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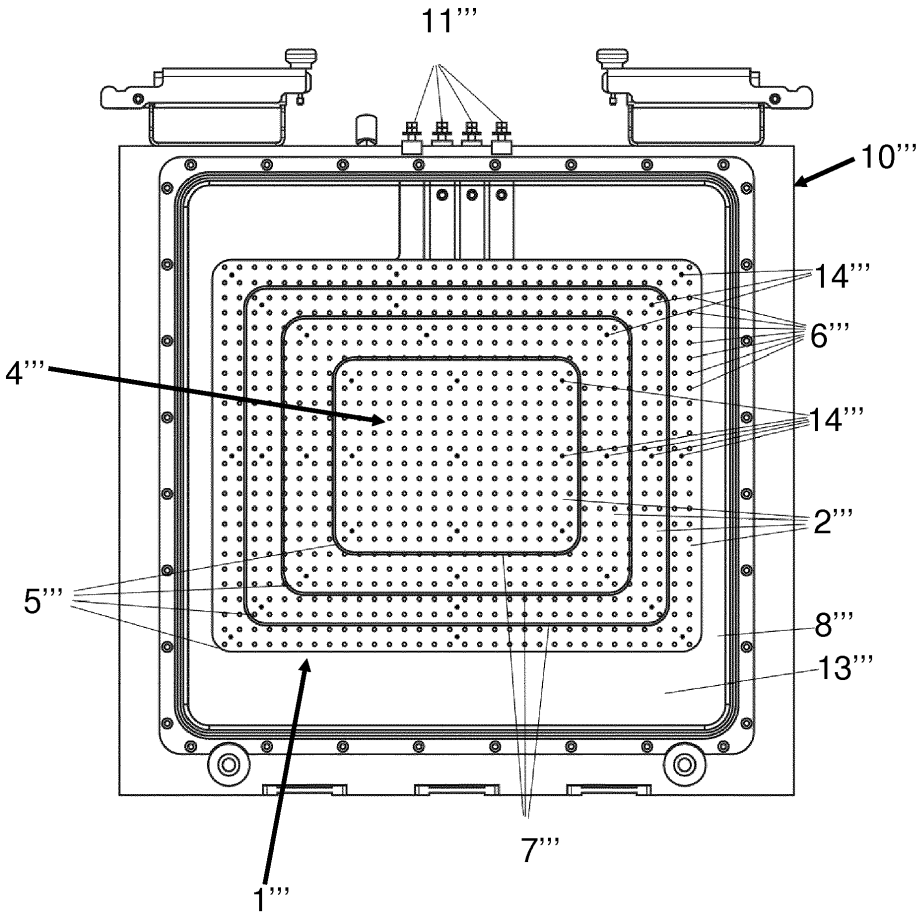
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(54) **SEGMENTED ANODE**

(57) The present invention refers to an anode providing improved coatings during electroplating, a module containing said anode and a treatment device containing said anode or module. Furthermore, the present invention refers to a method providing an improved coating using electroplating. Additionally, the present invention refers to the use of the inventive anode for electroplating.

Fig. 3a



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Description

Field of the Invention

[0001] The present invention refers to an improved type of anode and its use in galvanic coating processes. Furthermore, the present invention refers to a method of galvanic coating using such an improved type of anode.

Background of the Invention

[0002] Anodes used for, for example, electroplating are commonly known in the art. They are typically used as counter electrode to deposit a galvanic metal onto the surface of a substrate.

[0003] Despite the general concept of the anode being commonly known the recent developments, for example, in the field of electronics provide additional requirements. For example, the ongoing miniaturization requires a far more constant and reliable coating of conductive metals to provide circuit paths ready for the next generation of circuit boards.

[0004] Also, the requirements for integrated circuits are constantly increasing resulting in the search for improved ways to provide a very thin and constant coating on the surface of a wafer. Herein, the need for a decrease of the production time and low amount of space available for especially clean room processes presents a particular challenge to be solved to stay competitive and constantly provide new and improved products to the market.

Objective of the present Invention

[0005] Thus, it is an objective of the present invention to provide a new type of anode providing an improved coating for high quality products.

Summary of the Invention

[0006] The aforementioned problems are solved by the invention as disclosed in the independent claims and the description. Further modifications providing additional benefits are included in the dependent claims and the following description. However, even further benefits not being explicitly stated herein but being immediately derivable or discernible from the connections discussed herein are solved by the present invention and its embodiments disclosed herein.

[0007] The present invention refers to a segmented anode containing at least two, more preferred at least three, even more preferred at least four, anode segments, anode segment complexes or combinations thereof, wherein each anode segment or anode segment complex provides a front side, wherein the front side contains a front side area, wherein the at least two anode segments, anode segment complexes or combinations thereof provide an average front side area, wherein the front side area of each of the anode segments, anode segment complexes or combinations thereof deviates less than 20 %, more preferred less than 15 %, even more preferred less than 11 %, even more preferred less than 7 %, even more preferred less than 4 %, from the average front side area of the anode segments, anode segment complexes or combinations thereof.

[0008] Furthermore, the present invention refers to a module containing at least one inventive segmented anode and at least one carrier element detachably connected to the segmented anode.

[0009] Furthermore, the present invention refers a treatment device for electroplating, preferably for vertical electroplating, comprising an inventive segmented anode or an inventive module.

[0010] Furthermore, the present invention refers to a method for electroplating of a substrate using an inventive segmented anode or an inventive treatment device, wherein at least two, more preferred at least three, even more preferred at least four anode segments, anode segment complexes or combinations thereof are controlled or regulated separately.

[0011] Furthermore, the present invention refers to an use of at least one inventive segmented anode, at least one inventive module, or at least one inventive treatment device, for electroplating, preferably vertical electroplating.

Brief Description of the Figures

[0012] For a more complete understanding of the present invention, reference is made to the following Detailed Description of the Invention considered in conjunction with the accompanying figures, in which:

Fig. 1 shows a schematic front view of an inventive module of a preferrred first embodiment containing an inventive segmented anode mounted onto a carrier element.

Fig. 2a shows a schematic front view of an inventive module of a preferred second embodiment containing an inventive segmented anode mounted onto a carrier element.

Fig. 2b shows a schematic perspective view of the inventive module of the preferred second embodiment containing an inventive segmented anode mounted onto a carrier element.

Fig. 3a shows a schematic front view of an inventive module of a preferred third embodiment containing an inventive segmented anode mounted onto a carrier element.

Fig. 3b shows a schematic perspective view of the inventive module of the preferred third embodiment containing an inventive segmented anode mounted onto a carrier element.

Fig. 4 shows a schematic front view of an inventive module of a preferred fourth embodiment containing an inventive segmented anode mounted onto a carrier element.

Detailed Description of the Invention

[0013] The present invention refers to a segmented anode containing at least two anode segments, anode segment complexes or combinations thereof, wherein each anode segment or anode segment complex provides a front side, wherein the front side contains a front side area, wherein the at least two anode segments, anode segment complexes or combinations thereof provide an average front side area, wherein the front side area of each of the anode segments, anode segment complexes or combinations thereof deviates less than 20 %%, more preferred less than 15 %, even more preferred less than 11 %, even more preferred less than 7 %, even more preferred less than 4 %, from the average front side area of the anode segments, anode segment complexes or combinations thereof. It was noted that segmented anodes providing at least three, even more preferred at least four, anode segments, anode segment complexes or combinations thereof typically provides especially advantageous results. Such segmented anodes typically proved to be especially useful for treating substrates providing a front side area of at least 150 cm^2. Preferably, all anode segments and anode segment complexes of the segmented anode provide such front side area. Herein, it has to be noted that the front side area of an anode segment complex refers to the total front side area of the anode segments representing the anode segment complex.

[0014] The term "anode segment" as used herein refers to a single part of the segmented anode being adapted to be controlled or regulated separately from the other anode segments and anode segments complexes of the segmented anode.

[0015] The term "anode segment complex" as used herein refers to a combination of at least two anode segments, wherein said combination is adapted to be controlled or regulated separately from the other anode segments or anode segments complexes.

