-coplanar" architecture wherein the CCC layer 16 is not coplanar with the ACC layer 24. Of course, **FIG. 1** merely illustrates one possible arrangement for a TFB architecture amendable to fabrication using the device and method described below, and those of ordinary skill in the art will appreciate the concepts disclosed herein can be implemented to achieve various other TFB architectures. A non-limiting example of such an alternative architecture is a so-called "coplanar" architecture having a CCC layer coplanar with an ACC layer.

[0019] Referring to **FIG. 2**, a schematic illustration of an etching device 30 (hereinafter "the device 30") in accordance with a non-limiting embodiment of the present disclosure is shown. The device 30 may generally include an ablation tool 32, a gas jet 34, and a suction member 36 mounted adjacent one another on a movable carrier arm 38. The carrier arm 38 may be adapted to selectively move the ablation tool 32, gas jet 34, and suction member 36 vertically and horizontally relative to a surface 44 (e.g., a surface of a layer of a TFB) to be etched as further described below. In various alternative embodiments, the device 30 may have a fixed, static position (e.g., omitting a movable carrier arm) and the surface 44 may be vertically and horizontally movable relative to the device 30. In various other embodiments, the device 30 and the surface 44 may be movable.

[0020] The ablation tool 32 may be, and will be described hereinafter as, a laser adapted to emit a laser beam 46 from a tip 48 of the ablation tool 32 as shown in **FIG. 2**. In various alternative embodiments, the ablation tool 32 may be any type of precision ablation device, such as a media jet or blaster adapted to emit a jet of abrasive media (e.g., silica sand) suspended in a stream of pressurized gas. Abrasive media ablation may provide certain advantages relative to

laser ablation, including the absence of laser-induced plasma and associated HAZs on the surface 44. In other embodiments, the etching device 30 may include a laser and a media jet capable of being implemented selectively and interchangeably. In various embodiments wherein the ablation tool 32 is a laser, the laser may be a laser scanner independent of the carrier arm 38 and capable of scanning a laser beam at speeds of 50 meters per second or higher, much faster than can be achieved through mechanical movement of the carrier arm 38.

[0021] The ablation tool 32 may be operably connected to an electrical power source 50 and to a controller 52. The controller 52 may be adapted to dictate operation of the carrier arm 38 and the ablation tool 32 in a predetermined or preprogrammed manner, such as to etch a predefined pattern in the surface 44. If the ablation tool 32 is a media blaster or a similar device configured to emit a jet of abrasive media, the ablation tool 32 may additionally be coupled to a pressurized gas source and to a source of abrasive media (not shown) as may be appropriate.

[0022] The gas jet 34 of the device 30 may be coupled to a pressurized carrier gas source 54 and may be configured to emit a stream 56 of pressurized carrier gas from a tip 58 of the gas jet 34 disposed in close proximity to (e.g., in a range of 0.25 millimeters to 300 millimeters from) the tip 48 of the ablation tool 32. The stream 56 may be directed toward an area 58 of the surface 44 where the laser beam 46 emitted by the ablation tool 32 impinges. The gas jet 34 may further be coupled to the controller 52, wherein the controller 52 may be configured to dictate operation of the gas jet 34. For example, the controller 52 may be configured to operate the gas jet 34 in concert with the ablation tool 32, with the gas jet 34 being activated when the ablation tool 32 is active. In various embodiments, the controller 52 may be configured to activate the gas jet 34 a predetermined amount of time before or after activation of the ablation tool 32, and may be configured to deactivate the gas jet 34 a predetermined amount of time before or after

deactivation of the ablation tool 32. The embodiments of the present disclosure are not limited in this regard.

[0023] In various embodiments, the carrier gas emitted by the gas jet 34 may be any gas suitable for use within the vicinity of the surface 44. Examples of such gases include, with, clean dry air (CDA) with less than or equal to 8% moisture content, argon gas, nitrogen gas, etc. In various embodiments, the carrier gas may be specifically selected for an ability to suppress the formation of laser-induced plasma at the area 58 where the laser beam 46 emitted by the ablation tool 32 impinges. Non-limiting examples of such inert gases include Argon, Nitrogen, etc. The suppression of laser-induced plasma at the area 58 may mitigate the formation of HAZs in surrounding portions of the surface 44. More generally, the carrier gas may be selected based on factors such as the type and power of the laser emitted by the ablation tool 32, the nature of the environment of the surface 44, the material of the surface 44, etc.

