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DESCRIPTION

AREA OF THE INVENTION

[0001] The present invention relates to a substrate holder to be used in an electrolytic plating process. More specifically, the present invention relates to a substrate holder comprising a physically adaptable contact means arranged to provide electrical contact to cavities on the backside of an electrically conductive substrate attached to the substrate holder.

BACKGROUND ART

[0002] Electroplating is used for microelectronics in a wide range of applications such as interconnects, components, waveguides, inductors, contact pads etc.

[0003] A master electrode, such as prepared by the present invention, is suitable for applications involving production of micro and nano structures in single or multiple layers, fabrication of PWB (printed wiring boards), PCB (printed circuit boards), MEMS (micro electro mechanical systems), IC (integrated circuit) interconnects, above IC interconnects, sensors, flat panel displays, magnetic and optical storage devices, solar cells and other electronic devices. It can also be used for different types of structures in conductive polymers, structures in semiconductors, structures in metals, and others are possible to produce using this master electrode. Even 3D-structures in silicon, such as by formation of porous silicon, are possible.

[0004] Chemical vapour deposition and physical vapour deposition are processes that may also be used for metallization, but electroplating is often preferred since it is generally cheaper than other metallization processes and it can take place at ambient temperatures and at ambient pressures.

[0005] Electroplating of a work piece takes place in a reactor containing an electrolyte. An anode, carrying the metal to be plated, is connected to a positive voltage. In some cases, the anode is inert and the metal to be plated comes from the ions in the electrolyte. The conductivity of the work piece, such as a semiconductor substrate, is generally too low to allow the structures to be plated to be connected through the substrate to backside contacts. Therefore, the structures to be plated first have to be provided with a conductive layer, such as a seed layer. Leads connect the pattern to finger contacts on the front side. The finger contacts are in turn connected to a negative voltage. The electroplating step is an electrolytic process where the metal is transferred from the anode, or from the ions in the electrolyte, to the conductive pattern (cathode) by the electrolyte and the applied electric field between the anode and the conductive layer on the work piece, which forms the cathode.

[0006] As stated above, the work piece is usually made of a non-conductive material. As the

pattern to be plated is located on the front side, it is necessary to apply a voltage to the conductive layer on the front side. Additional leads and contact areas also have to be located on the front side since contacting the pattern directly with electrodes would disturb the plating process in those areas.

[0007] The resulting setup has a number of disadvantages:

- Having contact areas on the front side occupies a lot of space that could otherwise be used for the pattern to be plated.
- The contact areas are restricted to the periphery of the work piece in order to occupy as little space as possible.
- The plating process takes place at an accelerated rate proximate the electrodes, resulting in non-uniformity of the metallization. Plating uniformity would be improved if any portion of the work piece could be contacted.
- The finger electrodes applied to the contact areas are submerged in the damaging, such as corrosive, environment of the electrolyte during the process, leading to degraded electrodes.
- Constructing durable electrodes requires complex designs and expensive materials.

[0008] An alternative device and process is described in US6322678, wherein a substrate holder is constructed with electrodes that are applied to contact areas on the backside of a work piece, which contact areas are either connected to leads that reach around the edge of the work piece, or to conducting vias, leading through the substrate. However, US6322678 is still accompanied by the problem of leads and contact areas occupying space on the front side, since these leads and contact areas are impossible to coordinate with the intended plating. Also, the electrodes are fixed in a few locations close to the periphery of the substrate holder, only to ensure a peripheral contact with the conductive surface of the work piece intended to be plated, placing demands on the layout of the contact areas and leads of the work piece in order to ensure their correct placement in the corresponding locations on the backside of the work piece. Also, the substrate holder according to US6322678 is useless for plating ECPR master electrodes, especially master electrodes having insulating material also on the side not intended for plating, since it cannot be assured that the electrodes contact conducting parts of the master electrode. The substrate also has to be carefully aligned with the substrate holder's electrodes. Still further, the electrodes are arranged, such that they are slidable through the substrate holder, thus failing to ensure isolation of the back side of the work piece from electrolyte.

[0009] Other examples of substrate holders are disclosed in documents US 2004/074762 A1, US 2008/017503 A1 and US 2007/151858 A1.

SUMMARY OF THE INVENTION

[0010] Accordingly, the present invention seeks to mitigate, alleviate or eliminate one or more of the above-identified deficiencies and to provide an improved substrate holder of the kind referred to.

[0011] A substrate holder for holding a conductive substrate during plating thereof is provided. The substrate holder comprises the feature of claim 1.

BRIEF DESCRIPTION OF DRAWINGS

[0012] These and other aspects, features and advantages of which the invention is capable of will be apparent and elucidated from the following description of embodiments of the present invention, reference being made to the accompanying drawings, in which

Figure 1 is a cross-sectional view of an electroplating processing chamber;

Figures 2A-C illustrate exemplary designs of a conductive substrate for use in conjunction with the present invention;

Figures 3A, 3B, and 4 illustrate embodiments of the substrate holder;

Figure 5 illustrate loading/unloading embodiments of the substrate holder;

Figure 6 illustrates aligning embodiments of the substrate holder;

Figure 7 illustrates electrical contacting embodiments of the substrate holder;

Figure 8 illustrates electrical contacting embodiments of the substrate holder;

Figure 9 illustrates an electrical contacting embodiment of the substrate holder;

Figures 10A and 10B illustrate details of an embodiment of the contact elements of the substrate holder;

Figures 11A and 11B illustrate details of embodiments of the contact elements of the substrate holder;

Figures 12A and 12B illustrate embodiments of the contact means of the substrate holder ;

Figures 13A and 13B illustrate embodiments of the contact means of the substrate holder; and

Figures 14A and 14B illustrate embodiments of the contact means of the substrate holder according to the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0013] Below, several embodiments will be described with references to the drawings. These embodiments are described in illustrating purpose in order to enable a skilled person to carry out the invention. However, such embodiments do not limit the invention which is defined by the appended claim.

[0014] Referring to Figure 1, illustrated is a cross-sectional overview of an electroplating processing apparatus 100. The drawing is a sketch of the principles of operation of a plating process and is intended to illustrate the role of the substrate holder 101 in such a process .

[0015] During an electroplating process, a conductive substrate 102 is attached to a substrate holder 101. The conductive substrate 102 may be a wafer of conducting and/or semiconducting materials, for instance a metallic material, or of a doped semiconductor material, such as silicon. The conductive substrate 102 may be attached to the substrate holder 101 by an attachment means, sealing off the backside of the substrate from the electrolyte in the electroplating process. Such attachment means may for example be a clamping ring 104. The clamping ring 104 may be made of a rigid non-conductive material, such as Teflon.

[0016] In one embodiment said conductive substrate 102 comprises at least partly of a conducting silicon wafer.

[0017] One or several layers or patterns of insulating material may then be arranged on the conductive substrate 102. Alternatively, other conducting materials may be arranged on the conductive substrate 102. Also, one or several layers or patterns of insulating material may be combined with one or several layers or patterns of conducting material to pattern the conductive substrate 102.

[0018] In one embodiment the substrate holder 101 is made of an insulating material, such as PP (polypropylene), Teflon, or PEEK (polyetheretherketone), and in another embodiment of a conducting material, such as stainless steel. In a yet further embodiment, the substrate holder 101 is primarily of an insulating material but may comprise one or several conducting parts, different from the contact means described further in the present invention. The conductive substrate 102 is patterned with an electrically insulating layer 103. The insulating layer 103 forms raised structures between which cavities are formed. In said cavities conductive surfaces are exposed onto which a metal may be deposited during the electroplating process. The bowl 105 is constructed with a reservoir 106. During the electroplating process the reservoir 106 is filled with an electrolyte. The electrolyte is pumped from an external reservoir (not shown), in a gentle flow, through an anode 107. The anode 107 may be formed as a grating in order not to impede the flow of electrolyte, up towards the conductive substrate 102, which is submerged below the surface of the electrolyte. The electrolyte is made to flow past the conductive surfaces in the cavities formed by the insulating layer 103. A voltage is applied between the anode 107, which may be single-pieced or segmented, and the backside of the conductive substrate 102, which exposed conductive surface thereby forms the cathode in the process.