[0016] The term "front side" according to the present invention refers to the surface of the segmented anode, the anode segment or the anode segment complex adapted to be directed towards the substrate unless stated otherwise. The front side areas are determined by projecting the front side of the corresponding anode segment or anode segment complex along lines parallel to the axis of the segmented anode onto a plane perpendicular to the axis of the segmented anode. Herein, openings located on the front side resulting from through going conduits or fastening elements are disregarded for calculating the front side area.

[0017] Unless specified otherwise an "average" value as used herein refers to the arithmetic mean of said value calculated based on the sum of a certain number of values divided by their number (average value = sum of measured values / number of measured values). To achieve a statistical significant value at least a certain number of values have to be used for calculating said value, for example, at least 10, for example 10, values. The number of measurements, however, can be increased, for example, to at least 50, for example 50, or at least 100, for example 100, if the fluctuation of the values is high. Referring to the average thickness of the organic polymeric coating at least 10 measurements are taken, wherein the measurements are randomly selected and located in the area of the transport roller adapted to contact the substrate.

[0018] The term "average front side area" according to the present invention refers to the arithmetic mean of the front side areas of the anode segments, anode segment complexes or combinations thereof.

[0019] The phrase "axis of the segmented anode" according to the present invention refers to the line going through the center of the segmented anode being perpendicular to the front side of the segmented anode adapted to be directed towards the substrate.

[0020] Surprisingly, it was noted that splitting up the anode in such way allowed a very simple and efficient way to further improve the quality of the coating of the substrate during electroplating, especially vertical electroplating. It was noted that even applying the same current to each anode segment or anode segment complex already improved the quality of the coating. However, it was also noted that the inventive segmentation of the surface of the anode also provides very good results for optimizing the currents applied to each of the anode segments or anode segment complexes. It appears that the inventive segmentation of the anode correlates to typical fluctuations of the coating and varying the current according to the observations of a low number of test substrates allows to easily identify the ideal parameters for coating a substrate. Said effect seems to be typically especially pronounced, if the deviation from the average front side area of the anode segments, anode segment complexes or combinations thereof is less than 15 % and especially less than 11 %. However, using corresponding anode segments or anode segment complexes deviating less than 7 % or more preferred less than 4 % still provide a further increased effect, although, it seems to be typically less pronounced.

[0021] In further embodiments of the present invention the anode segments, anode segment complexes or combinations thereof are arranged in a shell like form. Herein, it is preferred that at least one, more preferred at least two, anode segments or anode segment complexes form a layer surrounding at least one more interior anode segment or anode segment complex.

[0022] The phrase "arranged in a shell like form" according to the present invention refers to an arrangement of the corresponding anode segments or anode segment complexes, wherein the front sides of at least one anode

segment or anode segment complex forms a center part and at least one, more preferred at least two, even more preferred at least three of the remaining specified anode segments or anode segment complexes form layers surrounding the center part and each more interior anode segment or anode segment complex. A preferred example of such arrangement of a shell like form is the concentric arrangement. It was noted that such layered structures provide a good balance of possibilities to compensate minor differences in the coating, while the number of parameters to be adjusted can be kept low.

[0023] In further embodiments of the present invention the segmented anode provides at least one, more preferred at least two, even more preferred at least three, layers of the shell like form being an anode segment. It was noted that using many anode segments being coupled to anode segments complexes can provide problems during long term run, if, for example, an electrical contact of an anode segment of an anode segment complex is partially covered and not sufficiently cleaned before fastening a new anode segment during maintenance. Reducing the number of required contacts by, for example, using single anode segments instead of anode segment complexes provide an increased security for the long term usage.

[0024] In further embodiments of the present invention the segmented anode provides essentially no gaps between the anode segments or anode segment complexes. The phrase "essentially no gaps" according to the present invention refers to forms and arrangements of anode segments and anode segments complexes, wherein the distance between two anode segments or an anode segment and an isolator layer separating at least two anode segments is less than 3 mm, more preferred less than 2 mm, even more preferred less than 1 mm.

[0025] In further embodiments of the present invention at least the front sides of the anode segments, anode segment complexes or combinations thereof surrounded by the most exterior layer of the anode segments provide rounded edges. Preferably all edges of the front sides of the anode segments or anode segments complexes directed towards edges of other anode segments or anode segment complexes are rounded.

[0026] In further embodiments of the present invention the anode segments or anode segment complexes are insoluble. Such inventive anodes typically provide very good results while the maintenance is simplified and the downtime is reduced.

[0027] In further embodiments of the present invention each of the anode segments or anode segment complexes provides an outer shape, wherein the outer shape provides at least one symmetry selected from the group consisting of point symmetry, rotational symmetry and mirror symmetry, more preferred from the group consisting of point symmetry and rotational symmetry. Preferably, the reference point of the point symmetry, the rotational symmetry or both is the center of the front side of the segmented anode and the mirror symmetry is based on a plane going through said center. Typically, it is even preferred that the anode segment or anode segment complexes provide at least two of the aforementioned symmetries. The use of such symmetric anode segments greatly simplifies the regulation of the current applied to the anode segment or anode segment complexes to adapt the electric field to specific substrates or different treatment solutions to further increase the quality of the coating on the substrates.

[0028] In further embodiments of the present invention the anode segments, anode segment complexes or combinations thereof provide an outer shape, wherein the outer shape of at least one anode segment or anode segment complex, more preferred of at least two anode segments, anode segment complexes or combinations thereof, even more preferred at least three anode segments, anode segment complexes or combinations thereof, is essentially circular, essentially elliptical or essentially polyangular, more preferred essentially circular or essentially rectangular. Preferably all anode segments and anode segments complexes provide such shape. It was noted that using such anode segment or anode segment complex shape provides a greatly simplified adaption of the currents to specific substrates and treatment liquids.

[0029] Such polyangular outer shapes preferably provide at most eight, more preferred at most six, even more preferred at most four, corners. Herein, it has to be noted that said corners are preferably rounded. An especially preferred form of the polyangular shaped anode segments are rectangular shaped anode segments like square shaped anode segments.

[0030] The term "outer shape" according to the present invention refers to the shape of the outer edges of the front side of the anode segment or the complete anode segment complex projected along lines parallel to the axis of the segmented anode onto a plane perpendicular to said axis unless specified otherwise.

[0031] The phrase "essentially circular" according to the present invention preferably refers to an outer shape deviating less than 10%, more preferred less than 7%, even more preferred less than 3 % from an ideal circle, based on the surface area of the ideal circle. Herein, the outer shape is approximated using an ideal geometrical circle and the lowest difference between the real outer shape and an ideal geometrical area is used.

[0032] The phrase "essentially elliptical" according to the present invention preferably refers to an outer shape deviating less than 8%, more preferred less than 6%, even more preferred less than 4 % from an ideal ellipse, based on the surface area of the ideal ellipse.

[0033] The phrases "essentially polyangular", "essentially rectangular" and "essentially square" according to the present invention preferably refers to a form deviating less than 12%, more preferred less than 8%, even more preferred less than 5 % from an ideal polyangular shape, an ideal rectangular shape, or an ideal square shape,

based on the surface area of an ideal polyangular shape, rectangular shape or square shape.

[0034] In further embodiments of the present invention each of the anode segments, anode segment complexes or combinations thereof provides an outer shape, wherein the corners of the outer shape of essentially polyangular anode segments or anode segment complexes being directed to other anode segments or anode segment complexes of the segmented anode are rounded. Preferably, the corners of the outer shape of all essentially polyangular anode segments or anode segment complexes of the segmented anode are rounded. Typically, it was noted that such essentially uniform curvature provides a further increased homogeneity of the applied coating. It is assumed that this results from a more consistent electric field avoiding a point source concentration of the field at the corners.

[0035] In further embodiments of the present invention the anode segments, anode segment complexes or combinations thereof provide through going conduits from the backside of the anode segment or anode segment complex to the front side of the anode segment or anode segment complex. The term "back side" according to the present invention refers to the side of the anode segment or anode segment complex being opposite to the front side. Such types of segmented anodes typically allowed a very efficient and homogenous transport of the treatment liquid to the substrate avoiding local points and areas of concentrated or depleted treatment liquid. Typically it is preferred that all anode segments or anode segment complexes of the inventive segmented anode provide through going conduits.