[0024] The suction member 36 of the device 30 may be coupled to a vacuum source 60 and may be configured to collect gas and/or particulate (as further described below) at an inlet 62 of the suction member 36 disposed in close proximity to (e.g., in a range of 0.25 millimeters to 300 millimeters from) the tip 48 of the ablation tool 32. Specifically, the inlet 62 may be disposed in the path of the stream 56 of carrier gas emitted by the gas jet 34 and may be directed toward the area 58 where the laser beam 46 impinges on the surface 44. The suction member 36 may further be coupled to the controller 52, wherein the controller 52 may be configured to dictate operation of the suction member 36. For example, the controller 52 may be configured to operate the suction member 36 in concert with the ablation tool 32 and/or the gas jet 34, with the suction member 36 being activated when the ablation tool 32 and/or the gas jet 34 are active. In various embodiments, the controller 52 may be configured to activate the suction member 36 a

predetermined amount of time before or after activation of the ablation tool 32 and/or the gas jet 34, and may be configured to deactivate the suction member 36 a predetermined amount of time before or after deactivation of the ablation tool 32 and/or the gas jet 34. The embodiments of the present disclosure are not limited in this regard.

[0025] During operation of the device 30, the suction member 36 may collect vapor and ablated particulate from the impingement area 58, wherein the ablated particulate may be suspended in the stream 56 of pressurized carrier gas emitted from the gas jet 34. If the ablation tool 32 is a media blaster or a similar device configured to emit a jet of abrasive media, the suction member 36 may collect the media emitted by the ablation tool 32 (i.e., after the media has impinged on the surface 44) as well as any gas suspending the media. The media and the suspension gas may be directed toward the inlet 62 of the suction member 36 by the stream 56 of the pressurized carrier gas emitted from the gas jet 34. Thus, the suction member 36 may prevent ablated particulate and any abrasive media (if abrasive media is used) from depositing on the surface 44, mitigating any undesirable effects associated with such deposition. The suction member 36 may also prevent the distribution and accumulation of carrier gas emitted by the gas jet 34 in the environment of the surface 44.

[0026] Referring to **FIG. 3**, a flow diagram illustrating an exemplary embodiment of a method for implementing the device 30 in accordance with the present disclosure is shown. The method will now be described in detail in conjunction with the schematic representation of the device 30 shown in **FIG. 2**.

[0027] At block 100 of the illustrated method, the carrier arm 38 of the device 30 may be operated move the ablation tool 32, the gas jet 34, and the suction member 36 to a designated position above a surface (e.g., the surface 44 shown in **FIG. 2**) to be etched. The movement of

the carrier arm 38 may be dictated and coordinated by the controller 52, and the designated position may be a position wherein the tip 48 of the ablation tool 32 is positioned directly above a starting point of a predetermined pattern to be etched in the surface 44.

[0028] At block 110 of the illustrated method, the ablation tool 32 may be activated (e.g., by the controller 52) and may emit a laser beam 46 (if the ablation tool 32 is a laser) or a jet of abrasive media (if the ablation tool 32 is media jet or blaster), collectively referred to as an "output" of the ablation tool 32, to etch an area 58 of the surface 44 where the output impinges.

[0029] At block 120 of the illustrated method, the gas jet 34 may be activated (e.g., by the controller 52) and may emit the stream 56 of pressurized carrier gas from the tip 58 of the gas jet 34 toward the impingement area 58 on the surface 44. The gas jet 34 may be operated in concert with the ablation tool 32, with the gas jet 34 being activated when the ablation tool 32 is activated. In various embodiments, the gas jet 34 may be activated a predetermined amount of time before or after activation of the ablation tool 32. As described above, stream 56 of carrier gas may entrain ablated particulate adjacent the impingement area 58. Additionally, if the carrier gas is selected appropriately (e.g., if the carrier gas is an inert gas), the carrier gas may suppress the formation of laser-induced plasma at the impingement area 58, mitigating the formation of HAZs adjacent the impingement area 58.