The voltage may be applied between the anode 107 and the backside of the conductive substrate 102 via the substrate holder 101, as will be further discussed below. Metal ions are released by the anode and are carried by the electrolyte and the applied electric field towards the exposed conductive surfaces where the metal ions are deposited as a plated metal layer.

[0019] In another embodiment, the anode is inert and the ions are provided only from the electrolyte. In this embodiment it is preferred to regularly replenish with a fresh ionic electrolyte.

[0020] According to another embodiment, a permeable membrane (not shown) may be arranged in the bowl between the anode 107 and the substrate holder 101 in order to allow a process using two electrolytes, creating a first compartment in the bowl, wherein the substrate holder 101 is located, and a second compartment, wherein the anode 107 is located. The permeable membrane may be permeable to in-organic substances, such as to the metal ions resulting from the dissolution of metal at the anode 107 and water, but impermeable to organic substances, such as brighteners and suppressors. The second electrolyte may be injected above the membrane in the first compartment, i.e. on the side of the membrane where the substrate holder 101 is located, and may contain brighteners and suppressors. Since the brighteners and suppressors could degrade at the anode 107 it may be important that they are separated from the anode 107 by the membrane. Introducing the permeable membrane between the substrate holder 101 and the anode 107 solves the above-identified problem.

[0021] Having flowed past the substrate, the electrolyte is made to overflow the bowl 105, as indicated by arrow 108, into an external electrolyte-collecting sink 109. From the sink, the electrolyte may be returned to the external reservoir (not shown) to be recirculated into the process. When recirculated, the electrolyte may possibly first pass a control station and/or filter (not shown) . The electrolyte may also be collected as waste liquid, which means that it will not be returned to the process. The process flow selected is chosen based on the requirements of the process in question.

[0022] Thus, during the preparation of the master electrode, the substrate holder immerses the substrate in the electrolyte and a metal is deposited by electroplating in the cavities on the front side of the substrate, while keeping the backside sealed off from the electrolyte. According to one embodiment the substrate holder 101 may be mounted to a piston 110 and an external process control apparatus (not shown) . During the whole process the substrate holder 101 may be made to rotate in either direction around the z-axis, as indicated in the Figure 1. This ensures uniformity of the plating process with regard to variations in the electric field and in the flow of the electrolyte across the substrate.

[0023] The embodiment depicted in Figure 1 shows the substrate holder 101 arranged horizontally, but it is equally possible to use the substrate holder 101 for an electroplating apparatus, such as a tilt plater. In a tilt plater the substrate holder may for example be tilted in the interval of 30° to 60°, such as 45°, with respect to the z-axis. Another alternative is to use the substrate holder 101 for an electroplating apparatus, such as a rack plater. In a rack plater

the substrate holder 101 is immersed substantially vertically in the electrolyte. The latter alternative may also allow for multiple substrate holders 101 to be used in parallel simultaneously in the same processing apparatus 100.

[0024] External conductors and/or air ducts, represented by the dashed line 111, supply power to the electrical contact means (not shown, but being comprised in the substrate holder 101) and gas pressure to the substrate holder 101 via the piston 110, respectively. Due to the rotating movement of the piston, electrical contact to the at least one external power source may need, but not necessarily always, to be established through brush contacts, sliding contacts, or similar frictional contact means as deemed appropriate by a person skilled in the art.

[0025] The purpose of said air ducts is to supply the substrate holder 101 with a gas pressure, e.g. for applications such as the attachment of a substrate 102 to the substrate holder 101, for the loading/unloading of a substrate 102 into or out of the substrate holder 101 or for actuating the movement of the clamping ring 104, etc.

[0026] Conductors and/or air ducts 111 may be routed from the piston 110 to an external unit 112 that comprises a collection of devices, such as at least one device selected from the group comprising a power supply, a gas pump, a user interface, such as a computer by which an operator may control the different parts of the apparatus and/or the process.

[0027] Referring to Figure 2A-B, illustrated are a number of exemplary embodiments of the conductive substrate 102 and the patterned insulating layer 103. The insulating material 103 may be provided on a first portion of the side of the conductive substrate 102 facing the substrate holder. Thus, the backside insulating layer 103A may be patterned to divide the backside into one or more contact areas 203, at a second portion of said side of the conductive substrate 102. The pattern on the backside is usually, but not necessarily always, in the shape of concentric circles or circle segments. The area in the middle, i.e. the center of the backside, is usually, but not necessarily always, left exposed to form one contact area. It is also within the scope of this embodiment that the whole backside is left exposed to form a single backside contact area 203, as further described in relation to Figure 2C. The patterned backside brings about the beneficial technical effect that master electrodes for ECPR, provided with pre-deposited material in cavities on the front side, may be connected to several voltages, from the different contact areas formed on the backside. This results in a possibility to control and assure an even distribution of plating efficiency over the entire master electrode. It is thus convenient to have also the backside patterned.

[0028] In an embodiment, the back side of the conductive substrate is provided with an insulating material forming at least one cavity exposing the front side of the conductive substrate, such that the at least one contact area is provided in said cavity. Thus, the first and the second portions of said back side of the conductive substrate are arranged such that said insulating material forms at least one cavity, wherein said at least one contact area 203 is provided in said cavity.

[0029] In one embodiment at least one contact area 203 covers at least 50% of a diagonal of the backside of the conductive substrate 102. In this respect at least 80%, such as at least 95%, of the diagonal of the backside of the conductive substrate 102 may be covered by contact areas 203. In this way an even distribution of voltages may be provided, ensuring an even plating height and plating speed on the front side. Also, this embodiment provides the technical effect that one specific backside pattern may interact with different configurations of contact means 304, according to below.

[0030] It is to be understood that the resistivity of the conductive substrate 102 in a lateral direction may be large enough, or that the lateral spacing between contact areas of different potentials, or between cavities on the front side, may be large enough to yield different potentials in at least two points along a radius on the front side of the conductive substrate 102.

[0031] The front side insulating layer 103B is patterned with the layout to be replicated when the substrate is used as a master electrode in an electrochemical pattern replication (ECPR) process. The cavities formed by the front side insulating layer 103B are pre-arranged (in an earlier process) with one or more layers of a substantially inert (in said electrolyte) conductive material 201, hereafter called electrode layer. The electrode layer may be of a material selected from the group comprising Au, Ti, TiW, Cr, Ni, Si, Pd, Pt, Rh, Co and/or alloys or heterogeneous mixtures thereof. During the electrolytic process, represented by the arrows 202, a metal is deposited on said pre-arranged electrode layer 201.

[0032] A conductive substrate allows the use of an edge insulating layer 103C, comprising at least one layer of at least one electrically insulating material, covering the edge of the conductive substrate 102. The purpose of the edge insulating layer 103C is to provide electrical insulation between the conductive substrate and a target wafer when said conductive substrate is used as a master electrode in an electrochemical pattern replication (ECPR) process. Another purpose of the edge insulating layer is to provide an air-tight seal together with the substrate holder 101 and to provide a surface that allows mechanical handling during the process, such as gripping by the substrate holder 101 or gripping by a robotic arm for loading or unloading of the wafer in the substrate holder 101. The edge insulating layer 103C is also used to form an air-tight seal together with a gasket when the substrate 102 is mounted on the substrate holder 101 during the process, in order to prevent the electrolyte from coming into contact with the backside of the substrate. It is preferable for the edge insulating layer 103C to cover at least 1 to 10 mm from the edge of the substrate.