[0036] In further embodiments of the present invention the segmented anode provides an arrangement of through going conduits on the front side of the segmented anode, wherein at least 50 %, more preferred at least 70 %, even more preferred at least 90 %, of the through going conduits provide at least one symmetry selected from the group consisting of point symmetry, rotational symmetry and mirror symmetry, more preferred from the group consisting of point symmetry and rotational symmetry. Preferably, the reference point of the point symmetry, the rotational symmetry or both is the center of the front side of the segmented anode and the mirror symmetry is based on a plane going through said center. Typically it is beneficial, if the front side of the segmented anode provides at least two of the aforementioned symmetries. Such arrangement on the front side refers to the arrangement of the openings of said through going conduits located on the front side of the segmented anode. It was noted that providing at least one of such symmetry, preferably at least two of such symmetries, typically provides a simplified adaption of the fluid stream according to the chosen substrate and the current used for coating to provide even further improved results.

[0037] In further embodiments of the present invention the front side area of each anode segment or anode segment complex is at least 20 cm^2, more preferred at least 30 cm^2, even more preferred at least 35 cm^2. Using smaller anode segments or anode segment complexes typically provides a less pronounced beneficial effect.

[0038] In further embodiments of the present invention the front side area of each anode segment or anode segments complex is at most 300 cm^2, more preferred at most 200 cm^2, even more preferred at most 170 cm^2. Using bigger anode segments or anode segment complexes typically provides a greatly increased complexity of regulating the current applied to said anode segments or anode segment complexes to further increase the quality of the coating.

[0039] In further embodiments of the present invention the front side area of each anode segment or anode segments complex is selected from the range from 20 cm^2 to 300 cm^2, more preferred from 30 cm^2 to 200 cm^2, even more preferred from 35 cm^2 to 170 cm^2.

[0040] In further embodiments of the present invention the segmented anode provides at least two, more preferred at least three, even more preferred at least four, contacts, wherein each contact is adapted to electrically connect one anode segment or one anode segment complex to a treatment device to supply current to the segmented anode for electroplating.

[0041] In further embodiments of the present invention the at least two, more preferred at least three, even more preferred at least four, anode segments, anode segment complexes or combinations thereof are separated by an isolator layer. Such isolator layer allows decreasing the distance between the anode segments, anode segment complexes or combinations thereof to provide a further increased homogeneity of the electric field. Such isolator layer can be, for example, placed on the sides of the anode segments or anode segment complexes. Such isolator layer ensures to provide a new isolator layer when the segmented anodes are replaced during maintenance. However, such isolator layer can also be, for example, integrated in a carrier element used to fasten the anode segments in a treatment device. In such cases the isolator layers can also provide a form to easily identify the exact position of each anode segment to be attached during assembly to simplify maintenance. Naturally, a combination of the aforementioned isolator layers can be used to provide an increased security to isolate the anode segments or anode segments complexes from each other.

[0042] Furthermore, the present invention refers to a module containing at least one inventive segmented anode and at least one carrier element detachably connected to the segmented anode.

[0043] The term "module" as used herein refers to a subunit of, for example, a treatment device. Preferably, such subunit can be easily removed from a treatment device to, for example, adapt the treatment device for different substrates or treatments or to replace parts of the module during maintenance. For example, such module can be a subunit of the treatment device being adapted to certain substrates or treatment liquids. Herein, the

inventive module provides the segmented anode being mounted onto a carrier element, wherein it is preferred that said segmented anode can be exchanged separately or along with the carrier element. Such modular construction allows to easily replace the anode segments during maintenance or adapt the module to, for example, substrates of a different size by replacing the carrier element as well as the segmented anode. However, it can also be preferred that only the segmented anode can be easily exchanged and to firmly attach the carrier element to the module to, for example, increase the long term stability of the module. The inventive treatment devices can be easily adapted to new treatment methods using, for example, very specific new treatment liquids by easily replacing the whole module with a new module being able to, for example, provide a different flow rate or being able to process treatment liquid providing a higher viscosity. Also, such modules easily allow to quickly change from one deposition step to another, as the simple exchange of the complete module avoids difficult rinsing processes to, for example, adapt the treatment device to the deposition of a different galvanic metal.

[0044] As used herein, the term "galvanic metal" refers to metals which are known to be suitable for electroplating, preferably vertical electroplating. Such galvanic metals contain gold, nickel, and copper, preferably copper.

[0045] In further embodiments of the present invention the module is used for vertical electroplating. Herein, the use of the inventive module provide the possibility to easily exchange the whole arrangement of segmented anode, carrier element and module providing, for example, a specific segmentation, size of the segmented anode, through goings conduits, and treatment liquid supply to greatly reduce the downtime resulting from, for example, maintenance or adaption of the treatment device to new treatments or substrates. This becomes, for example, especially useful for the inventive segmented anode, as the multiple anode segments require a higher amount outer shape provides at least one symmetry of time to be exchanged and the use of multiple small anode segments and their arrangement to each other require a higher precision than, for example, simply replacing a single big anode plate.

[0046] In further embodiments of the present invention the carrier element provides through going conduits adapted to provide a fluid stream from the backside of the carrier element through the through going conduits of the carrier element and the through going conduits of the anode segments to the front side of the segmented anode. Such carrier elements provide a simple and efficient distribution of the treatment liquid and increase the length of the through going conduit resulting in a more uniform stream of the treatment liquid.

[0047] In further embodiments of the present invention the segmented anode is mounted onto a carrier element adapted to provide electric current to the segmented anode. Integrating the electrical connection into the carrier element of the treatment device proved to be especially useful to secure the contacting of each and every anode segment. It was noted that providing a separate contacting to the anode segments provides the possibility of failures during assembly while exchanging the anode segments during maintenance. Integrating the contacts into the carrier element decreased corresponding dangers

[0048] In further embodiments of the present invention the carrier element provides at least one fastening element for each anode segment adapted to be controlled or regulated separately or being part of an anode segment complex adapted to fasten the anode segment or anode segment complex to the carrier element, wherein the at least one fastening element is adapted to supply electric current to the anode segment or wherein the carrier element provides at least one contact for each anode segment being controlled or regulated separately or being part of an anode segment complex not being integrated into the fastening element, or combinations thereof. Integrating the electrical supply into the fastening elements of the carrier element provides the benefit that fastening the anode segment to the carrier element simultaneously establishes the electrical connection and provides a reliable contacting without additional steps. Typically, it was preferred that the carrier element provides at least one fastening element being adapted to supply electric current for each of at least 60 %, more preferred at least 80 %, even more preferred all, of the anode segments adapted to be controlled or regulated separately or being part of an anode segment complex. Integrating the electrical supply into the parts of the carrier element not being adapted to fasten the anode segment to the carrier element typically increased the effort required during exchange of the anode segments during maintenance, however, for example provides requirements regarding the type and material of the fastening elements.

[0049] In further embodiments of the present invention the module provides at least one inlet and at least one connection from the inlet to the through going conduits of the carrier element adapted to provide a flow of the treatment liquid from said inlet to the through going conduits of the carrier element and the through going conduits of the segmented anode to the substrate. Typically, it is preferred that the module further contains a treatment liquid chamber being connected to the through going conduits of the carrier element. Such arrangement allows to easily connect and distribute the treatment liquid to the through going conduits of the carrier element and the segmented anode.

[0050] In further embodiments of the present invention the at least one fastening elements adapted to supply electric current to the anode segment contains at least one element selected from the group of clips, screws, bolts and spring locks, more preferred form the groups of screws and spring locks adapted to fasten the anode segment to the carrier element. According to further embodiments it is especially preferred that the at least one fastening element contains a screw. Using such fasten-

ing element proved to typically provide a reliable fastening and electrical supply to the segmented anode.

[0051] In further embodiments of the present invention the carrier element provides a front side adapted to be directed towards the segmented anode, wherein the front side of the carrier element provides recesses adapted to receive the anode segments. Preferably, the front side of the carrier element is shaped to provide an aligned transition from the front side of the carrier element not directly contacting with the segmented anode to the front side of the segmented anode. Such aligned arrangement provides a more homogenous flow of the treatment liquid along the front side of the substrate.

