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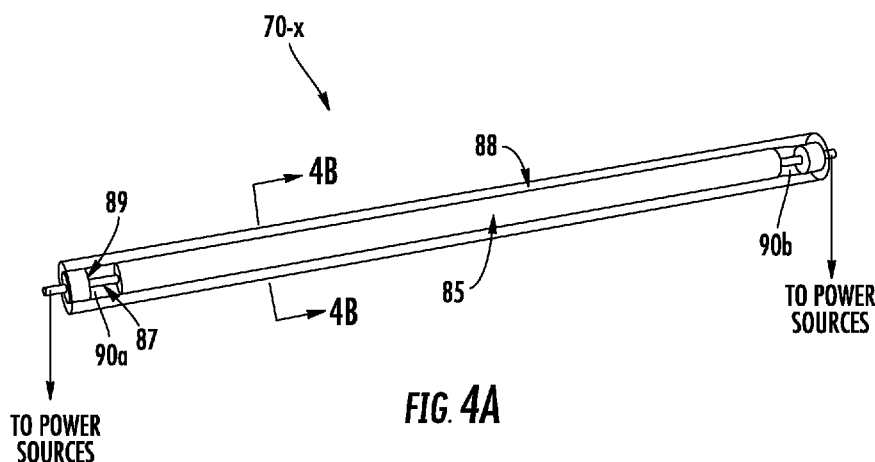
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(54) Title: CONDUCTIVE BEAM OPTIC CONTAINING INTERNAL HEATING ELEMENT



(57) Abstract: Provided herein are approaches for reducing particles in an ion implanter. An electrostatic filter may include a housing and a plurality of conductive beam optics within the housing. The conductive beam optics are arranged around an ion beam-line directed towards a wafer, and may include entrance aperture electrodes proximate an entrance aperture of the housing. The conductive beam optics may further include energetic electrodes downstream along the ion beam-line from the entrance aperture electrodes, and ground electrodes downstream from the energetic electrodes. The energetic electrodes are positioned farther away from the ion beam-line than the entrance electrodes and the ground electrodes, thus causing the energetic electrodes to be physically blocked from impact by an envelope of back-sputter material returning from the wafer. The electrostatic filter may further include an electrical system for independently delivering a voltage and a current to each of the conductive beam optics.

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MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
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CONDUCTIVE BEAM OPTIC CONTAINING INTERNAL HEATING ELEMENT**Field of the Disclosure**

[0001] The disclosure relates generally to ion implanters, and more particularly, to conductive beam optics for improving the performance and extending the lifetime of components within a processing chamber by reducing particle accumulation.

Background of the Disclosure

[0002] Ion implantation is a process of introducing dopants or impurities into a substrate via bombardment. In semiconductor manufacturing, the dopants are introduced to alter electrical, optical, or mechanical properties. For example, dopants may be introduced into an intrinsic semiconductor substrate to alter the type and level of conductivity of the substrate. In manufacturing an integrated circuit (IC), a precise doping profile provides improved IC performance. To achieve a desired doping profile, one or more dopants may be implanted in the form of ions in various doses and various energy levels.

[0003] Ion implantation systems may comprise an ion source and a series of beam-line components. The ion source may comprise a chamber where desired ions are generated. The ion source may also comprise a power source and an extraction electrode assembly disposed near the chamber. The beam-line components may include, for example, a mass analyzer, a first acceleration or deceleration stage, a collimator, and a second acceleration or deceleration stage. Much like a series of optical lenses for manipulating a light beam, the beam-line components can filter, focus, and manipulate

ions or ion beam having desired species, shape, energy, and other qualities. The ion beam passes through the beam-line components and may be directed toward a substrate or wafer mounted on a platen or clamp. The substrate may be moved in one or more dimensions (e.g., translate, rotate, and tilt) by an apparatus, sometimes referred to as a roplat.

[0004] The ion implanter generates a stable, well-defined ion beam for a variety of different ion species and extraction voltages. After several hours of operation using source gases (such as AsH₃, PH₃, BF₃, and other species), beam constituents eventually create deposits on the beam optics. Beam optics within a line-of-sight of the wafer also become coated with residues from the wafer, including Si and photoresist compounds. These residues build up on the beam-line components, causing spikes in the DC potentials during operation (e.g., in the case of electrically biased components). Eventually the residues flake off, causing an increased likelihood of particulate contamination on the wafer.

[0005] One way to prevent the effect of the material accumulation is to intermittently replace beam-line components of the ion implanter system. Alternatively, beam-line components may be manually cleaned, including powering down the ion source, and releasing the vacuum within the system. After replacing or cleaning the beam-line components, the system is then evacuated and powered to reach an operational condition. Accordingly, these maintenance processes may be time consuming. In addition, the beam-line component is not used during the maintenance processes. As such, frequent

maintenance processes may decrease the time available for IC production, thus increasing overall manufacturing cost.

Summary

[0006] In view of the foregoing, provided herein are systems and methods for configuring a plurality of conductive beam optics within an energy purity module (EPM) to reduce particle build-up within the EPM. In one or more embodiments, an electrostatic filter for delivering an ion beam to a wafer may include a housing, and a plurality of conductive beam optics within the housing, the plurality of conductive beam optics arranged around an ion beam-line, wherein at least one conductive beam optic of the plurality of conductive beam optics includes an internal heating element.

[0007] In one or more embodiments, an energy purity module (EPM) for delivering an ion beam to a workpiece may include a housing having an exit proximate the wafer; and a plurality of conductive beam optics. The plurality of conductive beam optics may include a set of entrance aperture electrodes proximate an entrance aperture of the housing, and a set of energetic electrodes downstream along the ion beam-line from the set of entrance aperture electrodes. The plurality of conductive beam optics may further include a set of ground electrodes downstream along the ion beam-line of the set of energetic electrodes, wherein the set of energetic electrodes is positioned farther away from the ion beam-line than the set of entrance aperture electrodes and the set of ground electrodes. At least one of the plurality of conductive beam optics includes an internal heating element.

[0008] In one or more embodiments, an ion implantation system may include an electrostatic filter for delivering an ion beam to a wafer. The electrostatic filter may include a housing having an exit proximate the wafer, and a plurality of conductive beam optics within the housing, the plurality of conductive beam optics arranged around an ion beam-line. The plurality of conductive beam optics may include a set of entrance aperture electrodes proximate an entrance aperture of the housing, and a set of energetic electrodes downstream along the ion beam-line from the set of entrance aperture electrodes. The plurality of conductive beam optics may further include a set of ground electrodes downstream along the ion beam-line of the set of energetic electrodes. The set of energetic electrodes is positioned farther away from the ion beam-line than the set of entrance aperture electrodes and the set of ground electrodes, and wherein at least one of the plurality of conductive beam optics includes an internal heating element. The ion implantation system may further include an electrical system in communication with the electrostatic filter, the electrical system configured to supply a voltage and a current to the plurality of conductive beam optics.

Brief Description of the Drawings

[0009] **FIG. 1** is a schematic view illustrating an ion implantation system in accordance with embodiments of the present disclosure.

[0010] **FIGs. 2A-B** are semi-transparent isometric views illustrating a component of the ion implantation system shown in **FIG. 1** in accordance with embodiments of the present disclosure.

[0011] **FIG. 3** is a side cross-sectional view illustrating the component of **FIG. 2** in accordance with embodiments of the present disclosure.

[0012] **FIG. 4A** is a perspective view a conductive beam optic including an internal heating element in accordance with embodiments of the present disclosure.

[0013] **FIG. 4B** is an end view the conductive beam optic of **FIG. 4A** in accordance with embodiments of the present disclosure.

[0014] **FIG. 5** is a side cross-sectional view illustrating the component of **FIG. 3** operating with an electrical system in accordance with embodiments of the present disclosure.

[0015] **FIG. 6** is a side cross-sectional view illustrating the component of **FIG. 3** operating with a gas supply in accordance with embodiments of the present disclosure.

[0016] **FIGs. 7-8** are side cross-sectional views illustrating the component of **FIG. 3** operating with a set of relays in accordance with embodiments of the present disclosure.

[0017] **FIG. 9** is a flowchart illustrating an exemplary method in accordance with embodiments of the present disclosure.

[0018] The drawings are not necessarily to scale. The drawings are merely representations, not intended to portray specific parameters of the disclosure. The drawings are intended to depict exemplary embodiments of the disclosure, and therefore are not be considered as limiting in scope. In the drawings, like numbering represents like elements. Furthermore, certain elements in some of the figures may be omitted, or

illustrated not-to-scale, for illustrative clarity. Still furthermore, for clarity, some reference numbers may be omitted in certain drawings.

Detailed Description

[0019] A system and method in accordance with the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings, where embodiments of the system and method are shown. The system and method may be embodied in many different forms and are not be construed as being limited to the embodiments set forth herein. Instead, these embodiments are provided so the disclosure will be thorough and complete, and will fully convey the scope of the system and method to those skilled in the art.

[0020] For the sake of convenience and clarity, terms such as “top,” “bottom,” “upper,” “lower,” “vertical,” “horizontal,” “lateral,” and “longitudinal” will be used herein to describe the relative placement and orientation of various components and their constituent parts, as appearing in the figures. The terminology will include the words specifically mentioned, derivatives thereof, and words of similar import.

[0021] As used herein, an element or operation recited in the singular and proceeded with the word “a” or “an” are understood as not excluding plural elements or operations, until such exclusion is explicitly recited. Furthermore, references to “one embodiment” of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments also incorporating the recited features.

[0022] Provided herein are approaches for reducing particles in an ion implanter. An electrostatic filter may include a housing and a plurality of conductive beam optics within the housing. The conductive beam optics are arranged around an ion beam-line directed towards a wafer, and may include entrance aperture electrodes proximate an entrance aperture of the housing. The conductive beam optics may further include energetic electrodes downstream along the ion beam-line from the entrance aperture electrodes, and ground electrodes downstream from the energetic electrodes. The energetic electrodes are positioned farther away from the ion beam-line than the entrance electrodes and the ground electrodes, thus causing the energetic electrodes to be physically blocked or shielded from being coated by an envelope of back-sputter material returning from the wafer. The electrostatic filter may further include an electrical system for delivering a voltage and a current to each of the conductive beam optics.