[0033] Another advantage of the edge insulating layer 103C is during the use of the substrate 102 as a master electrode in a subsequent ECPR process. When the master electrode is pressed to a substrate being patterned, the edge insulating layer 103C ensures that the substrate being patterned is not short-circuited along the edge.

[0034] Referring to Figure 2C, illustrated is another exemplary embodiment of the conductive

substrate 102. In this embodiment the whole backside is left exposed to form a single backside contact area 203 in a second portion of the side of the conductive substrate facing the substrate holder. The front side has been structured and an electrode layer 201 is arranged in the depressions. The sidewalls are covered by an insulating layer 103B.

[0035] Referring to Figure 3A and 3B, illustrated are embodiments of the substrate holder 101 and the working principles of the physically adaptable contact means 304. The physically adaptable contact means may be any electrical contact means that is electrically insulated from the substrate holder 101, except from any further described interconnections that are arranged to provide electrical contact between said electrical contact means 304 and any external power supply. Further interconnections may for example be leads passing through or around the substrate holder 101. Such physically adaptable contact means may adapt to - and establish electrical contact with - a structured surface in a vertical direction, while at the same time covering a substantial surface area of a substrate in a lateral direction. Since a subsequent ECPR process requires a certain step height between the surface of the insulating layer (e.g. such as the edge insulating layer 103C) and the bottom of the cavities, it also becomes necessary to be able to make good electrical contact to the backside of the substrate 102. This is ensured by the use of the physically adaptable contact means 304 of the substrate holder 101. The contact means 304 may for example be physically adaptable by being resilient and attached to the surface of the substrate holder intended to face the backside of the substrate 102. When the contact means 304 are resilient and attached to the surface of the substrate holder 101, the electrical contact to the external power supply may be assured by leads passing through or around the substrate holder 101. When the electrical contact to the external power supply is assured by leads passing through the substrate holder 101, the leads may be integrated with the substrate holder 101, such that the leads are not movable within the substrate holder. This ensures a good sealing effect between an inner space 306 and the environment surrounding the substrate holder.

[0036] Regardless of the layout or thickness of a pattern of the insulating layer 103A, 103C on the backside of the substrate 102, an operator of the present invention may be certain of making contact with any exposed contact areas 203 using the substrate holder 101, equipped with the physically adaptable contact means 304, illustrated by the arrows in figure 3A and 3B. The arrows are only intended to show the principle of vertical adaptation and lateral coverage. The arrows of Figure 3A and 3B do not represent any physical device.

[0037] Typically, if not the whole backside is to be contacted, the physically adaptable contact means may connect at the backside of the conductive substrate 102 to at least two contact areas 203, or two contact points along a distance from the centre of the conductive substrate to the peripheral edge of the conductive substrate. These at least two contact areas 203 may be located along at least one radius. By contacting the backside of the substrate 102 in at least two contact areas 203 along at least one radius the current is distributed more evenly, which allows a higher rate of plating than only one contact area 203 along at least one radius. Thus, a first portion of the side of the conductive substrate facing the substrate holder is provided with an insulating material 103A, 103C, and a second portion of the side of the conductive

substrate facing the substrate holder forms at least one contact area 203; wherein the resilient contact means 304 is in contact with at least one contact point in said at least one contact area.

[0038] In an embodiment the arrangement of the contact means 304 is patterned, such that several contact points are provided on the front side of the conductive substrate.

[0039] Referring to Figure 3A, the conductive substrate 102 is normally secured to the substrate holder 101 with a clamping ring 302. The clamping ring can be made of a rigid, insulating and inert material, such as PP (polypropylene), Teflon, PEEK (polyetheretherketone), or a metal or ceramic ring coated with mentioned insulated inert materials. In figure 3A the clamping ring 302 is mounted by screwing it onto the substrate holder 101 by threaded surfaces on the vertical interface between the clamping ring 302 and the substrate holder 101. The lower part of the clamping ring 302 may be provided with a slanting, low-profile structure 305. This design brings about the technical effect that the clamping ring 302 will reduce the disturbance or hindering of the flow of the electrolyte in the vicinity of the front side of the substrate 102. The distance d should preferably be in the range of less than 10 mm, such as less than 5 mm, for instance less than 2 mm.

[0040] The clamping ring 302 may have any suitable peripheral or circumferential form, as long as it is adapted for the substrate holder 101 and the substrate 102, for which the clamping ring is intended. Thus, the peripheral or circumferential form may be circular, square, rectangular, or polygonal.

[0041] In order to ensure that no electrolyte leaks to the backside of the substrate, gaskets 303A-C may be provided. Furthermore, as disclosed above, the contact means 304 may be attached to the surface of the substrate holder 101, with integrated leads in the substrate holder, said leads connecting the contact means and external power supply, to ensure that no electrolyte leaks to the backside of the substrate. The gaskets 303A-C may be lip seals, double lip seals or o-rings. Gasket 303A seals the inner space 306 between the substrate holder 101 and the conductive substrate 102. During or before/after operation the inner space 306 may be evacuated of air to a pressure < 1 atm through air ducts in the substrate holder 101 and in the piston 110 (not shown). The underpressure is established to secure the substrate 102 to the substrate holder 101.

[0042] It is also feasible, to secure the substrate 102 to the substrate holder 101, by mechanically pressing the clamping ring 302 towards the substrate holder 101. This may be accomplished by providing a screw vice action between the substrate holder 101 and the clamping ring 302, for example by means of a screw/bolt configuration known to the skilled artisan. Preferably, the screw/bolt configuration is then covered by an insulating material after arrangement, to escape electroplating on said configuration, when said configuration is of a conducting material.

[0043] An additional pressure chamber (not shown) may be provided in the bulk of the

substrate holder 101. The purpose of this chamber, which is directly connected by ducts to the inner space 306, is to safeguard the attachment of the substrate 102 against unexpected pressure fluctuations, for instance due to leaks in the valves of the duct system (not shown). The underpressure can be provided to the air ducts from an external source, such as a vacuum pump. A valve may be arranged between said external source and said air ducts. In one embodiment, underpressure is continuously provided to the air ducts during processing, to ensure that a desirable underpressure is achieved, even if there are unexpected leaks through any valves or gaskets. In another embodiment, said valve is open to provide underpressure when loading or unloading the substrate, but closed during the electroplating operation, which can reduce the risk of flowing electrolyte into the vacuum system, in the unexpected event of leaks. The underpressure may also be provided through a detachable connector. In this case the substrate holder may comprise a check valve for ensuring that the underpressure is maintained. The outer space 307 is sealed off from the outside environment by gaskets 303B and 303C and from the inner space by gasket 303A. In one embodiment the gas over or underpressure line may be provided with a ball bearing valve, whereby the substrate holder may be rotated without rotating the pressure supplying means. The outer space 307 may optionally be increased to a pressure > 1 atm, e.g. by introducing compressed air or preferably a substantially inert gas such as nitrogen gas, in order for the outer space 307 to act as an additional safeguard against the electrolyte leaking through gaskets 303B and 303C. Pressure sensors (not shown) may also be arranged to monitor the pressures of the inner space 306 and the outer space 307 in order to provide a measured value to the external unit 112 and to warn an operator or to automatically initiate precautionary measures in the case of unforeseen pressure fluctuations. Measures may include automatic correction of the pressure or abortion or pausing of the process.

[0044] The conductive substrate 102 may also be attached to the substrate holder 101 solely by the clamping ring 302, as described above, in which case also the inner space 306 may be provided with an increased pressure, for instance by using nitrogen gas.

[0045] The nozzles 308 of the air ducts may be shaped as grooves or holes in the front surface of the substrate holder 101. The nozzles 308 may be laid out in patterns of concentric circles or radial lines, or a combination of both. Different pressures may be applied to different nozzles 308 or groups of nozzles 308 of different radial position, i.e. the applied pressure may be equal along concentric circles of the substrate holder 101.