[0052] In further embodiments of the present invention the carrier element provides at least two, more preferred at least three, even more preferred at least four, contacts, wherein each contact is electrically connected to one anode segment or one anode segment complex and the contact is adapted to supply current to the anode segment or anode segment complex for electroplating.

[0053] Furthermore, the present invention refers a treatment device for electroplating comprising an inventive segmented anode or an inventive module.

[0054] In further embodiments of the present invention the segmented anode is mounted onto a carrier element adapted to provide electric current to the segmented anode. Such defined carrier element provides the benefit to exactly place the anode segments and electrically contact the anode segment without the need to contact each anode segment separately. Such assembly, for example, shortens the required time during maintenance.

[0055] In further embodiments of the present invention the treatment device is a device for vertical electroplating. It was noted that the inventive segmented anodes proved to be especially useful for vertical electroplating devices providing a defined position of the substrate to be treated during treatment. Herein, the substrate is preferably first placed in front of the segmented anode before the electroplating process is started.

[0056] In further embodiments of the present invention the carrier element provides at least one fastening element for each anode segment adapted to be controlled or regulated separately or being part of an anode segment complex adapted to fasten the anode segment to the carrier element, wherein the at least one fastening element is adapted to supply electric current to the anode segment or wherein the carrier element provides at least one contact for each anode segment adapted to be controlled or regulated separately or being part of an anode segment complex to supply electric current to the anode segment, wherein said contact is not integrated into a fastening element, or combinations thereof.

[0057] In further embodiments of the present invention the at least one fastening elements adapted to supply electric current to the anode segment contains at least one element selected from the group of clips, screws, bolts and spring locks, more preferred from the groups of screws and spring locks adapted to fasten the anode segment to the carrier element. Using screws proved to the especially beneficial

[0058] In further embodiments of the present invention the carrier element provides a front side adapted to be directed towards the segmented anode providing recesses adapted to receive the anode segments, anode segment complexes or combinations thereof.

[0059] Furthermore, the present invention refers to a kit containing at least one inventive segmented anode and at least one carrier element adapted to receive the anode segments, anode segment complexes or combinations thereof.

[0060] Furthermore, the present invention refers to a method for electroplating of a substrate using an inventive segmented anode, an inventive module, or an inventive treatment device, wherein at least two, more preferred at least three, even more preferred at least four anode segments, anode segment complexes or combinations thereof are controlled or regulated separately.

[0061] In further embodiments of the present invention at least two, more preferred at least three, even more preferred at least four, different currents are applied to different anode segments, anode segment complexes or combinations thereof at the same time. Preferably, such different currents are applied over at least 50 % of the processing time. The term "processing time" according to the present invention refers to the time a substrate is treated using the inventive segmented anode, wherein a current is applied to the segmented anode. Such application of different currents to different zones of the segmented anode allows to adapt the coating to the specific substrate and treatment liquid to further improve the coating.

[0062] Furthermore, the present invention refers to an use of at least one inventive segmented anode, at least one inventive module, or at least one inventive treatment device, for electroplating, preferably vertical electroplating.

[0063] It was noted that the inventive anodes, inventive modules and inventive treatment devices proved to be especially useful for vertical electroplating. Such process can be, for example, used to deposit galvanic metals like copper or nickel onto a surface of a semiconductor wafer. Herein, the inventive anodes, modules and treatment devices provide an improved coating, wherein the embodiments as disclosed in the detailed description provides further improvements to fulfill specific requirements especially when combining several embodiments as disclosed herein.

[0064] The following non-limiting examples are provides to illustrate preferred embodiments of the present invention and to facilitate understanding of the invention, but are not intended to limit the scope of the invention, which is defined by the claims appended hereto.

[0065] Figure 1 shows a schematic front view of an inventive module 10' of a preferred first embodiment containing an inventive segmented anode 1' mounted onto a carrier element 8'. The segmented anode 1' contains

a front side 4' with two anode segments 2'. These anode segments 2' provide the same front side area. The anode segments 2' of the segmented anode 1' as shown in Figure 1' are separated by an isolator layer 7'. Herein, the carrier element 8' of Figure 1 is made from a transparent material showing the treatment liquid chamber 13' behind said carrier element 8'.

[0066] The two anode segments 2' are in a shell like form, wherein the outer most anode segment 2' forms a layer surrounding the other anode segment 2'. Herein, the outer shape of the anode segments 2' provides point symmetry, rotational symmetry and mirror symmetry. Additionally, the two anode segments 2' show through going conduits 6' reaching from the backside of the anode segment 2' to the front side 4' of the anode segment 2'. Herein, the through going conduits 6' are shown greatly magnified to increase the visibility of the openings of said through going conduits 6' in the Figure. Said magnification results in an overlapping of said through going conduits 6' and the isolator layer in the schematic Figure. Herein, the arrangement of the through going conduits 6' on the front side 4' of the segmented anode 1' provides point symmetry, rotational symmetry and mirror symmetry. Said through going conduits 6' of the anode segments 2' are located in front of through going conduits of the carrier element 8' to allow a flow of the treatment liquid from the treatment liquid chamber 13' of the module 10' though said through going conduits to the front side 4' of the segmented anode 1'.

[0067] The example of the inventive segmented anode 1' is mounted onto a carrier element 8' detachably connected to the segmented anode 1' and being part of a module 10', wherein said module 10' can be easily removed from a treatment device. The four indicated points 14' of the fastening element 9' for each anode segment 2' are shown on the front side 4' of the anode segments 2'. Said points of Figure 1' only represent indications of the fastening element located on the backside of the corresponding anode segment 2'. It is typically preferred that said fastening elements do not reach to the front side 4', as such fastening elements tend to influence the surface structure of the segmented anode 1' and can result in disturbances of the electric field or the flow of the treatment liquid along the front side 4' of the segmented anode 1'. In case of the inventive first embodiment a thread is attached to the backside of the anode segment 2', wherein the anode segment 2' is fastened to the carrier element 8' by means of a screw being screwed through the carrier element 8' into said thread. In case of the inventive first embodiment said fastening elements are further used to provide the electric current to the anode segments 2'. Herein, the contacts 11' are placed on the top of the module 10' to easily contact the anode segments 2' after placing the module 10' into a treatment device.

[0068] The anode segments 2' themselves are attached in recesses of the carrier element 8' to provide an aligned transition from the anode segments 2' to the carrier element 8' to prevent influences on the stream of the treatment liquid flowing along the front side 4' of the segmented anode 1'. The isolator layer 7' separating the two segments in this embodiment is a protrusion of the polymeric material of the carrier element 8' securely separating the anode segments 2'.

[0069] Figure 2a shows a schematic front view of an inventive module 10" of a preferred second embodiment containing an inventive segmented anode 1" mounted onto a carrier element 8". The segmented anode 1" contains a front side 4" with three anode segments 2". These anode segments 2" provide the same front side area. The anode segments 2" of the segmented anode 1" as shown in Figure 2a" are separated by an isolator layer 7".

[0070] The three anode segments 2" are in a shell like form. Herein, the outer shape of the anode segments 2" provides point symmetry, rotational symmetry and mirror symmetry. Additionally, the three anode segments 2" show through going conduits 6" reaching from the backside of the anode segment 2" to the front side 4" of the anode segment 2". Herein, the through going conduits 6" are shown greatly magnified to increase the visibility of the openings of said through going conduits 6" in the Figure. Said magnification results in an overlapping of said through going conduits 6" and the isolator layer in the schematic Figure. Herein, the arrangement of the through going conduits 6" on the front side 4" of the segmented anode 1" provides point symmetry, rotational symmetry and mirror symmetry. Said through going conduits 6" of the anode segments 2" are located in front of through going conduits of the carrier element 8" to allow a flow of the treatment liquid from the treatment liquid chamber 13" of the module 10" though said through going conduits to the front side 4" of the segmented anode 1".

[0071] The example of the inventive segmented anode 1" is mounted onto a carrier element 8" detachably connected to the segmented anode 1" and being part of a module 10", wherein said module 10" can be easily removed from a treatment device. The fastening elements 9" used to fasten the anode segments 2" are screwed from the front side and, thus, are visible in the Figure. Such type of fastening provides a simplified fastening of the anode segment 2" during maintenance. In case of the inventive second embodiment said fastening elements are further used to provide the electric current to the anode segments 2". Herein, the contacts 11" are placed on the top of the module 10" to easily contact the anode segments 2" after placing the module 10" into a treatment device.