[0023] The electrostatic filter may be an energy purity module having a plurality of energetic electrodes “hidden” behind the ground electrodes so the back-sputter material is less likely to reach the energetic electrodes. In some embodiments, one or more conductive beam optics of the EPM include an internal heating element operable to raise a temperature thereof. In situ cleaning and chemical etch from a gas bleed within the EPM further keeps the energetic electrodes and apertures free from the deposition of the back-sputter materials. As a result, performance and accuracy of the ion implanter is improved.

[0024] Referring now to **FIG. 1**, shown is an exemplary embodiment demonstrating an ion implanter or ion implantation system (hereinafter “system”) 10 for delivering an

ion beam to a wafer or workpiece, and for performing in-situ plasma cleaning of one or more components, such as conductive beam optics within an electrostatic filter. The system 10 represents a process chamber containing, among other components, an ion source 14 for producing an ion beam 18, an ion implanter, and a series of beam-line components. The ion source 14 may comprise a chamber for receiving a flow of gas 24 and generating ions. The ion source 14 may also comprise a power source and an extraction electrode assembly disposed near the chamber. The beam-line components 16 may include, for example, a mass analyzer 34, a first acceleration or deceleration stage 36, a collimator 38, and an energy purity module (EPM) 40 corresponding to a second acceleration or deceleration stage. Although described hereinafter with respect to the EPM 40 of the beam-line components 16 for the sake of explanation, the embodiments described herein for in-situ plasma cleaning are also applicable to different/additional components of the system 10.

[0025] In exemplary embodiments, the beam-line components 16 may filter, focus, and manipulate ions or the ion beam 18 to have a desired species, shape, energy, and other qualities. The ion beam 18 passing through the beam-line components 16 may be directed toward a substrate mounted on a platen or clamp within a process chamber 46. The substrate may be moved in one or more dimensions (e.g., translate, rotate, and tilt).

[0026] As shown, there may be one or more feed sources 28 operable with the chamber of the ion source 14. In some embodiments, material provided from the feed source 28 may include source material and/or additional material. The source material may contain dopant species introduced into the substrate in the form of ions. Meanwhile,

the additional material may include diluent, introduced into the ion source chamber of the ion source 14 along with the source material to dilute the concentration of the source material in the chamber of the ion source 14. The additional material may also include a cleaning agent (e.g., an etchant gas) introduced into the chamber of the ion source 14 and transported within the system 10 to clean one or more of the beam-line components 16.

[0027] In various embodiments, different species may be used as the source and/or the additional material. Examples of the source and/or additional material may include atomic or molecular species containing boron (B), carbon (C), oxygen (O), germanium (Ge), phosphorus (P), arsenic (As), silicon (Si), helium (He), neon (Ne), argon (Ar), krypton (Kr), nitrogen (N), hydrogen (H), fluorine (F), and chlorine (Cl). Those of ordinary skill in the art will recognize the above listed species are non-limiting, and other atomic or molecular species may also be used. Depending on the application(s), the species may be used as the dopants or the additional material. In particular, one species used as the dopants in one application may be used as the additional material in another application, or vice-versa.

[0028] In exemplary embodiments, the source and/or additional material is provided into the ion source chamber of the ion source 14 in gaseous or vapor form. If the source and/or additional material is in non-gaseous or non-vapor form, a vaporizer (not shown) may be provided near the feed source 28 to convert the material into gaseous or vapor form. To control the amount and the rate the source and/or the additional material is provided into the system 10, a flowrate controller 30 may be provided.

[0029] The EPM 40 is a beam-line component configured to independently control deflection, deceleration, and focus of the ion beam 18. In one embodiment, the EPM 40 is a vertical electrostatic energy filter (VEEF) or electrostatic filter (EF). As will be described in greater detail below, the EPM 40 may include an electrode configuration comprising a set of upper electrodes disposed above the ion beam 18 and a set of lower electrodes disposed below the ion beam 18. The set of upper electrodes and the set of lower electrodes may be stationary and have fixed positions. A difference in potentials between the set of upper electrodes and the set of lower electrodes may also be varied along the central ion beam trajectory to reflect an energy of the ion beam at each point along the central ion beam trajectory for independently controlling deflection, deceleration, and/or focus of an ion beam.

[0030] Referring now to **FIGS. 2A-B**, the EPM 40 according to exemplary embodiments will be described in greater detail. As shown, the EPM 40 includes an EPM chamber 50 extending above and partially encasing EPM 40. The EPM chamber 50 is configured to receive a gas and generate a plasma therein. In one embodiment, as shown in **FIG. 2A**, the EPM chamber 50 may receive a flow of the gas 24 (**FIG. 1**) from the ion source 14 at a gas inlet 52 through a sidewall 54. In another embodiment, as shown in **FIG. 2B**, the EPM chamber 50 may receive a flow of gas 56 at a gas inlet 58 through a top section 60 of the EPM chamber 50. The gas 56 may be supplied from a supplementary gas source 62 separate from the flow of gas 24 from the ion source 14. In an exemplary embodiment, an injection rate of the gas 56 into the EPM chamber 50 may be controlled by a flow controller 64 (e.g., a valve).

[0031] EPM 40 further operates with one or more vacuum pumps 66 (FIG. 1) to adjust a pressure of the EPM chamber 50. In exemplary embodiments, the vacuum pump 66 is coupled to the process chamber 46, and pressure is adjusted within the EPM chamber 50 through one or more flow paths 68. In another embodiment, the EPM 40 may include one or more additional pumps more directly coupled to the EPM chamber 50.

[0032] Referring now to **FIG. 3**, an exemplary embodiment demonstrating the structure and operation of the EPM 40 in accordance with the present disclosure is shown. As shown, the EPM 40 may include a plurality of conductive beam optics 70A-P, such as a plurality of graphite electrode rods, disposed along opposite sides of the ion beam 18. The ion beam 18 is delivered through the EPM 40, along an ion-beam line, entering at an entrance aperture 53 of a housing 49, and exiting at an exit 47 for impact with a wafer 57 and a dose cup 59. As shown, the plurality of conductive beam optics 70A-P provides a space/opening to allow the ion beam 18 (e.g., a ribbon beam) to pass therethrough. As described above, the vacuum pump 66 may be directly or indirectly connected to the housing 49 for adjusting a pressure of an environment therein.

[0033] In exemplary embodiments, the conductive beam optics 70A-P include pairs of conductive pieces electrically coupled to each other. Alternatively, the conductive beam optics 70A-P may be a series of unitary structures each including an aperture for the ion beam to pass therethrough. In the embodiment shown, upper and lower portions of each electrode pair may have different potentials (e.g., in separate conductive pieces) in order to deflect the ion beam passing therethrough. Although the plurality of

conductive beam optics 70A-P are depicted as including sixteen (16) elements, a different number of elements (or electrodes) may be utilized. For example, the configuration of conductive beam optics 70A-P may utilize a range of three (3) to ten (10) electrode sets.

[0034] In one non-limiting embodiment, the conductive beam optics 70A-P may include a set of entrance aperture electrodes, or aperture terminals, 70A-B proximate the entrance aperture 53 of the housing 49. Downstream of the set of entrance aperture electrodes 70A-B is a set of energetic electrodes 70C-F. Between the set of entrance aperture electrodes 70A-B and the set of energetic electrodes 70C-F may be a set of terminal electrodes 70G-H. The plurality of conductive beam optics 70A-P may further include a set of ground electrodes 70I-P, wherein ground electrodes 70M, 70N, 70O, and 70P may represent a set of exit apertures positioned proximate the exit 47. As shown, the set of energetic electrodes 70C-F are positioned farther away from the ion beam 18 than the set of entrance aperture electrodes 70A-B and the set of ground electrodes 70I-P.

[0035] As further shown, the housing 49 may include a set of exit plates 45 extending therefrom. In some embodiments, the set of exit aperture plates 45 are each oriented approximately parallel to a direction of travel of the ion beam 18. As shown, a first pair of exit apertures, such as ground electrodes 70O and 70P, is positioned proximate a downstream end 51 of the set of exit plates 45. A second pair of exit apertures, such as ground electrodes 70M and 70N, is positioned proximate an upstream end 41 of the set of exit plates 45. The first and second pairs of exit apertures are operable to deliver the ion beam 18 to the wafer 57, and to control material bouncing off/back from the wafer 57, along the direction of the ion beam 18 and into the EPM 40.

[0036] For example, during use, impact of the ion beam 18 on the wafer 57 generates material tending to travel upstream along the ion beam 18 and into the EPM 40. The set of exit apertures 70M-P define a maximum envelope 61 of back-sputter material and an actual envelope 63 of back-sputter material traveling from the wafer 57 and through the exit 47, between the set of exit apertures 70M-P. In some embodiments, the maximum envelope 61 is defined by an area within the EPM 40 between the exit apertures 70O and 70P, and between the ground electrodes 70K and 70L. The actual envelope 63 may be defined by upper and lower borders/edges of the ion beam 18, for example, proximate the exit 47 of the housing 49.

[0037] As shown, a position of the set of energetic electrodes 70C-F relative to the set of exit apertures 70M-P and the ground electrodes 70I, 70J, 70K, and 70L prevents both the maximum envelope 61 of back-sputter material and the actual envelope 63 of back-sputter material from reaching the set of energetic electrodes 70C-F. Said another way, the set of energetic electrodes 70C-F are positioned away from the ion beam 18 so as to be hidden or blocked, along an upstream or opposite ion beam direction, behind the set of exit apertures 70M-P and the ground electrodes 70I, 70J, 70K, and 70L.

[0038] Turning now to **FIGs 4A-4B**, a conductive beam optic 70X containing a heating element according to embodiments of the present disclosure will be described in greater detail. The conductive beam optic 70X may represent one or more of conductive beam optics 70A-P shown in **FIG. 3**. In some embodiments, each of the conductive beam optics 70A-P contains an internal heating element. In other embodiments, just the set of energetic electrodes 70C-F are each devoid of an internal heating element. In yet

other embodiments, just the set of energetic electrodes 70C-F each contain an internal heating element.

[0039] As shown, representative conductive beam optic 70X may include an internal heating element 85, such as a tubular quartz heating lamp electrically connected with a conductor 87, and to one or more power sources. Concentrically surrounding the internal heating element is a hollow shell 88, such as a glassy carbon or graphite. Glassy carbon advantageously has low electrical resistance, high hardness, high temperature resistance, and resistance to chemical attack. As further shown, an insulator 89 may be disposed within openings 90A-B at each end of the hollow shell 88.