[0046] Referring to Figure 3B, illustrated is a cross-section of an exemplary embodiment wherein the conductive substrate 102 is attached to the substrate holder 101 by underpressure alone. Gasket 303A seals the inner space 306 from the electrolyte.

[0047] Referring to figure 4, illustrated is another embodiment wherein an underpressure is established in the inner space 306. The pressure is sufficiently small to bend the conductive substrate 102 towards the substrate holder 101. Electrical contact may thereby be established with a contact means (not shown), such as a conductive plate that covers substantially the whole front side of the substrate holder 101. In this embodiment the backside of the conductive

substrate 102 may be left more or less completely exposed. In further embodiments, underpressure in the inner space 306 may be used together with any contact means described in the present invention, in order to improve the electrical contact between the contact means and the conductive substrate 101.

[0048] Figure 4 does not include the clamping ring 302, but it is equally possible to bend the substrate 102 towards the substrate holder 101 while using the clamping ring 302.

[0049] Referring to Figure 5, illustrated is a cross-section of another embodiment. Instead of screwing the clamping ring 302 to the substrate holder 101, the clamping ring 302 and substrate holder 101 may be linked to each other by guiding elements 501, spaced along the periphery of the ring/holder. The clamping ring 302 may thus be lowered to a loading/unloading position or raised to a processing position by an actuator (not shown) such as a linear motor, stepper or rotational motor or by a pneumatic actuator. In a loading/unloading position the substrate 102 may be loaded/unloaded automatically by a robotic arm (not shown) or manually by an operator. A loading operation could be carried out by lifting the substrate 102 into contact with gasket 303A where attachment is secured by an underpressure that is subsequently established according to the description of Figure 3A. Dropping the substrate onto gasket 303B and lifting it into contact with gasket 303A may also be used to load a substrate 102.

[0050] It is preferred that the distance between at least two of the guiding elements 501 is greater than the diameter of the substrate 102 in order to facilitate the loading and unloading of the substrate 102 into or out of the substrate holder 101.

[0051] Another embodiment of the loading/unloading device may be in the form of pressure actuators 502A and/or 502B which may be connected to said at least one duct, the pressure actuators being able to hold a conductive substrate by underpressure, said pressure actuators being extendable and retractable to bring the conductive substrate into proximity of or away from the first surface of the substrate holder. The pressure actuator 502A may for example be vacuum pins or vacuum pads, while pressure actuator 502B for example may be a vacuum chuck. The pressure actuators 502A and/or 502B may thus be mounted in the front side of the substrate holder 101. When the substrate 102 is brought into proximity of the substrate holder 101, either manually or by a robotic arm, the actuators 502A and/or 502B are extended to hold the backside of the substrate 102 by vacuum suction. The actuators 502A and/or 502B are then retracted to bring the substrate 102 into contact with gasket 303A. The actuators 502A may be arranged in a circle with a maximum internal spacing of 120°, such as when having three actuator vacuum pins 502A. The actuator 502B, such as a vacuum chuck, may be mounted in the center of the substrate holder 101. The actuator 502B has a diameter that is smaller than the conductive substrate 102. The extension and retraction of the actuators 502A and 502B may be by pneumatic means, or by a linear motor, or stepper motor, or a rotational motor (not shown).

[0052] Instead of a clamping ring 302, an edge gripper (not shown), such as hooks or an edge

grip ring (different from the clamping ring), may be used to grip the edge of the conductive substrate 102 and to pull it against the substrate holder 101 and the gasket 303A.

[0053] Referring to Figure 6, illustrated is a cross-section of another embodiment. The substrate holder 101 and the clamping ring 302 are here designed with slanted guiding surfaces 601A and 601B, respectively. The guiding surfaces 601A and 601B are used to align the substrate 102 laterally and horizontally with respect to the substrate holder 101 during a loading operation. The substrate holder 101 and the clamping ring 302 may still be provided with gaskets 303A and 303B, respectively. For the sake of clarity, they have been left out of Figure 6.

[0054] The clamping ring 302 depicted in Figure 6 may for example be attached by screw-fit to the substrate holder 101, as described above. However, it is equally possible to use the design with guiding elements 501, as described in conjunction with Figure 5.

[0055] When a backside insulating layer 103A is used it may be necessary to align the pattern of the backside insulating layer 103A with the contact means of the substrate holder 101 when loading the substrate 102 into the substrate holder 101.

[0056] Referring to Figure 7, illustrated is an exemplary embodiment of the front side of the substrate holder 101, and the physically adaptable contact means 701.

[0057] In one embodiment physically adaptable contact means 701 means that the device comprises both contact elements 701A and the interconnection structure 701B.

[0058] The physically adaptable contact means 701 is here laid out in a star-shaped pattern, with individual contact elements 701A evenly spaced along interconnection structure 701B. The pattern of the interconnection structure 701B may be designed as concentric circles or a combination of concentric circles and a star. However, any shape that is able to cover a substantial part of the conductive substrate 102 is within the scope of the present invention. In the embodiment according to figure 7A the contact elements 701A are electrically connected in parallel with each other, through the interconnection structure 701B. The contact elements 701A are then electrically connected in parallel with each other, through the interconnection structure 701B, to a common potential node 702. The node 702 may, or may not be, located in the center of the substrate holder 101. The node 702 is in turn connected through the piston 110 to at least one external potential (not shown) as described in conjunction with Figure 1. It is equally possible to connect the contact elements 701A individually, or in groups of at least two contact elements 701A, to different potentials in order to apply different potentials to different parts of the conductive substrate 102. In such a case it may be necessary to route a number of conductors through the piston 110 to at least one external power source to provide different potential to different contact elements 701A. Usually when applying different potentials to different parts of the conductive substrate 102 it is preferable to keep the potential of the contact elements 701A, at a certain radius from the center, at a certain level, e.g. to apply voltage in concentric equipotential circles.

[0059] The contact elements 701A may be designed in a number of different ways without departing from the concept of the present disclosure. It is however preferred that the common and characterizing feature of all designs is that the contact elements 701A should be flexible/resilient in a vertical direction. Thus enabling establishment of electrical contact with the backside of a conductive substrate 102, regardless of the structural topography of the substrate surface. Different designs of the contact elements 701A will be described more closely in conjunction with Figures 9 to 13 below.

[0060] Referring to Figure 8, illustrated is another exemplary embodiment, displaying the front side of the substrate holder 101 and the physically adaptable contact means 701. The device of Figure 8 differs from the device of 7A only in that there is a larger contact element 701C in the center. In all other respects the devices are the same and offer the same alternatives for configuration of electrical connections and layout of the physically adaptable contact means 701.

[0061] In one embodiment the contact elements 701A is made of a conductive material and designed like a hook, which is resiliently flexible in a vertical direction. The contact element 701A then makes electrical contact with the backside of the conductive substrate 102. The contact element 701A, which is part of the physically adaptable contact means 701 is electrically connected in parallel to other similar contact elements 701A through the interconnection structure 701B, for example as disclosed in figures 7A and 7B. The contact element 701A may then be somewhat compressed, making physical contact with the backside insulating layer 103A of the conductive substrate 102.

