(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 March 2010 (25.03.2010)

PCT

(10) International Publication Number
WO 2010/033712 A2

(51) International Patent Classification:
H01L 21/205 (2006.01) *H01L 31/042* (2006.01)
H05H 1/34 (2006.01)

(21) International Application Number:
PCT/US2009/057333

(22) International Filing Date:
17 September 2009 (17.09.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/097,772 17 September 2008 (17.09.2008) US

(71) Applicant *(for all designated States except US)*: **ENERGY PHOTOVOLTAICS, INC.** [US/US]; 276 Bakers Basin Road, Lawrenceville, NJ 08648 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **DELAHOY, Alan, E.** [GB/US]; 33 Washington Street, Rocky Hill, NJ 08553 (US). **VARVAR, Anthony** [US/US]; 37 Tanglewood Drive, Mercerville, NJ 08691 (US).

(74) Agents: **PROSCIA, James, W.** et al.; Brooks Kushman, 1000 Town Center, Twenty-second Floor, Southfield, MI 48075 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

[Continued on next page]

(54) Title: ELECTRODE SYSTEM FOR LARGE BATCH PRODUCTION OF THIN PHOTOVOLTAIC MODULES

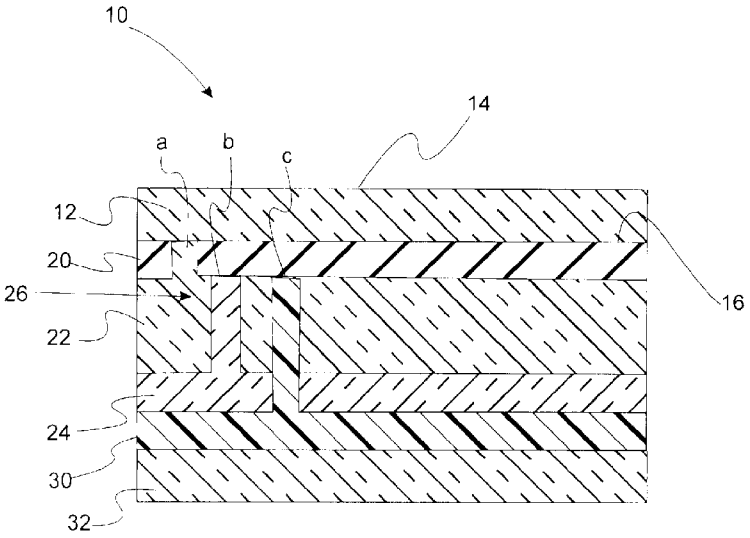

Figure 1

(57) Abstract: An electrode system for utilization in a plasma CVD reactor includes one or more RF electrodes and one or more counter-electrodes. At least one RF electrode has a contact edge and a cascading arrangement of slots with each slot having a longitudinal dimension substantially parallel to the contact edge. The RF electrodes are adapted to receive RF-power at a position adjacent to the contact edge. A plasma deposition system incorporating the electrode system set forth above is also provided.

WO 2010/033712 A2

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

ELECTRODE SYSTEM FOR LARGE BATCH PRODUCTION OF THIN PHOTOVOLTAIC MODULES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and systems for efficiently forming photovoltaic modules.

2. Background Art

The escalating price of fossil fuels has once again provided an impetus to the development of improved renewable energy sources. Photovoltaic devices such as solar cells which harvest energy from solar radiation have long been a popular renewable source.

Solar cells convert solar radiation into usable electrical energy. The energy conversion occurs as the result of the photovoltaic effect. Solar radiation incident on a photovoltaic device is absorbed by a photoactive region of a semiconductor material, (e.g. an intrinsic i-layer of amorphous silicon). The absorbed radiation generates electron-hole pairs in the active region which are separated by an electric field of a junction in the photovoltaic device. The electrons and holes are separated by an electric field of a junction in the photovoltaic device. The separation of the electrons and holes by the junction results in the generation of an electric current and voltage. The electrons flow toward the region of the semiconductor material having an n-type conductivity. The holes flow toward the region of the semiconductor material having a p-type conductivity. Current will flow through an external circuit connecting the n-type region to the p-type region as long as light continues to generate electron-hole pairs in the photovoltaic device.

Amorphous single-junction devices are comprised of three layers. The layers are the p- and n-layers which are extrinsic or doped and the i-layer which is intrinsic or undoped (at least containing no intentional doping). The i-layer is much thicker than the doped layers. The i-layer is thicker so that light is efficiently absorbed and converted to electrical power which can be used in an external circuit. The thickness of the i-layer determines how much light is absorbed. When a photon of light is absorbed in the i-layer, it gives rise to a unit of electrical current (an electron-hole pair). The p- and n-layers contain charged dopant ions that set up a strong electric field across the i-layer. The electric field separates electron-hole pairs from the i-layer. Concurrent with this separation, an external circuit may be formed which can provide power for electrical components.

Thin film solar cells are formed by depositing photoactive semiconductor layers onto a suitable substrate. Suitable substrates include glass and metal. Soda lime glass formed from the float process is the preferred substrate due to the low cost and durability of this material. Metal substrates include, but are not limited to, stainless and other steels, aluminum and titanium. Glass substrates are typically coated with a transparent electrically conductive coating prior to deposition of the photoactive layers. Examples of useful transparent conductors include doped tin oxides, indium tin oxide, doped zinc oxide, and the like. Tin oxides are typically doped by fluorine and antimony. Zinc oxides are typically doped with fluorine, aluminum, and boron, forming the semiconductor-containing film. A metallic contact can be formed on the back of the solar cell. Solar cells are often placed in metal frames to provide attractive photovoltaic modules.