[0072] The anode segments 2" themselves are attached in recesses of the carrier element 8" to provide an aligned transition from the anode segments 2" to the carrier element 8" to prevent influences on the stream of the treatment liquid flowing along the front side 4" of the segmented anode 1". The isolator layer 7" separating the two segments in this embodiment is a protrusion of the polymeric material of the carrier element 8" securely separating the anode segments 2".

[0073] Figure 2b shows a schematic perspective view of the inventive module 10" of the preferred second embodiment containing an inventive segmented anode 1" mounted onto a carrier element 8" as shown in Figure 2a.

[0074] Figure 3a shows a schematic front view of an inventive module 10"' of a preferred third embodiment containing an inventive segmented anode 1"' mounted onto a carrier element 8"'. The segmented anode 1"' contains a front side 4"' with four anode segments 2"'. These anode segments 2"' provide the same front side area. The anode segments 2"' of the segmented anode 1"' as shown in Figure 3a are separated by an isolator layer 7"'. Herein, the carrier element 8"' of Figure 3a is made from a transparent material showing the treatment liquid chamber 13"' behind said carrier element 8"'.

[0075] The four anode segments 2"' are in a shell like form. Herein, the outer shape of the anode segments 2"' provides point symmetry, rotational symmetry and mirror symmetry. Furthermore, the anode segments 2"' provide essentially rectangular outer shapes with rounded corners 5"'. Additionally, the four anode segments 2"' show through going conduits 6"' reaching from the backside of the anode segment 2"' to the front side 4"' of the anode segment 2"'. Herein, the through going conduits 6"' are shown greatly magnified to increase the visibility of the openings of said through going conduits 6"' in the Figure. Said magnification results in an overlapping of said through going conduits 6"' and the isolator layer in the schematic Figure. Herein, the arrangement of the through going conduits 6"' on the front side 4"' of the segmented anode 1"' provides point symmetry, rotational symmetry and mirror symmetry. Said through going conduits 6"' of the anode segments 2"' are located in front of through going conduits of the carrier element 8"' to allow a flow of the treatment liquid from the treatment liquid chamber 13"' of the module 10"' though said through going conduits to the front side 4"' of the segmented anode 1"'.

[0076] The example of the inventive segmented anode 1"' is mounted onto a carrier element 8"' detachably connected to the segmented anode 1"' and being part of a module 10"', wherein said module 10"' can be easily removed from a treatment device. The indicated points 14"' of the fastening element for each anode segment 2"' are shown on the front side 4"' of the anode segments 2"'. Said points of Figure 3a only represent indications of the fastening element located on the backside of the corresponding anode segment 2"'. In case of the inventive third embodiment according to Figure 3a a thread is attached to the backside of the anode segment 2"', wherein the anode segment 2"' is fastened to the carrier element 8"' by means of a screw being screwed through the carrier element 8"' into said thread. In case of the inventive third embodiment said fastening elements are further used to provide the electric current to the anode segments 2"'. Herein, the contacts 11"" are placed on the top of the module 10"' to easily contact the anode segments 2"' after placing the module 10"' into a treatment device.

[0077] The anode segments 2"' themselves are attached in recesses of the carrier element 8"' to provide an aligned transition from the anode segments 2"' to the carrier element 8"' to prevent influences on the stream of the treatment liquid flowing along the front side 4"' of the segmented anode 1"'. The isolator layer 7"' separating the two segments in this embodiment is a protrusion of the polymeric material of the carrier element 8"' securely separating the anode segments 2"'.

[0078] Figure 3b shows a schematic perspective view of the inventive module 10"' of the preferred third embodiment containing an inventive segmented anode 1"' mounted onto a carrier element 8"'. Herein, three openings 12"' of the treatment liquid chamber 13"' are visible connecting said chamber to the inlets of the module 10"'. The through going conduits and the indicated points of the fastening elements 9"' are difficult to differentiate in the perspective view and are, therefore, not labelled.

[0079] Figure 4 shows a schematic front view of an inventive module 10"" of a preferred fourth embodiment containing an inventive segmented anode 1"" mounted onto a carrier element 8"". The segmented anode 1"" contains a front side 4"" with a combination of two anode segments 2"" and two anode segment complexes 3"". These anode segments 2"" and anode segment complexes 3"" provide the same front side area. The anode segments 2"" and anode segment complexes 3"" of the segmented anode 1"" as shown in Figure 4 are separated by an isolator layer 7"". Herein, the carrier element 8"" of Figure 4"" is made from a transparent material showing the treatment liquid chamber 13"" behind said carrier element 8"".

[0080] The four anode segments 2"" are in a shell like form. Herein, the outer shape of the anode segments 2"" and the anode segment complexes 3"" provides point symmetry, rotational symmetry and mirror symmetry. Furthermore, the anode segments 2"" and anode segment complexes 3"" provide essentially rectangular outer shapes with rounded corners 5. Additionally, the two anode segments 2"" and the two anode segment complexes 3"" show through going conduits 6"" reaching from the backside of the anode segment 2"" or anode segment complex 3"" to the front side 4"" of the anode segment 2"" or anode segment compelx 3"". Herein, the through going conduits 6"" are shown greatly magnified to increase the visibility of the openings of said through going conduits 6"" in the Figure. Said magnification results in an overlapping of said through going conduits 6"" and the isolator layer 7"" in the schematic Figure. Herein, the arrangement of the through going conduits 6"" on the front side 4"" of the segmented anode 1"" provides point symmetry, rotational symmetry and mirror symmetry. Said through going conduits 6"" of the anode segments 2"" and anode segment complexes 3"" are located in front of through going conduits of the carrier element 8"" to allow a flow of the treatment liquid from the treatment liquid chamber 13"" of the module 10"" through said through going conduits to the front side 4"" of the seg-

mented anode 1"".

[0081] The example of the inventive segmented anode 1"" is mounted onto a carrier element 8"" detachably connected to the segmented anode 1"" and being part of a module 10"", wherein said module 10"" can be easily removed from a treatment device. The indicated points 14"" of the fastening element 9"" for each anode segment 2"" and part of the anode segment complex 3"" are shown on the front side 4"" of the anode segments 2"". Said points of Figure 4 only represent indications of the fastening element located on the backside of the corresponding anode segment 2"". In case of the inventive fourth embodiment according to Figure 4 a thread is attached to the backside of the anode segment 2"" and the parts of the anode segment complexes 3"", wherein the anode segment 2"" or anode segment complex 3"" is fastened to the carrier element 8"" by means of a screw being screwed through the carrier element 8"" into said thread. In case of the inventive fourth embodiment said fastening elements are further used to provide the electric current to the anode segments 2"" and anode segment complexes 3"". Herein, the contacts 11"" are placed on the top of the module 10"" to easily contact the anode segments 2"" and anode segment complexes 3"" after placing the module 10"" into a treatment device.

[0082] The anode segments 2"" and anode segment complexes 3"" themselves are attached in recesses of the carrier element 8"" to provide an aligned transition from the anode segments 2"" and anode segment complexes 3"" to the carrier element 8"" to prevent influences on the stream of the treatment liquid flowing along the front side 4"" of the segmented anode 1"". The isolator layer 7"" separating the anode segments 2"" and anode segment complexes 3"" in this embodiment is a protrusion of the polymeric material of the carrier element 8"" securely separating the anode segments 2"" and anode segment complexes 3"".