[0040] The internal heating element 85 may evaporate any solid back sputter material forming upon an exterior surface of the hollow shell 88. In one non-limiting embodiment, the internal heating element 85 raises the temperature of the conductive beam optic 70X to approximately 200°C to 900°C to evaporate all the solid back sputter material on and around the conductive beam optic 70X.

[0041] Turning now to **FIG. 5**, an electrical system 65 in communication with the EPM 40 according to embodiments of the present disclosure will be described in greater detail. As shown, the electrical system 65 is operable to supply a voltage and a current to each of the plurality of conductive beam optics 70A-P. In some embodiments, the plurality of conductive beam optics 70A-P are each connected in parallel via the electrical system 65 to allow independent supply/adjustment of voltage and current. In some embodiments, the electrical system 65 may include a first power source 67 (e.g., a terminal) and a second power source 69 (e.g., ground). The first power source 67 and the

second power source 69 are operable to deliver a high voltage (e.g., 200V) to the plurality of conductive beam optics 70A-P, including to any of the conductive beam optics 70A-P containing the internal heating element 85. More specifically, the first power source 67 may be electrically connected with the set of entrance aperture electrodes 70A-B, and with the set of terminal electrodes 70G-H, via a first electrical path 73. Meanwhile, the second power source 69 may be connected with each of the set of energetic electrodes 70C-F, and with each of the set of ground electrodes 70I-P, via a second electrical path 75. Used herein, the term energetic electrodes refers to electrodes receiving the high voltage from either the first or second power sources 67, 69.

[0042] In some embodiments, at least one conductive beam optic of the plurality of conductive beam optics 70A-P includes the internal heating element 85 operable to increase the temperature thereof. For example, the internal heating element 85 may be within one or more of the set of entrance aperture electrodes 70A-B and within one or more of the set of terminal electrodes 70G-H. The internal heating element 85 may also be within each of the set of ground electrodes 70I-P. As shown, the internal heating elements 85 may be powered via a third electrical path 77 and a fourth electrical path 79. In some embodiments, the internal heating element 85 may be a quartz heater lamp buried within each respective electrode to evaporate the solid back-sputter materials 78 into a gaseous form to be pumped out of the EPM 40.

[0043] In the non-limiting embodiment of **FIG. 5**, four (4) energetic electrodes 70C-F are provided. The energetic electrodes 70C-F are positioned so as to be “hidden” behind the set of ground electrodes 70I-P, thus preventing the energetic electrodes 70C-F

from the splashing and coating of the back-sputter material within the maximum envelope 61 and/or the actual envelope 63. The back-sputter material is stopped and collected by the set of entrance aperture electrodes 70A-B, the set of terminal electrodes 70G-H, and the set of ground electrodes 70I-P. The heating element(s) 85 buried within one or more of the set of entrance aperture electrodes 70A-B, the set of terminal electrodes 70G-H, and/or the set of ground electrodes 70I-P may evaporate the solid back-sputter material 78 into the gaseous form to be pumped out of the EPM 40.

[0044] In some embodiments, accumulation of the solid back-sputter material may be more severe, e.g., when carborane, SiF_4 or GeF_4 is used as the source material. To prevent excessive accumulation, the EPM 40 of the present disclosure may operate in two modes: a processing mode and a cleaning mode. During the processing mode, the EPM 40 may operate normally to process the ion beam 18. During the cleaning mode, the EPM 40 may be in situ cleaned. In one non-limiting embodiment, a second voltage and a second current may be supplied to the conductive beam optics 70A-P of the EPM 40. The conductive beam optics 70A-P may be electrically driven in parallel (e.g., individually) or in series to enable uniform and/or independent cleaning thereof. The second voltage and the second current may be supplied by the first power supply 67.

[0045] Turning now to **FIG. 6**, the EPM 40 may be in situ cleaned during the cleaning mode. To accomplish the cleaning, an etchant gas (e.g., H_2 or O_2) may be introduced into the EPM 40 at a selected flow/injection rate from a gas supply component 81. In exemplary embodiments, the gas supply component 81 is a gas bleed device

including a conduit having plurality of apertures formed therein to allow the etchant gas to be distributed within the EPM 40. For example, through the gas bleed device, 1 to 5 standard cubic centimeters per minute (SCCM) of gas such as O₂ or H₂ may be introduced into the EPM chamber to chemically etch away the depositions of the back-sputter material 78 from the set of entrance aperture electrodes 70A-B, the set of terminal electrodes 70G-H, and the set of ground electrodes 70I-P. In other non-limiting examples, the etchant gas may be introduced at a flow rate of approximately 25 SCCM to approximately 200 SCCM. In one embodiment, the etchant gas may be introduced at approximately 50 SCCM to approximately 100 SCCM to maintain high pressure flow around the conductive beam optics 70A-P.

[0046] Various species may be introduced as the cleaning agent of the etchant gas. The cleaning agent may be atomic or molecular species containing chemically reactive species. Such species, when ionized, may chemically react with the deposits accumulated on one or more of the conductive beam optics 70A-P. Although a cleaning agent with chemically reactive species will be described herein, the present disclosure does not preclude utilizing chemically inert species. In another embodiment, the cleaning agent may contain heavy atomic species to form ions with high atomic mass units (amu) when ionized. Non-limiting examples of the cleaning agent may include atomic or molecular species containing H, He, N, O, F, Ne, Cl, Ar, Kr, and Xe, or a combination thereof. In one embodiment, NF₃, O₂, or a mixture of Ar and F₂, or a combination thereof, may be used as the cleaning agent.

[0047] The composition of the etchant gas can be chosen to optimize chemical etching based on a composition of the deposit(s) formed on the conductive beam optics 70A-P. For example, fluorine-based plasmas may be used to etch beam components containing B, P, and As, while oxygen-based plasmas may be used to etch photoresist materials. In one embodiment, adding Ar or other heavy species to the plasma mixture increases ion bombardment, resulting in an improved removal rate of the deposit(s) from the conductive beam optics 70A-P when using a chemically enhanced ion sputtering process. Plasma or ion bombardment also provokes heating of the surfaces to aid chemical etch rates and to help agitate the deposit(s) from the surface of the conductive beam optics 70A-P.

[0048] Turning now to **FIGs. 7-8**, operation of a set of relays 84A-D within the EPM 40 according to embodiments of the disclosure will be described in greater detail. As shown, the EPM 40 may include the set of relays 84A-D operable to switch each of the set of energetic electrodes 70C-F between the high voltage first power supply 67 and the second power supply 69 (ground). In the configuration shown, the energetic electrodes 70C-F may have internal heating elements 85 buried within. As such, the set of relays 84A-D may be operable to control the voltage and the current to each of the internal heating elements 85 of the energetic electrodes 70C-F. During an ion implantation, as depicted in **FIG. 7**, the energetic electrodes 70C-F are connected to the high voltage power supply 67, and internal heating elements 85 are turned OFF.

[0049] As depicted in **FIG. 8**, during beam setup, or during the period when the implanter is idle, the energetic electrodes 70C-F may be connected to the second power

supply 69, and the internal heating elements 85 may be turned ON. In some embodiments, the energetic electrodes 70C-F are maintained above 200°C during implantation to ensure the energetic electrodes 70C-F are free from the deposition due to condensation of the gaseous back-sputter materials. In situ cleaning and chemical etch from the gas supply component 81 within the EPM 40 keeps the energetic electrodes 70C-F and the exit apertures 70M, 70N, 70O, and 70P free from the deposition of the back-sputter materials. As a result, performance and accuracy of the ion implanter is improved.

[0050] Referring now to **FIG. 9**, a flow diagram illustrating a method 100 for reducing particles in an ion implanter in accordance with embodiments of the present disclosure is shown. The method 100 will be described in conjunction with the representations shown in **FIGS. 1-8**.

[0051] At block 101, the method 100 may include providing a set of entrance aperture electrodes disposed proximate an entrance aperture of a housing of the EPM. In some embodiments, the EPM includes a plurality of conductive beam optics, including the set of entrance aperture electrodes. In some embodiments, the plurality of conductive beam optics includes a plurality of electrode rods. In some embodiments, one or more of the plurality of conductive beam optics include an internal heating element operable to raise a temperature thereof. The internal heating element may be a heating lamp, such as a quartz heating lamp, surrounded by a hollow shell and electrically connected to a conductor.

[0052] At block 103, the method 100 may include providing a set of energetic electrodes disposed downstream along the ion beam-line from the set of entrance aperture electrodes. At block 105, the method 100 may include providing a set of ground electrodes disposed downstream along the ion beam-line of the set of energetic electrodes, wherein the set of energetic electrodes is positioned farther away from the ion beam-line than the set of entrance aperture electrodes and the set of ground electrodes.

[0053] In some embodiments, block 105 of the method 100 may include providing a set of exit apertures of the set of ground electrodes proximate the exit, and providing a set of exit plates extending from the housing, wherein the set of exit apertures is oriented approximately parallel to the ion beam-line. Block 105 of the method 100 may further include positioning a first pair of exit apertures of the set of exit apertures proximate a downstream end of the set of exit plates, wherein a second pair of exit apertures of the set of exit apertures is positioned proximate an upstream end of the set of exit plates. The set of exit apertures may define an envelope of back-sputter material traveling from the wafer and then through the exit aperture.

[0054] At block 107, the method 100 may include enabling an electrical system to independently supply a voltage and a current to each of the plurality of conductive beam optics. In some embodiments, a first voltage and a first current is supplied to the plurality of conductive beam optics during a processing mode. In some embodiments, the first voltage and the first current are supplied by a direct current (DC) power supply. In some embodiments, the method 100 further includes switching from the processing mode to a cleaning mode. In some embodiments, block 107 includes automatically switching from

the processing mode to the cleaning mode in the case a predetermined threshold is achieved, e.g., a maximum acceptable number of beam glitches.

[0055] During the cleaning mode, a second voltage and a second current may be supplied to the conductive beam optics. In some embodiments, the second voltage and the second current are applied the conductive beam optics to generate a plasma. In some embodiments, the second voltage and the second current are supplied from a direct current (DC) power supply or a radio frequency (RF) power supply.