Amorphous silicon solar cells are often fabricated by the glow discharge of silane. The process of glow discharge involves the discharge of energy through a gas at relatively low pressure and high temperature in a partially evacuated chamber. A typical process for fabricating an amorphous silicon solar cell comprises placing a substrate on a heated element within a vacuum chamber. While silane at low pressure is introduced into the vacuum chamber, a glow discharge is established between the two electrodes and an

amorphous silicon film deposits upon the substrate. The segments, layers or cells of multi-junction solar cells, are electrically interconnected, such as by laser scribing. As in all manufacturing processes, throughput is an important consideration impacting the cost of solar cells. The substrates in the amorphous silicon process are necessarily heated in order to form efficient solar cells. Substrate heating is one bottleneck in the process due to the long times associated in heating the substrates to the proper temperature (usually about 200 to 350° C).

Accordingly, there exists a need for improved methods and systems for fabricating photovoltaic modules for fuel cell applications.

SUMMARY OF THE INVENTION

The present invention solves one or more problems of the prior art by providing in at least one embodiment an electrode system for utilization in a plasma CVD reactor. The electrode system of this embodiment includes one or more RF electrodes and one or more counter-electrodes. At least one RF electrode has a contact edge and a cascading arrangement of slots with each slot having a longitudinal dimension substantially parallel to the contact edge. The RF electrode is adapted to receive RF-power at a position adjacent to the contact edge.

In another embodiment, a plasma deposition system incorporating the electrode system set forth above is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIGURE 1 is a schematic cross section of a photovoltaic module fabricated by the method of an embodiment of the invention;

FIGURE 2 is a schematic illustration of a photovoltaic fabrication process using an exemplary embodiment of a substrate carrier;

FIGURE 3 is side view of an exemplary embodiment of a substrate carrier used in a photovoltaic module fabrication process;

FIGURE 4 is a perspective view of an RF electrode used in the photovoltaic module fabrication process; and

FIGURE 5 is a schematic illustration showing placement of a substrate holder in a deposition chamber.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Reference will now be made in detail to presently preferred compositions, embodiments and methods of the present invention, which constitute the best modes of practicing the invention presently known to the inventors. The Figures are not necessarily to scale. However, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. Therefore, specific details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for any aspect of the invention and/or as a representative basis for teaching one skilled in the art to variously employ the present invention.

It is also to be understood that this invention is not limited to the specific embodiments and methods described below, as specific components and/or conditions may, of course, vary. Furthermore, the terminology used herein is used only for the purpose of describing particular embodiments of the present invention and is not intended to be limiting in any way.

It must also be noted that, as used in the specification and the appended claims, the singular form "a," "an," and "the" comprise plural referents unless the context clearly indicates otherwise. For example, reference to a component in the singular is intended to comprise a plurality of components.

Throughout this application, where publications are referenced, the disclosures of these publications in their entireties are hereby incorporated by reference into this application to more fully describe the state of the art to which this invention pertains.

With reference to Figure 1, a schematic cross-section of a photovoltaic module formed by the methods and systems of the present invention is provided. Photovoltaic module 10 includes transparent substrate 12. Transparent substrate 12 is typically glass. Transparent substrate 12 includes exterior surface 14 and interior surface 16. Front electrical contact 20 is disposed over transparent substrate 12. Photovoltaic active layer(s) 22 are disposed over front electrical contact 20. Photovoltaic module 10 further includes back electrical contact 24 which is disposed over photovoltaic active layer(s) 22. Interconnects 26 provide electrical contact between front electrical contact 20 and back electrical contact 24 of adjacent solar cells. Encapsulant 30 environmentally seals the components of photovoltaic module 10 and laminates front and rear glasses. Rear cover glass 32 is disposed over encapsulant 30. Photovoltaic module 10 includes cuts a, b, and c which define and interconnect the solar cells.

The system of the present embodiment is advantageously used to incorporate a number of different types of photoactive layers. Examples of material useful for photovoltaic active layer(s) 22 include, but are not limited to, CdS, $In_{1-x}Ga_xN$ alloy as disclosed in U.S. Patent 4,233,085; $In_{1-x}Ga_xN$ alloy (Indium, Gallium, and Nitrogen) as disclosed in U.S. Patent 7,217,882; a Cd(Se,Te) Alloy as disclosed in U.S. Patent 4,296,188; silicon 51-88% lithium 3-30% alumina 0.5-29% fluorine 0.5-8% hydrogen 1-12% vanadium 0-5% as disclosed in U.S. Patent 4633031, silicon 51-88% lithium 3-30% alumina 0.5-29% fluorine 0.5-8% hydrogen 0.5-12% antimony 0.01-20%