Reference Signs

[0083]

1', 1 ", 1"', 1"": segmented anode
2', 2", 2"', 2"": anode segment
3"": anode segment complex
4', 4", 4"', 4"": front side of the segmented anode
5"': corner
6', 6", 6"', 6"": through going conduits
7', 7", 7"', 7"": isolator layer
8', 8", 8"', 8"": carrier element
9", 9"': fastening element
10', 10", 10"', 10"": module
11', 11 ", 11"', 11"": contact of the module
12"': opening of the treatment chamber connected to an inlet
13', 13", 13"', 13"": treatment liquid chamber
14', 14"', 14"": indicated point of the fastening element

Claims

1. A segmented anode (1', 1", 1"', 1"") containing at least two anode segments (2', 2", 2"', 2""), anode segment complexes (3"") or combinations thereof,
wherein each anode segment (2', 2", 2"', 2"") or anode segment complex (3"") provides a front side (4', 4", 4"', 4""),
wherein the front side (4', 4", 4"', 4"") contains a front side area,
wherein the at least two anode segments (2', 2", 2"', 2""), anode segment complexes (3"") or combinations thereof provide an average front side area,
wherein the front side area of each of the anode segments (2', 2", 2"', 2""), anode segment complexes (3"") or combinations thereof deviates less than 20 % from the average front side area of the anode segments, anode segment complexes or combinations thereof.

2. The segmented anode (1', 1 ", 1"', 1"") according to claim 1, wherein the anode segments (2', 2", 2"', 2""), anode segment complexes (3"") or combinations thereof are arranged in a shell like form, and
wherein at least one anode segment (2', 2", 2"', 2"") or anode segment complex (3"") forms a layer surrounding at least one more interior anode segment (2', 2", 2"', 2"") or anode segment complex (3"").

3. The segmented anode (1', 1 ", 1"', 1"") according to any of claims 1 to 2, wherein each of the anode segments (2', 2", 2"', 2"") or anode segment complexes (3"") provides an outer shape,
wherein the outer shape provides at least one symmetry selected from the group consisting of point symmetry, rotational symmetry and mirror symmetry.

4. The segmented anode (1', 1 ", 1"', 1"") according to any of claims 1 to 3, wherein each of the anode segments (2', 2", 2"', 2""), anode segment complexes (3"") or combinations thereof provides an outer shape,
wherein the corners (5"') of the outer shape of essentially polyangular anode segments (2', 2", 2"', 2"") or anode segment complexes (3"") being directed to other anode segments (2', 2", 2"', 2"") or anode segment complexes of the segmented anode (1', 1", 1"', 1"") are rounded.

5. The segmented anode (1', 1", 1"', 1"") according to any of claims 1 to 4, wherein the anode segments (2', 2", 2"', 2""), anode segment complexes (3"") or combinations thereof provide through going conduits (6', 6", 6"', 6"") from the backside of the anode segment (2', 2", 2"', 2"") or anode segment complex (3"") to the front side (4', 4", 4"', 4"") of the anode segment (2', 2", 2"', 2"") or anode segment complex (3""), and

wherein the segmented anode (1', 1 ", 1"', 1"") provides an arrangement of through going conduits (6', 6", 6"', 6"") on the front side (4', 4", 4"', 4"") of the segmented anode (1', 1 ", 1"', 1""), wherein at least 50 % of the through going conduits (6', 6", 6"', 6"") provide at least one symmetry selected from the group consisting of point symmetry, rotational symmetry and mirror symmetry.

6. The segmented anode (1', 1", 1"', 1"") according to any of claims 1 to 5, wherein the front side area of each anode segment (2', 2", 2"', 2"") or anode segment complex (3"") is at least 20 cm^2.

7. The segmented anode (1', 1", 1"', 1"") according to any of claims 1 to 6, wherein the front side area of each anode segment (2', 2", 2"', 2"") or anode segments complex (3"") is at most 300 cm^2.

8. The segmented anode (1', 1", 1"', 1"") according to any of claims 1 to 7, wherein the at least two anode segments (2', 2", 2"', 2""), anode segment complexes (3"") or combinations thereof are separated by an isolater layer (7', 7", 7"', 7"").

9. Module (10', 10", 10"', 10"") containing at least one segmented anode (1', 1 ", 1"', 1"") according to any of claims 1 to 8 and at least one carrier element (8', 8", 8"', 8"") detachably connected to the segmented anode (1', 1 ", 1"', 1"").

10. The module (10', 10", 10"', 10"") according to claim 9, wherein the module (10', 10", 10"', 10"") provides at least one inlet and at least one connection from the inlet to the through going conduits of the carrier element adapted to provide a flow of the treatment liquid from said inlet to the through going conduits of the carrier element and the through going conduits (6', 6", 6"', 6"") of the segmented anode (1', 1 ", 1"', 1"") to the substrate.

11. The module (10', 10", 10"', 10"") according to any of claims 9 to 10, wherein the carrier element (8', 8", 8"', 8"") contains a front side, wherein the front side of the carrier element (8', 8", 8"', 8"") contains recesses for receiving the anode segments (2', 2", 2"', 2"").

12. Treatment device for electroplating comprising a segmented anode (1', 1 ", 1"', 1"") according to any of claims 1 to 8 or a module (10', 10", 10"', 10"") according to any of claims 9 to 11.

13. The treatment device according to claim 12, wherein the treatment device is a device for vertical electroplating.

14. Method for electroplating of a substrate using a segmented anode (1', 1", 1"', 1"") according to any of claims 1 to 8, a module (10', 10", 10"', 10"") according to any of claims 9 to 11, or a treatment device according to any of claims 12 to 13, wherein at least two anode segments (2', 2", 2"', 2""), anode segments complexes (3"") or combinations thereof are controlled or regulated separately.

15. Use of at least one segmented anode (1', 1", 1"', 1"") according to any of claims 1 to 8, at least one module (10', 10", 10"', 10"") according to any of claims 9 to 11, or at least one treatment device according to any of claims 12 to 13, for electroplating.