[0030] At block 130 of the illustrated method, the suction member 36 may be activated (e.g., by the controller 52) and may collect vapor and ablated particulate from the impingement area 58, wherein the ablated particulate may be suspended in the stream 56 of pressurized carrier gas emitted from the gas jet 34. If the ablation tool 32 is a media blaster or a similar device configured to emit a jet of abrasive media, the suction member 36 may collect the media emitted by the ablation tool 32 (i.e., after the media has impinged on the surface 44) as well as any gas

suspending the media. The media and the suspension gas may be directed toward the inlet 62 of the suction member 36 by the stream 56 of the pressurized carrier gas emitted from the gas jet 34. Thus, the suction member 36 may prevent ablated particulate and abrasive media (if abrasive media is used) from depositing on the surface 44, mitigating any undesirable effects associated with such deposition. The suction member 36 may also prevent the distribution and accumulation of carrier gas emitted by the gas jet 34 in the environment of the surface 44. The suction member 36 may be operated in concert with the ablation tool 32 and/or the gas jet 34, with the suction member 36 being activated when the ablation tool 32 and/or the gas jet 34 are activated. In various embodiments, the suction member 36 may be activated a predetermined amount of time before or after activation of the ablation tool 32 and/or the gas jet 34.

[0031] At block 140 of the illustrated method, the controller 52 may operate the carrier arm 38 to move the ablation tool 32, the gas jet 34, and the suction member 36 along a predetermined path relative to the surface 44, such as for etching a predetermined pattern in the surface 44. For example, the active ablation tool 32 may be moved along a path defining the predetermined pattern. If the ablation tool 32 is not mounted on the carrier arm 38 (e.g., if the ablation tool 32 is a laser scanner), the controller 52 may operate the ablation tool 32 to impinge on the surface 44 in the predefined pattern. The predefined pattern may be stored in a memory of the controller 52 or may be communicated to the controller 52 via external input means, for example. As the pattern is etched in the surface 44, the active gas jet 34 and suction member 36 may operate in the manner described above to collect vapor and particulate and to suppress the formation of laser-induced plasma in the etched surface 44.

[0032] At block 150 of the illustrated method, after a predetermined pattern has been etched into the surface 44, the ablation tool 32, the gas jet 34, and the suction member 36 may be

deactivated (e.g., by the controller 52). In various embodiments, the gas jet 34 may be activated a predetermined amount of time before or after deactivation of the ablation tool 32, and the suction member 36 may be deactivated a predetermined amount of time before or after deactivation of the ablation tool 32 and/or the gas jet 34.

[0033] The device and method of the present disclosure provide numerous advantages. These include precise, maskless etching of a TFB layer while suppressing the formation of laser-induced plasma (in the case of laser ablation) and preventing the deposition of etched material on the etched layer. The device and method of the present disclosure further facilitate high-precision ablation of a TFB layer using abrasive media while preventing the deposition of the abrasive media on the etched layer. HAZs and leakage currents in etched layers are thus mitigated, facilitating the manufacture of better performing and more reliable TFBs.

[0034] The present disclosure is not to be limited in scope by the specific embodiments described herein. Indeed, other various embodiments of, and modifications to, the present disclosure, in addition to those described herein, will be apparent to those of ordinary skill in the art from the foregoing description and accompanying drawings. Thus, such other embodiments and modifications are intended to fall within the scope of the present disclosure. Furthermore, the present disclosure has been described herein in the context of a particular implementation in a particular environment for a particular purpose, while those of ordinary skill in the art will recognize the usefulness is not limited thereto and the present disclosure may be beneficially implemented in any number of environments for any number of purposes. Thus, the claims set forth below are to be construed in view of the full breadth and spirit of the present disclosure as described herein.

What is claimed is:

1. A device for maskless thin film etching comprising:
an ablation tool;
a gas jet associated with a source of carrier gas and adapted to emit a stream of the carrier gas; and
a suction member associated with a vacuum source and adapted to collect gas and particulate;
wherein the ablation tool, the gas jet, and the suction member are mounted adjacent one another.
2. The device of claim 1, wherein the ablation tool, the gas jet, and the suction member are mounted adjacent one another on a carrier arm, wherein the carrier arm is adapted to move the ablation tool, the gas jet, and the suction member relative to a surface to be etched.
3. The device of claim 1, wherein the ablation tool is a laser.
4. The device of claim 1, wherein the ablation tool is adapted to emit an abrasive media.
5. The device of claim 1, wherein the gas jet is adapted to emit the stream of the carrier gas at an area of a surface where an output of the ablation tool impinges.
6. The device of claim 1, wherein the carrier gas is an inert gas selected for an ability to suppress formation of laser-induced plasma.