Cobalt 0.01-6% as disclosed in U.S. Patent 4,633,031; a silicon-germanium alloy as disclosed in U.S. Patent 4,609,771, silicon alloy materials, germanium alloy materials, silicon-germanium alloy materials, cadmium telluride, cadmium selenide, gallium arsenide, and copper indium diselenide as disclosed in U.S. Patent 4,713,492; copper-indium-gallium-diselenide ($CuIn_x$ $Ga_{1-X}Se_2$); mercury cadmium telluride (Hg Cd(fe) as disclosed in U.S. Patent 3,638,026; $Pb_xCd_{(1-x)}S$ (lead-cadmium-sulphide) alloy as disclosed in U.S. Patent 4,529,832; $Cd_{1-x}Zn_xTe$, $CdTe_{1-y}S_y$, $CdTe_{1-y}Se_y$ as disclosed in us, Patent 4,568,792; silicon, germanium, indium phosphide, gallium arsenide, aluminum antimonide, gallium phosphide, gallium antimonide, cadmium sulfide, cadmium sellinide, cadmium telluride, zinc oxide, zinc sulfide, zinc sellinide, cupric sulfide, cupric oxide. titanium dioxide, aluminum arsenide, and gallium aluminum arsenide as disclosed in U.S. Patent 3,978,333, incorporated herein by reference, and the like.

In one exemplary embodiment, photovoltaic active layer(s) 22 comprise amorphous silicon. Suitable semiconductor materials include, but are not limited to, hydrogenated amorphous silicon, hydrogenated amorphous silicon carbon, hydrogenated amorphous silicon germanium and the like. Photovoltaic active layer(s) 22 can be arranged as single, tandem or triple junction cells. In a refinement of the present invention, photovoltaic active layer(s) 22 are a single junction amorphous silicon solar cell configured as pin or nip. In such configurations, the positively doped (p doped) amorphous silicon p-layer is positively doped with boron. The boron is provided in the deposition process set forth below by providing a boron source in the reactant gases. Examples of boron sources include, but are not limited to, diborane (B_2H_6), BF_3, trimethylboron (TMB) and the like. An amorphous silicon, undoped, active intrinsic i-layer is disposed between the p-layer and a negatively doped (n-doped) amorphous silicon n-layer. The n-layer is disposed over the i-layer and can be amorphous silicon carbon or amorphous silicon negatively doped with phosphorus. The phosphorus is provided in the deposition process set forth below by providing a phosphorus source in the reactant gases. An example of a phosphorus source includes, but is not limited to, phosphine (PH_3).

The encapsulant 30 is made of a polymer and a moisture barrier. Examples of suitable polymers for encapsulation include, but are not limited to, ethylene vinyl acetate (EVA), polyvinyl acetate (PVA), polyvinyl butyral (PVB), Tedlar-type plastic, Nuvasil-type plastic, Tefzel-type plastic, ultraviolet curable coatings, combinations thereof and the like. The moisture barrier can be made of glass or can be a multi-layer structure such as a type of plastic surrounding a metal film such as aluminum and the like.

As set forth above, photovoltaic device 10 includes front electrical contact 20. In a refinement, front electrical contact 20 is configured as a multi-layer structure that includes a transparent metallic oxide layer, a dielectric layer and optionally additional layers. The transparent metallic oxide layer is typically doped to ensure sufficient electrical conductivity. Examples of transparent metal oxides include, but are not limited to, doped tin oxides, indium tin oxide, doped zinc oxide, cadmium stannate and the like. The dielectric layer is usually disposed over transparent substrate 12 contacting inner surface 16. The dielectric layer inhibits components in the substrate such as sodium from contaminating the metallic oxide layer or the photoactive layers. The dielectric layer can be deposited by atmospheric pressure chemical vapor deposition (APCVD), low pressure chemical vapor deposition (LPCVD), and the like.

Photovoltaic device 10 also includes back electrical contact 24. In a refinement, back contact 24 is also configured as a multi layered structure that includes a transparent conducting metal oxide and a metal. Suitable metals include, but are not limited to, silver, molybdenum, platinum, steel, iron, niobium, titanium, chromium, bismuth, antimony, aluminum and the like. Suitable materials for the conducting metal oxide include, but are not limited to, doped tin oxides, indium tin oxide, doped zinc oxide, cadmium stannate and the like. In a refinement, the conducting metal oxide is disposed over and contacts a photovoltaic active layer. The conducting metal oxide can be deposited by sputtering, low pressure chemical vapor deposition (LPCVD), atmospheric pressure chemical vapor deposition (APCVD), spray pyrolysis, and the like. The metallic layer can be deposited by sputtering, evaporation, and the like.

With reference to Figure 2, a system for depositing the photovoltaic module of Figure 1 is provided. In fabrication stage 30, transparent substrate 12 coated with a transparent electrically conductive coating 20 is seamed and washed. The cleaned substrate is subsequently patterned with laser patterning system 34. The substrates are then washed again to remove any residues formed by the laser patterning.

In stage 38 of the fabrication process, a plurality of substrates is loaded into a variation of the substrate carrier 40. The substrate carrier 40 is then loaded into preheat chamber 42. The substrate carrier 40 includes an integral rear and front flow directing baffle for allowing hot gas in the preheat chamber to be directed between individual substrates held in the carrier. The directing of hot gas flow in this manner allows each substrate to be rapidly heated.