Fig. 1

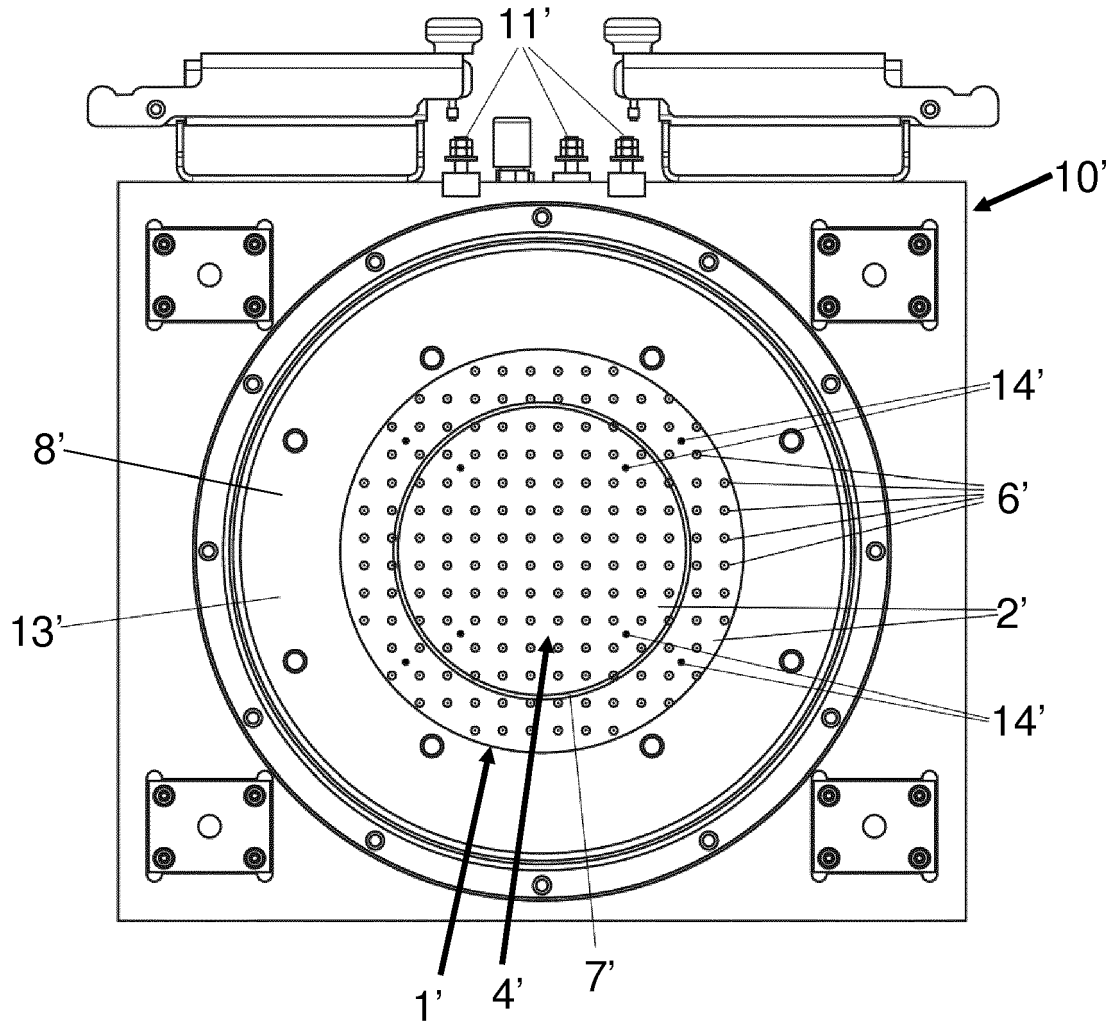


Fig. 2a

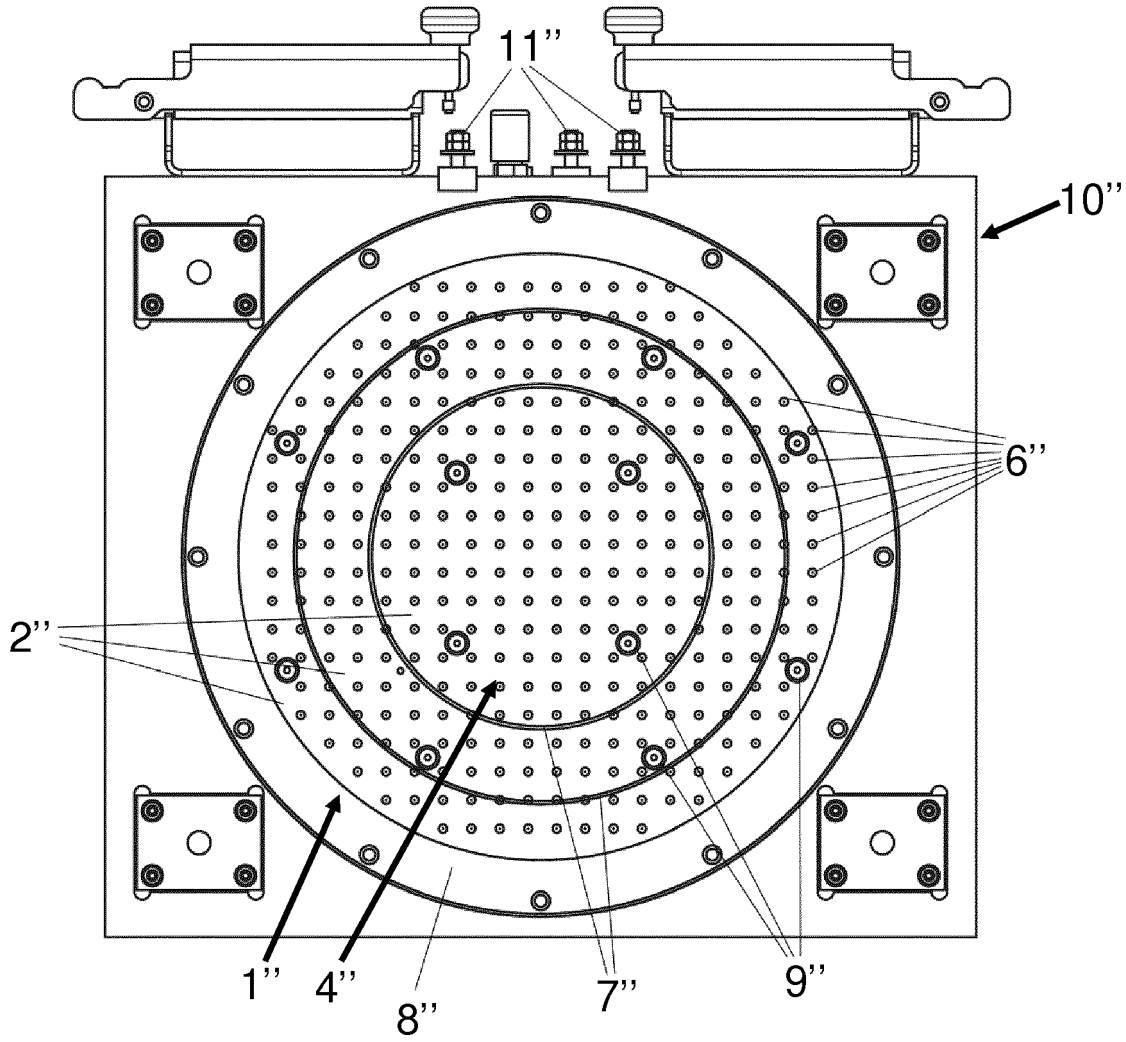


Fig. 2b

