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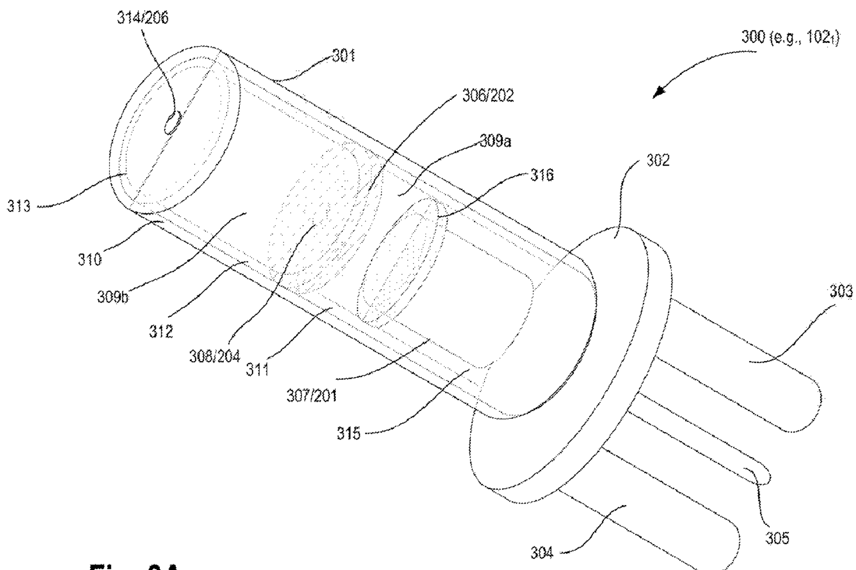

Fig. 3A

(57) Abstract: An apparatus is provided which comprises: a first layer comprising metal which is coupled to a first voltage supply; a second layer comprising metal which is coupled to a second voltage supply, wherein the second layer includes a hole for effusion; and a third layer comprising metal, wherein the second layer is between the first and third layers, wherein the second layer is separated from the first and third layers by a first space and a second space, respectively.

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[Continued on next page]

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HIGH THROUGHPUT DRIFT ENHANCED EFFUSION SOURCE FOR MOLECULAR BEAM EPITAXY

BACKGROUND

[0001] Molecular beam epitaxy (MBE) is an epitaxy mechanism for depositing thin-film of single crystals. MBE is a method for making crystals. Other types of epitaxy mechanisms include MOVPE (metalorganic vapor phase epitaxy), OMVPE (organometallic vapor phase epitaxy), MOCVD (metal organic chemical vapor deposition), PVD (physical vapor deposition), and ALD (atomic layer deposition). Among these epitaxy mechanisms, PVD generally results in the lowest quality of crystallinity with the highest speed of deposition. Conversely, MBE creates excellent epitaxial and crystalline films, but with the lowest speed of deposition. The epitaxial and crystalline films from MBE are stabilized in metastable states via strain and lattice conditions. MBE also maintains the quantum mechanical nature of coupling across atomic interfaces. For example, exchange bias is maintained between atomic interfaces. However, existing MBE use is limited. For example, MBE is used to create wafers with super lattices for optical electronics and high electron mobility transistors. Currently, due to poor speed of deposition (among some reasons), MBE does not exist as a tool for an integrated chip manufacturing process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] The embodiments of the disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure, which, however, should not be taken to limit the disclosure to the specific embodiments, but are for explanation and understanding only.

[0003] **Fig. 1** illustrates a high-level cross-section of a molecular beam epitaxy (MBE) apparatus with drift enhanced effusion sources, according to some embodiments of the disclosure.

[0004] **Figs. 2A-B** illustrate effusion sources with drift enhancement and with different apertures, according to some embodiments of the disclosure.

[0005] **Fig. 2C** illustrates an effusion source of the MBE with drift enhancement and with electron emitter, according to some embodiments of the disclosure.

[0006] **Fig. 3A** illustrates a three dimensional (3D) view of an effusion source for generating ionized atoms through a single bore, according to some embodiments of the disclosure.

[0007] **Fig. 3B** illustrates a cross-sectional view of the effusion source of **Fig. 3A**, according to some embodiments of the disclosure.

[0008] **Fig. 4A** illustrates a 3D view of an effusion source for generating ionized atoms through multiple bores, according to some embodiments of the disclosure.

[0009] **Fig. 4B** illustrates a cross-sectional view of the effusion source of **Fig. 4A**, according to some embodiments of the disclosure.

[0010] **Fig. 5A** illustrates a 3D view of an effusion source for generating neutralized atoms through a single bore, according to some embodiments of the disclosure.

[0011] **Fig. 5B** illustrates a cross-sectional view of the effusion source of **Fig. 5A**, according to some embodiments of the disclosure.

[0012] **Fig. 6A** illustrates a 3D view of an effusion source with electron source/sink for combining electrons with atoms, and a biased interface for generating neutralized effused atoms through a single bore, according to some embodiments of the disclosure.

[0013] **Fig. 6B** illustrates a cross-sectional view of the effusion source of **Fig. 6A**, according to some embodiments of the disclosure.

[0014] **Fig. 7** illustrates a perovskite lattice and possible material sources for use by the effusion sources, in accordance with some embodiments.

[0015] **Fig. 8** illustrates a high-level cross-section of an MBE apparatus which is configured for atomic layer etching (ALE), in accordance with some embodiments.

[0016] **Figs. 9A-E** illustrate the process of ALE performed by the MBE apparatus of **Fig. 8**, in accordance with some embodiments.

[0017] **Figs. 10A-C** illustrate various techniques for ALE, in accordance with some embodiments.

[0018] **Fig. 11** illustrates a smart device or a computer system or a SoC (System-on-Chip) having a substrate processed by the MBE apparatus, according to some embodiments of the disclosure.

DETAILED DESCRIPTION

[0019] As device dimension shrink over process nodes, fabricating devices with extreme accuracy is highly desirable. While traditional molecular beam epitaxy (MBE) allows for fabricating extremely thin films of molecules in a very precise and controlled manner, it is a very slow process that is not suitable for high volume manufacturing (HVM). For example, crystal growth rate is typically a few microns per hour which makes HVM a challenge.

[0020] Some embodiments describe an MBE apparatus which is enabled for integrated chip (IC) manufacturing process. Some embodiments describe a high speed effusion cell or source which utilizes drift enhancement to enable increases in source material deposition. Some embodiments describe an effusion cell that generates ionized atoms/molecules and uses drift enhancement. Some embodiments describe an effusion cell that generates neutralized effused atoms/molecules and uses drift enhancement. Some embodiments describe an effusion cell that generates neutralized effused atoms/molecules combined with electrons, and also uses drift enhancement. The effusion sources of various embodiments can be used to deposit traditional material used for depositing by existing effusion sources, and also to deposit perovskites, in accordance with some embodiments.

[0021] The drift enhancement in effusion cells of various embodiments increases the rate of creation of ionic or molecular sources for use in the MBE apparatus. As such, throughput of material source and deposition speed of material in MBE apparatus is increased. The drift enhancement in effusion cells of various embodiments allows control of the charge state of the species (or material source). The drift enhancement in effusion cells of various embodiments reduces the deposition on the side walls of the MBE apparatus (or chamber) to increase the utilization of the target elements. As such, there is less wastage and redepositing of material. Other technical effects of drift enhancement in effusion cells will be evident from the various embodiments and figures.

[0022] Some embodiments describe an atomic layer etching (ALE) apparatus with chemical (e.g., elemental and/or molecular) sources for ALE. In some embodiments, this apparatus can also be used for insitu atomistic cleaning which enables the propagation of strain and quantum mechanical couplings across the interfaces. In some embodiments, the ALE apparatus is integrated into the MBE chamber. In some embodiments, the ALE apparatus comprises a first effusion source that can inject a first material (e.g., chlorine, bromine, fluorine) into the MBE chamber for a first chemical reaction. This chemical reaction can be used for ALE on substrate 101, in accordance with some embodiments. In some embodiments, the first chemical reaction can also be used for cleaning the inner walls of the MBE chamber. In some embodiments, a second effusion source is provided to inject a second material (e.g., ionized hydrogen, argon, krypton, fluorine, etc.) into the MBE chamber for a second chemical reaction.

[0023] In some embodiments, the first chemical reaction is potentially a self-limiting reaction. For example, the first chemical reaction is limited to a single or few unit cell chemical reaction. In some embodiments, the second chemical reaction is selective only to react with the chemical product of reaction of the first material with the substrate (or target). Depending on the stoichiometry of the substrates (or targets), different elemental source for the first material can be used. In some embodiments, the relative modulation of the first and second chemical reactions controls the ALE rate. In some embodiments, the energy of the second material is controlled via a bias applied to the substrate. In some embodiments, the ALE is performed by pulsing the first and second materials. In some embodiments, the phase of the pulses for the first and second materials are offset (e.g., by 180 degrees) so that the first and second chemical reactions can take place in separate time intervals. In some embodiments, ALE and MBE can be performed either in a serial fashion or ALE can be combined into an MBE process to enable novel stack configurations.

[0024] In the following description, numerous details are discussed to provide a more thorough explanation of embodiments of the present disclosure. It will be apparent, however, to one skilled in the art, that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring embodiments of the present disclosure.

[0025] Note that in the corresponding drawings of the embodiments, signals are represented with lines. Some lines may be thicker, to indicate more constituent signal paths, and/or have arrows at one or more ends, to indicate primary information flow direction. Such indications are not intended to be limiting. Rather, the lines are used in connection with one or more exemplary embodiments to facilitate easier understanding of a circuit or a logical unit. Any represented signal, as dictated by design needs or preferences, may actually comprise one or more signals that may travel in either direction and may be implemented with any suitable type of signal scheme.

[0026] Throughout the specification, and in the claims, the term "connected" means a direct connection, such as electrical, mechanical, or magnetic connection between the things that are connected, without any intermediary devices. The term "coupled" means a direct or indirect connection, such as a direct electrical, mechanical, or magnetic connection between the things that are connected or an indirect connection, through one or more passive or active intermediary devices. The term "circuit" or “module” may refer to one or more passive and/or active components that are arranged to cooperate with one another to provide a desired function. The term "signal" may refer to at least one current signal, voltage signal, magnetic signal, or data/clock signal. The meaning of "a," "an," and "the" include plural references. The meaning of "in" includes "in" and "on."

[0027] The term “scaling” generally refers to converting a design (schematic and layout) from one process technology to another process technology and subsequently being reduced in layout area. The term “scaling” generally also refers to downsizing layout and devices within the same technology node. The term “scaling” may also refer to adjusting (e.g., slowing down or speeding up – i.e. scaling down, or scaling up respectively) of a signal frequency relative to another parameter, for example, power supply level. The terms “substantially,” “close,” “approximately,” “near,” and “about,” generally refer to being within +/- 10% of a target value.

[0028] Unless otherwise specified the use of the ordinal adjectives “first,” “second,” and “third,” etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking or in any other manner.

[0029] For the purposes of the present disclosure, phrases “A and/or B” and “A or B” mean (A), (B), or (A and B). For the purposes of the present disclosure, the phrase “A, B, and/or C” means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

[0030] The terms “left,” “right,” “front,” “back,” “top,” “bottom,” “over,” “under,” and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions. For the purposes of present disclosure the terms “spin” and “magnetic moment” are used equivalently. More rigorously, the direction of the spin is opposite to that of the magnetic moment, and the charge of the particle is negative (such as in the case of electron).

[0031] **Fig. 1** illustrates a high-level cross-section of an MBE apparatus 100 with drift enhanced effusion sources, according to some embodiments of the disclosure. MBE apparatus 100 mainly comprises of chamber 101, effusion sources 102_{1-4}, RHEED (reflection high energy electron diffraction) gun 103, RHEED screen 104, mass spectrometer 105, handle 106, substrate 107, and interface 108 to a buffer chamber.

[0032] In some embodiments, chamber 101 is made from metal and ceramics, and is completely sealed to realize an ultra-high vacuum chamber. Sealing is needed to provide a clean and dust free environment to avoid any contamination that may ruin deposition of material. The temperature inside chamber 101 can typically rise to 500-600 degrees centigrade.

[0033] In some embodiments, the effusion sources (or cells) 102_{1-4} are used to fire precise beams of atoms or molecules into chamber 101 towards substrate 107. For sake of brevity, four effusion sources (or cells) 102_{1-4} are shown. However, any number of effusion sources (or cells) 102_{1-4} may be used. Effusion is the process in which a gas escapes through a hole of a diameter considerably smaller than the mean free path of the molecules. The rate of effusion can be expressed as:

$$Rate = \frac{\rho A N_A}{\sqrt{2\pi MRT}}$$

where ρ is the pressure of target chamber 101, A is the area of the effusion hole, N_A is the Avogadro number, M is the mass of the atom being effused, T is the temperature, and R is the Rydberg constant. The drift assistance causes the rate to be greater than $\frac{\rho A N_A}{\sqrt{2\pi MRT}}$ in accordance with various embodiments.

[0034] In some embodiments, each effusion source is used to fire off a different material into chamber 101. Effusion sources (or cells) 102_{1-4} generally comprise of a crucible and an insert with a small bore for effusion to take place. It includes a heater and a place for elemental target material. Effusion sources are used for the evaporation of film materials. One kind of effusion cell for use in MBE follows the design of Knudsen cell (e.g., a thermodynamic system where the escaping gas has to pass through a bore smaller than the thermal mean fee path). Several factors affect performance of a Knudsen cell, which include rapid thermal response, low outgassing rate for materials, and uniformity of heating.

[0035] Some embodiments describe high speed effusion cells or sources (e.g., one or more of 102_{1-4}) which utilize drift enhancement to enable increases in source deposition. Some embodiments describe high speed effusion cells or sources (e.g., one or more of 102_{1-4}) that generate ionized atoms and also use drift enhancement. Some embodiments describe high speed effusion cells or sources 102_{1-4} that generate neutralized effused atoms and also use drift enhancement. Some embodiments describe high speed effusion cells or sources (e.g., one or more of 102_{1-4}) that generate neutralized effused atoms combined with electrons, and also uses drift enhancement. The effusion sources of various embodiments can be used to deposit traditional material used for depositing by existing effusion sources, and also to deposit perovskites.

[0036] In some embodiments, the substrate 107 may be heated by a filament (not shown) behind it. In some embodiments, substrate 107 or die is positioned facing down so that it faces the effusion sources (or cells) 102_{1-4}. In MBE, separate beams of different material are fired from effusion sources (or cells) 102_{1-4} which layer as molecules on the surface of substrate 107.

[0037] The drift enhancement in effusion cells $102_{1\text{-}4}$ of various embodiments increases the rate of creation of ionic or molecular sources for use in MBE apparatus 100. As such, throughput of material source and deposition speed of material in MBE apparatus 100 is increased. The drift enhancement in effusion cells $102_{1\text{-}4}$ of various embodiments allows control of the charge state of the species (or material source). The drift enhancement in effusion cells $102_{1\text{-}4}$ of various embodiments reduces the deposition on the side walls of MBE apparatus (or chamber) 101 to increase the utilization of the target elements. As such, there is less wastage and redepositing of material.