Still referring to Figure 2, in stage 43 of the photovoltaic module fabrication process photovoltaic active layer(s) 22 is formed. The heated substrates are transported to deposition chamber 44. Photovoltaic active layer(s) 22 is deposited over the substrate while the substrate carrier is resident therein. Photovoltaic active layer(s) 22 is formed by a glow discharge process with suitable gases introduced between the substrates. The substrate carrier has a rectangular gas manifold, whose major plane is perpendicular to the substrate planes, bearing rows of holes such that the source gases for deposition are supplied from a row of holes positioned between each adjacent pair of substrates 12 and running along the length of the substrates 12. The gas flow direction is in the direction of the short dimension of the substrate 12. The substrate carrier has planar electrodes made of aluminum, whose sequence alternates between grounded and RF-powered electrodes. As set forth above, the system of the present embodiment is advantageously used to form an amorphous silicon solar cell that includes a p-type layer, an i-type layer and an n-type layer. Amorphous silicon is formed by the plasma decomposition of a silicon hydride gas. Suitable examples of useful silicon-containing gases include, but are not limited to, silane, disilane, and higher silanes. Suitable dopants are introduced into deposition chamber 44 to form the various doped layers. For example,

diborane (B_2H_6) is added to the silane introduced into deposition chamber 44 to form a p-type amorphous silicon layer. After the p-type layer has been formed, the diborane flow is stopped to form an intrinsic region. Thereafter, an n-type dopant, such as phosphine (PH_3), is added to the silane flow in order to form an n-type amorphous silicon layer. In a refinement of the present embodiment, the p-i interface is amorphous silicon carbon containing perhaps 5% carbon at the edge of the p-layer. After the desired layers are deposited, the reactant gas flow and the glow discharge are stopped. The substrates are then allowed to cool. In a refinement of the present embodiment, the substrate carrier is removed from deposition chamber 44 for at least a portion of the cool down process. The coated transparent substrates 12 are unloaded and transferred to a transport cart.

In the stage 48 of the present process, back electrical contact 24 is formed over photovoltaic active layer(s) 22. In a refinement of the present embodiment, back electrical contact 24 includes a transparent conductive oxide ("TCO") such as zinc oxide, which is sputtered onto photovoltaic active layer(s) 22 at sputtering coater 50. The coated substrates are patterned by laser patterning system 52. At sputter coater 54, a metal layer (e.g. aluminum) is deposited over either photovoltaic active layer(s) 22 or over the TCO, if present. The aluminum layer is then patterned by laser patterning system 54. Finally, encapsulation is attended to the photovoltaic device at encapsulation station 56. Following the patterning step of the aluminum, the edge of the panel 10 is encapsulated.

With reference to Figure 3, a schematic illustration of a substrate carrier used in the process set forth above is provided. Substrate carrier 60 includes a plurality of electrodes comprising a set of RF electrodes 62 and a set of ground counter-electrodes 64. In a refinement, the plurality of electrodes comprises from about 3 to about 61 electrodes in all. Typically, the electrodes comprise a metal or metal alloy. Examples of suitable metals include, but are not limited to, aluminum, aluminum alloys, nickel, stainless steels, nickel alloys, titanium and combinations thereof. RF electrodes 62 and ground electrodes 64 are arranged substantially parallel to each other in an order alternating between RF electrode and ground electrode. Substrate carrier 60 includes

frame 70 for holding RF electrodes 62 and ground electrodes 64. Frame 70 includes side walls 72, 74 which are also typically grounded. Structural rods 78 support RF electrodes 62 and ground electrodes 64 while holding side walls 72, 74 together. At least a portion of a set of RF electrodes 62 and a set of ground electrodes 64 form the plurality of electrodes being adapted to hold substrates for coating. Substrates may also be mounted on grounded side walls 72, 74. Frame 70 defines a front opening and a rear opening. Substrate carrier 60 further includes gas manifold 90 for dispersing the reactive gas composition between the plurality of electrodes. Gas manifold 90 includes plenum 92 and a plurality of orifices 94 for introducing a reactive gas composition between the electrodes.

With reference to Figure 4, a perspective view of an electrode used in the deposition of photovoltaic active layers 22 is provided. Electrode 62 includes slots 96, 97, 98. Electrode 62 also includes contact region 108, which is adapted to attach to an RF power source so as to provide RF power to the electrode. Contact region 108 is adjacent to contact edge 110. In a refinement, a plasma deposition system includes one or more RF electrodes of the design of Figure 4 and one or more counter-electrodes. In another refinement, slot 96 is positioned at a first distance d_1 from contact edge 110, slot 97 is positioned at a second distance d_2 from contact edge 110, and slot 98 is positioned at a third distance d_3 from contact edge 110. Distance d_1 is smaller than both distances d_2 and d_3. In one refinement, distances d_2 and d_3 differ by at most 40 percent. In another refinement, distances d_2 and d_3 are substantially equal. In a useful configuration of the present embodiment, slots 96, 97, 98 are arranged in a triangular configuration. In a further refinement, electrode 62 further includes one or more additional slots, which may also be arranged in a cascading manner so that overall all the electrodes are in such a cascading configuration. Moreover, such additional slots will typically have a longitudinal dimension that is substantially parallel to the contact edge. In a refinement, for a 25 by 49 inch electrode, slots 97 and 98 are about 1/8 inch wide by 12.36 inches long and slot 96 is about 1/8 inch wide by 9.64 inches long. For 28 inch by 52 inch electrode, slots 97 and 98 are about 1/8 inch wide by 13.86 inches long and slot 96 is about 1/8 inch wide by 9.64 inches long.

With reference to Figure 5, a schematic illustration showing placement of the substrate holder in deposition chamber 44 is provided. Reactive gases flow between the electrodes and substrates along directions 100, 102. After reaction, the spent gases are exhausted through outlet port 108.