[0062] Referring to Figure 9, illustrated is another exemplary embodiment of the front side of the substrate holder 101, and the physically adaptable contact means 901. The physically adaptable contact means 901 is here laid out in a star-shaped pattern, with individual contact elements 901A, in the form of a conductive resilient tube, connected to the interconnection structure 901B. The tube may, for instance be made of conductive rubber. The pattern of the interconnection structure 901B and contact elements 901A may also be designed as concentric circles or a combination of concentric circles and a star. Any shape that is able to cover a substantial part of the conductive substrate 102 is within the scope of the present invention restricted only by the wording of claim 1. In this embodiment the contact elements 901A are electrically connected in parallel with each other, through the interconnection structure 901B, to a common potential node 902 in the center of the substrate holder 101. The node 902 is in turn connected through the piston 110 (not shown) to at least one external power source (not shown), as described in conjunction with Figure 1. It is equally possible to divide the contact element 901A, along its length, into shorter, contact segments (not shown), electrically insulated from each other. The contact segments may then be connected individually or in groups of at least two contact segments, to different potentials in order to apply different potentials to different parts of the conductive substrate 102. This may improve the voltage distribution in the conductive substrate which can lead to a more uniform rate of electroplating material on the conductive substrate. A more uniform plating rate allows plating

more material into depressions of the conductive substrate 102 without overfilling certain areas. To avoid overfilling is crucial if the conductive substrate is to be used as a master electrode and is being put in contact with a target wafer substrate in a subsequent Electrochemical Pattern Replication (ECPR) process, since overfilled material would short circuit the master electrode with said target substrate whereas no ECPR process could be performed. This is especially important when high rates are desirable. In such a case it may be necessary to route multiple conductors through the piston 110 to at least one external power source to provide different potentials to different segments. Usually, when applying different potentials to different parts of the conductive substrate 102 it is preferable to keep the potential of the contact segments, at a certain radius from the center, at a certain level, e.g. to apply voltage in concentric equipotential circles.

[0063] Figures 10A and 10B illustrate the flexibility of the physically adaptable contact means 901.

[0064] Referring to Figure 10A, illustrated is a detailed view of one of the contact elements 901A, according to one embodiment. The depicted exemplary embodiment of contact element 901A is made of a relatively soft, tube-shaped material, which may be conductive or whose surface may be coated with a conductive, flexible film 1001. The inside 1002 of the contact element 901A may be hollow or filled with another flexible material. Figure 10A shows how the contact element 901A makes electrical contact with the backside of the conductive substrate 102. The contact element 901A, which is part of the physically adaptable contact means 901 is electrically connected in parallel to other similar contact elements 901A through the interconnection structure 701B.

[0065] Referring to Figure 10B, illustrated is a somewhat compressed contact element 901A, making physical contact with the backside insulating layer 103A of the conductive substrate 102.

[0066] The contact element 901A may in another embodiment be a spring of a conductive material. The spring may be laid out in a star pattern as depicted in Figure 9, but may also be laid out as concentric circles or as a combination of the two. Any other features of the device in Figure 9, 10A and 10B are also applicable to said spring.

[0067] Referring to Figure HA, illustrated is another view of an exemplary embodiment of a physically adaptable contact means 1101. Contact elements HO1A comprise micro bellows 1102A, which may be inflated or deflated by an actuator such as an external pump unit or other pneumatic actuator (not shown), as required. The bellows 1102A may, for instance, be deflated as the substrate is loaded into the substrate holder 101 and then inflated to establish electrical contact at the contact areas 203. Air conduits 1103 are provided in the substrate holder 101 and connected to the external pneumatic actuator through at least one valve 1104, via air ducts in the piston 110 (not shown).

[0068] Overpressure or vacuum may in another embodiment be provided to the air conduits

through a detachable connector. In this case a check valve can be used to maintain the vacuum or pressure.

[0069] As shown in the figure, the contact elements HOIA are connected in parallel through the interconnection structure HOIB. As described previously, in conjunction with Figures 7 to 10, the contact elements HOIA may also be connected individually or in groups in order to be able to apply different voltages to different contact elements HOIA or to different groups of contact elements HOIA.

[0070] Instead of bellows it would be equally possible to mount the contact elements HOIA on a member that is actuated by a linear motor, stepper motor, or rotational motor .

[0071] Referring to Figure HB, illustrated is another detailed view of an exemplary embodiment of a physically adaptable contact means HOI. Here, the contact elements HOIA are mounted on resilient springs 1102B. The resilient springs 1102B are, in a mechanically unstressed state, sufficiently extended to allow the contact elements 1101A to reach contact areas 203 when a substrate 102 is loaded into the substrate holder 101. As shown in the figure, the contact elements 1101A are connected in parallel through the interconnection structure 1101B. As described previously, in conjunction with Figures 7 to 10, the contact elements 1101A may also be connected individually or in groups in order to be able to apply different voltages to different contact elements 1101A or to different groups of contact elements HOIA.

[0072] Referring to figure 12A and 12B, illustrated is another exemplary embodiment of the physically adaptable contact means 1201. Contact elements 1201A are mounted on a relatively soft, flexible resilient layer 1202 that is attached to the substrate holder 101 (not shown) . Thus, the resilient layer 1202 is located proximally of the contact elements 1201A, and the contact elements 1201A is located distally of the resilient layer 1202. When a substrate 102 is loaded into the substrate holder 101 (not shown) the flexible resilient layer will adapt according to the pressure from the contact elements 1201A. Contact elements 1201A that make contact with the backside insulating layer 103A pushed into the flexible resilient layer 1202, as shown in Figure 12B. Other contact elements 1201A will reach into the cavities and make contact with the contact areas 203.

[0073] The contact elements 1201A may be connected in parallel to a common voltage or may be connected individually, or in groups of at least two contact elements 1201A, through the flexible resilient layer 1202, via an interconnection structure (not shown), to at least one external voltage source (not shown).

[0074] In one embodiment a flexible conductive film 1203 may be arranged between the contact elements 1201A and the conductive substrate 102, i.e. distally of the contact elements 1201A. The flexible conductive film 1203 then acts as an interface between the contact elements 1201A and the conductive substrate 102. In case different voltages are required at different parts of the conductive substrate 102, the conductive film may need to be divided into concentric circles that are electrically insulated from each other.

[0075] Referring to Figure 13A and 13B, illustrated is another exemplary embodiment of the physically adaptable contact means 1301. A rigid conductive layer 1302 is applied to, and electrically connected with the substrate holder 101 (not shown) . The contact element 1301A is formed as a conductive foil that comprises protruding structures 1303. The structures may for instance be flexibly resilient point-like protrusions or elongated corrugations. Such flexible protruding structures may for instance be manufactured in a conductive foil by cutting, corrugating, lasercutting, punching, waterjet cutting or by grinding out the desired structures on the foil. The protrusions are either created directly by the shaping process or in a subsequent step where the shaped portions are deformed/bent to protrude from the flat foil.

[0076] When the contact element 1301A is pressed against a substrate 102 that is loaded into the substrate holder 101 (not shown), the protrusions 1303 that make physical contact with the backside insulating layer 103A are resiliently deformed to allow other protrusions 1303 to reach into the cavities and establish electrical contact with the contact areas 203.

[0077] In case different voltages are required at different parts of the conductive substrate 102, both the rigid conductive layer 1302 and the contact element 1301A may be divided into concentric circles that are electrically insulated from each other. The resulting contact elements 1301A may then be connected in parallel to a common voltage or may be connected individually, or in groups of at least two contact elements 1301A, through the rigid conductive layer 1302, via an interconnection structure (not shown), to at least one external voltage source (not shown) .

[0078] Referring to Figure 14A and 14B, illustrated is another exemplary embodiment of the physically adaptable contact means 1401. A relatively soft elastic layer 1402 is applied to the substrate holder 101 (not shown) . The contact element 1401A is formed as a flat, compliant and conductive foil, applied distally of said elastic layer 1402. When the elastic layer 1402 is pressed against the conductive substrate 102 by the substrate holder 101 the elastic layer 1402 will resiliently deform to reach into the cavities formed by the backside insulating layer 103A, thereby also pressing the compliant contact element 1401A into electrical contact with the conductive substrate 102.

[0079] An interconnection structure (not shown) may be arranged on the substrate holder 101 and be connected to the contact element 1401A through the elastic layer 1402.

[0080] In case different voltages are required at different parts of the conductive substrate 102, contact element 1401A may be divided into concentric circles that are electrically insulated from each other. The resulting contact elements 1401A may then be connected in parallel to a common voltage or may be connected individually, or in groups of at least two contact elements 1401A, through the elastic layer 1402, via an interconnection structure (not shown), to at least one external voltage source (not shown) .