[0038] In some embodiments, during operation of the MBE, RHEED gun 103 and screen 104 are used to monitor the growth of the crystal formed on substrate 107 by effusion sources (or cells) $102_{1\text{-}4}$. In some embodiments, mass spectrometer 105 is also used to measure performance of the operation. In some embodiments, handle 106 can be used to orient the substrate 107, and to also provide stability to substrate 107 by holding it in place without vibration.

[0039] The fast deposition of target material on substrate 107 using the drift enhanced effusion sources allows for fabricating extremely thin films of molecules (e.g., traditional material, perovskites, and other oxides) in a very precise and controlled manner, which is suitable for HVM.

[0040] **Figs. 2A-B** illustrate effusion sources $200/101_1$ and $220/101_1$ of the MBE with drift enhancement and with different apertures, respectively. It is pointed out that those elements of **Figs. 2A-B** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0041] Effusion sources $200/101_1$ and $220/101_1$ are similar in function and principal, but with different bore sizes. In some embodiments, drift enhanced effusion sources are a tube like structure that include a heater, source material (e.g., Al, Ga, In, Tl, Si, Ge, Sn, Pb, perovskites, oxides, etc.), cathode plate, anode plate, bore, water cooling, controllable shutter, etc. A simplified form is shown as effusion sources $200/101_1$ and $220/101_1$ to highlight the effect of the bore size in drift effusion. Typically, the metal plates (if any) in effusion sources are neutral (e.g., not charged), and material in gas form is allowed to effuse through effusion hole at a rate of:

$$Rate = \frac{\rho A N_A}{\sqrt{2\pi MRT}}$$

[0042] This rate is, however, very slow. Such slow rate makes traditional MBE apparatus to be unsuitable for integrated chip manufacturing. In some embodiments, to enhance the drift of the material through the effusion hole, the metal plates are charged or biased.

[0043] In some embodiments, plate 201 is an anode and plate 202 is a cathode. In some embodiments, the material for effusion is placed in the space between plates 201 and 202. In some embodiments, material 205 is heated and ionized, and the potential difference between plates 201 and 202 causes material 205 to drift through the hole 204/224 towards plate 203. In some embodiments, plate 203 is also biased. For example, plate 203 is charged to be an anode to further enhance speed of ejection of effused material 205. In some embodiments, plate 203 includes a single hole 206 to eject the effused material 205. In some embodiments, plate 203 includes multiple holes (not shown).

[0044] In some embodiments, the electric field applied in the effusion cell due to anode 201 and cathode 202 directs the material molecules 205 to pass through bore 204/224. As the bore size increases from 204 to 224, more molecules pass through. These molecules are then released into chamber 101 at a controlled rate. In some embodiments, a shutter (not shown) is attached to plate 203 and is used to control the number of molecules fired by the effusion cell. For example, the shutter can cover some holes so to reduce the number of molecules released by the effusion cell. The rate of effusion from drift assistance is higher than the traditional rate of effusion without drift assistance, in accordance with various embodiments.

[0045] **Fig. 2C** illustrates effusion sources 230/101_1 of the MBE with drift enhancement and with electron emitter, according to some embodiments of the disclosure. It is pointed out that those elements of **Figs. 2C** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0046] In some embodiments, electron emitter 231 (e.g., a heater comprising material W, To, Ta, etc.) is inserted between plates 202 and 203. In some embodiments, electron 231 emitter is used to source electrons that combine with atoms 205 to neutralize them (as indicated by neutralized atoms/molecule 207. As such, neutralized effused atoms 207 are released from plate 203 by drift assistance through hole 206.

[0047] **Fig. 3A** illustrates a 3D view of an effusion source 300 (e.g., 102_1) for generating ionized atoms through a single bore, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 3A** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0048] In some embodiments, effusion source 300 comprises outer covering or housing 301, flange 302, power supply interfaces 303 and 304, control signal interface 305, cathode 305/202, anode container 307/201, cathode bore 308/204, first space region 309a, second space region 309b, material 310 for cryogenic cooling for high melting cells, heater 311, conductor 312 to avoid adsorption, ejection plate 313/203, ejection hole 314/206, cooling material 315, and stopper 316. A person skilled in the art would appreciate that all components of an effusion source are not shown here so as to focus on the various embodiments.

[0049] In some embodiments, covering or housing 301 contains the crucible and material for effusion (also referred to as the source material) along with other components as shown. In some embodiments, housing 301 holds cryogenic cooling material to keep the effusion cell from overheating. In some embodiments, flange 302 is used to hold the crucible (in housing 301) and to provide support for housing 301 when it is inserted into chamber 101 of MBE apparatus 100. In some embodiments, flange 302 includes holes for screwing in the effusion cell into chamber 101 of MBE apparatus 100 so that the effusion cell is held in place.

[0050] In some embodiments, a power supply cable is connected to interfaces 303 and 304 to provide power to the effusion cell. In some embodiments, control interface 305 is coupled to one or more signal source (or to a computing device) to provide controls for various biases to metal electrodes in housing 301. These controls can be used to manage the shutter speed, bias voltage levels, etc.

[0051] In some embodiments, electrode 306/202 behaves as a cathode and is biased. In some embodiments, electrode 306/202 receives a separate power supply which may be derived from the power supply provided by interfaces 303/304. In some embodiments, the bias provided to electrode 306/202 is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths. In some embodiments, the intensity of the bias (e.g., voltage, current, etc.) can be adjusted using control interface 305.

[0052] In some embodiments, electrode 307/201 behaves as an anode and is biased. In some embodiments, electrode 307/201 is coupled to ground. Any suitable conducting material can be used for forming electrode 307/301. In some embodiments, electrode

307/201 is formed of a material that does not release gas when heated so that it may not contaminate the material for effusion.

[0053] In some embodiments, electrode 307/201 receives a separate power supply which may be derived from the power supply provided by interfaces 303/304. In some embodiments, the bias provided to electrode 307/201 is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths. In some embodiments, the intensity of the bias (e.g., voltage, current, etc.) can be adjusted using control interface 305. In various embodiments, the drift assistance provided to the material for effusion is caused by the potential difference between electrode 306/202 and electrode 307/201. In some embodiments, an electrical bias is maintained between the target source (e.g., electrode 307) and the collection aperture 308 of electrode 306.

[0054] In some embodiments, electrode 307/301 is formed as a container to contain the material for effusion. In some embodiments, electrode 307/301 is shaped like a cone such that the wider circle of the cone seals cooling material 315 from escaping into first space region 309a. In some embodiments, a stopper 316 is coupled to electrode 307/201 to enable that cooling material 315 does not escape into first space region 309a. Any suitable cooling material can be used. In some embodiments, electrode 307/301 can be removed or accessed to provide the material for effusion.

[0055] In some embodiments, heater 311 is used to heat the material for effusion thereby making a crucible. In some embodiments, heater 311 is formed of a material that when heated does not release gas that may contaminate the material for effusion. In some embodiments, heater 311 comprises a material including one of: W, Mo, Ta, or their carbides.

[0056] In some embodiments, conductor 312 is biased to avoid adsorption. For example, conductor 312 is biased to avoid sticking of effused material along the inner sidewalls of the effusion source. In some embodiments, conductor 312 extends from electrode 306/202 to ejection plate 313, which is the second space region 309b. In some embodiments, conductor 312 receives a separate power supply which may be derived from the power supply provided by interfaces 303/304. In some embodiments, the bias provided to conductor 312 is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[0057] In some embodiments, ejection plate 313/203 include an ejection hole 314/206 which disperses or ejects the effused material (or source material) into chamber 101. In some embodiments, ejection plate is made of a conducting metal. Any suitable material that can operate at high temperatures without generating contaminants may be used for ejection plate

313/203. In some embodiments, effusion source 300 comprises a shutter (not shown) attached to ejection plate 313/203. The shutter can be used to shut or block ejection hole(s) 314/206.

[0058] In some embodiments, covering or housing 301 holds cryogenic cooling material 310 to keep the effusion cell from overheating. In some embodiments, cryogenic cooling material 310 flows along the surge of the effusion cell (e.g., just under covering 301) to reduce the sublimation of wall material into MBE vacuum.

[0059] **Fig. 3B** illustrates a cross-sectional view 320 of the effusion source of **Fig. 3A**, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 3B** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such. Here, material 320 for effusion is shown which is ionized as ionized atoms or molecules. These ionized atoms or molecules drift from first space region 309a into second pas region 309b through hole 307 due to drift enhanced effusion, and eventually to ejection hole 314.

[0060] **Fig. 4A** illustrates a 3D view of effusion source 400 for generating ionized atoms through multiple bores, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 4A** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such. Effusion source 400 is similar to effusion source 300 but for the design of ejection plate 313/203 which includes an ejection hole 314/206. In some embodiments, effusion source 400 comprises ejection plate 413/203 with multiple ejection holes 414/206. More holes mean more ejection of effused material into chamber 101. Note, Coulomb blockade may allow one atom to come out of a hole at a time. In some embodiments, the shutter attached to ejection plate 413/203 can be used to mechanically cover one or more holes (or all holes) in ejection plate 413/203 to control the rate of ejection of source material into chamber 101.

[0061] **Fig. 4B** illustrates a cross-sectional view 420 of the effusion source of **Fig. 4A**, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 4B** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0062] **Fig. 5A** illustrates a 3D view of effusion source 500 for generating neutralized effused atoms through a single bore, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 5A** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such. Effusion source 500 is similar to effusion source 300 but for ejection plate 313/203. In some embodiments, effusion source 500 comprises ejection plate 513/203 biased for neutralization. In some embodiments, ejection plate 513/203 has a single ejection hole 514. In some embodiments, ejection plate 513/203 comprises multiple ejection holes (not shown).

[0063] In some embodiments, ejection plate 513/203 receives a separate power supply which may be derived from the power supply provided by interfaces 303/304. In some embodiments, the bias provided to ejection plate 513/203 is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths. In some embodiments, ejection plate 513/203 can behave as a shutter or for neutralizing the effused ionized atoms. For example, in some embodiments, effused ionized atoms/molecules are neutralized by negatively biased ejection plate 513/203. As such, the neutralized effused ionized atoms/molecules are ejected into chamber 101.

[0064] **Fig. 5B** illustrates a cross-sectional view 520 of the effusion source of **Fig. 5A**, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 5B** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0065] **Fig. 6A** illustrates a 3D view of effusion source 600 with electron source/sink for combining electrons with atoms, and a biased interface for generating neutralized effused atoms through a single bore, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 6A** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such. Effusion source 600 is similar to effusion source 500 but for conductor 312. In some embodiments, conductor 312 is replaced with electron source/sink 612. In some embodiments, electron source/sink 612 comprises a material including one of: W, Mo, Ta, or their carbides. In some embodiments, electron source/sink 612 generates electrons that are generated by heating electron source/sink 612. The electrons generated by electron source/sink 612 combine with effused material in second space region 309b. One technical effect of the electron source/sink 612 is that it allows neutralizing the species (or source material), for example.

[0066] **Fig. 6B** illustrates a cross-sectional view 620 of the effusion source of **Fig. 6A**, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 6B** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0067] **Fig. 7** illustrates a perovskite lattice 700 and possible material sources for use by the effusion sources, in accordance with some embodiments. A perovskite has a cubic structure with general formula of ABO_3. In this cubic structure, 'A' represents A-site ion (e.g., alkaline earth or rare earth element) which is positioned on the corners of the lattice, 'B' represents B-site ion (e.g., 3d, 4d, and 5d transition metal elements) on the center of the lattice, and oxide 'O' within the lattice forming an angled cube. The periodic table shown in **Fig. 7** has elements shaded with three different shades for choices for A, B, and O.

[0068] **Fig. 8** illustrates a high-level cross-section of an MBE apparatus 800 which is configured for atomic layer etching (ALE), in accordance with some embodiments. It is pointed out that those elements of **Fig. 8** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0069] ALE is a technique that removes thin layers of material. The concept is similar to atomic layer deposition (ALD), except that removal occurs instead of a second adsorption step. As such, layer-by-layer subtraction results in place of addition. ALE is a semiconductor manufacturing process in which a sequence alternating between self-limiting chemical modification steps and etching steps.

[0070] The first step is the self-limiting chemical modification step that affects only the top atomic layers of the wafer. For example, the modification step form a reactive layer (also referred to as the modified layer), and this reactive layer is then removed. Here, the term "self-limiting" generally refers to a reaction that slows down or stops as a function of time or, equivalently, as a function of species dosage. The reactive surface layer has well-defined thickness that is subsequently more readily removed than the unmodified material (e.g., Si). The reactive surface layer is characterized by a sharp gradient in chemical composition and/or physical structure of the outermost layer of a material.

[0071] The second step is the etching step which removes only the chemically-modified areas (e.g., the reactive layer). The etching step (or removal step) takes away the modified layer while keeping the underlying substrate intact. As such, the surface is reset to a pristine or near-pristine state for the next etching cycle.

[0072] The separation of reaction means that the composite process executed as a repeated series of two or more independent unit steps. One advantage of separation is that it decouples the generation and transport of ions, electrons, and neutral. As such, access to desirable species fluxes and their relative rations increases. The two alternating steps allow for the removal of individual atomic layers. In some embodiments, for etching of silicon, alternating reaction with chlorine and etching with argon ions is used.

[0073] In some embodiments, a first effusion source 801 is provided which is at least partially embedded in chamber 101. In some embodiments, first effusion source 801 is to deposit a first material to substrate 107. In some embodiments, the first material includes one of: Chlorine, Bromine, or Fluorine. In some embodiments, the deposition of the first material is the self-limiting chemical modification step which affects the top atomic layers of substrate 101. In some embodiments, first effusion source 801 is drift enhanced effusion source that is capable of providing pulsed output by biasing as described by various embodiments. In some embodiments, effusion source 801 is a traditional effusion source.

[0074] In some embodiments, a second effusion source 802 is provided which is at least partially embedded in chamber 101. In some embodiments, second effusion source 802 is to deposit a second material to substrate 107 so that it chemically reacts with the first material (which has already reacted with a layer of substrate). In some embodiments, the second material includes one of: Hydrogen, Argon, Krypton, or Fluorine.

[0075] In some embodiments, the deposition of the second material results in removal of first material which previously chemically modified the surface of substrate 107. In some embodiments, second effusion source 802 is drift enhanced effusion source that is capable of providing pulsed output by biasing as described by various embodiments. In some embodiments, effusion source 802 is a traditional effusion source.

[0076] In some embodiments, MBE apparatus 800 can also be used for insitu atomistic cleaning which enables the propagation of strain and quantum mechanical couplings across the interfaces. In some embodiments, the first chemical reaction from effusion source 801 can also be used for cleaning the inner walls of the MBE chamber. For example, a cleaning agent is deposited on the walls of chamber 101, and then that material is etched out. In some embodiments, second effusion source 802 injects a second material (e.g., ionized hydrogen, argon, krypton, fluorine, etc.) into the MBE chamber 101 for a second chemical reaction.

[0077] In some embodiments, the first chemical reaction is potentially a self-limiting reaction. For example, the first chemical reaction is limited to a single or few unit cell chemical reaction. In some embodiments, the second chemical reaction is selective only to react with the chemical product of reaction of the first material with the substrate. Depending on the stoichiometry of the chemicals deposited on the walls of the chamber 101, different elemental source for the first material can be used.