While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. An electrode system for utilization in a plasma CVD reactor, the electrode system comprising;

one or more RF electrodes and one or more counter-electrodes, at least one RF electrode having a contact edge and a cascading arrangement of slots, each slot having a longitudinal dimension substantially parallel to the edge,

wherein the RF electrodes are adapted to receive RF-power at a position adjacent to the contact edge.

2. The electrode system of claim 1 wherein the cascading arrangements of slots comprise a first slot, a second slot, and a third slot, the first slot positioned at a first distance from the contact edge, the second slot positioned at a second distance from the contact edge, and the third slot positioned at a third distance from the contact edge, wherein the first distance is smaller than the second distance and the third distance.

3. The electrode system of claim 2 wherein the second distance and the third distance differ by at most 40 percent.

4. The electrode system of claim 3 wherein the second distance and the third distance are substantially equal.

5. The electrode system of claim 4 wherein the first, second, and third slots are arranged in a triangular configuration.

6. The electrode system of claim 2 further comprising one or more additional slots.

7. The electrode system of claim 2 wherein the one or more additional slots having a longitudinal dimension that is substantially parallel to the contact edge.

8. The electrode system of claim 2 wherein all electrodes are arranged in a cascading configuration.

9. The electrode system of claim 1 wherein the one or more RF electrodes and the one or more counter electrodes comprise a metal or metal alloy.

10. The electrode system of claim 1 wherein the metal is selected from the group consisting of aluminum, nickel, stainless steels, nickel alloys, titanium and combinations thereof.

11. An electrode system for utilization in a plasma CVD reactor, the electrode system comprising;

one or more RF electrodes and one or more counter-electrodes, the one or more RF electrodes having a contact edge and a cascading arrangement of slots, each slot having a longitudinal dimension substantially parallel to the edge,

wherein the one or more RF electrodes are each adapted to receive RF-power at a position adjacent to the contact edge.

12. A plasma deposition system comprising:

a deposition chamber;

an electrode system positioned within the deposition chamber, the electrode system having one or more RF electrodes and one counter-electrodes, each RF electrodes having a contact edge and a cascading arrangement of slots, each slot having a longitudinal dimension substantially parallel to the edge wherein RF-power is supplied at a position adjacent to the contact edge;

a gas supply for introducing a reactive gas composition into the reaction chamber; and

a power supply for providing RF power to the one or more RF electrodes in order to induce reaction of the reactive gas composition.

13. The deposition system of claim 12 wherein the cascading arrangements of slots comprising a first slot, a second slot, and a third slot, the first slot positioned at a first distance from the contact edge, the second slot positioned at a second distance from the contact edge, and the third slot positioned at a third distance from the contact edge, wherein the first distance is smaller than the second distance and the third distance.

14 The deposition system of claim 13 wherein the second distance and the third distance differ by at most 40 percent.

15. The deposition system of claim 13 wherein the second distance and the third distance are substantially equal.

16. The deposition system of claim 15 wherein the first, second, and third slots are arranged in a triangular configuration.

17. The deposition system of claim 12 further comprising one or more additional slots.

18. The deposition system of claim 12 wherein the reactive gas composition comprising a silicon-containing compound.

19. The deposition system of claim 12 wherein the silicon-containing compound is selected from the group consisting of silane, disilane, polysilanes, and combinations thereof.