[0056] At block 109, the method 100 may include supplying an etchant gas and/or adjusting a temperature of one or more of the plurality of conductive beam optics to reduce particles in the ion implanter and to enable etching. In some embodiments, an injection rate of the etchant gas is adjusted. In some embodiments, a composition of the etchant gas is selected to optimize etching of the component based on a composition of the deposit formed on a surface of the component. In some embodiments, at least one conductive beam optic of the plurality of conductive beam optics includes an internal heating element operable to increase a temperature thereof.

[0057] In view of the foregoing, at least the following advantages are achieved by the embodiments disclosed herein. In a first advantage, the EPM reduces particles by eliminating or greatly reducing deposition of the back-sputter materials onto the EPM electrodes and apertures, thus improving device yield and productivity of the ion implanter. In a second advantage, the EPM may include just four (4) energetic electrodes hidden behind the ground electrodes and apertures, thus preventing the energetic electrodes from the splashing and coating of the back-sputter material. The

back-sputter materials are stopped and collected by the ground electrodes/apertures and the terminal electrodes/apertures. In a third advantage, one or more of the conductive beam optics may include a heater lamp buried within to evaporate the back-sputter material into gaseous form to be pumped out of the EPM. The self and in situ cleaning mechanism, in addition to the hidden energetic electrodes, helps to keep all the EPM electrodes and apertures free from the deposited back-sputter materials during the implanting.

[0058] While certain embodiments of the disclosure have been described herein, the disclosure is not limited thereto, as the disclosure is as broad in scope as the art will allow and the specification may be read likewise. Therefore, the above description are not to be construed as limiting. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

Claims

What is claimed is:

1. An electrostatic filter for delivering an ion beam to a wafer, the electrostatic filter comprising:

a housing; and

a plurality of conductive beam optics within the housing, the plurality of conductive beam optics arranged around an ion beam-line, wherein at least one conductive beam optic of the plurality of conductive beam optics includes an internal heating element.

2. The electrostatic filter of claim 1, wherein the internal heating element is a heating lamp, and wherein the at least one conductive beam optic further includes:

a hollow shell surrounding the heating lamp; and

a conductor electrically connected with the heating lamp.

3. The electrostatic filter of claim 2, wherein the hollow shell is a glassy carbon.

4. The electrostatic filter of claim 2, wherein the hollow shell is graphite.

5. The electrostatic filter of claim 2, further comprising an insulator disposed within each end of the hollow shell.

6. The electrostatic filter of claim 1, the plurality of conductive beam optics comprising:

a set of entrance aperture electrodes proximate an entrance aperture of the housing;

a set of energetic electrodes downstream along the ion beam-line from the set of entrance aperture electrodes; and

a set of ground electrodes downstream along the ion beam-line of the set of energetic electrodes, wherein the set of energetic electrodes is positioned farther away from the ion beam-line than the set of entrance aperture electrodes and the set of ground electrodes.

7. The electrostatic filter of claim 6, wherein each of the set of energetic electrodes includes an internal heating element.

8. The electrostatic filter of claim 1, further comprising an electrical system in communication with the plurality of conductive beam optics, the electrical system configured to independently supply a voltage and a current to each of the plurality of conductive beam optics.

9. The electrostatic filter of claim 8, the electrical system comprising a set of relays operable to control the voltage and the current to the internal heating element.

10. An ion implantation system, comprising:
- an electrostatic filter for delivering an ion beam to a wafer, the electrostatic filter comprising:
 - a housing having an exit proximate the wafer; and
 - a plurality of conductive beam optics within the housing, the plurality of conductive beam optics arranged around an ion beam-line, and the plurality of conductive beam optics comprising:
 - a set of entrance aperture electrodes proximate an entrance aperture of the housing;
 - a set of energetic electrodes downstream along the ion beam-line from the set of entrance aperture electrodes; and
 - a set of ground electrodes downstream along the ion beam-line of the set of energetic electrodes, wherein the set of energetic electrodes is positioned farther away from the ion beam-line than the set of entrance aperture electrodes and the set of ground electrodes, and wherein at least one of the plurality of conductive beam optics includes an internal heating element; and
 - an electrical system in communication with the electrostatic filter, the electrical system configured to supply a voltage and a current to the plurality of conductive beam optics.

11. The ion implantation system of claim 10, wherein the internal heating element is a heating lamp, and wherein the at least one of the plurality of conductive beam optics including the internal heating element comprises:

a hollow shell concentrically surrounding the heating lamp;

a conductor electrically connected with the heating lamp, wherein the conductor is part of the electrical system; and

an insulator disposed within an opening at each end of the hollow shell.

12. The ion implantation system of claim 10, wherein each of the plurality of conductive beam optics is connected in parallel to allow independent adjustment of the voltage and the current.

13. The ion implantation system of claim 10, further comprising a set of exit plates extending from the housing, wherein the set of exit plates is oriented approximately parallel to a direction of travel of the ion beam.

14. The ion implantation system of claim 13, wherein the set of ground electrodes comprises a set of exit apertures proximate the exit, wherein the set of exit apertures define a maximum envelope of back-sputter material traveling from the wafer and through the exit, between the set of exit apertures, wherein a first pair of exit apertures of the set of exit apertures is positioned proximate a downstream end of the set of exit plates, and wherein a second pair of exit apertures of the set of exit apertures is positioned proximate an upstream end of the set of exit plates.

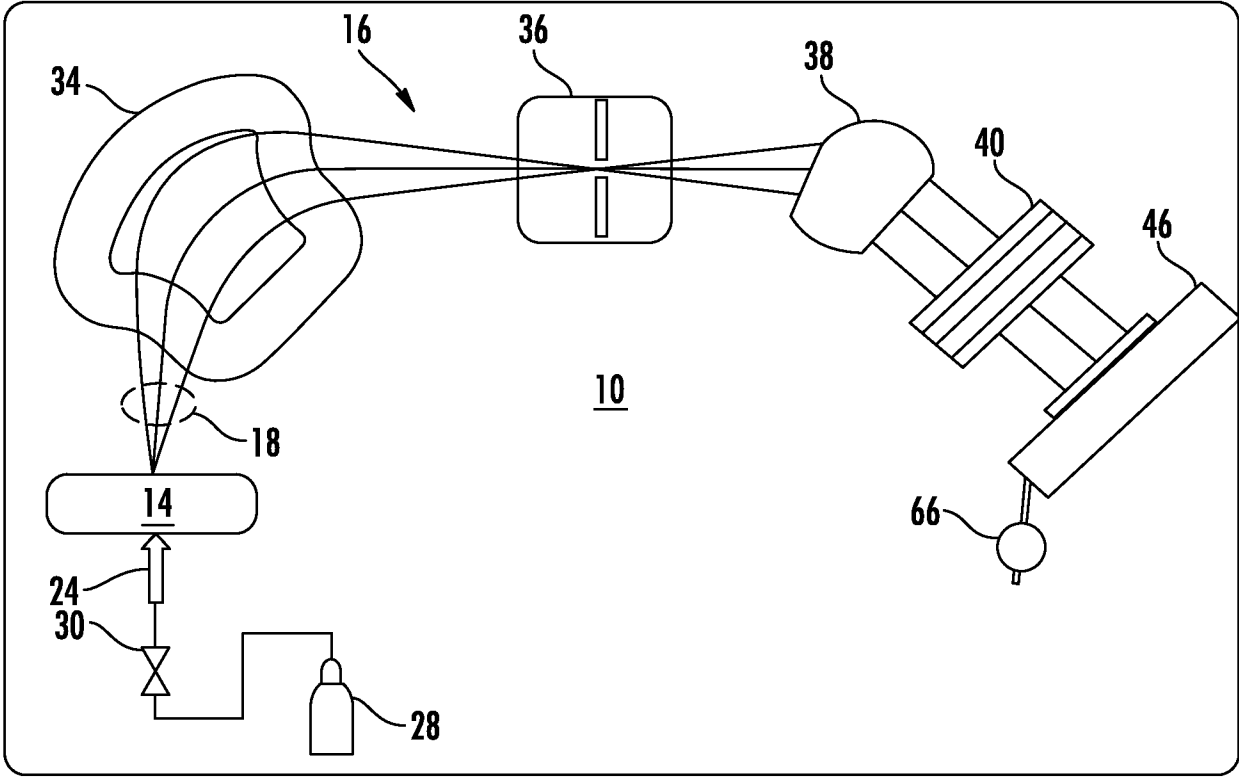


FIG. 1

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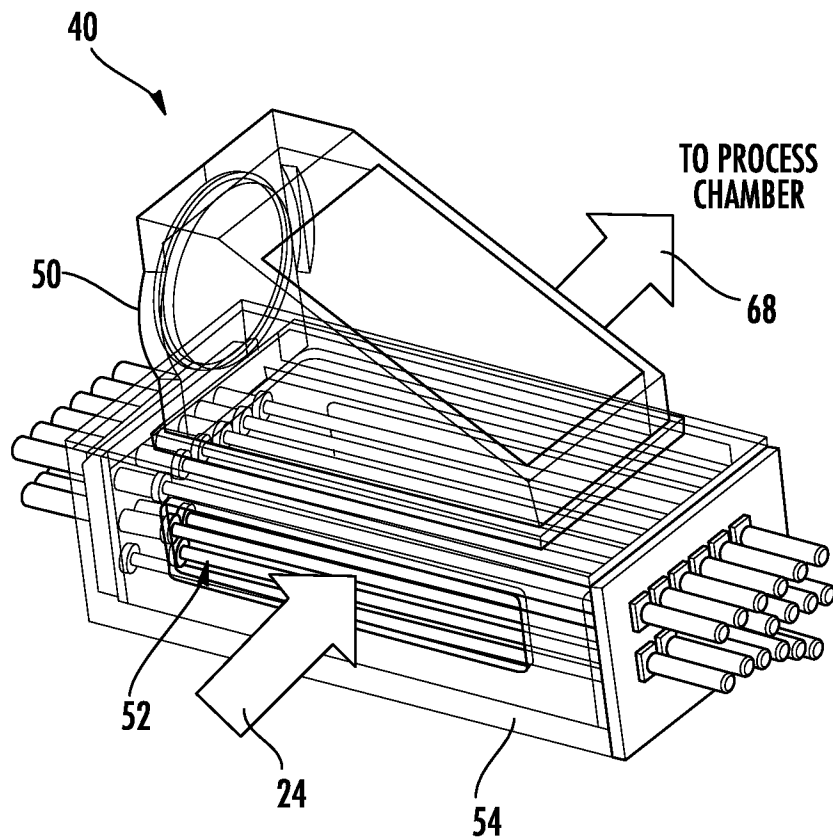