7. The device of claim 1, further comprising a controller operatively coupled to the ablation tool, the gas jet, and the suction member and configured to operate the ablation tool, the gas jet, and the suction member in a predefined, coordinated manner.

8. A device for maskless thin film etching comprising:

an ablation tool adapted to emit an ablative output for etching a surface;

a gas jet associated with a source of carrier gas and adapted to emit a stream of the carrier gas at an area of the surface where the output of the ablation tool impinges; and

a suction member associated with a vacuum source and adapted to collect ablated particulate from the area of the surface where the output of the ablation tool impinges;

wherein the ablation tool, the gas jet, and the suction member are mounted adjacent one another.

9. A method for maskless thin film etching comprising:

positioning an ablation tool adjacent a surface to be etched;

positioning a gas jet adjacent the ablation tool, wherein the gas jet is associated with a source of carrier gas and is adapted to emit a stream of the carrier gas; and

positioning a suction member adjacent the ablation tool, wherein the suction member associated with a vacuum source and is adapted to collect gas and particulate.

10. The method of claim 9, wherein the ablation tool, the gas jet, and the suction member are mounted on a carrier arm, the method further comprising moving the carrier arm relative to the surface.
11. The method of claim 9, wherein the ablation tool is a laser.
12. The method of claim 9, wherein the ablation tool is adapted to emit an abrasive media.
13. The method of claim 9, further comprising the gas jet emitting the stream of the carrier gas at an area of the surface where an output of the ablation tool impinges.
14. The method of claim 9, wherein the carrier gas is an inert gas selected for an ability to suppress formation of laser-induced plasma.
15. The method of claim 9, further comprising a controller operating the ablation tool, the gas jet, and the suction member in a predefined, coordinated manner.