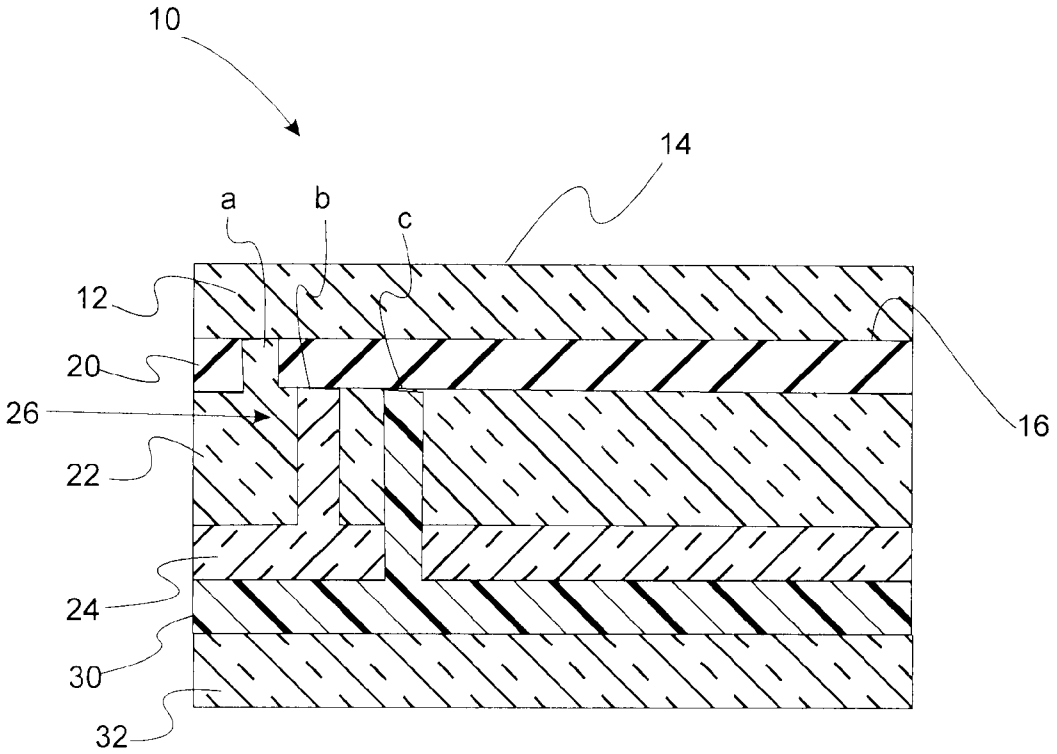

Figure 1

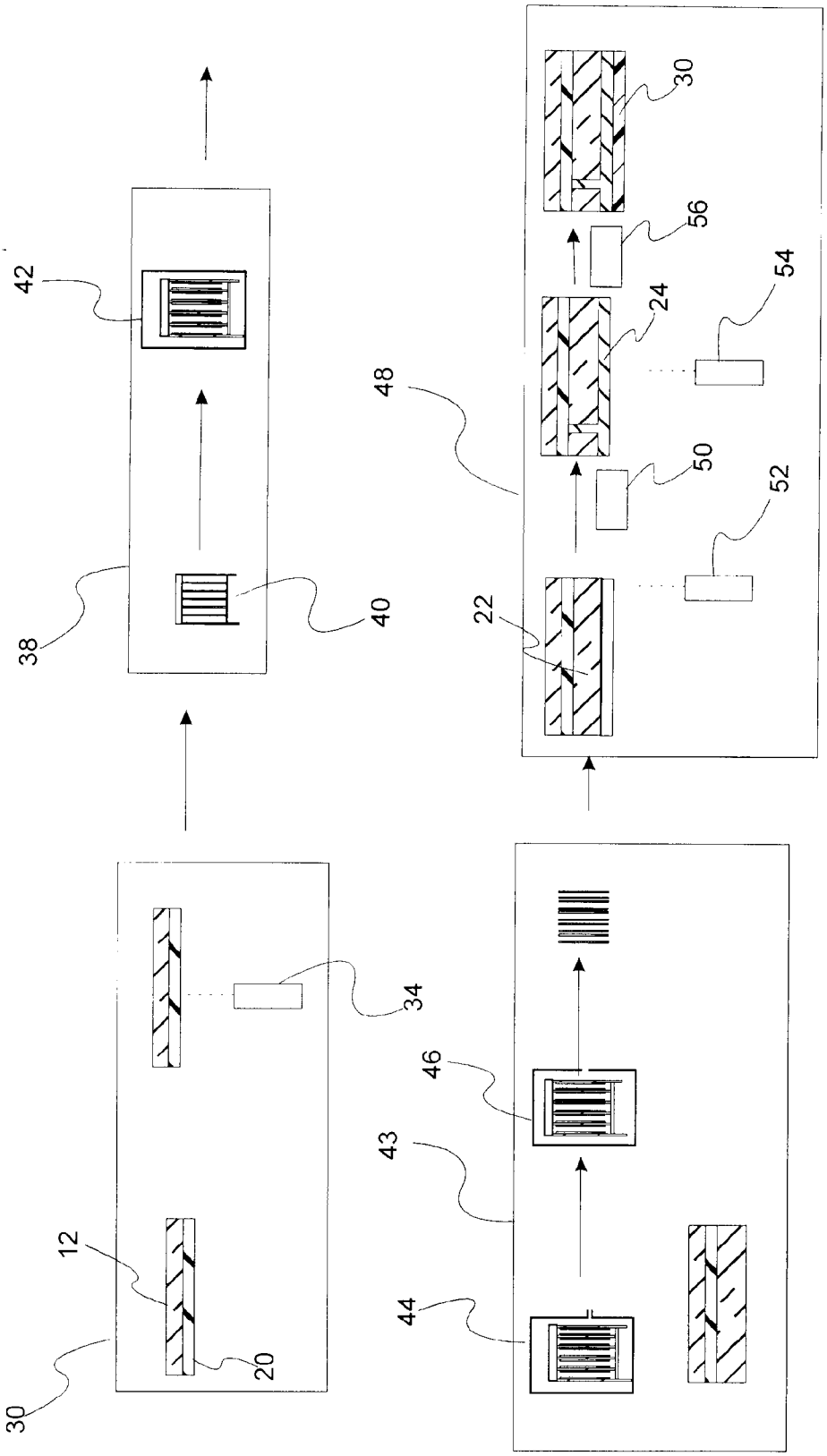