[0078] In some embodiments, the relative modulation of the first and second chemical reactions controls the ALE rate. In some embodiments, the energy of the second material is controlled via a bias applied to the substrate. In some embodiments, the ALE is performed by pulsing the first and second materials. In some embodiments, the phase of the pulses for the first and second materials are offset (e.g., by 180 degrees) so that the first and second chemical reactions can take place in separate time intervals. In some embodiments, ALE and MBE can be performed either in a serial fashion or ALE can be combined into an MBE process to enable novel stack configurations.

[0079] **Figs. 9A-E** illustrate processes 900, 920, 930, 940, and 950, respectively, of ALE performed by the MBE apparatus of **Fig. 8**, in accordance with some embodiments. It is pointed out that those elements of **Figs. 9A-E** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0080] **Figs. 9A-C** illustrate the process of self-limiting chemical modification step that affects only the top atomic layer 901 of the wafer. For example, the modification step forms a reactive layer 921 (also referred to as the modified layer), and this reactive layer 921 is then removed. In one example, the reactive layer 921 is formed by depositing a layer of chlorine on silicon substrate for regions that need etching. Once the region of interest is covered with a layer of reactive material, as shown by indicator 931, the process of etching can begin.

[0081] **Figs. 9C-E** illustrate the process of etching which removes only the chemically-modified areas (e.g., the reactive layer 931). In some embodiments, ionized Argon atoms are passed over or deposited on reactive layer 931, and these ionized argon atoms remove the reactive layer 931. The etching step (or removal step) takes away the modified layer 931 while keeping the underlying substrate intact (e.g., the atomic layer below top layer 901). As such, the silicon surface is reset to a pristine or near-pristine state for the next etching cycle as shown by layer 951.

[0082] While the various embodiments here are described with reference to ALE for a silicon substrate, the embodiments are not limited to such. For example, a person skilled in the art may select a different material for first and second materials according to the chemical structure of the to-be etched material.

[0083] **Figs. 10A-C** illustrate various techniques 1000, 1020, and 1030 for ALE, respectively, in accordance with some embodiments. Technique 1000 illustrates how reactive material and then the material for etching are deposited on a substrate (or any target layer) over time. Here, neutrals 1001 are the reactive materials (e.g., one of Chlorine, Bromine, or Fluorine) that realize the modification step, while ion energy 1002 refers to ionized atoms used for etching (e.g., ionized hydrogen, argon, krypton, fluorine, etc.). Technique 1000 illustrates the case were neutrals 1001 and ionized atoms 1002 are deposited constantly together over time as indicated by straight lines 1010 and 1011, according to some embodiments. For instance, effusion sources 801 and 802 inject their respective material into chamber 101 together and constantly. Here, the x-axis for the lines is time and the y-axis is voltage.

[0084] Technique 1020 illustrates the case where neutrals 1001 (e.g., reactive material) are deposited constantly while ionized atoms 1002 are deposited in a pulsed fashion. For example, effusion source 802 injects ionized atoms 1002 when the pulse 1022 is high and stops injecting ionized atoms 1002 into chamber 101 when the pulse 1022 is low, while effusion source 801 continues to deposit neutrals 1001 constantly as indicated by line 1021. A reverse function can also be realized by the pulse. For example, effusion source 802 stops injecting ionized atoms 1002 when the pulse 1022 is high and injects ionized atoms 1002 into chamber 101 when the pulse 1022 is low.

[0085] Technique 1030 illustrates the case where both neutrals 1001 (e.g., reactive material) and ionized atoms 1002 are deposited in a pulsed fashion as shown by pulses 1031 and 1032. For example, effusion sources 801 and 802 inject neutrals 1001 and ionized atoms 1002 when their respective pulses 1031 and 1032 are high and stops injecting neutrals 1001 and ionized atoms 1002 into chamber 101 when their respective pulses 1031 and 1032 are low. A reverse function can also be realized by the pulse. For example, effusion source 802 stops injecting ionized atoms 1002 when the pulse 1032 is high and injects ionized atoms 1002 into chamber 101 when the pulse 1032 is low. In some embodiments, pulses 1031 and 1032 are phase shifted. For example, pulses 1031 and 1032 are phase shifted by 180 degrees so that alternate steps of modification and etching are achieved to have better control on etching of a material layer. In some embodiments, the phase shift can be other than 180 degrees. For example, phase shift between pulses 1031 and 1032 is 90 degrees.

[0086] In various embodiments, the pulsing effect from effusion sources 801/802 can be realized by providing biased pulses to cathode 306 and/or ejection plate 513. In some embodiments, the pulsing effect from effusion sources 801/802 can be realized by opening and closing the mechanical shutter attached to ejection plate 313/413/513.

[0087] **Fig. 11** illustrates a smart device or a computer system or a SoC (System-on-Chip) having a substrate processed by the MBE apparatus, according to some embodiments of the disclosure. It is pointed out that those elements of **Fig. 11** having the same reference numbers (or names) as the elements of any other figure can operate or function in any manner similar to that described, but are not limited to such.

[0088] For purposes of the embodiments, the transistors in various circuits and logic blocks described here are metal oxide semiconductor (MOS) transistors or their derivatives, where the MOS transistors include drain, source, gate, and bulk terminals. The transistors and/or the MOS transistor derivatives also include Tri-Gate and FinFET transistors, Gate All Around Cylindrical Transistors, Tunneling FET (TFET), Square Wire, or Rectangular Ribbon Transistors, ferroelectric FET (FeFETs), or other devices implementing transistor functionality like carbon nanotubes or spintronic devices. MOSFET symmetrical source and drain terminals i.e., are identical terminals and are interchangeably used here. A TFET device, on the other hand, has asymmetric Source and Drain terminals. Those skilled in the art will appreciate that other transistors, for example, Bi-polar junction transistors (BJT PNP/NPN), BiCMOS, CMOS, etc., may be used without departing from the scope of the disclosure.

[0089] **Fig. 11** illustrates a block diagram of an embodiment of a mobile device in which flat surface interface connectors could be used. In some embodiments, computing device 1600 represents a mobile computing device, such as a computing tablet, a mobile phone or smart-phone, a wireless-enabled e-reader, or other wireless mobile device. It will be understood that certain components are shown generally, and not all components of such a device are shown in computing device 1600.

[0090] In some embodiments, computing device 1600 includes first processor 1610 formed using MBE, according to some embodiments discussed. Other blocks of the computing device 1600 may also be formed using MBE, according to some embodiments. The various embodiments of the present disclosure may also comprise a network interface within 1670 such as a wireless interface so that a system embodiment may be incorporated into a wireless device, for example, cell phone or personal digital assistant.

[0091] In some embodiments, processor 1610 (and/or processor 1690) can include one or more physical devices, such as microprocessors, application processors, microcontrollers, programmable logic devices, or other processing means. The processing operations performed by processor 1610 include the execution of an operating platform or operating system on which applications and/or device functions are executed. The processing operations include operations related to I/O (input/output) with a human user or with other devices, operations related to power management, and/or operations related to connecting the computing device 1600 to another device. The processing operations may also include operations related to audio I/O and/or display I/O.

[0092] In some embodiments, computing device 1600 includes audio subsystem 1620, which represents hardware (e.g., audio hardware and audio circuits) and software (e.g., drivers, codecs) components associated with providing audio functions to the computing device. Audio functions can include speaker and/or headphone output, as well as microphone input. Devices for such functions can be integrated into computing device 1600, or connected to the computing device 1600. In one embodiment, a user interacts with the computing device 1600 by providing audio commands that are received and processed by processor 1610.

[0093] In some embodiments, computing device 1600 comprises display subsystem 1630. Display subsystem 1630 represents hardware (e.g., display devices) and software (e.g., drivers) components that provide a visual and/or tactile display for a user to interact with the computing device 1600. Display subsystem 1630 includes display interface 1632, which includes the particular screen or hardware device used to provide a display to a user. In one embodiment, display interface 1632 includes logic separate from processor 1610 to perform at least some processing related to the display. In one embodiment, display subsystem 1630 includes a touch screen (or touch pad) device that provides both output and input to a user.

[0094] In some embodiments, computing device 1600 comprises I/O controller 1640. I/O controller 1640 represents hardware devices and software components related to interaction with a user. I/O controller 1640 is operable to manage hardware that is part of audio subsystem 1620 and/or display subsystem 1630. Additionally, I/O controller 1640 illustrates a connection point for additional devices that connect to computing device 1600 through which a user might interact with the system. For example, devices that can be attached to the computing device 1600 might include microphone devices, speaker or stereo systems, video systems or other display devices, keyboard or keypad devices, or other I/O devices for use with specific applications such as card readers or other devices.

[0095] As mentioned above, I/O controller 1640 can interact with audio subsystem 1620 and/or display subsystem 1630. For example, input through a microphone or other audio device can provide input or commands for one or more applications or functions of the computing device 1600. Additionally, audio output can be provided instead of, or in addition to display output. In another example, if display subsystem 1630 includes a touch screen, the display device also acts as an input device, which can be at least partially managed by I/O controller 1640. There can also be additional buttons or switches on the computing device 1600 to provide I/O functions managed by I/O controller 1640.

[0096] In some embodiments, I/O controller 1640 manages devices such as accelerometers, cameras, light sensors or other environmental sensors, or other hardware that can be included in the computing device 1600. The input can be part of direct user interaction, as well as providing environmental input to the system to influence its operations (such as filtering for noise, adjusting displays for brightness detection, applying a flash for a camera, or other features).

[0097] In some embodiments, computing device 1600 includes power management 1650 that manages battery power usage, charging of the battery, and features related to power saving operation. Memory subsystem 1660 includes memory devices for storing information in computing device 1600. Memory can include nonvolatile (state does not change if power to the memory device is interrupted) and/or volatile (state is indeterminate if power to the memory device is interrupted) memory devices. Memory subsystem 1660 can store application data, user data, music, photos, documents, or other data, as well as system data (whether long-term or temporary) related to the execution of the applications and functions of the computing device 1600.

[0098] Elements of embodiments are also provided as a machine-readable medium (e.g., memory 1660) for storing the computer-executable instructions (e.g., instructions to implement any other processes discussed herein). The machine-readable medium (e.g., memory 1660) may include, but is not limited to, flash memory, optical disks, CD-ROMs, DVD ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, phase change memory (PCM), or other types of machine-readable media suitable for storing electronic or computer-executable instructions. For example, embodiments of the disclosure may be downloaded as a computer program (e.g., BIOS) which may be transferred from a remote computer (e.g., a server) to a requesting computer (e.g., a client) by way of data signals via a communication link (e.g., a modem or network connection).

[0099] In some embodiments, computing device 1600 comprises connectivity 1670. Connectivity 1670 includes hardware devices (e.g., wireless and/or wired connectors and communication hardware) and software components (e.g., drivers, protocol stacks) to enable the computing device 1600 to communicate with external devices. The computing device 1600 could be separate devices, such as other computing devices, wireless access points or base stations, as well as peripherals such as headsets, printers, or other devices.

[00100] Connectivity 1670 can include multiple different types of connectivity. To generalize, the computing device 1600 is illustrated with cellular connectivity 1672 and wireless connectivity 1674. Cellular connectivity 1672 refers generally to cellular network connectivity provided by wireless carriers, such as provided via GSM (global system for mobile communications) or variations or derivatives, CDMA (code division multiple access) or variations or derivatives, TDM (time division multiplexing) or variations or derivatives, or other cellular service standards. Wireless connectivity (or wireless interface) 1674 refers to wireless connectivity that is not cellular, and can include personal area networks (such as Bluetooth, Near Field, etc.), local area networks (such as Wi-Fi), and/or wide area networks (such as WiMax), or other wireless communication.

[00101] In some embodiments, computing device 1600 comprises peripheral connections 1680. Peripheral connections 1680 include hardware interfaces and connectors, as well as software components (e.g., drivers, protocol stacks) to make peripheral connections. It will be understood that the computing device 1600 could both be a peripheral device ("to" 1682) to other computing devices, as well as have peripheral devices ("from" 1684) connected to it. The computing device 1600 commonly has a "docking" connector to connect to other computing devices for purposes such as managing (e.g., downloading and/or uploading, changing, synchronizing) content on computing device 1600. Additionally, a docking connector can allow computing device 1600 to connect to certain peripherals that allow the computing device 1600 to control content output, for example, to audiovisual or other systems.

[00102] In addition to a proprietary docking connector or other proprietary connection hardware, the computing device 1600 can make peripheral connections 1680 via common or standards-based connectors. Common types can include a Universal Serial Bus (USB) connector (which can include any of a number of different hardware interfaces), DisplayPort including MiniDisplayPort (MDP), High Definition Multimedia Interface (HDMI), Firewire, or other types.

[00103] Reference in the specification to "an embodiment," "one embodiment," "some embodiments," or "other embodiments" means that a particular feature, structure, or characteristic described in connection with the embodiments is included in at least some embodiments, but not necessarily all embodiments. The various appearances of "an embodiment," "one embodiment," or "some embodiments" are not necessarily all referring to the same embodiments. If the specification states a component, feature, structure, or characteristic "may," "might," or "could" be included, that particular component, feature,

structure, or characteristic is not required to be included. If the specification or claim refers to "a" or "an" element, that does not mean there is only one of the elements. If the specification or claims refer to "an additional" element, that does not preclude there being more than one of the additional element.

[00104] Furthermore, the particular features, structures, functions, or characteristics may be combined in any suitable manner in one or more embodiments. For example, a first embodiment may be combined with a second embodiment anywhere the particular features, structures, functions, or characteristics associated with the two embodiments are not mutually exclusive.

[00105] While the disclosure has been described in conjunction with specific embodiments thereof, many alternatives, modifications and variations of such embodiments will be apparent to those of ordinary skill in the art in light of the foregoing description. The embodiments of the disclosure are intended to embrace all such alternatives, modifications, and variations as to fall within the broad scope of the appended claims.

[00106] In addition, well known power/ground connections to integrated circuit (IC) chips and other components may or may not be shown within the presented figures, for simplicity of illustration and discussion, and so as not to obscure the disclosure. Further, arrangements may be shown in block diagram form in order to avoid obscuring the disclosure, and also in view of the fact that specifics with respect to implementation of such block diagram arrangements are highly dependent upon the platform within which the present disclosure is to be implemented (i.e., such specifics should be well within purview of one skilled in the art). Where specific details (e.g., circuits) are set forth in order to describe example embodiments of the disclosure, it should be apparent to one skilled in the art that the disclosure can be practiced without, or with variation of, these specific details. The description is thus to be regarded as illustrative instead of limiting.

[00107] The following examples pertain to further embodiments. Specifics in the examples may be used anywhere in one or more embodiments. All optional features of the apparatus described herein may also be implemented with respect to a method or process.

[00108] Example 1 is an apparatus comprising: a first layer comprising metal which is coupled to a first voltage supply; a second layer comprising metal which is coupled to a second voltage supply, wherein the second layer includes a hole for effusion; and a third layer comprising metal, wherein the second layer is between the first and third layers, wherein the second layer is separated from the first and third layers by a first space and a second space, respectively.

[00109] Example 2 includes all features of example 1, and comprises an electron emitter between the second and third layers.