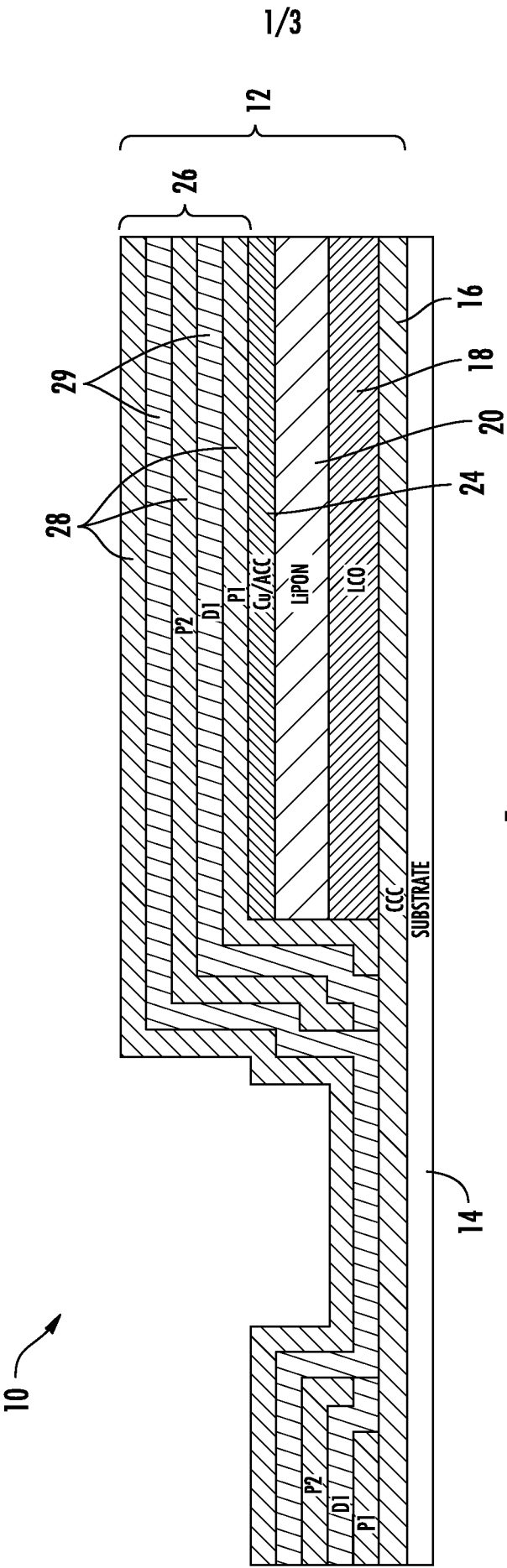


FIG. 1

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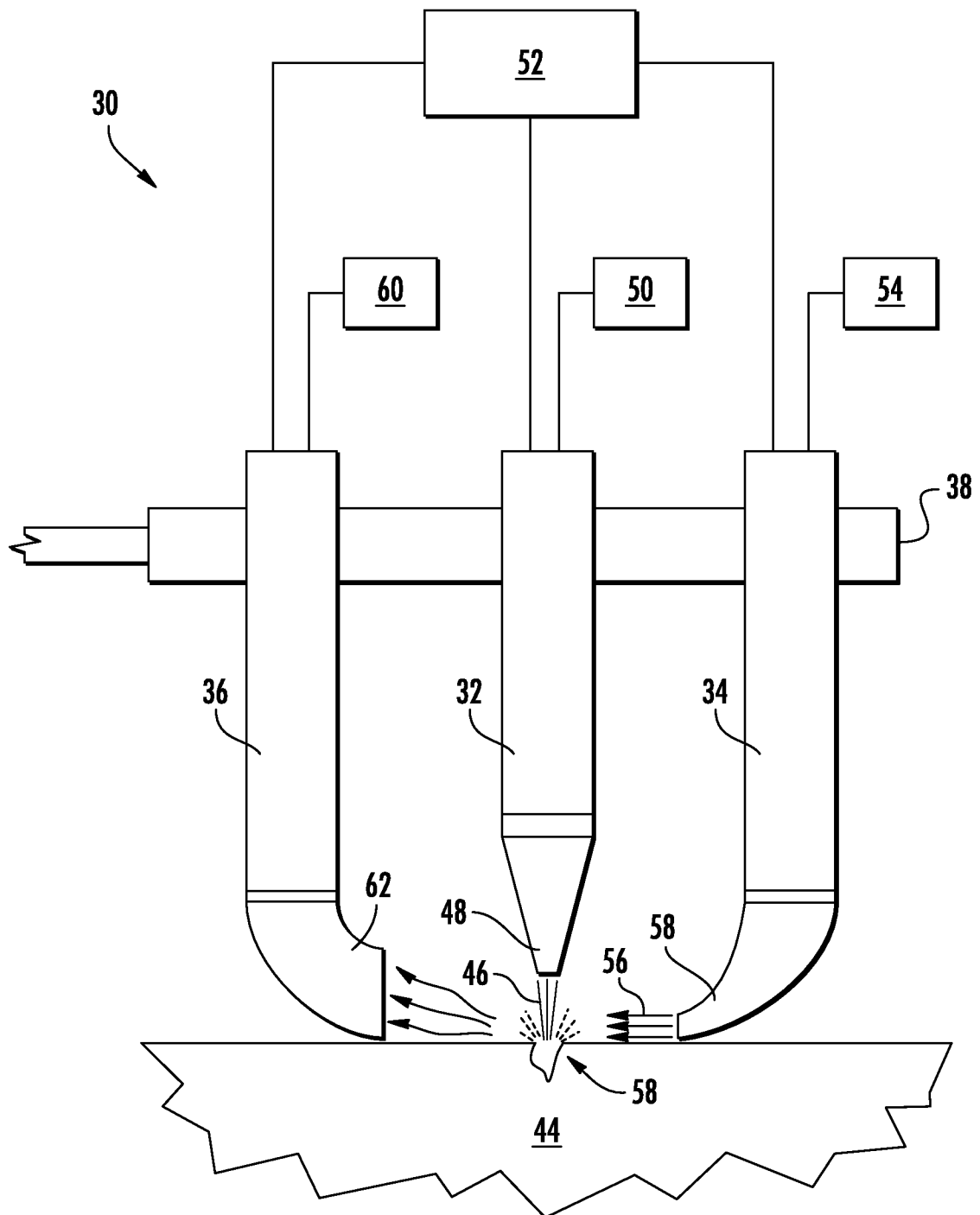
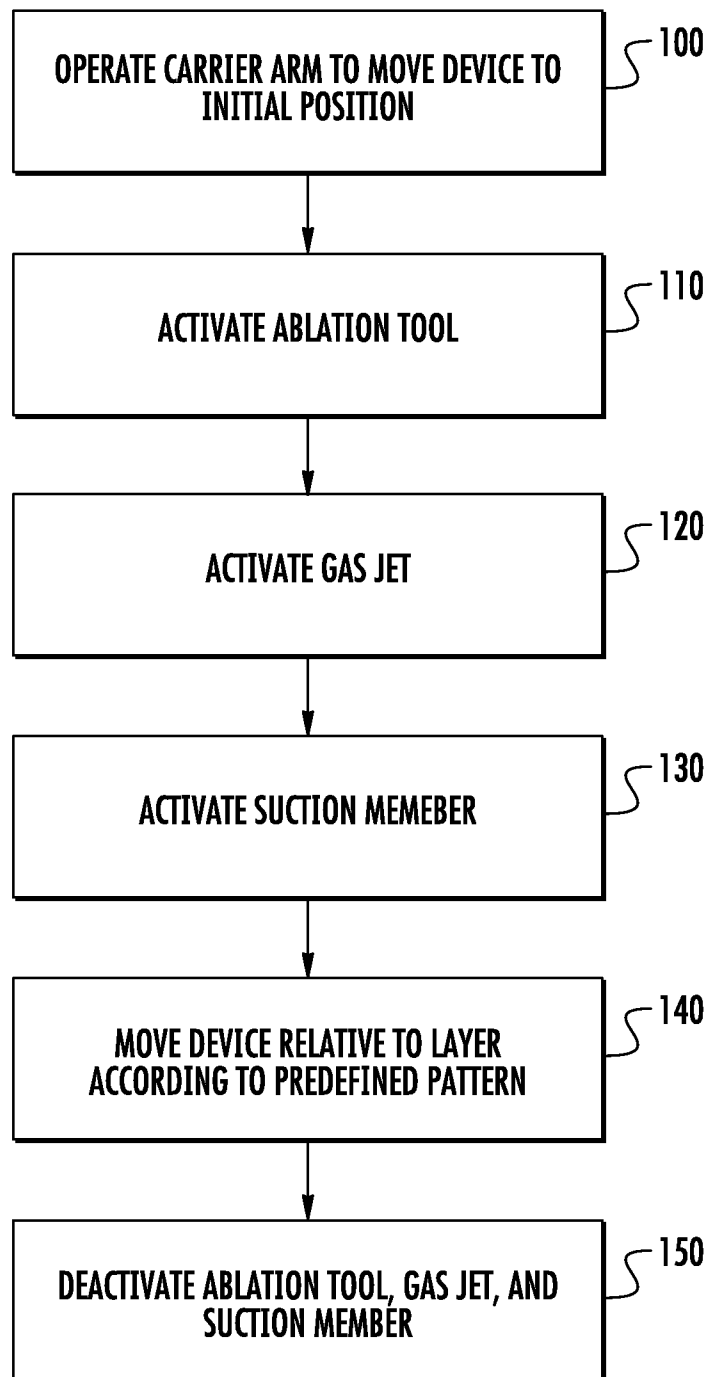