Figure 2

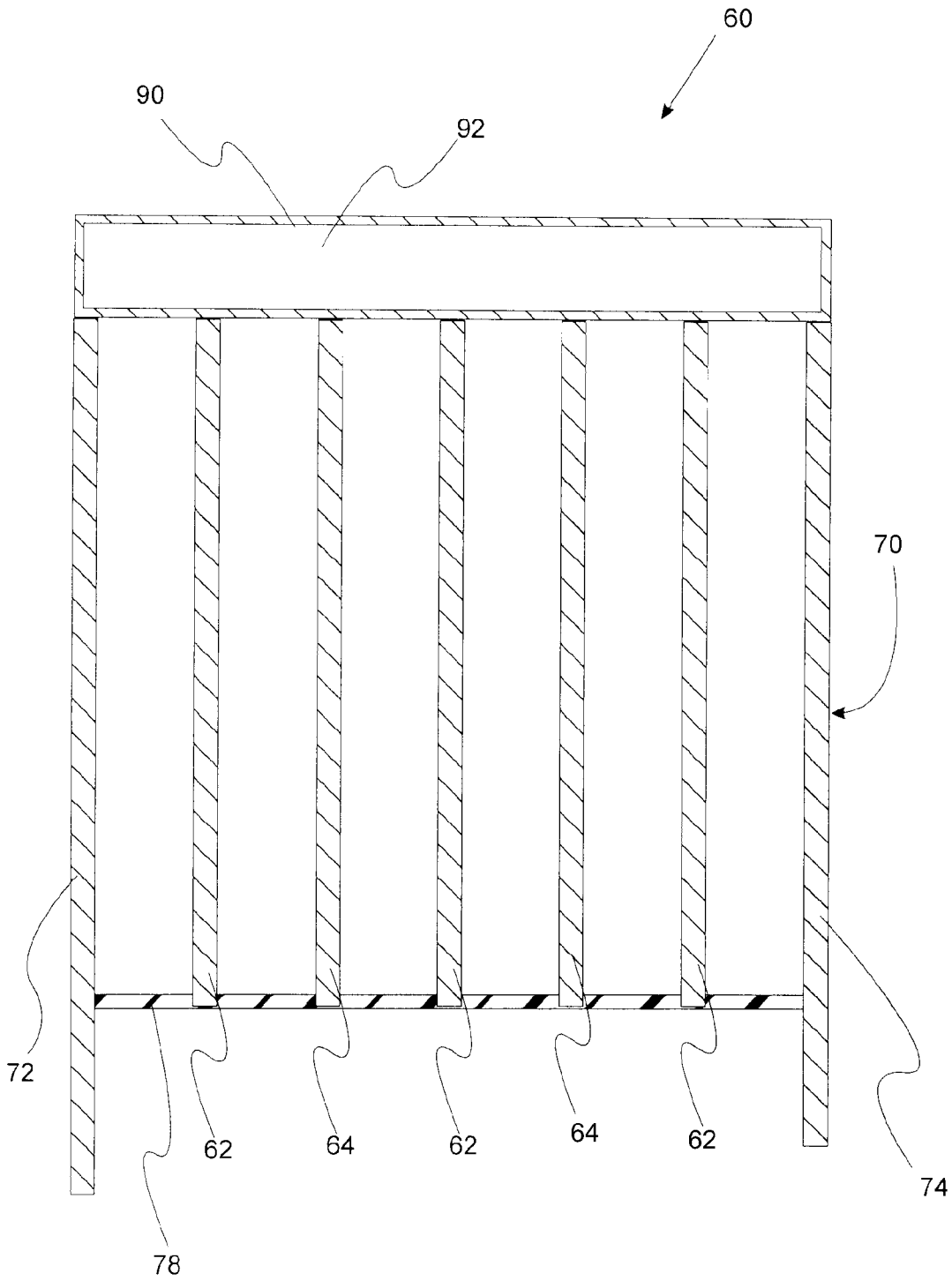

Figure 3