FIG. 2A

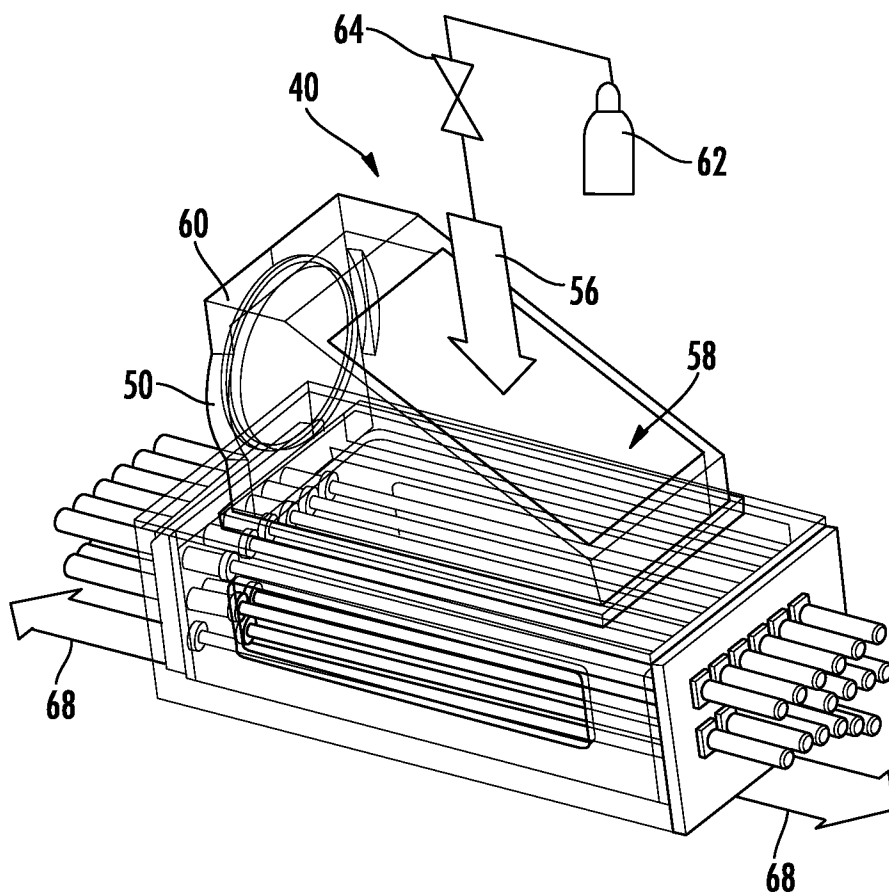


FIG. 2B

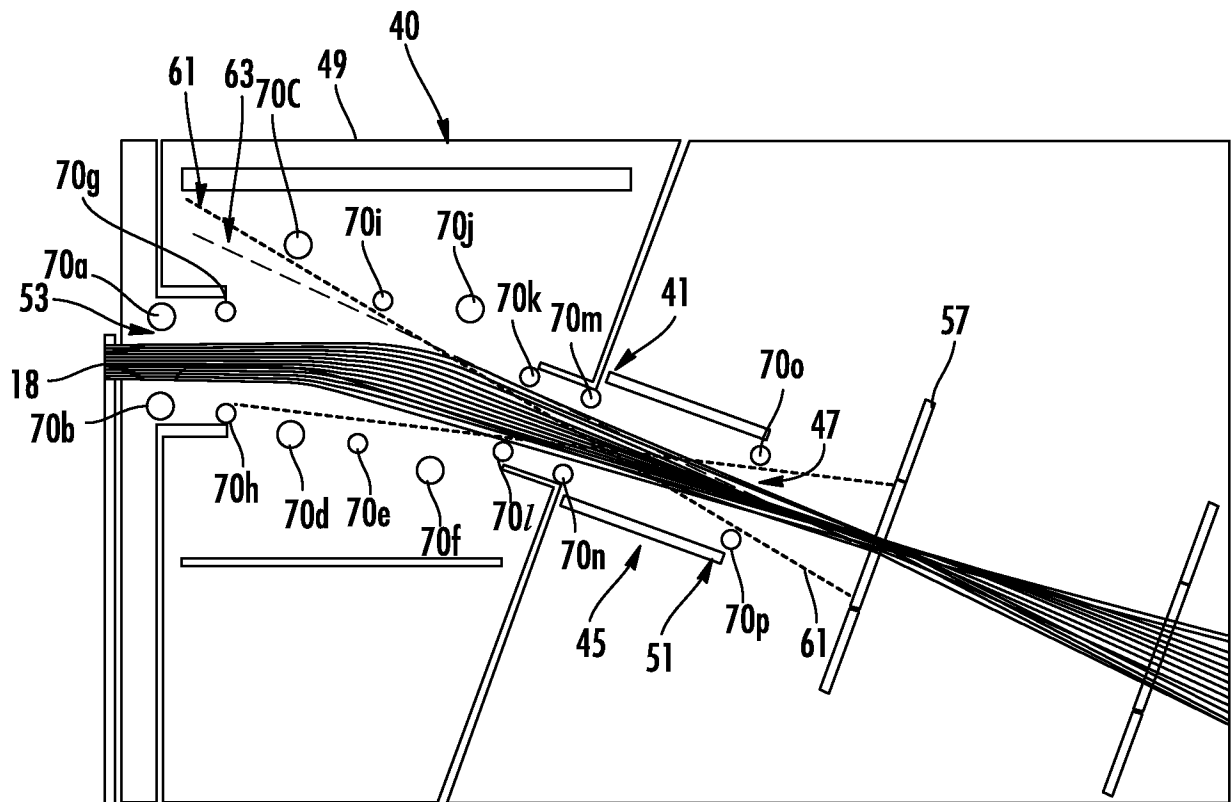


FIG. 3

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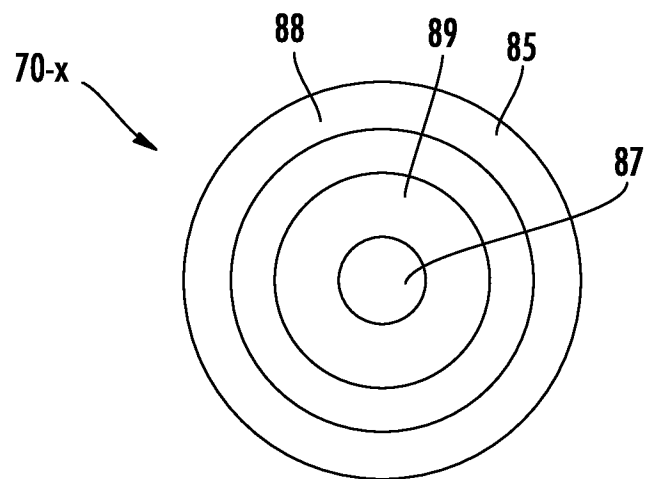
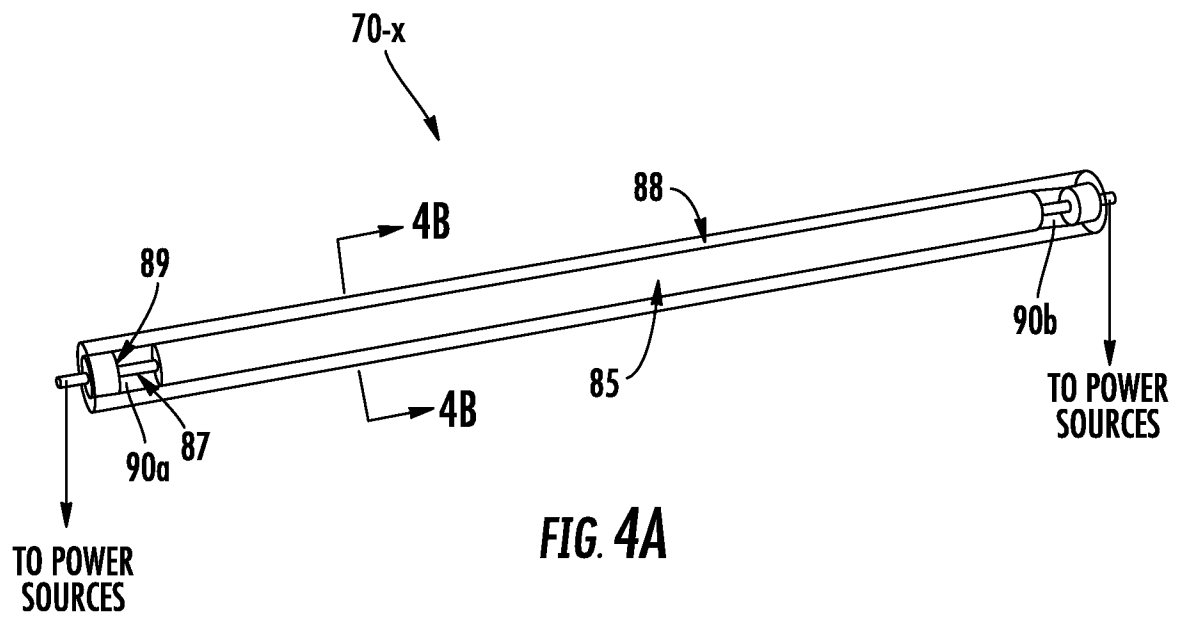