[00110] Example 3 is according to any of the preceding claims, wherein the third layer includes at least one hole.

[00111] Example 4 is according to any of the preceding examples, wherein: the first voltage supply is a positive voltage supply, and the second voltage supply is a negative voltage supply, or wherein: the first voltage supply is a negative voltage supply, and the second voltage supply is a positive voltage supply.

[00112] Example 5 is according to any of the preceding claims, wherein the first voltage supply is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00113] Example 6 is according to any of the preceding claims, wherein the second voltage supply is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00114] Example 7 is according to any of the preceding claims, wherein the third layer is coupled to a third voltage supply which is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00115] Example 8 is according to any of the preceding examples, wherein the first space is to contain a material for effusion, and wherein the second space is to contain, in transition, the effused material.

[00116] Example 9 includes all features of example 8, wherein the material includes an elemental component of a perovskite.

[00117] Example 10 is according to any of examples 1 to 8, and comprises a heater surrounding the first layer.

[00118] Example 11 includes all features of example 10, wherein the heater comprises a material which includes one of: W, Mo, Ta, or their carbides.

[00119] Example 12 is according to any of examples 10 to 11, and comprises a cooling material between the heater and the first layer.

[00120] Example 13 is according to any of preceding examples, and comprises a fourth layer comprising metal, wherein the fourth layer is positioned between the second and third layers.

[00121] Example 14 includes all features of example 12, wherein the fourth layer is coupled to a fourth voltage supply, wherein the fourth voltage supply is one of: a constant

positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00122] Example 15 is according to any of examples 13 or 14, wherein the fourth layer is a heater which comprises a material including one of: W, Mo, Ta, or their carbides.

[00123] Example 16 is according to any of preceding examples, wherein the first layer is encased within a covering including hermetically sealed coolant.

[00124] Example 17 is a system which comprises: a chamber for molecular beam epitaxy (MBE); an effusion source at least partially embedded in the chamber; and a handle in the chamber to hold a substrate, wherein the effusion source is according to any one of claims 1 to 16, and wherein the effusion source is to provide a material for depositing on the substrate.

[00125] Example 18 includes all features of example 17, wherein the effusion source is to provide ionized effused atoms or molecules of the material.

[00126] Example 19 is according to any one of examples 17 to 18, and comprises a reflection high energy electron diffraction (RHEED) gun at least partially embedded in the chamber.

[00127] Example 20 is according to any one of examples 17 to 19, and comprises a mass spectrometer which is partially embedded in the chamber.

[00128] Example 21 is an apparatus comprises: a flange to provide power supply and one or more control signals; and a housing coupled to the flange via one or more support structures, wherein the housing includes: a container comprising metal which is biased by a first bias controllable by at least one of the one or more control signals, wherein the container is to contain material for effusion and a layer comprising metal which is biased by a second bias controllable by at least one of the one or more control signals, the layer including a bore for effusion.

[00129] Example 22 includes all features of example 21, and comprising a second layer parallel to the layer, wherein the second layer comprises metal and includes at least one bore.

[00130] Example 23 includes all features of claim 22, wherein the second layer is biased by a third bias controllable by at least one of the one or more control signals, wherein the third bias is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00131] Example 24 is according to any of examples 22 to 23, and comprises an electron emitter between the layer and the second layer.

[00132] Example 25 is according to any of claims 22 to 23, and comprises a third layer comprising metal, wherein the third layer is between the layer and the second layer, and wherein the third layer is biased by a fourth bias which is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00133] Example 26 is according to any of examples 21 to 25, and comprises a heater, wherein the container is at least partially surrounded by the heater which comprises a material including one of: W, Mo, Ta, or their carbides.

[00134] Example 27 is according to any of examples 21 to 26, and comprises a hermetically sealed coolant between the container and the heater.

[00135] Example 28 is according to any of examples 21 to 27, wherein the material in the container includes a perovskite.

[00136] Example 29 is according to any of examples 21 to 28, wherein the second bias is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00137] Example 30 is according to any of examples 21 to 29, wherein the first bias is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00138] Example 31 is according to any of examples 21 to 30, wherein the housing includes a crucible.

[00139] Example 32 is a method which comprises: forming a first layer comprising metal which is coupled to a first voltage supply; forming a second layer comprising metal which is coupled to a second voltage supply, wherein the second layer includes a hole for effusion; and forming a third layer comprising metal, wherein the second layer is between the first and third layers, wherein the second layer is separated from the first and third layers by a first space and a second space, respectively.

[00140] Example 33 includes all features of example 32, and comprises forming an electron emitter between the second and third layers.

[00141] Example 34 is according to any of examples 32 to 33, wherein the third layer includes at least one hole.

[00142] Example 35 is according to any of examples 32 to 34, and comprises: providing a positive voltage supply as the first voltage supply; and providing a negative voltage supply as the second voltage supply.

[00143] Example 36 is according to any of examples 32 to 35, wherein the first voltage supply is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00144] Example 37 is according to any of examples 32 to 36, wherein the second voltage supply is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00145] Example 38 is according to any of examples 32 to 37, wherein the third layer is coupled to a third voltage supply which is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00146] Example 39 is according to any of examples 32 to 38, and comprises providing a material for effusion in the first space.

[00147] Example 40 includes all features of 39, wherein the material includes a perovskite.

[00148] Example 41 is according to any of examples 32 to 40, and comprises forming a heater surrounding the first layer.

[00149] Example 42 includes all features of example 41, wherein the heater comprises a material which includes one of: W, Mo, Ta, or their carbides.

[00150] Example 43 is according to any of examples 41 to 42, and comprises providing a cooling material between the heater and the first layer.

[00151] Example 44 includes all features of example 32, and comprises: forming a fourth layer comprising metal; and positioning the fourth layer between the second and third layers.

[00152] Example 45 is according to any of examples 32 to 44, and comprises providing a fourth voltage supply for the fourth layer, wherein the fourth voltage supply is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00153] Example 46 includes all features of example 44, wherein the fourth layer is a heater which comprises a material including one of: W, Mo, Ta, or their carbides.

[00154] Example 47 is according to any of examples 32 to 46, and comprises encasing at least part of the first layer with a hermetically sealed coolant.

[00155] Example 48 is an apparatus which comprises: a chamber for molecular beam epitaxy (MBE); a handle in the chamber to hold a substrate; a first effusion source at least partially embedded in the chamber, wherein the first effusion source is to deposit a first material to the substrate, and wherein the first material is to chemically react with the

substrate to form a modified layer; and a second effusion source at least partially embedded in the chamber, wherein the second effusion source is to deposit a second material to the substrate after the first material is deposited such that the second material chemically reacts with the modified layer and removed the modified layer.

[00156] Example 49 includes all features of example 48, wherein the second effusion source is to eject the second material into the chamber in pulses.

[00157] Example 50 is according to any of examples 48 to 49, wherein the first material includes one of: Chlorine, Bromine, or Fluorine.

[00158] Example 51 is according to any of examples 48 to 50, wherein the second material includes one of: Hydrogen, Argon, Krypton, or Fluorine.

[00159] Example 52 is according to any of claims 48 to 51, wherein the first effusion source is to eject the first material into the chamber in pulses.

[00160] Example 53 includes all features of example 52, wherein the pulses associated with the first effusion source are phase shifted relative to the pulses associated with the second effusion source.

[00161] Example 54 includes all features of example 52, and comprises a signal source to provide a bias to the substrate, wherein the bias is to influence rate of deposition of the first and second materials.

[00162] Example 55 includes all features of example 54, wherein the bias is one of: a constant positive DC bias; a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

[00163] Example 56 is according to any one of examples 48 to 55, and comprises a reflection high energy electron diffraction (RHEED) gun at least partially embedded in the chamber.

[00164] Example 57 is a method for atomic layer etching, the method comprising: depositing a first material to a substrate suspended in a chamber for molecular beam epitaxy (MBE); forming a modified layer after the first material is to chemically react with the substrate; injecting a second material into the chamber after the first material is deposited on the substrate such that the second material chemically reacts with the modified layer; and removing the modified layer.

[00165] Example 58 includes all features of example 57, wherein the second material is injected in a pulsed manner.

[00166] Example 59 includes all features of example 57, wherein the first material includes one of: Chlorine, Bromine, or Fluorine.

[00167] Example 60 is according to any of examples 57 to 59, wherein the second material includes one of: Hydrogen, Argon, Krypton, or Fluorine.

[00168] Example 61 is according to any of examples 57 to 60, wherein depositing the first material comprises injecting the first material into the chamber in a pulsed manner.

[00169] Example 62 is according to any of examples 57 to 61 comprises biasing the substrate to influence rate of deposition of first and second materials.

[00170] Example 63 is an apparatus for atomic layer etching, the apparatus comprising: means for depositing a first material to a substrate suspended in a chamber for molecular beam epitaxy (MBE); means for forming a modified layer after the first material is to chemically react with the substrate; means for injecting a second material into the chamber after the first material is deposited on the substrate such that the second material chemically reacts with the modified layer; and means for removing the modified layer.

[00171] Example 64 includes all features of example 63, wherein the first material includes one of: Chlorine, Bromine, or Fluorine.

[00172] Example 65 is according to any of examples 63 to 64, wherein the second material includes one of: Hydrogen, Argon, Krypton, or Fluorine.

[00173] Example 66 is according to any of examples 63 to 65, wherein the means for depositing the first material comprises means for injecting the first material into the chamber in a pulsed manner.

[00174] Example 67 is according to any of examples 63 to 65, and comprises means for biasing the substrate to influence rate of deposition of first and second materials.

[00175] An abstract is provided that will allow the reader to ascertain the nature and gist of the technical disclosure. The abstract is submitted with the understanding that it will not be used to limit the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

We claim:

1. An apparatus comprising:
   a first layer comprising metal which is coupled to a first voltage supply;
   a second layer comprising metal which is coupled to a second voltage supply, wherein the second layer includes a hole for effusion; and
   a third layer comprising metal, wherein the second layer is between the first and third layers, wherein the second layer is separated from the first and third layers by a first space and a second space, respectively.

2. The apparatus of claim 1 comprises an electron emitter between the second and third layers.

3. The apparatus according to any of the preceding claims, wherein the third layer includes at least one hole.

4. The apparatus according to any of the preceding claims,
   wherein:
   the first voltage supply is a positive voltage supply, and
   the second voltage supply is a negative voltage supply, or
   wherein:
   the first voltage supply is a negative voltage supply, and
   the second voltage supply is a positive voltage supply.

5. The apparatus according to any of the preceding claims, wherein the first voltage supply is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

6. The apparatus according to any of the preceding claims, wherein the second voltage supply is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

7. The apparatus according to any of the preceding claims, wherein the third layer is coupled to a third voltage supply which is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

8. The apparatus according to any of the preceding claims, wherein the first space is to contain a material for effusion, and wherein the second space is to contain, in transition, the effused material.

9. The apparatus of claim 8, wherein the material includes an elemental component of a perovskite.

10. The apparatus according to any of claims 1 to 8 comprises a heater surrounding the first layer.

11. The apparatus of claim 10, wherein the heater comprises a material which includes one of: W, Mo, Ta, or their carbides.

12. The apparatus according to any of claims 10 to 11 comprises a cooling material between the heater and the first layer.

13. The apparatus according to any of preceding claims comprises a fourth layer comprising metal, wherein the fourth layer is positioned between the second and third layers, wherein the fourth layer is coupled to a fourth voltage supply, wherein the fourth voltage supply is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

14. The apparatus according to any of claims 12 or 13, wherein the fourth layer is a heater which comprises a material including one of: W, Mo, Ta, or their carbides.

15. The apparatus according to any of preceding claims, wherein the first layer is encased within a covering including hermetically sealed coolant.

16. A system comprising:

a chamber for molecular beam epitaxy (MBE);

an effusion source at least partially embedded in the chamber; and

a handle in the chamber to hold a substrate, wherein the effusion source is according to any one of claims 1 to 16, and wherein the effusion source is to provide a material for depositing on the substrate.

17. The system of claim 16, wherein the effusion source is to provide ionized effused atoms or molecules of the material.

18. The system according to any one of claims 16 to 17 comprises a mass spectrometer which is partially embedded in the chamber.

19. An apparatus comprising:

a flange to provide power supply and one or more control signals; and

a housing coupled to the flange via one or more support structures, wherein the housing includes:

a container comprising metal which is biased by a first bias controllable by at least one of the one or more control signals, wherein the container is to contain material for effusion and

a layer comprising metal which is biased by a second bias controllable by at least one of the one or more control signals, the layer including a bore for effusion.

20. The apparatus of claim 19 comprising a second layer parallel to the layer, wherein the second layer comprises metal and includes at least one bore.

21. The apparatus of claim 20, wherein the second layer is biased by a third bias controllable by at least one of the one or more control signals, wherein the third bias is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

22. The apparatus according to any of claims 19 to 21, comprises an electron emitter between the layer and the second layer.

23. The apparatus according to any of claims 19 to 22, comprises a third layer comprising metal, wherein the third layer is between the layer and the second layer, and wherein the

third layer is biased by a fourth bias which is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

24. The apparatus according to any of claims 19 to 24 comprises:

a heater, wherein the container is at least partially surrounded by the heater which comprises a material including one of: W, Mo, Ta, or their carbides.

a hermetically sealed coolant between the container and the heater, wherein the material in the container includes a perovskite.

25. The apparatus according to any of claims 19 to 24, wherein the second bias is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths, and wherein the first bias is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths, and wherein the housing includes a crucible.

AMENDED CLAIMS
received by the International Bureau on 11 Oct 2018 (11.10.2018)

1. An apparatus comprising:

a first layer comprising metal which is coupled to a first voltage supply;

a second layer comprising metal which is coupled to a second voltage supply, wherein the second layer includes a hole for effusion; and

a third layer comprising metal, wherein the second layer is between the first and third layers, and wherein the second layer is separated from the first and third layers by a first space and a second space, respectively.

2. The apparatus of claim 1 comprises an electron emitter between the second and third layers.

3. The apparatus according to any of the preceding claims, wherein the third layer includes at least one hole.

4. The apparatus according to any of the preceding claims,
wherein:
the first voltage supply is a positive voltage supply, and
the second voltage supply is a negative voltage supply, or
wherein:
the first voltage supply is a negative voltage supply, and
the second voltage supply is a positive voltage supply.

5. The apparatus according to any of the preceding claims, wherein the first voltage supply is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

6. The apparatus according to any of the preceding claims, wherein the second voltage supply is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

7. The apparatus according to any of the preceding claims, wherein the third layer is coupled to a third voltage supply which is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

8. The apparatus according to any of the preceding claims, wherein the first space is to contain a material for effusion, and wherein the second space is to contain, in transition, the effused material.

9. The apparatus of claim 8, wherein the material includes an elemental component of a perovskite.

10. The apparatus according to any of claims 1 to 8 comprises a heater surrounding the first layer.

11. The apparatus of claim 10, wherein the heater comprises a material which includes one of: W, Mo, Ta, or their carbides.

12. The apparatus according to any of claims 10 to 11 comprises a cooling material between the heater and the first layer.