[0081] Referring now to Figure 15A and 15B, illustrated is another exemplary embodiment of

the physically adaptable contact means 1501. The contact element 1501A is a thin electrically conductive foil that is fixed to the substrate holder 101 along the periphery by an airtight seal, such as an o-ring, lip-seal or a glued seal, or with a mechanical fixture, such as a clamping ring. An overpressure may be established in the volume enclosed between the contact element 1501A and the substrate holder 101 via nozzles (not shown) in the substrate holder 101, i.e. proximally of said contact element 1501A. When the substrate holder 101, together with the pressurized contact element 1501A, is subsequently pressed against the conductive substrate 102, the contact element 1501A is deformed to reach into the cavities formed by the back side insulating layer 103A, thereby establishing electrical contact with the conductive substrate 102.

[0082] Referring now to Figure 15C and 15D, illustrated is an alternative embodiment of the device shown in Figure 15A and 15B. Here, the contact element has been divided into concentric circles that are electrically insulated from each other. The resulting contact elements 1501A may then be connected in parallel to a common voltage or may be connected individually, or in groups of at least two contact elements 1501A, through the substrate holder 101, via an interconnection structure (not shown), to at least one external voltage source (not shown), for instance connecting various voltages or currents to different individual or groups of contact elements. A trench 1503 may be formed between the circle segments and valves 1502 may be arranged in the trench in order to provide an under-pressure outside the volume enclosed between the contact elements 1501A and the substrate holder 101. Such an under-pressure may be in addition to the overpressure described above. The purpose of the under-pressure is to improve surface adaptability of the contact element 1501A. The contacting parts 701A, 901A, 1001, 1101A, 1201A, 1203, 1301A, 1401A and 1501A may be made of a durable, relatively flexible material of high electrical conductivity, that is resistant to chemicals and corrosion, such as a metal selected from Cu, Au, Pt, Pd, Ti or steel, or of metal alloys. They may also be coated with a metal layer or be made of an insulating material that is coated with a metal layer. The coating may be selected from durable and chemically resistant materials, such as Pt, Pd, Ir, Au or mixed conductive oxides.

[0083] The interconnection structure 701B, 901B, 1101B and any interconnection structure of Figures 12, 13, 14 and 15 (not shown) may be provided with resistors, particularly variable resistors, and resistance meters, or any other means as deemed appropriate, in order to exercise control over the different voltages applied to different parts of the conductive substrate 102 while only using one external potential. Control of the variable resistors and the display of measured values are linked to the external unit 112 of Figure 1.

[0084] The interconnection structure 701B, 901B, 1101B and any interconnection structure of Figures 12, 13, 14 and 15 (not shown) may also be provided with switches to allow the electrical connection or disconnection of different parts of the contact means.

[0085] Said at least one external power supply or voltage source may have multiple channels for supplying, and/or controlling, different potentials and/or currents to different individual contact means or groups of contact means .

[0086] In any embodiment of the invention it is also possible to introduce an additional insulating layer or film, which may be patterned, between the substrate holder 101 and the conductive substrate 102. The purpose of such an insulating layer or film is to cover certain exposed contact areas 203 should modifications to the backside insulating layer 103A be required. Said insulating layer may be easily removable or exchangeable in order to easily modify the shape or size of exposed contact areas 203 for different applications, such as for different conductive substrates with different front or back side insulating pattern or conducting material.

[0087] The embodiments disclosed in figures 7 to 15 may comprise the air ducts and nozzles 308, disclosed in figures 1 and 3 to 6, and the specification related thereto according to above. Such air ducts and nozzles may be located behind the layers disclosed in figures 12 to 15, if these different layers are permeable to air and/or other gases, such as nitrogen. If the layers disclosed in figures 12 to 15 are not permeable to air and/or other gases, such as nitrogen, the different layers may be provided with locally situated channels through the layers, corresponding to the nozzles 308 in the front surface of the substrate holder 101, whereby pressure or underpressure still may be provided in the inner space 306, in accordance with the other embodiments described in connection to figures 1 to 6.

[0088] In the same way the embodiments disclosed in figures 7 to 15 may comprise the pressure actuators 502A and 502B, disclosed in figure 5, and the specification related thereto according to above. Such pressure actuators 502A and 502B may then run in channels through layers disclosed in figures 12 to 15, whereby the actuators still may grip the substrate 102, in accordance with the other embodiments described in connection to figure 5.

[0089] Substrate holders according to embodiments of the present invention may be used for the fabrication and preparation of a master electrode, i.e. an electrode in the form of a conductive substrate on which an insulating layer forms a pattern of cavities, in which cavities the conductive surface of the substrate is exposed. During the preparation of the master electrode the substrate holder immerses the substrate in an electrolyte and a metal is deposited by electroplating in the cavities on the front side of the substrate, while keeping the backside sealed off from the electrolyte. In a subsequent electrochemical pattern replication (ECPR) process the substrate is used as a master electrode to fabricate electronic components, waveguides, etc.

[0090] The substrate holder according the invention greatly improves control over the deposition process by allowing the electrical contact means to physically adapt to any pattern layout of the substrate and by allowing exact control of the voltage applied to different parts of the substrate .

[0091] Although the present invention has been described above with reference to specific illustrative embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the invention is limited only by the accompanying claim.

[0092] In the claim, the term "comprises/comprising" does not exclude the presence of other elements or steps. In addition, singular references do not exclude a plurality. The terms "a", "an", "first", "second" etc do not preclude a plurality. Reference signs in the claims are provided merely as a clarifying example and shall not be construed as limiting the scope of the claims in any way.

REFERENCES CITED IN THE DESCRIPTION

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Patentkrav

1. Substratholder til at holde et ledende substrat under plettering deraf, der omfatter
- 5 et fastgørelsesmiddel til at fastgøre det ledende substrat på substratholderen, således at en første overflade af substratholderen vender mod den anden side af det ledende substrat; og elastisk kontaktmiddel, der er fastgjort til den første overflade af substratholderen, og som kan forbindes til
- 10 i det mindste et udvendigt potentiale, der omfatter et elastisk lag (1402), som er påført på den første overflade af substratholderen (101), hvor kontaktelementet (1401A) er en eftergivende og ledende folie distalt for det elastiske lag (1402).