FIG. 4B

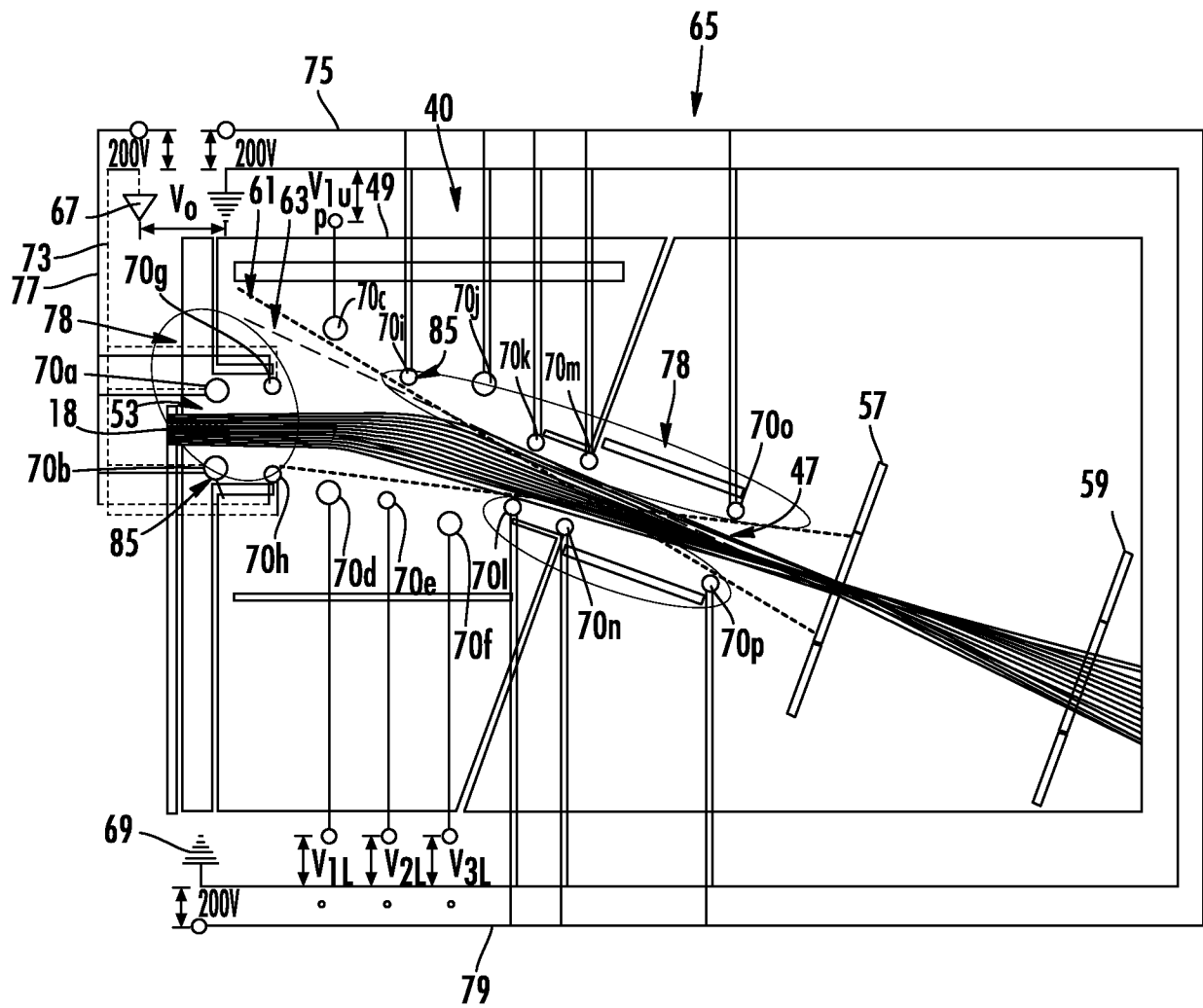


FIG. 5

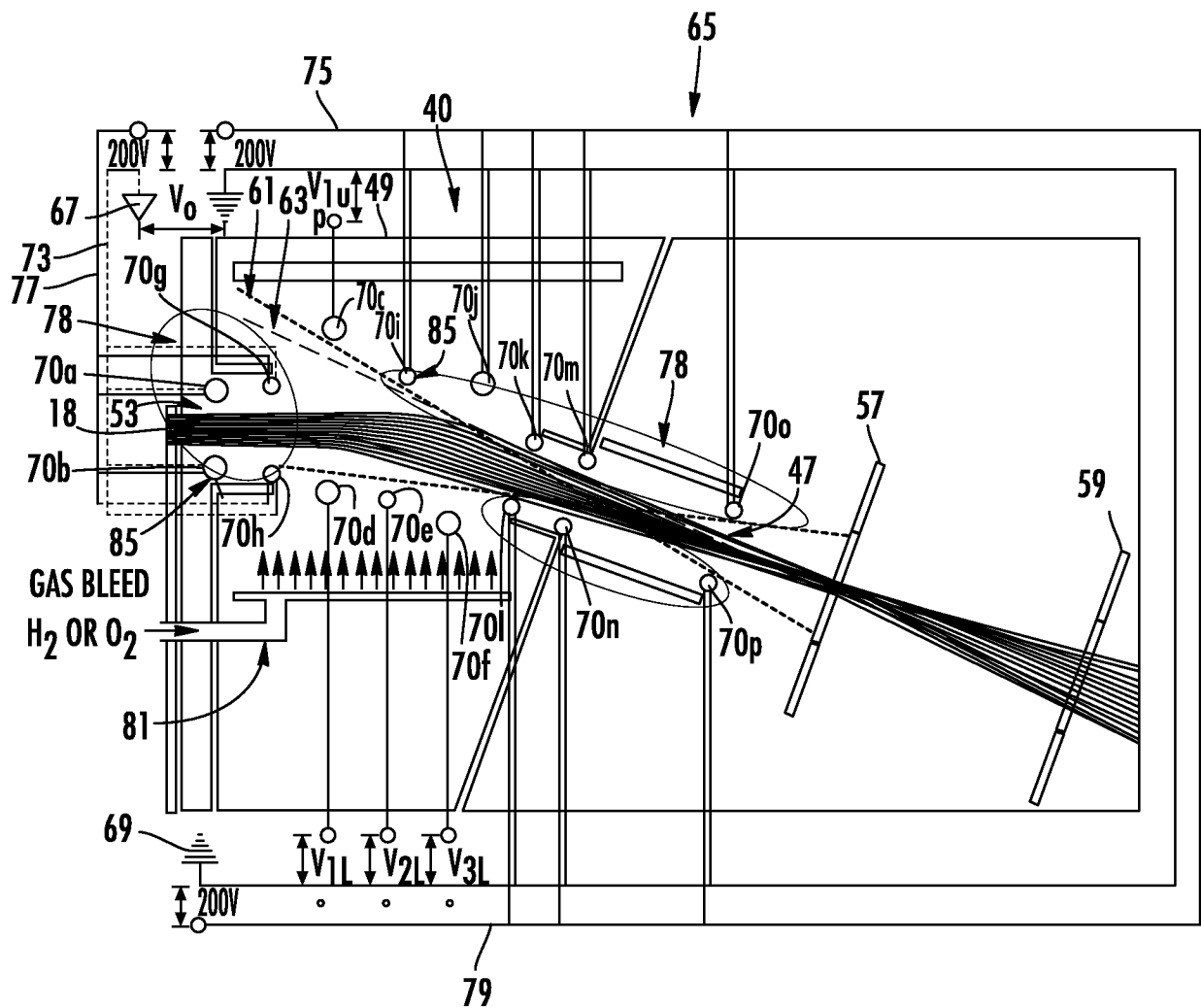


FIG. 6

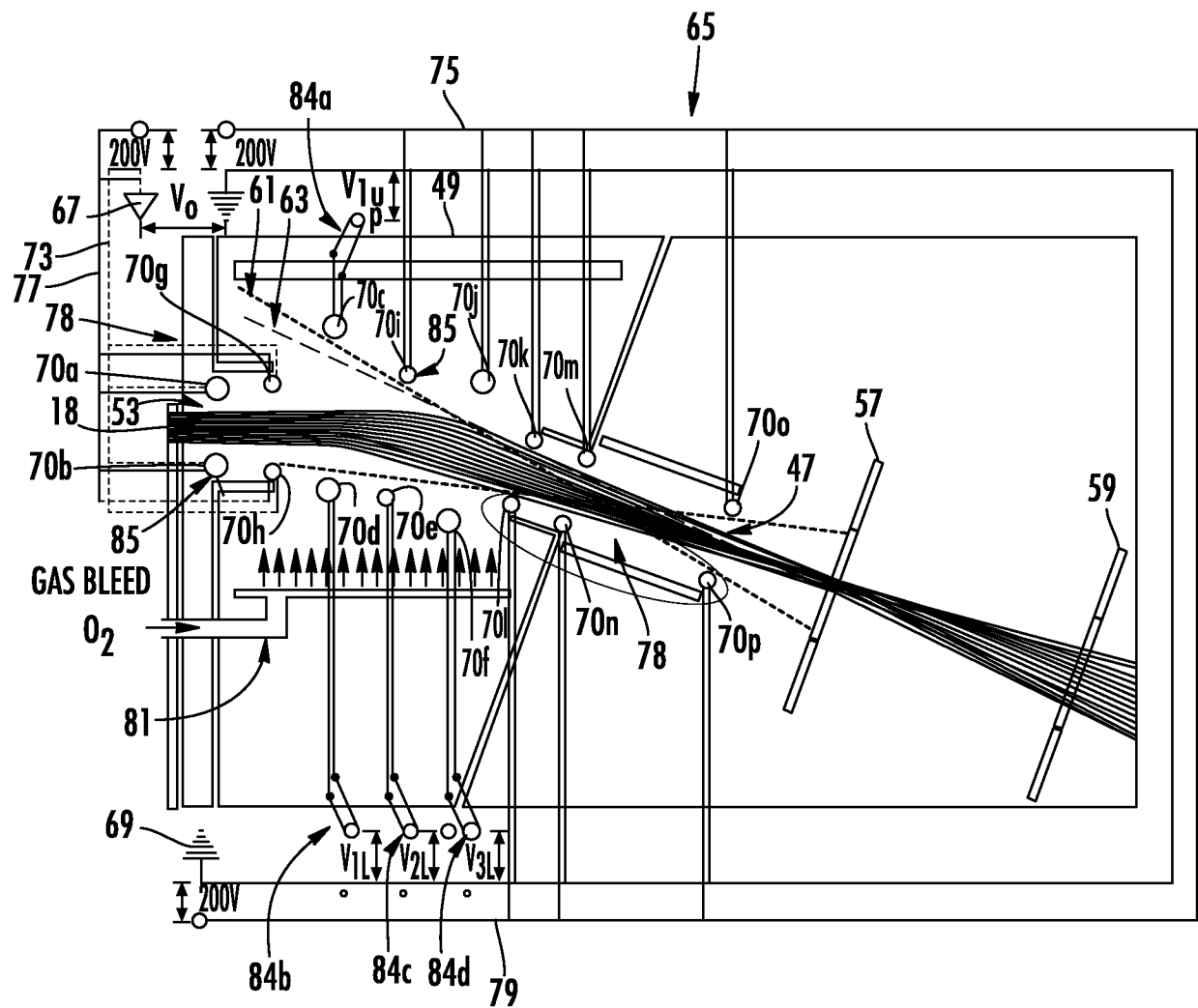


FIG. 7

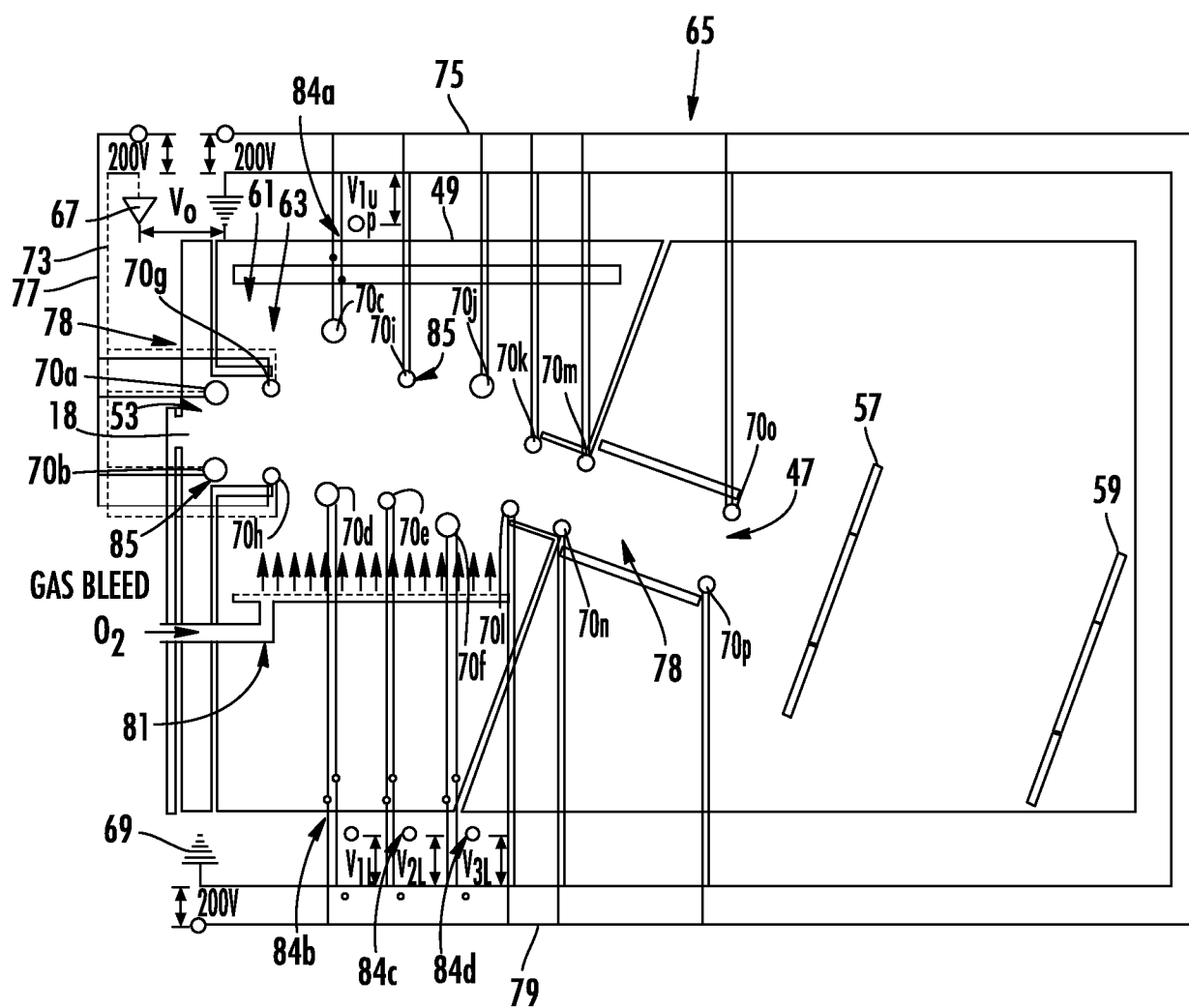
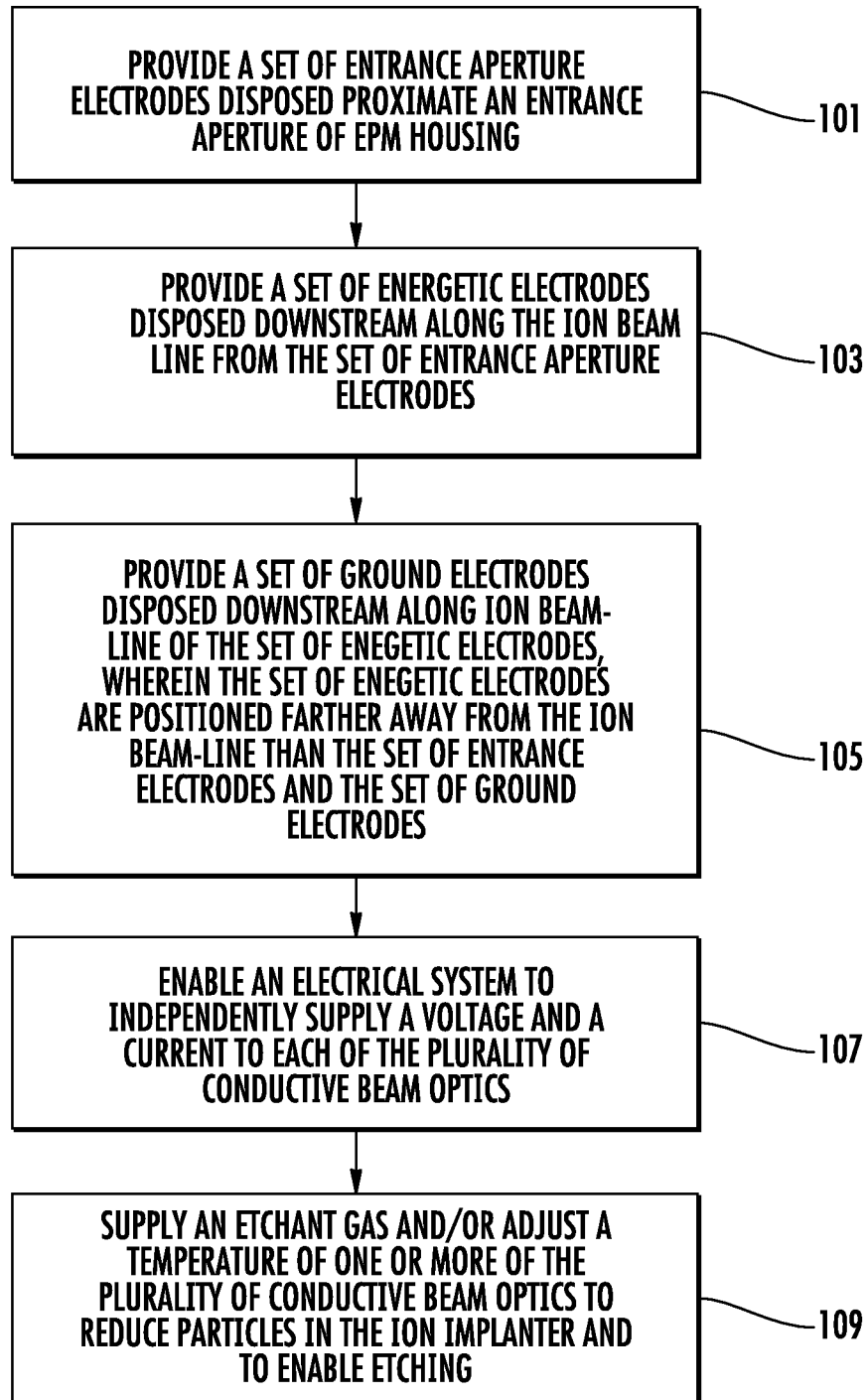


FIG. 8

100

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**FIG. 9**

A. CLASSIFICATION OF SUBJECT MATTER**H01J 37/147(2006.01)i, H01J 37/317(2006.01)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)

H01J 37/147; C23C 14/48; H01J 37/05; H01J 37/12; H01J 37/317; H01L 21/265

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: heat, ion, beam, implantation, filter, electrode, ground, lamp

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2014-022045 A1 (VARIAN SEMICONDUCTOR EQUIPMENT ASSOCIATES, INC.) 06 February 2014 See paragraphs 34-38, and figures 4a-5.	1-14
A	US 2010-0107980 A1 (THOMAS N. HORSKY et al.) 06 May 2010 See paragraphs 155-165, and figures 1-1D.	1-14
A	US 2017-0032924 A1 (VARIAN SEMICONDUCTOR EQUIPMENT ASSOCIATES, INC.) 02 February 2017 See paragraphs 28-32, and figure 2.	1-14
A	US 2015-0380206 A1 (ADVANCED ION BEAM TECHNOLOGY, INC.) 31 December 2015 See paragraphs 25-27, and figure 4.	1-14
A	JP 2015-191740 A (SUMITOMO HEAVY INDUSTRIES ION TECHNOLOGY CO., LTD.) 02 November 2015 See the whole document.	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

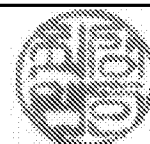


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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/014541