13. The apparatus according to any of preceding claims comprises a fourth layer comprising metal, wherein the fourth layer is positioned between the second and third layers, wherein the fourth layer is coupled to a fourth voltage supply, wherein the fourth voltage supply is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

14. The apparatus according to any of claims 12 or 13, wherein the fourth layer is a heater which comprises a material including one of: W, Mo, Ta, or their carbides.

15. The apparatus according to any of preceding claims, wherein the first layer is encased within a covering including hermetically sealed coolant.

16. A system comprising:

a chamber for molecular beam epitaxy (MBE);

an effusion source at least partially embedded in the chamber; and

a handle in the chamber to hold a substrate, wherein the effusion source is according to any one of claims 1 to 16, and wherein the effusion source is to provide a material for depositing on the substrate.

17. The system of claim 16, wherein the effusion source is to provide ionized effused atoms or molecules of the material.

18. The system according to any one of claims 16 to 17 comprises a mass spectrometer which is partially embedded in the chamber.

19. An apparatus comprising:

a flange to provide power supply and one or more control signals; and

a housing coupled to the flange via one or more support structures, wherein the housing includes:

a container comprising metal which is biased by a first bias controllable by at least one of the one or more control signals, wherein the container is to contain material for effusion and

a layer comprising metal which is biased by a second bias controllable by at least one of the one or more control signals, the layer including a bore for effusion.

20. The apparatus of claim 19 comprising a second layer parallel to the layer, wherein the second layer comprises metal and includes at least one bore.

21. The apparatus of claim 20, wherein the second layer is biased by a third bias controllable by at least one of the one or more control signals, wherein the third bias is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

22. The apparatus according to any of claims 19 to 21, comprises an electron emitter between the layer and the second layer.

23. The apparatus according to any of claims 19 to 22, comprises a third layer comprising metal, wherein the third layer is between the layer and the second layer, and wherein the third layer is biased by a fourth bias which is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths.

24. The apparatus according to any of claims 19 to 24 comprises:

a heater, wherein the container is at least partially surrounded by the heater which comprises a material including one of: W, Mo, Ta, or their carbides[[.]]; and

a hermetically sealed coolant between the container and the heater, wherein the material in the container includes a perovskite.

25. The apparatus according to any of claims 19 to 24, wherein the second bias is one of: a constant negative DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths, wherein the first bias is one of: a constant positive DC bias; a pulse; a pulse train with fixed pulse widths; or a pulse train with variable pulse widths, and wherein the housing includes a crucible.

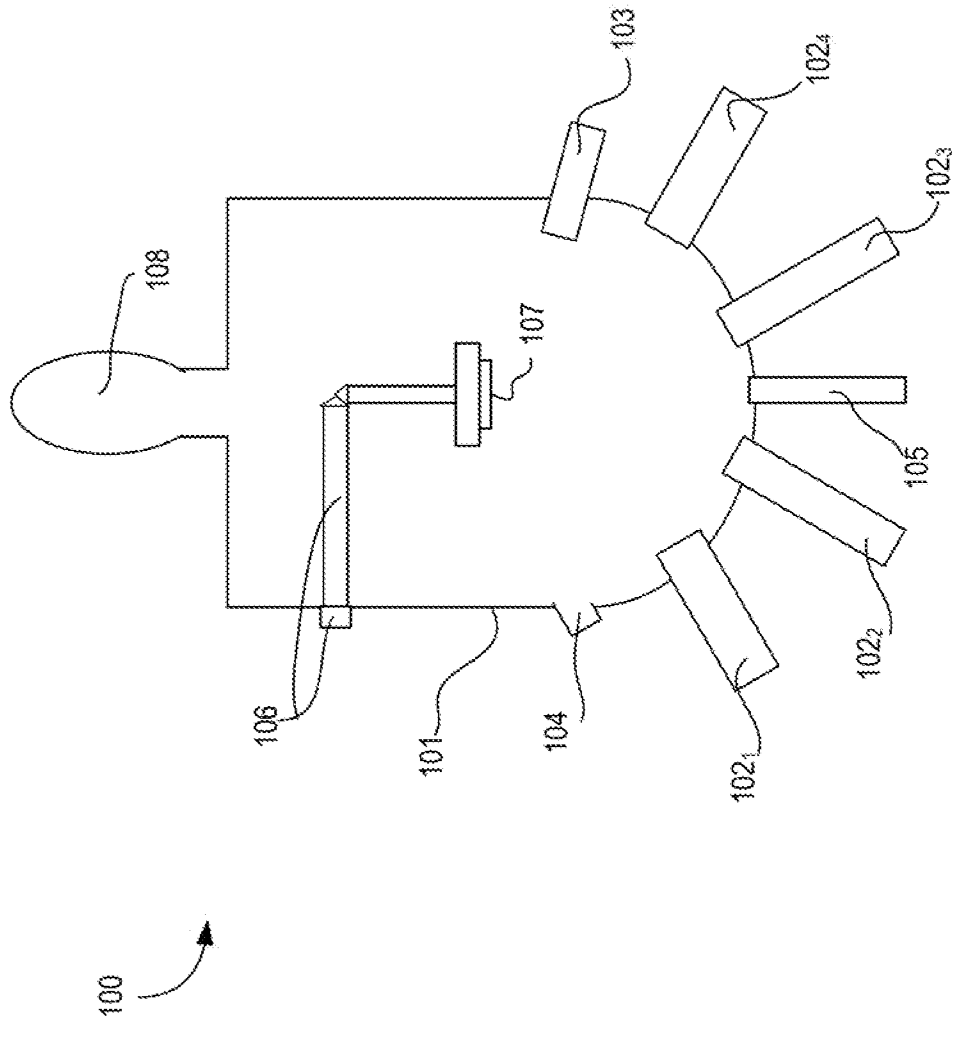


Fig. 1

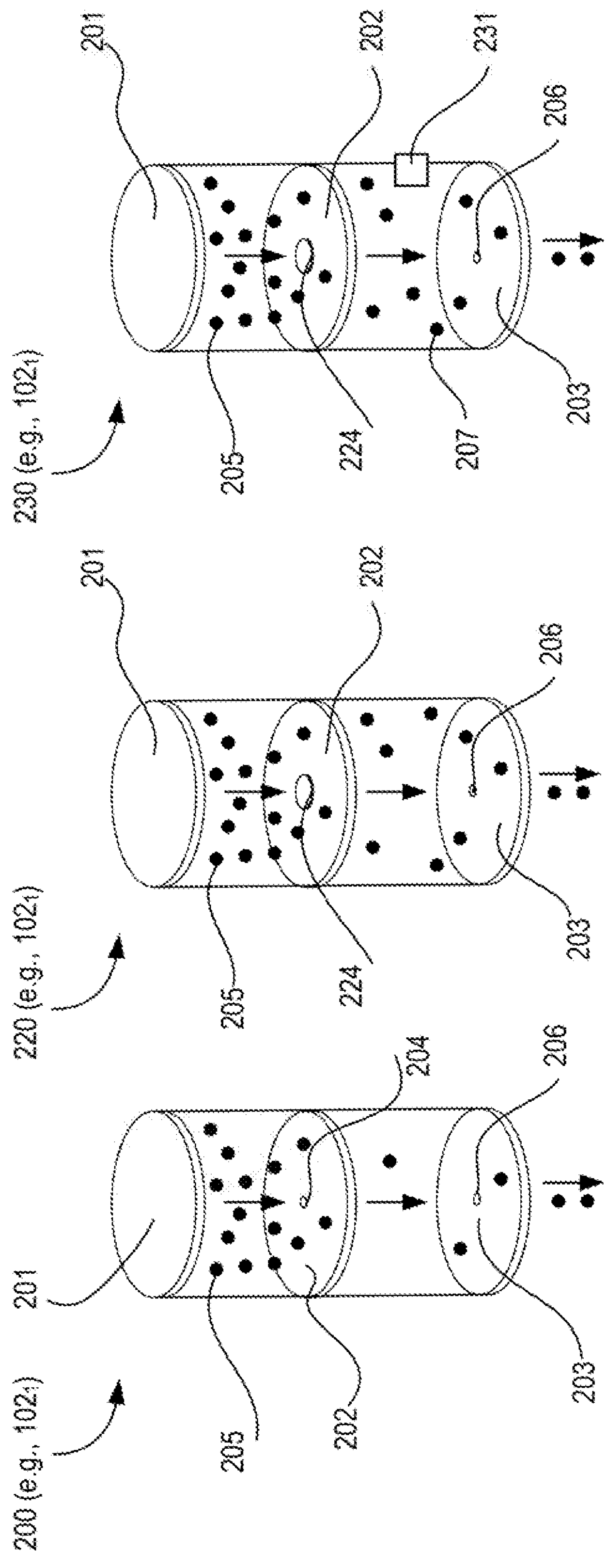
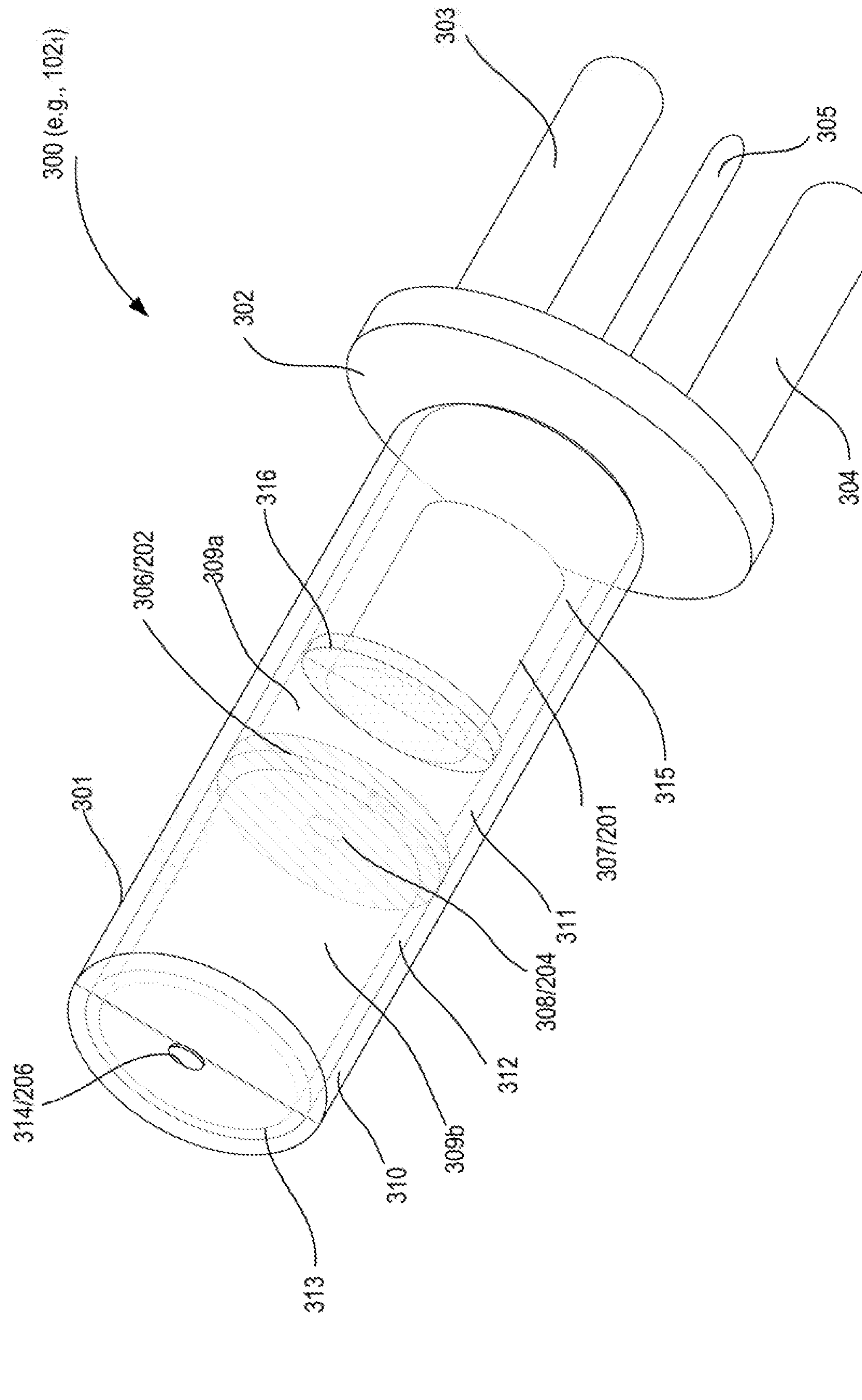


Fig. 2A

Fig. 2B

Fig. 2C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305
302
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315
307/201
311
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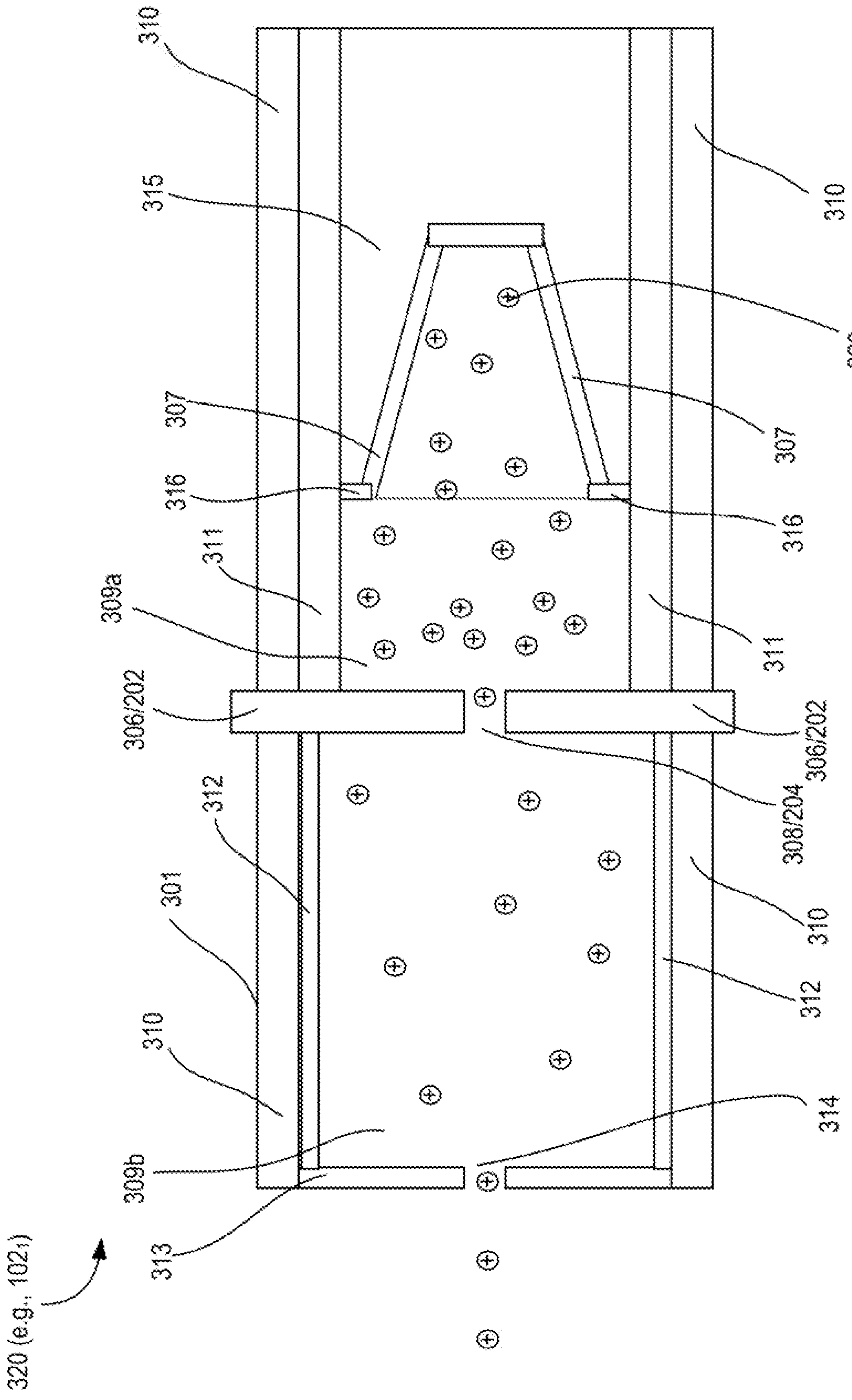
312
309b
310
314/206
313