DRAWINGS

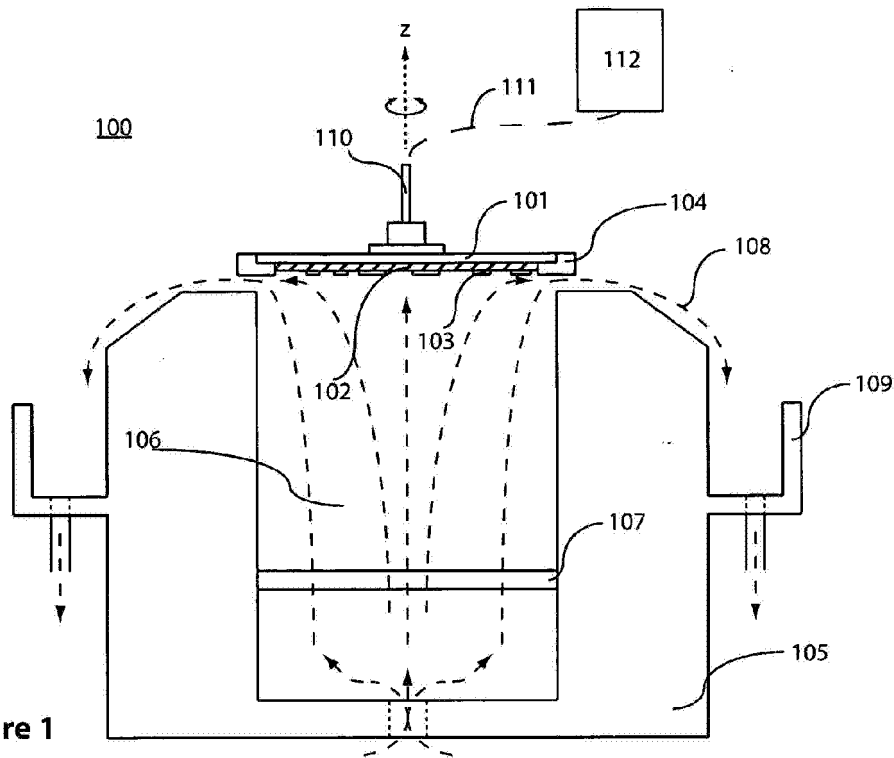


Figure 1

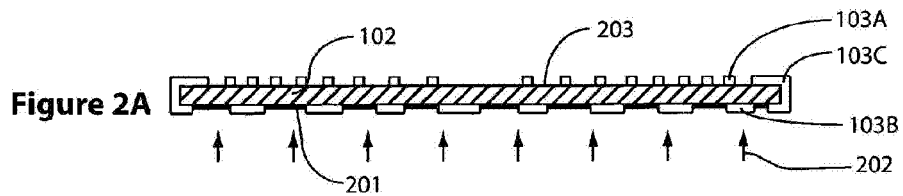


Figure 2A

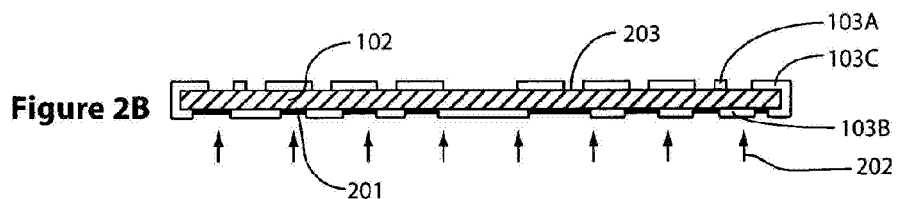


Figure 2B

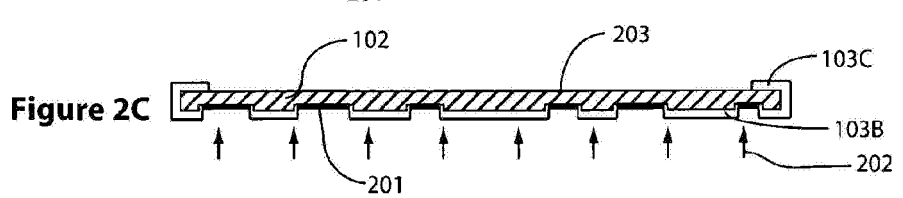
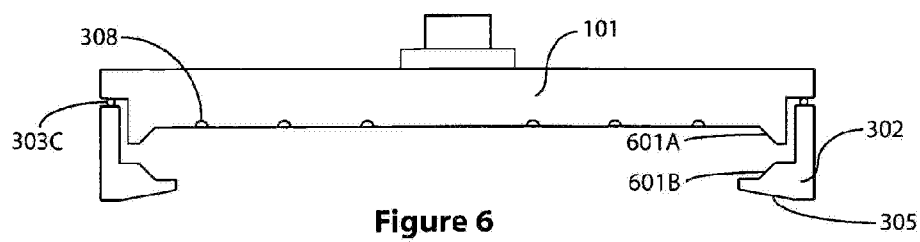
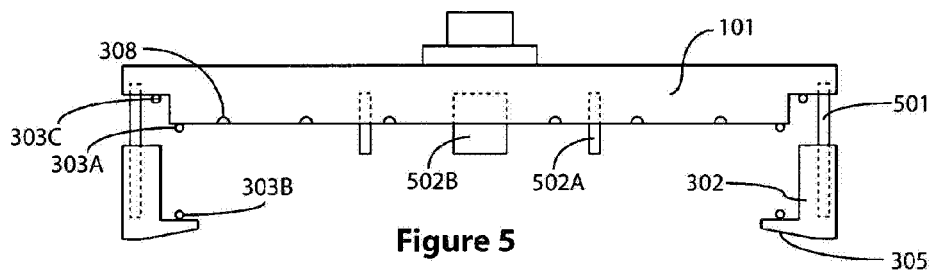
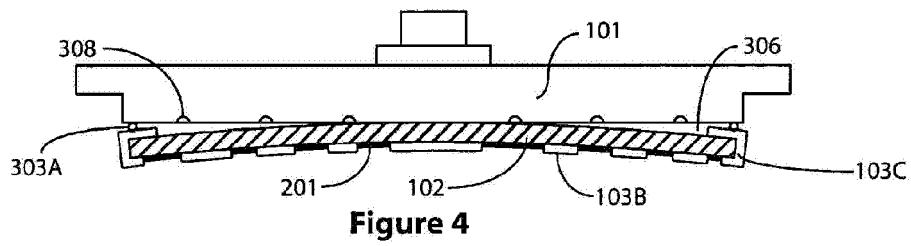
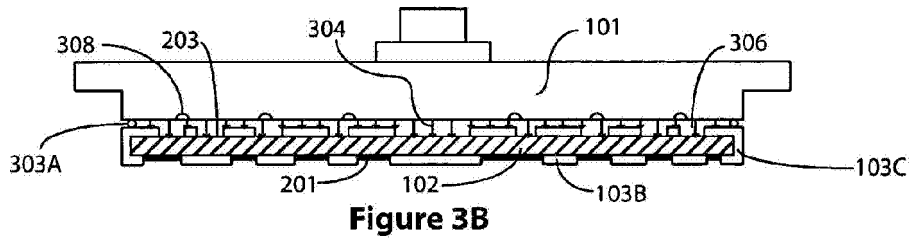
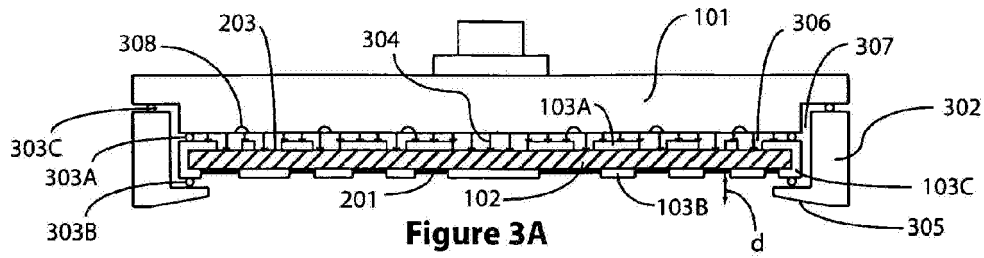