FIG. 2

3/3

**FIG. 3**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/027536**A. CLASSIFICATION OF SUBJECT MATTER****B23K 26/362(2014.01)i, B23K 26/142(2014.01)i, B23K 101/36(2006.01)n**

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)

B23K 26/362; B23K 26/36; B23K 26/16; B23K 26/14; B23K 26/364; B23K 26/00; B29C 35/08; B23K 26/142; B23K 101/36

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: ablation, laser, suction, gas jet, thin film, etching, arm, mount, and controller

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6566628 B2 (VOGT et al.) 20 May 2003	1,3-6,8-9,11-14
Y	See column 7, line 26 - column 8, line 48, claim 1, and figure 3.	2,7,10,15
Y	KR 10-2012-0013665 A (JUSUNG ENGINEERING CO., LTD.) 15 February 2012 See paragraphs [0054]-[0055], [0063]-[0067], [0071]-[0072] and claims 1-3.	2,10
Y	KR 10-1346317 B1 (SIS CO., LTD.) 31 December 2013 See paragraphs [0043]-[0052], claim 1, and figures 1-2.	7,15
A	JP 2010-017732 A (MITSUBISHI ELECTRIC CORP.) 28 January 2010 See claims 1-2, 6 and figure 1.	1-15
A	US 2011-0031655 A1 (TOTH et al.) 10 February 2011 See claims 1, 30.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"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

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Date of the actual completion of the international search

17 July 2017 (17.07.2017)

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Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/027536

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