Fig. 3A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315
307
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311
309a
306/202
312
301
310
309b
313
320 (e.g., 102₁)
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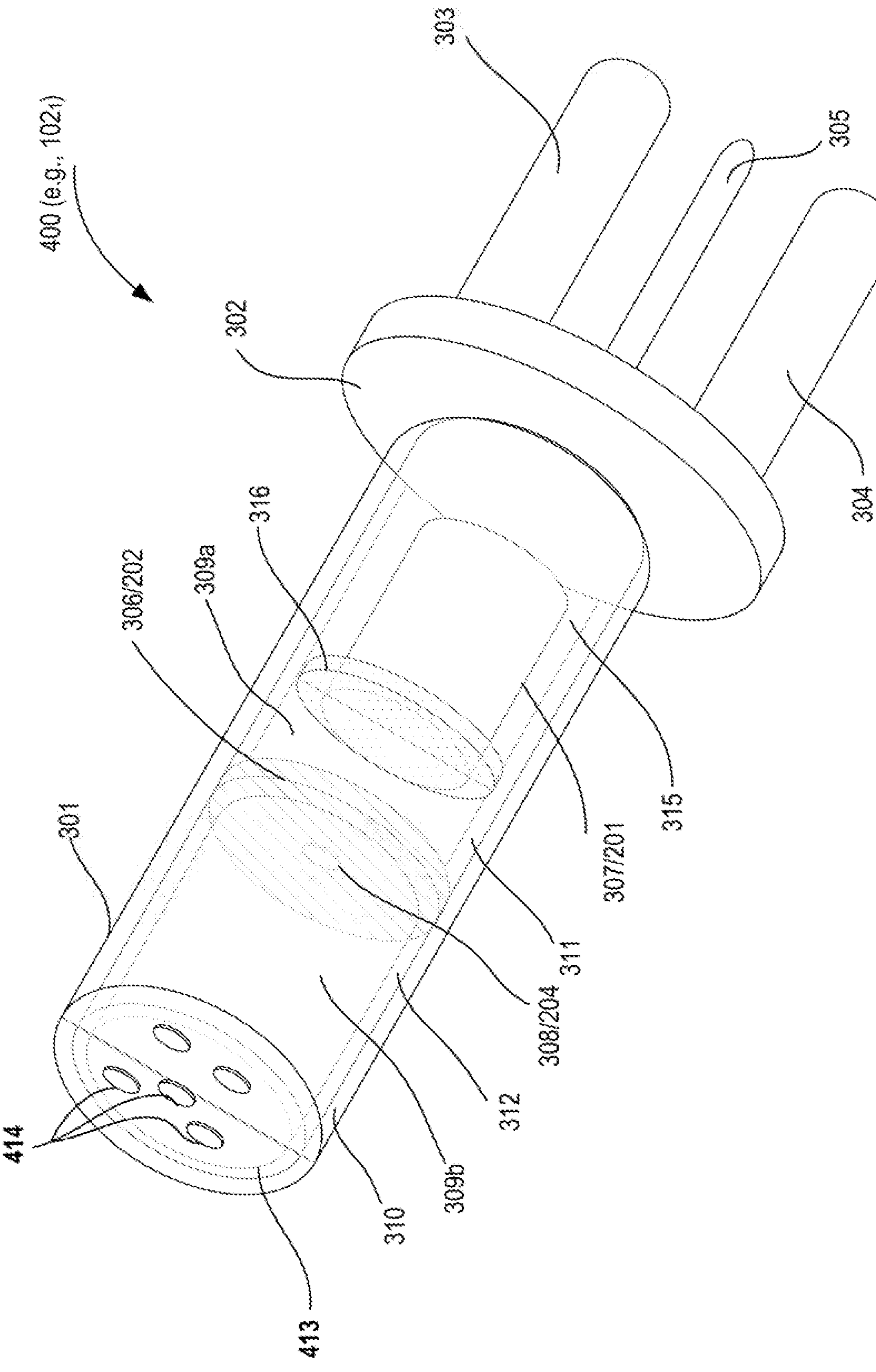
320
307
316
311
306/202
308/204
310
312
314

Fig. 3B


400 (e.g., 102_1)
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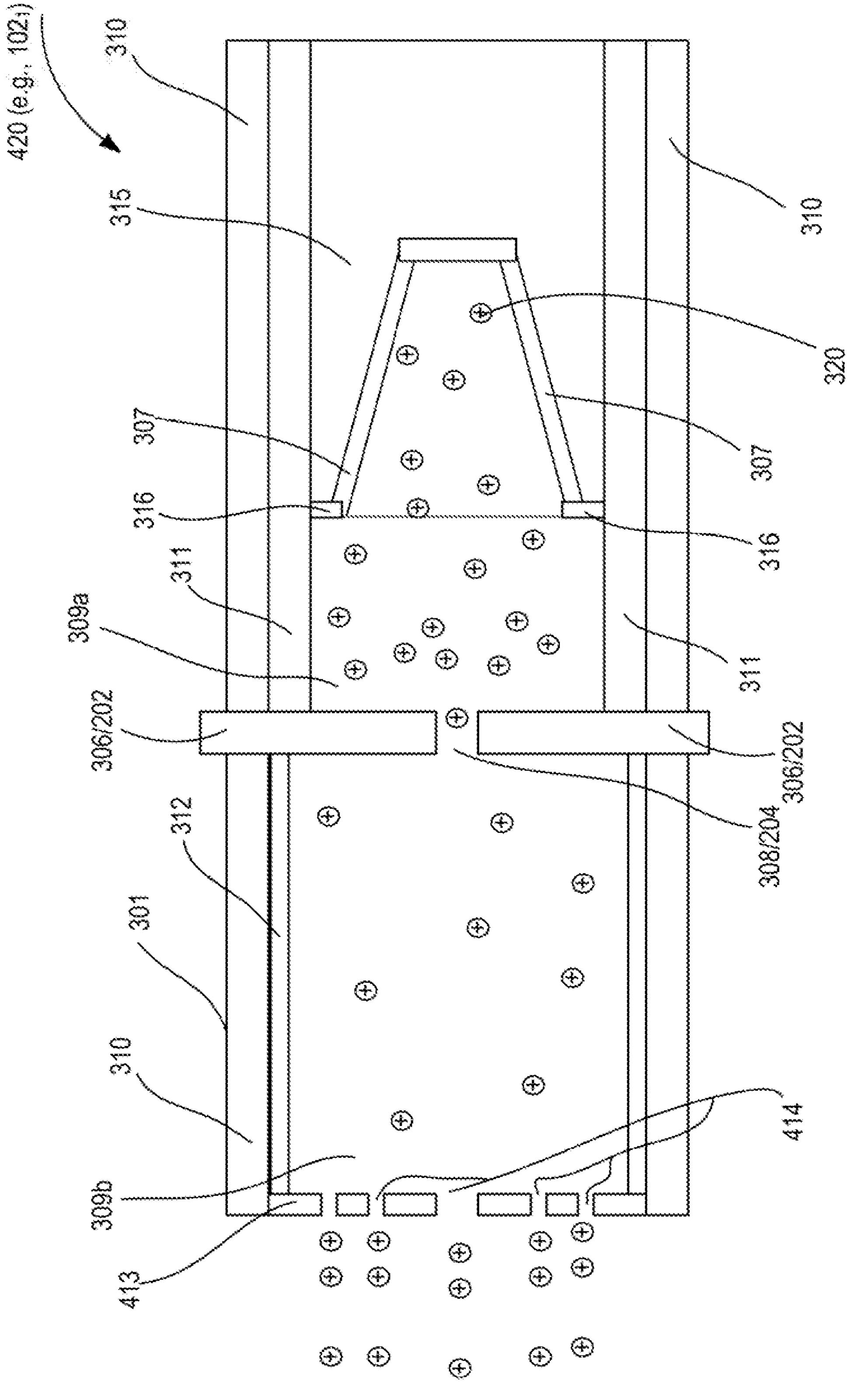
308/204
312
309b
310
414
413

Fig. 4A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309b
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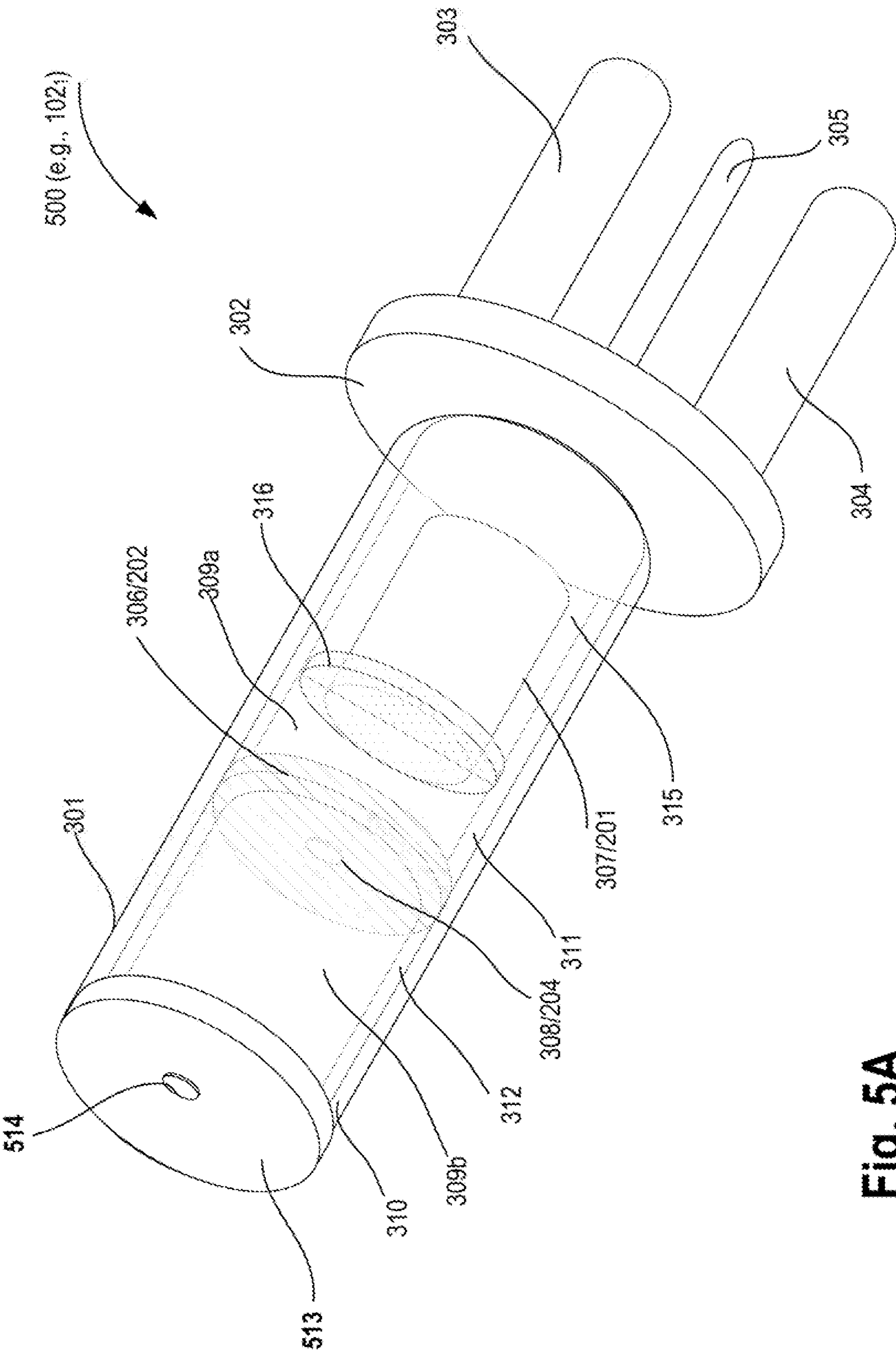
414

Fig. 4B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304
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309a
306/202
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307/201
301
311
308/204
312
514
309b
310
513