Figure 2C



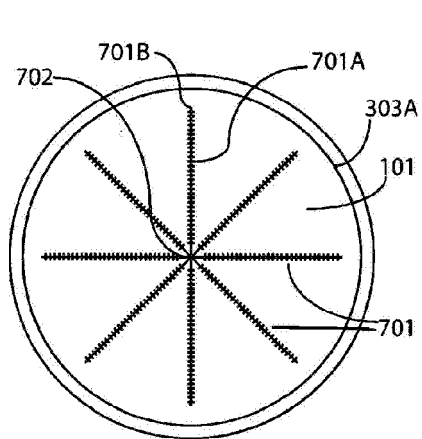


Figure 7

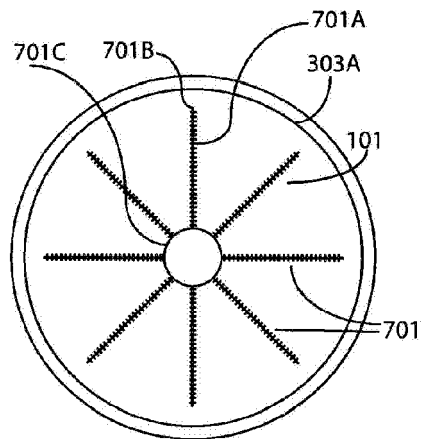
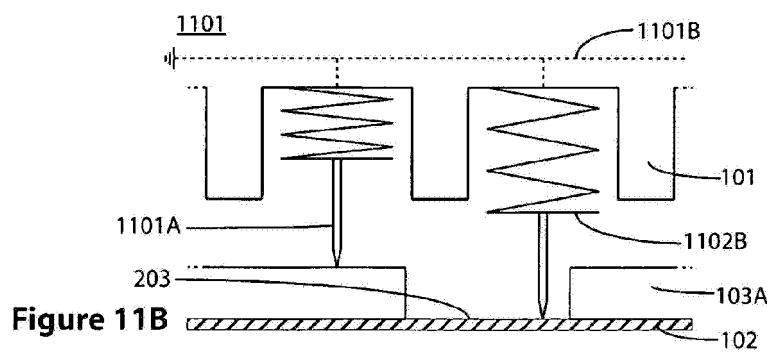
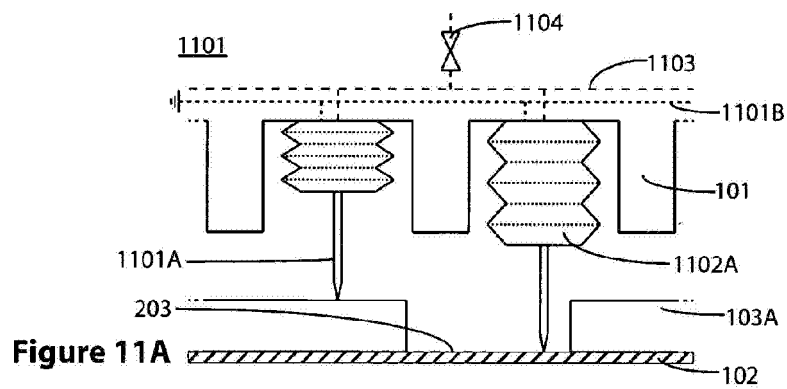
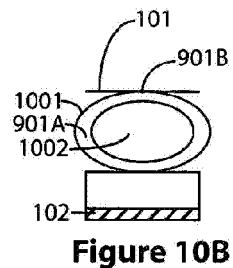
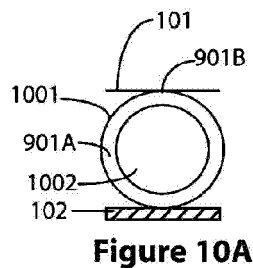
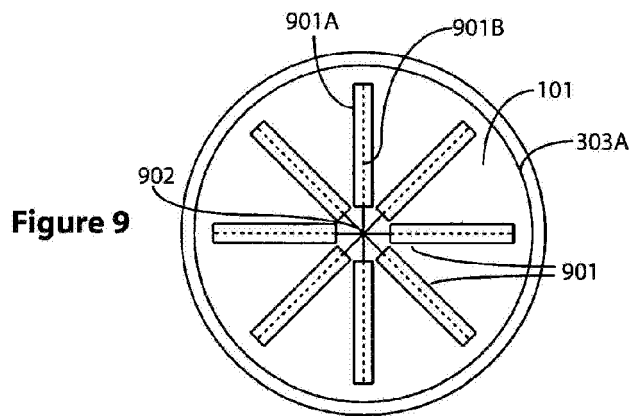
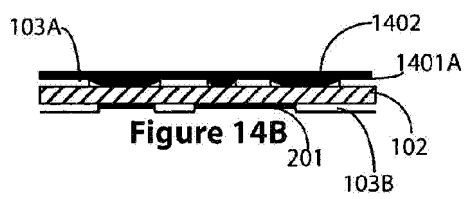
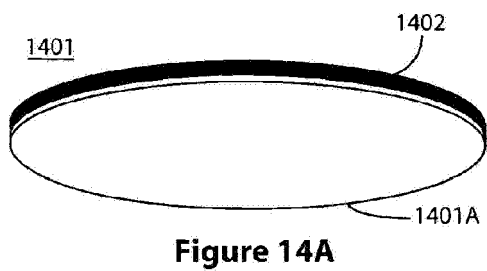
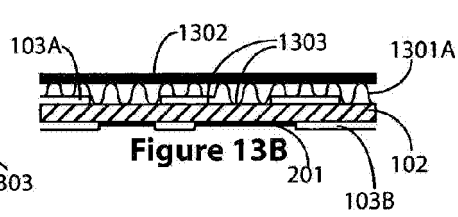
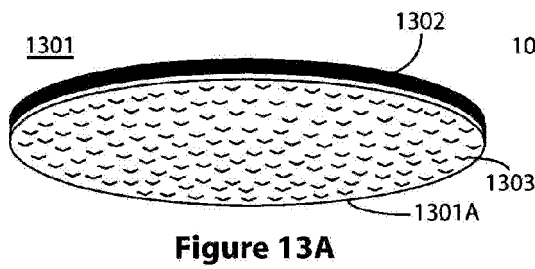
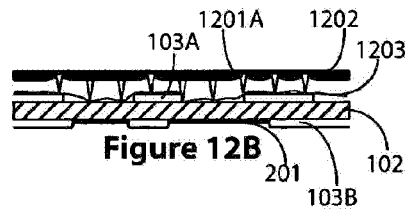
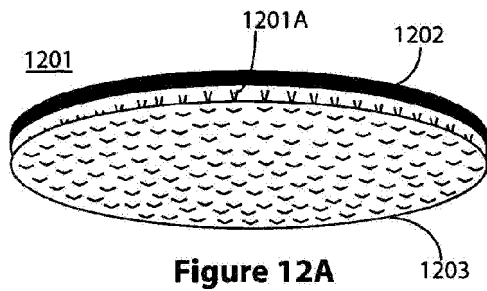


Figure 8





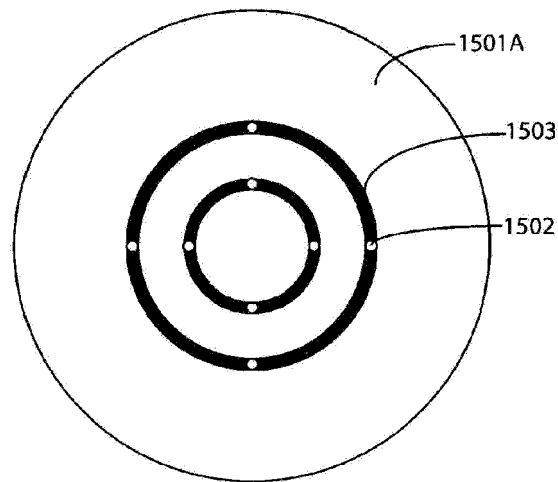
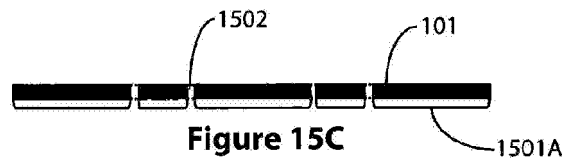
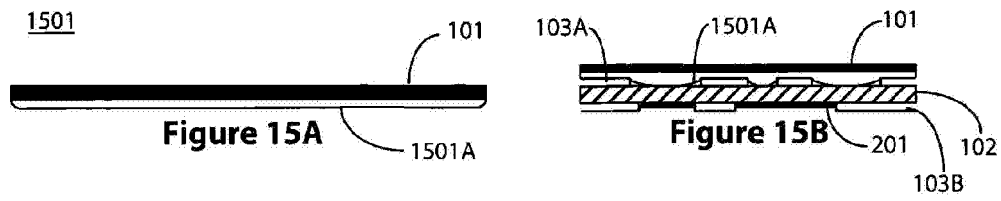


Figure 15D