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014-022045 A1	06/02/2014	CN 104662637 A	27/05/2015
		CN 104662637 B	15/09/2017
		JP 2015-523702 A	13/08/2015
		JP 5791089 B2	07/10/2015
		KR 10-1626082 B1	31/05/2016
		KR 10-2015-0038432 A	08/04/2015
		TW 201407656 A	16/02/2014
		TW I532070 B	01/05/2016
		US 2014-0034843 A1	06/02/2014
		US 2015-0048254 A1	19/02/2015
		US 8907295 B2	09/12/2014
US 2010-0107980 A1	06/05/2010	AU 2001-24306 A1	18/06/2001
		AU 2001-66847 A1	11/06/2002
		AU 2003-247495 A1	19/01/2004
		AU 2003-258960 A1	19/01/2004
		AU 2003-258960 A8	19/01/2004
		CN 100385605 C	30/04/2008
		CN 101308785 A	19/11/2008
		CN 101308785 B	09/06/2010
		CN 101308822 A	19/11/2008
		CN 101308822 B	25/12/2013
		CN 101384747 A	11/03/2009
		CN 101384747 B	20/11/2013
		CN 101512716 A	19/08/2009
		CN 101512716 B	18/01/2012
		CN 101908473 A	08/12/2010
		CN 101908473 B	13/03/2013
		CN 102034665 A	27/04/2011
		CN 102034665 B	25/06/2014
		CN 1477984 A	25/02/2004
		CN 1679153 A	05/10/2005
		CN 1894763 A	10/01/2007
		CN 1894763 B	08/12/2010
		CN 1964620 A	16/05/2007
		CN 1964620 B	21/07/2010
		CN 1973346 A	30/05/2007
		CN 1973346 B	18/05/2011
		EP 1245036 A1	02/10/2002
		EP 1245036 A4	22/04/2009
		EP 1245036 B1	19/06/2013
		EP 1347804 A1	01/10/2003
		EP 1347804 A4	22/04/2009
		EP 1535324 A1	01/06/2005
		EP 1535324 A4	27/02/2008
		EP 1535324 B1	06/06/2012
		EP 1538655 A2	08/06/2005
		EP 1538655 A3	03/06/2009
		EP 1579481 A2	28/09/2005

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/014541

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		EP 1579481 A4	27/02/2008
		EP 1579481 B1	04/12/2013
		EP 1675154 A2	28/06/2006
		EP 1675154 A3	15/07/2009
		EP 1695038 A2	30/08/2006
		EP 1695038 A4	20/05/2009
		EP 1695038 B1	13/02/2013
		EP 1695369 A2	30/08/2006
		EP 1695369 A4	04/11/2009
		EP 1945832 A1	23/07/2008
		EP 1945832 A4	10/11/2010
		EP 2027601 A2	25/02/2009
		EP 2027601 A4	20/04/2011
		EP 2426692 A2	07/03/2012
		EP 2426692 A3	21/08/2013
		EP 2426693 A2	07/03/2012
		EP 2426693 A3	16/01/2013
		JP 2004-507861 A	11/03/2004
		JP 2004-519070 A	24/06/2004
		JP 2005-531156 A	13/10/2005
		JP 2006-147599 A	08/06/2006
		JP 2006-196465 A	27/07/2006
		JP 2006-515711 A	01/06/2006
		JP 2007-115704 A	10/05/2007
		JP 2007-518221 A	05/07/2007
		JP 2007-521398 A	02/08/2007
		JP 2009-515301 A	09/04/2009
		JP 2009-540534 A	19/11/2009
		JP 2010-140908 A	24/06/2010
		JP 2010-156047 A	15/07/2010
		JP 2010-157518 A	15/07/2010
		JP 2010-161072 A	22/07/2010
		JP 2010-232668 A	14/10/2010
		JP 2010-262930 A	18/11/2010
		JP 2010-267623 A	25/11/2010
		JP 2011-066022 A	31/03/2011
		JP 2013-127976 A	27/06/2013
		JP 2014-053319 A	20/03/2014
		JP 2014-075346 A	24/04/2014
		JP 4643588 B2	02/03/2011
		JP 4646920 B2	09/03/2011
		JP 4744141 B2	10/08/2011
		JP 4749713 B2	17/08/2011
		JP 4820038 B2	24/11/2011
		JP 4927859 B2	09/05/2012
		JP 5026711 B2	19/09/2012
		JP 5107567 B2	26/12/2012
		JP 5128640 B2	23/01/2013
		JP 5457816 B2	02/04/2014
		KR 10-0569213 B1	10/04/2006

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/014541

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		KR 10-0702582 B1	04/04/2007
		KR 10-0703121 B1	05/04/2007
		KR 10-0788472 B1	24/12/2007
		KR 10-0788474 B1	24/12/2007
		KR 10-0797138 B1	22/01/2008
		KR 10-0827670 B1	07/05/2008
		KR 10-0864048 B1	17/10/2008
		KR 10-0883148 B1	10/02/2009
		KR 10-1160642 B1	28/06/2012
		KR 10-2003-0062360 A	23/07/2003
		KR 10-2005-0012825 A	02/02/2005
		KR 10-2005-0013636 A	04/02/2005
		KR 10-2006-0118019 A	17/11/2006
		KR 10-2006-0118621 A	23/11/2006
		KR 10-2006-0118622 A	23/11/2006
		KR 10-2006-0118623 A	23/11/2006
		KR 10-2006-0126994 A	11/12/2006
		KR 10-2006-0126995 A	11/12/2006
		KR 10-2008-0003014 A	04/01/2008
		KR 10-2008-0065276 A	11/07/2008
		KR 10-2009-0023380 A	04/03/2009
		TW 200405518 A	01/04/2004
		TW 200520021 A	16/06/2005
		TW 200523977 A	16/07/2005
		TW 200529271 A	01/09/2005
		TW 200620394 A	16/06/2006
		TW 200733243 A	01/09/2007
		TW 200739821 A	16/10/2007
		TW 511113 B	21/11/2002
		TW 521295 B	21/02/2003
		TW I263249 B	01/10/2006
		TW I264053 B	11/10/2006
		TW I288964 B	21/10/2007
		TW I326102 B	11/06/2010
		TW I328244 B	01/08/2010
		TW I334196 B	01/12/2010
		US 2002-0070672 A1	13/06/2002
		US 2003-0085663 A1	08/05/2003
		US 2003-0230986 A1	18/12/2003
		US 2004-0000647 A1	01/01/2004
		US 2004-0002202 A1	01/01/2004
		US 2004-0104682 A1	03/06/2004
		US 2004-0188631 A1	30/09/2004
		US 2004-0195973 A1	07/10/2004
		US 2004-0245476 A1	09/12/2004
		US 2005-0051096 A1	10/03/2005
		US 2005-0269520 A1	08/12/2005
		US 2006-0097193 A1	11/05/2006
		US 2006-0097645 A1	11/05/2006
		US 2006-0238133 A1	26/10/2006

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/014541

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2006-0272775 A1	07/12/2006
		US 2006-0272776 A1	07/12/2006
		US 2007-0105325 A1	10/05/2007
		US 2007-0107841 A1	17/05/2007
		US 2007-0108394 A1	17/05/2007
		US 2007-0108395 A1	17/05/2007
		US 2007-0170372 A1	26/07/2007
		US 2007-0176114 A1	02/08/2007
		US 2007-0176115 A1	02/08/2007
		US 2007-0181830 A1	09/08/2007
		US 2007-0194252 A1	23/08/2007
		US 2007-0210260 A1	13/09/2007
		US 2007-0241689 A1	18/10/2007
		US 2007-0262262 A1	15/11/2007
		US 2007-0278417 A1	06/12/2007
		US 2008-0042580 A1	21/02/2008
		US 2008-0047607 A1	28/02/2008
		US 2008-0073559 A1	27/03/2008
		US 2008-0087219 A1	17/04/2008
		US 2008-0121811 A1	29/05/2008
		US 2008-0223409 A1	18/09/2008
		US 2009-0014667 A1	15/01/2009
		US 2009-0090872 A1	09/04/2009
		US 2010-0148089 A1	17/06/2010
		US 2010-0320395 A1	23/12/2010
		US 2011-0226969 A1	22/09/2011
		US 2012-0076475 A1	29/03/2012
		US 2014-0061816 A1	06/03/2014
		US 6452338 B1	17/09/2002
		US 6686595 B2	03/02/2004
		US 6744214 B2	01/06/2004
		US 7022999 B2	04/04/2006
		US 7023138 B2	04/04/2006
		US 7064491 B2	20/06/2006
		US 7107929 B2	19/09/2006
		US 7112804 B2	26/09/2006
		US 7185602 B2	06/03/2007
		US 7394202 B2	01/07/2008
		US 7479643 B2	20/01/2009
		US 7491953 B2	17/02/2009
		US 7528550 B2	05/05/2009
		US 7609003 B2	27/10/2009
		US 7629590 B2	08/12/2009
		US 7723700 B2	25/05/2010
		US 7732787 B2	08/06/2010
		US 7791047 B2	07/09/2010
		US 7800312 B2	21/09/2010
		US 7820981 B2	26/10/2010
		US 7834554 B2	16/11/2010
		US 7838842 B2	23/11/2010

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/014541

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 7838850 B2	23/11/2010
		US 7960709 B2	14/06/2011
		US 7994031 B2	09/08/2011
		US 8071958 B2	06/12/2011
		US 8154210 B2	10/04/2012
		US 8368309 B2	05/02/2013
		US 8410459 B2	02/04/2013
		US 8502161 B2	06/08/2013
		US 8618514 B2	31/12/2013
		WO 01-43157 A1	14/06/2001
		WO 02-063653 A1	15/08/2002
		WO 02-43803 A1	06/06/2002
		WO 2004-003973 A2	08/01/2004
		WO 2004-003973 A3	26/10/2006
		WO 2004-003990 A1	08/01/2004
		WO 2005-059942 A2	30/06/2005
		WO 2005-059942 A3	13/10/2005
		WO 2005-060602 A2	07/07/2005
		WO 2005-060602 A3	04/01/2007
		WO 2007-056249 A1	18/05/2007
		WO 2007-149727 A2	27/12/2007
		WO 2007-149727 A3	27/11/2008
US 2017-0032924 A1	02/02/2017	TW 201703863 A	01/02/2017
		US 9721750 B2	01/08/2017
		WO 2017-019335 A1	02/02/2017
US 2015-0380206 A1	31/12/2015	US 9281162 B2	08/03/2016
JP 2015-191740 A	02/11/2015	CN 104952681 A	30/09/2015
		CN 104952681 B	19/06/2018
		JP 6257411 B2	10/01/2018
		KR 10-2015-0112785 A	07/10/2015
		TW 201537608 A	01/10/2015
		US 2015-0279612 A1	01/10/2015
		US 9293295 B2	22/03/2016