Fig. 5A

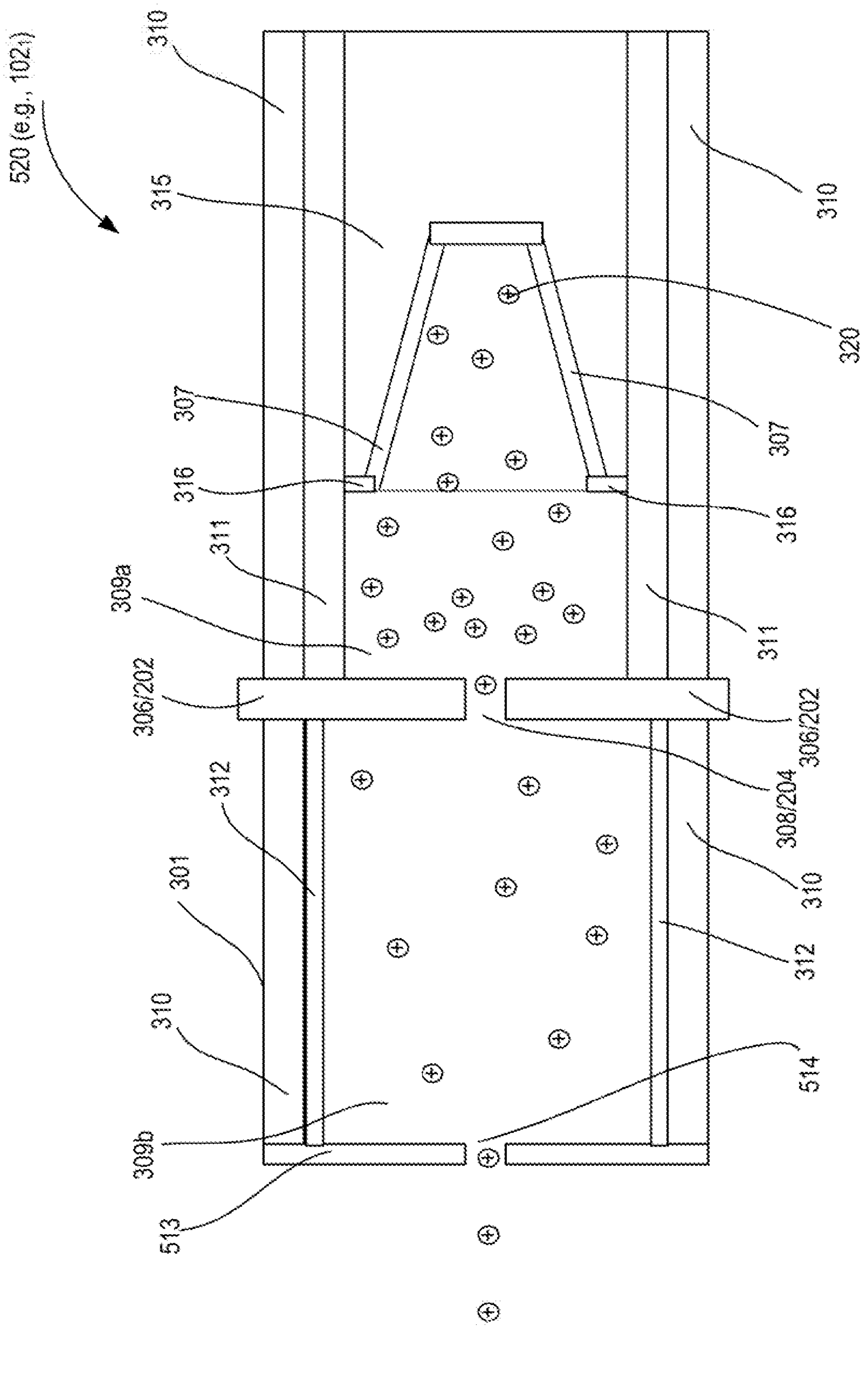
520 (e.g., 102₁)
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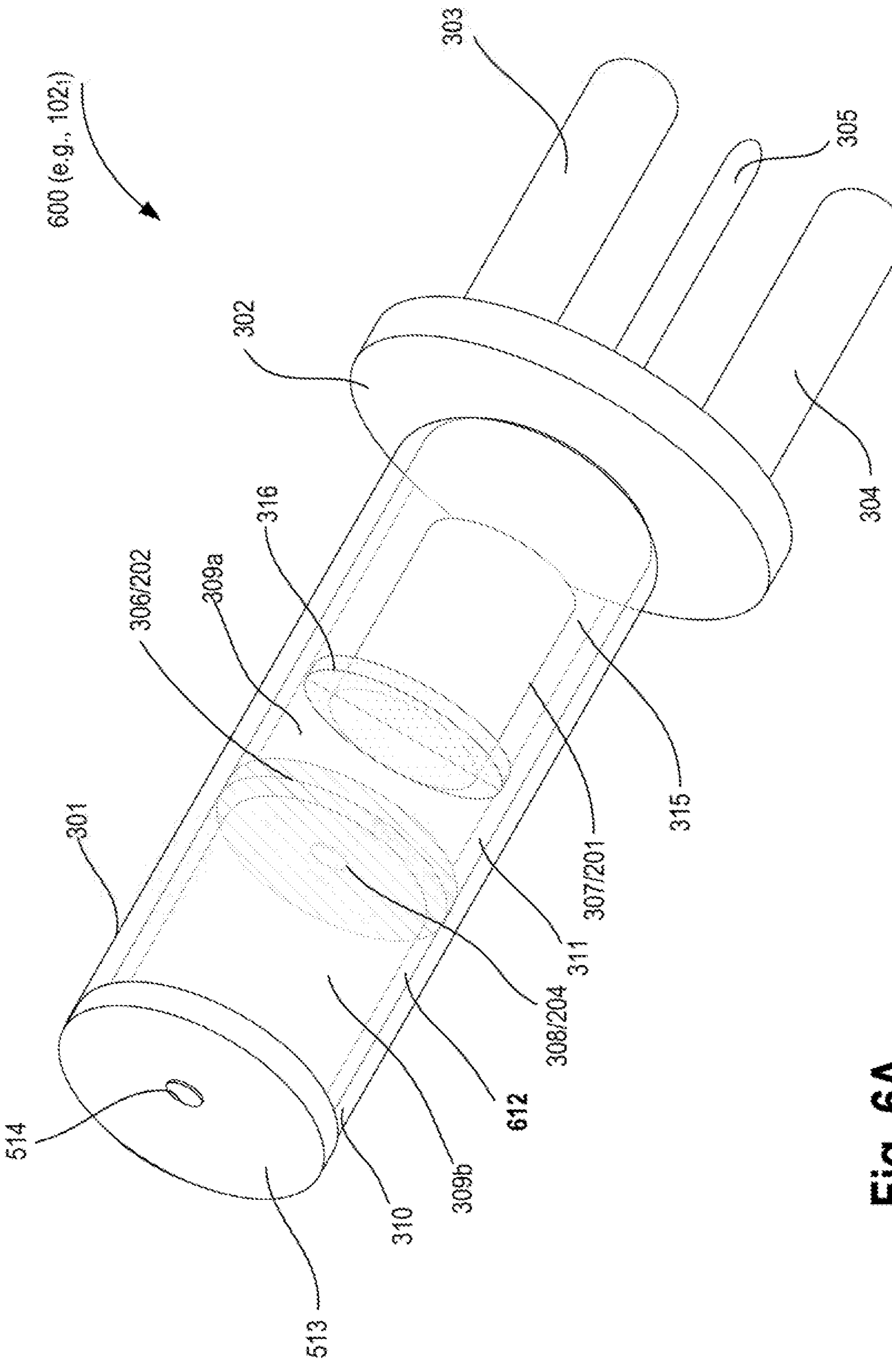
Fig. 5B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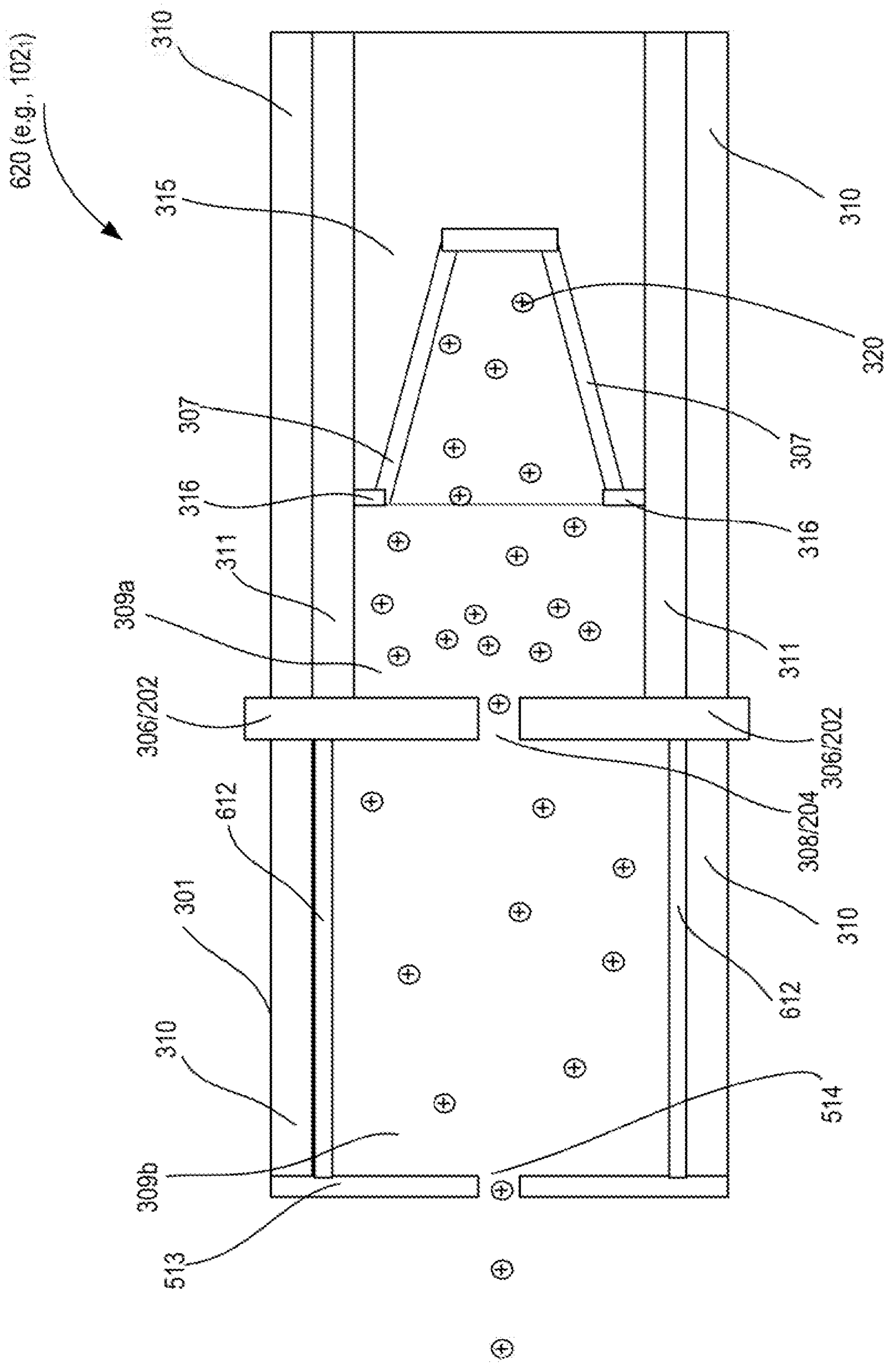
309b
310
513

Fig. 6A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311
309a
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308/204
612
301
310
612
310
514
309b
513

Fig. 6B

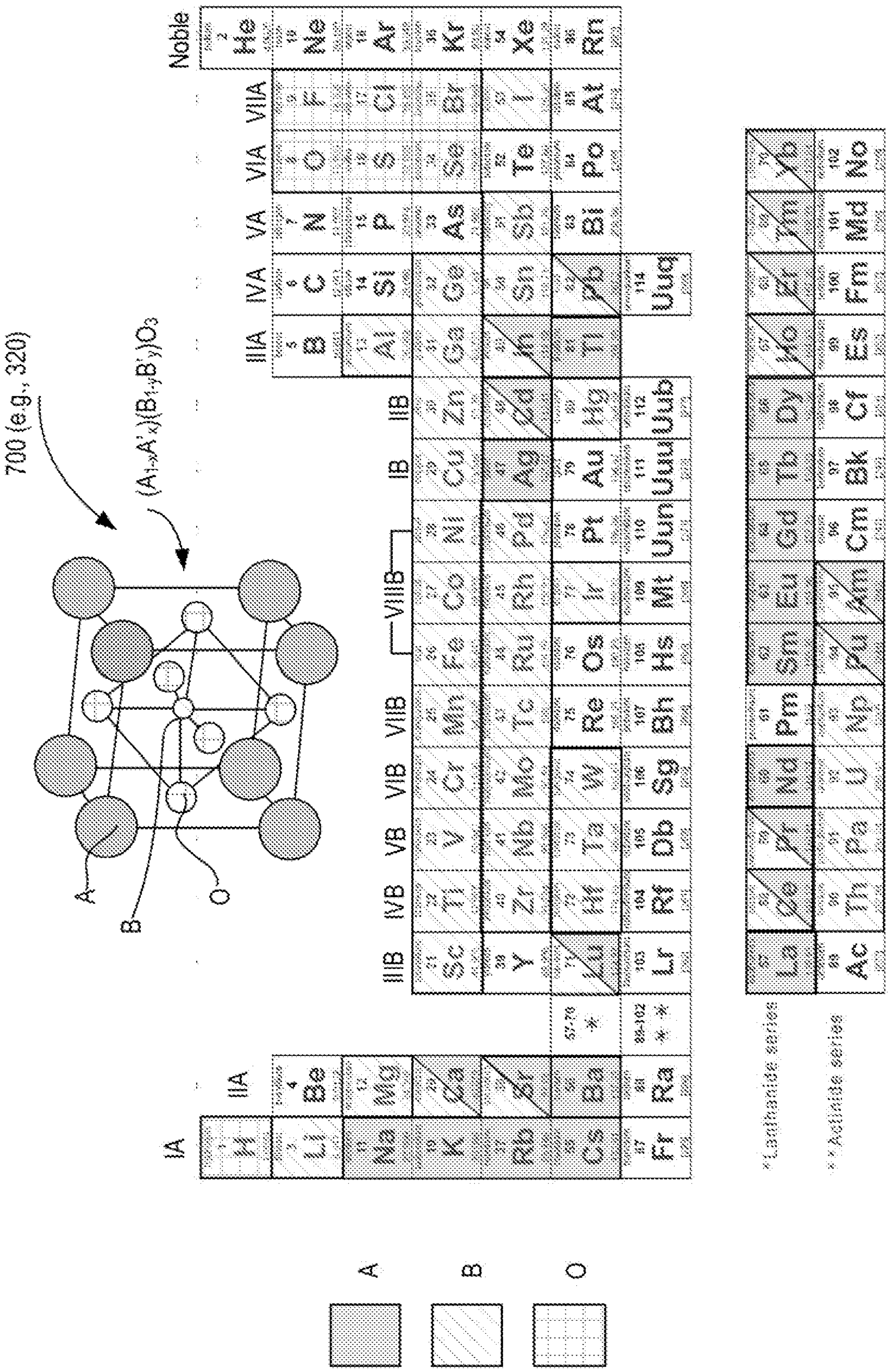

700 (e.g., 320)
$(A_{1-x}A'_x)(B_{1-y}B'_y)O_3$
A
B
O
IA
IIA
IIIB
IVB
VB
VIB
VIIB
VIIIB
IB
IIB
IIIA
IVA
VA
VIA
VIIA
Noble
*Lanthanide series
**Actinide series