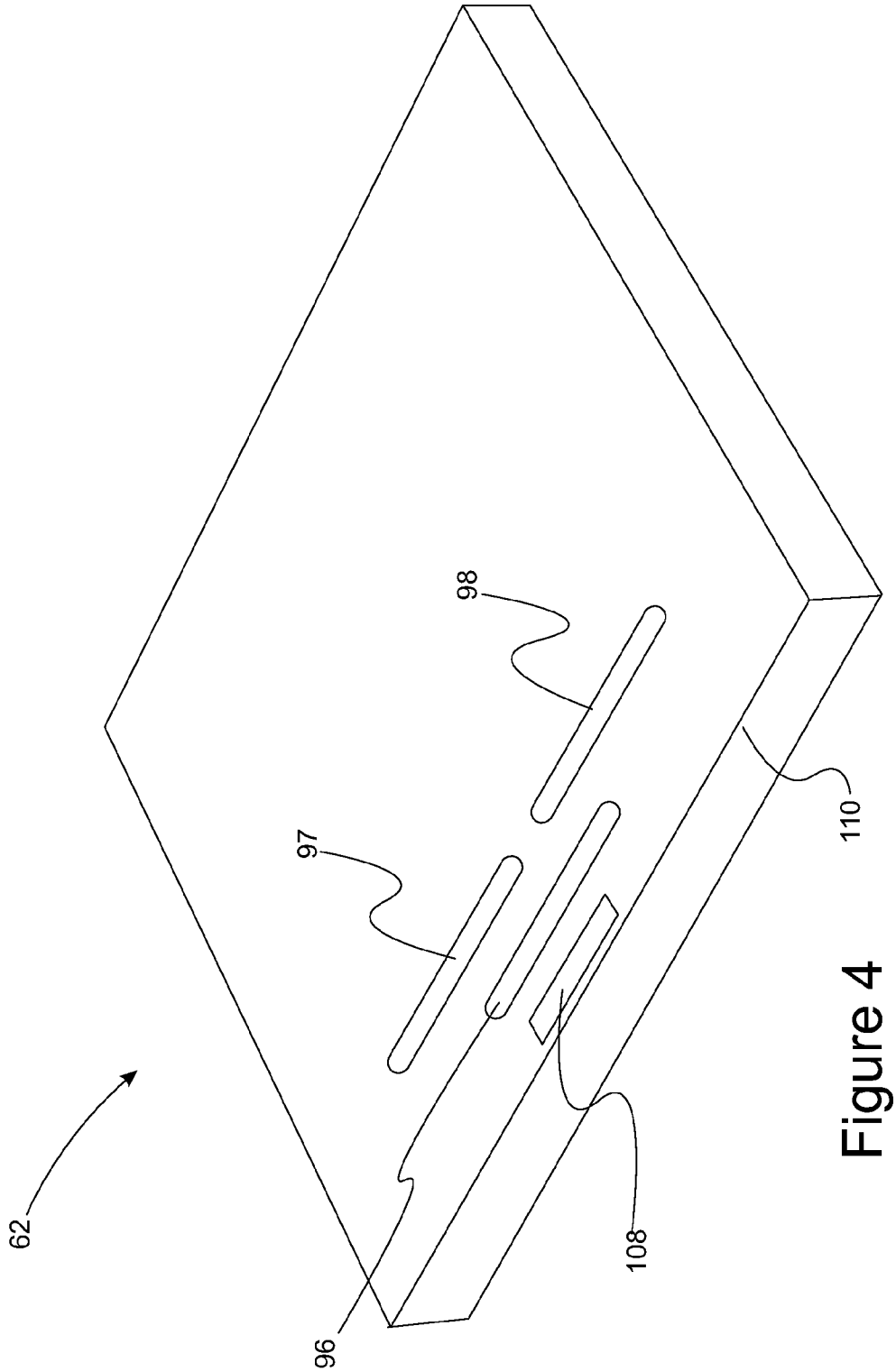

Figure 4

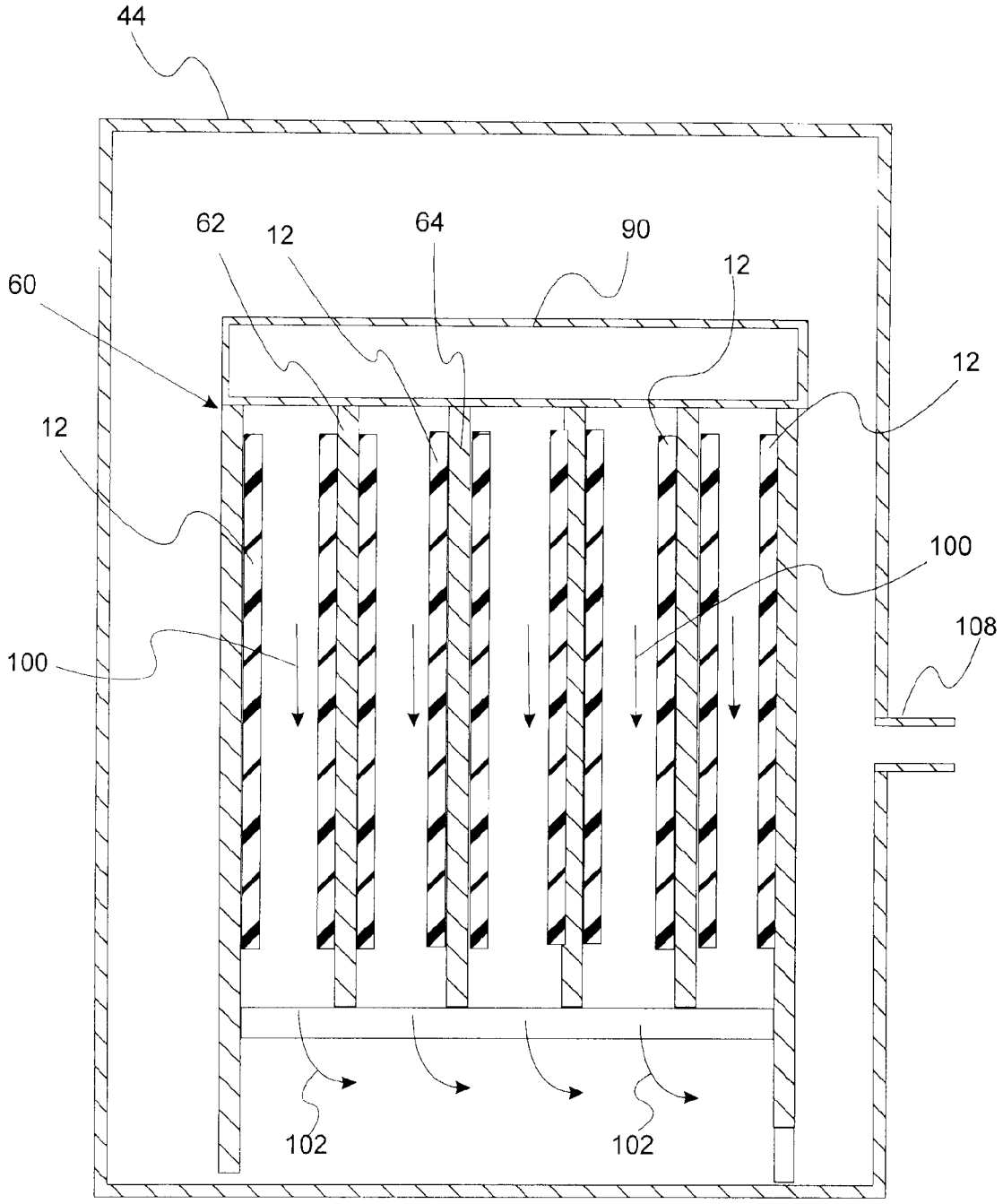

Figure 5