Fig. 7

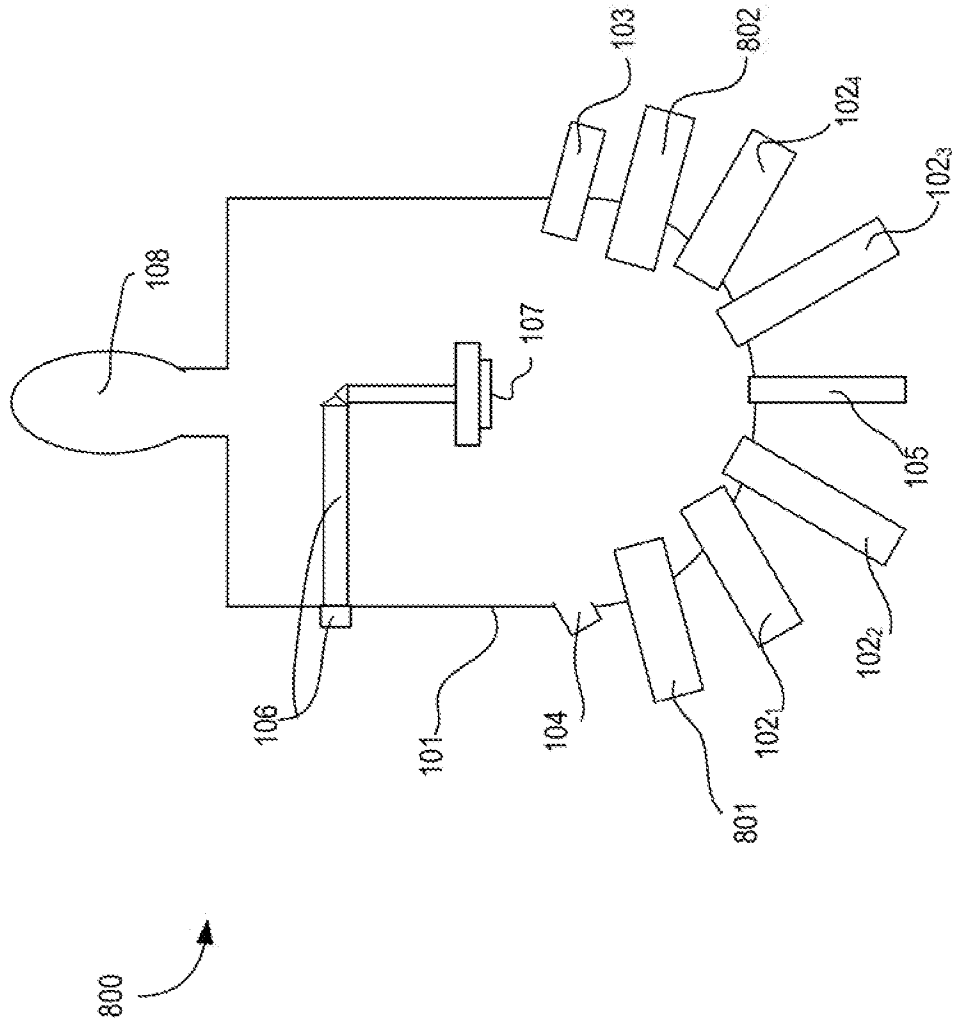


Fig. 8

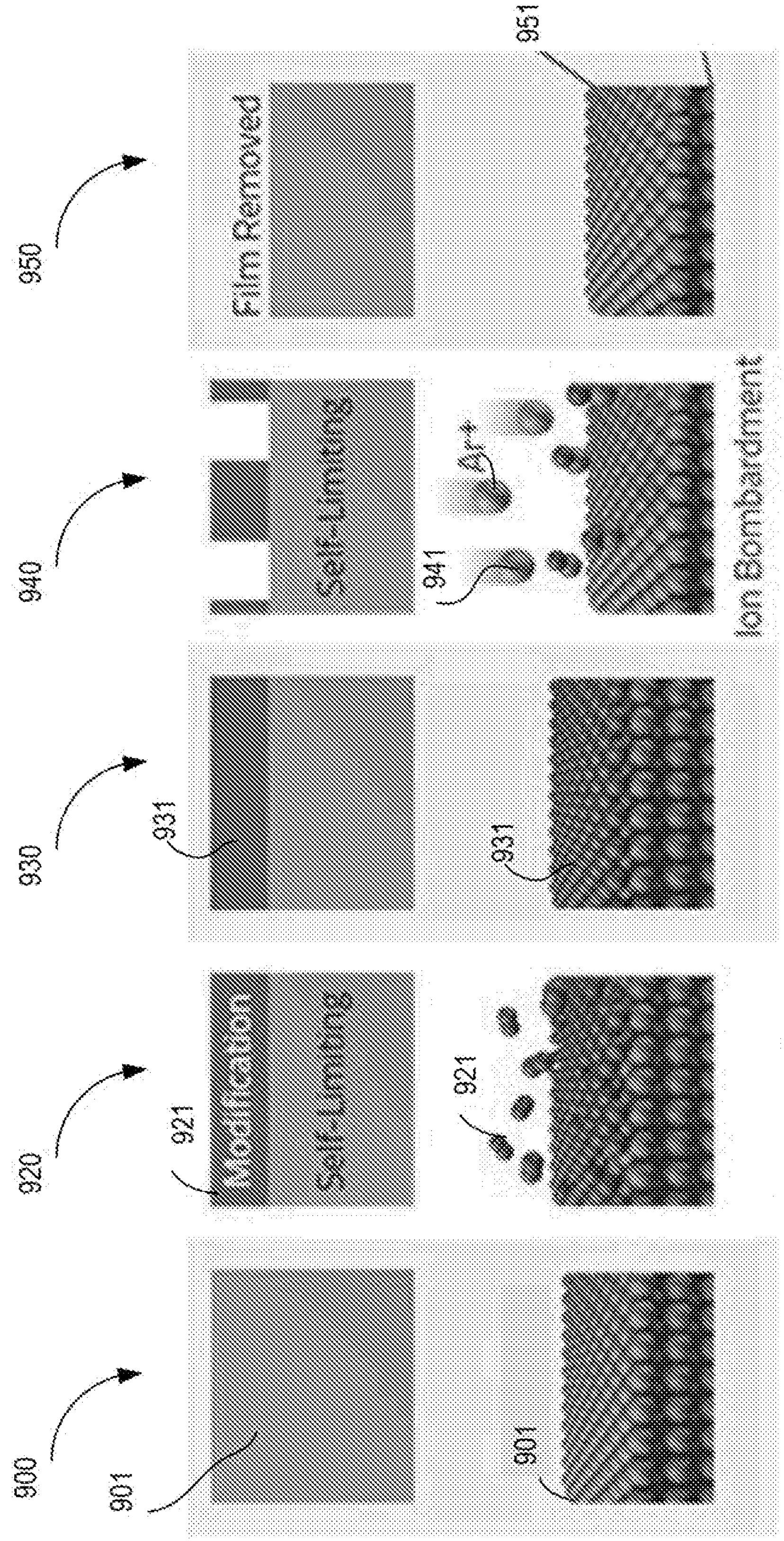


Fig. 9A

Fig. 9B

Fig. 9C

Fig. 9D

Fig. 9E

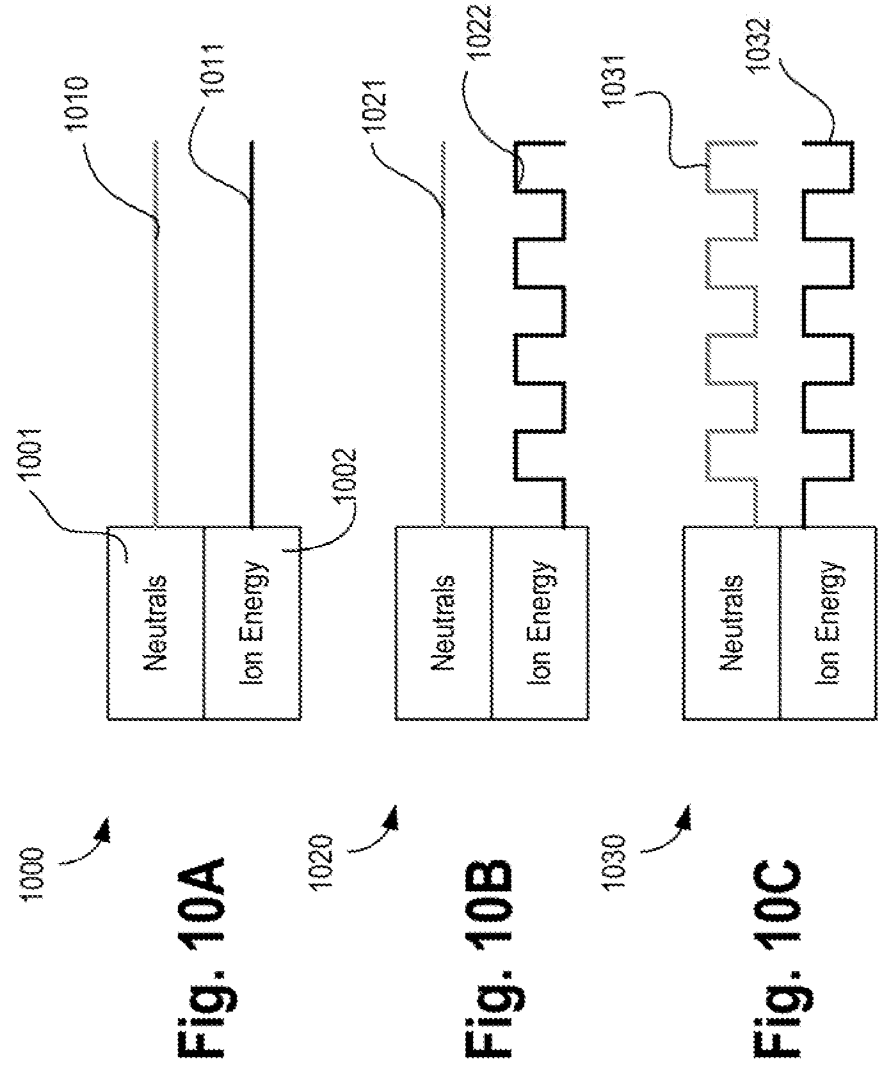
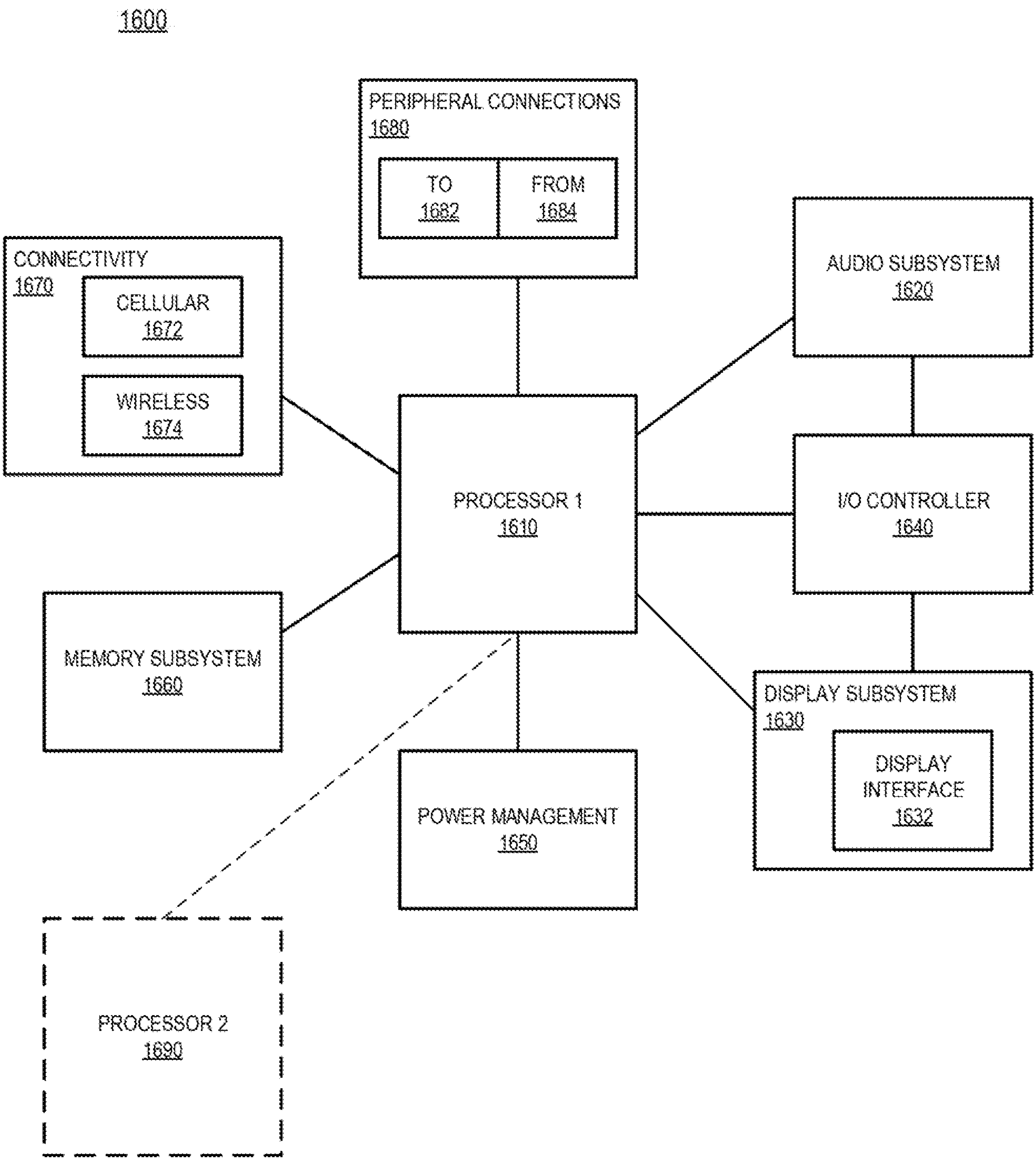


Fig. 10A

Fig. 10B

Fig. 10C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WIRELESS
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1620
PROCESSOR 1
1610
I/O CONTROLLER
1640
MEMORY SUBSYSTEM
1660
DISPLAY SUBSYSTEM
1630
DISPLAY
INTERFACE
1632
POWER MANAGEMENT
1650
PROCESSOR 2
1690

Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/040465

A. CLASSIFICATION OF SUBJECT MATTER

C30B 23/02(2006.01)i, C30B 31/20(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)
C30B 23/02; C30B 1/00; C30B 23/00; H01L 21/20; C30B 25/16; C30B 23/08; C30B 25/10; H05H 1/00; B01J 19/08; C30B 31/20

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:molecular beam epitaxy, effusion, metal plate, hole, voltage supply, source, flange, cathode, anode

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002-0000779 A1 (ANDERS, ANDRE) 03 January 2002 See paragraphs [0010], [0048], [0054], [0060], [0074]-[0076], [0078], [0080], [0087], [0126], [0150]; claim 28; and figures 2, 8.	1-3,19-22
A	US 2012-0304927 A1 (DOOLITTLE, W. ALAN et al.) 06 December 2012 See paragraphs [0038]-[0039]; claims 1-3; and figure 2.	1-3,19-22
A	WO 97-16246 A1 (CHORUS CORPORATION) 09 May 1997 See pages 5-7; and figure 2.	1-3,19-22
A	US 2003-0145784 A1 (THOMPSON, MARGARITA P. et al.) 07 August 2003 See paragraphs [0055]-[0059]; and figure 3.	1-3,19-22
A	US 5544618 A (STALL, RICHARD A. et al.) 13 August 1996 See columns 29-30; and figure 16a.	1-3,19-22

☐ 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
"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
26 February 2018 (26.02.2018)	**26 February 2018 (26.02.2018)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
KIM, Sun Hee
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/040465

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 9,11,17
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 9, 11, and 17 refer to multiple dependent claims which do not comply with PCT Rule 6.4(a).

3. ☒ Claims Nos.: 4-8,10,12-16,18,23-25
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/040465

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002-0000779 A1	03/01/2002	US 6137231 A	24/10/2000
		US 6140773 A	31/10/2000
		US 6388381 B2	14/05/2002
US 2012-0304927 A1	06/12/2012	US 2008-0047487 A1	28/02/2008
		US 2012-0306508 A1	06/12/2012
		US 8261690 B2	11/09/2012
		US 8360002 B2	29/01/2013
		US 8377518 B2	19/02/2013
WO 97-16246 A1	09/05/1997	AU 7481696 A	22/05/1997
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US 2003-0145784 A1	07/08/2003	US 6518637 B1	11/02/2003
		US 7074272 B2	11/07/2006
US 5544618 A	13/08/1996	US 5336324 A	09/08/1994