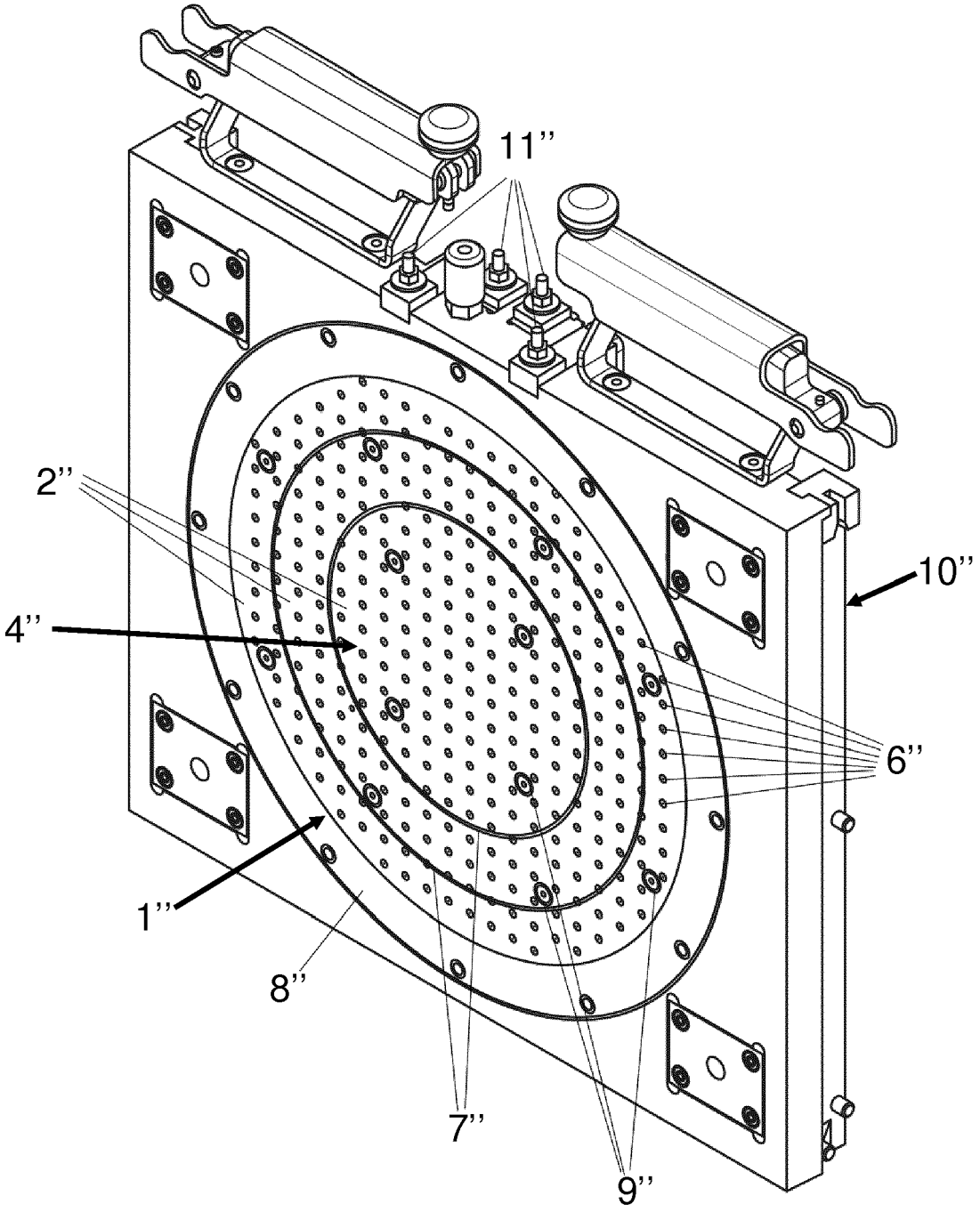


Fig. 3a

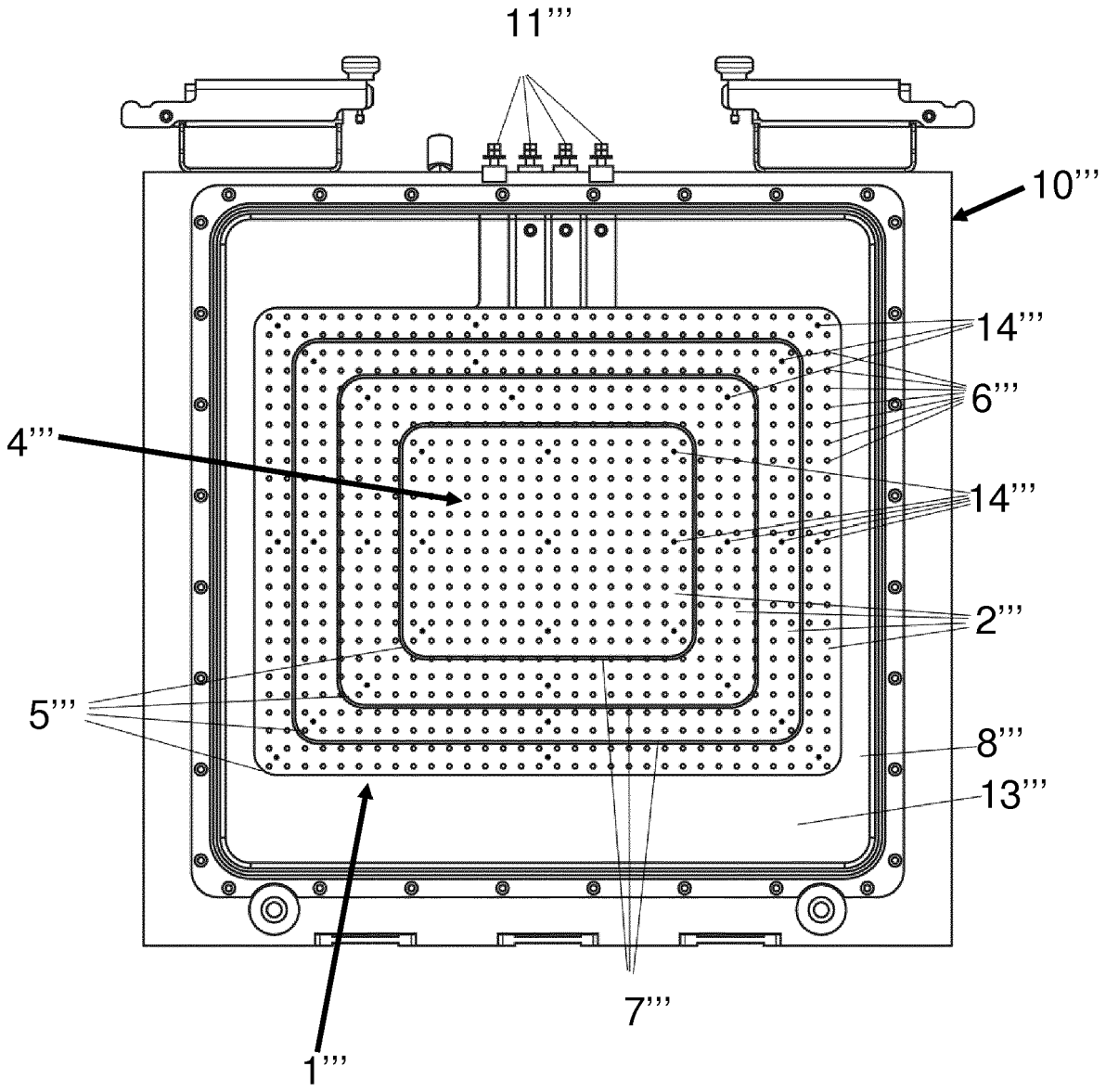


Fig. 3b

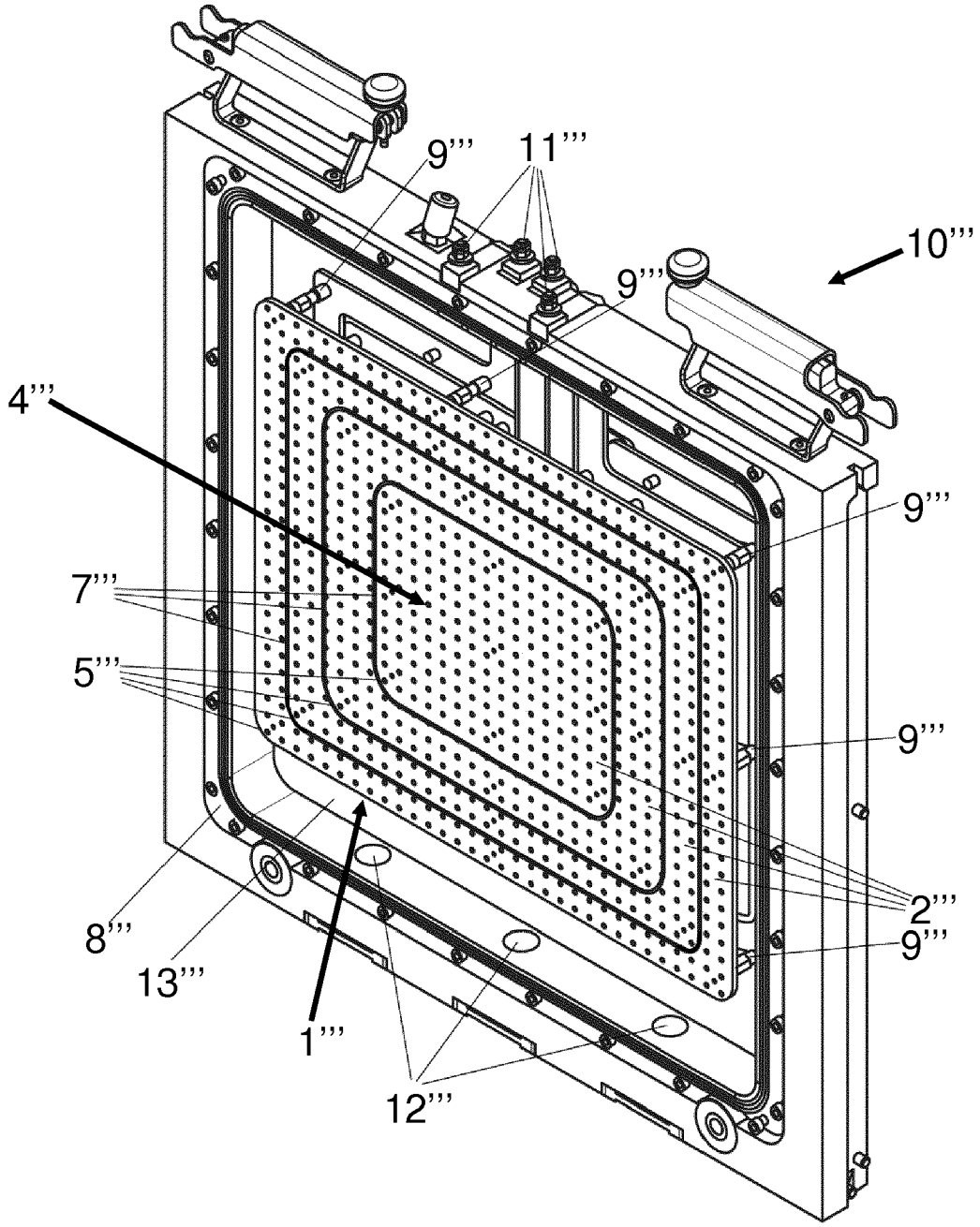
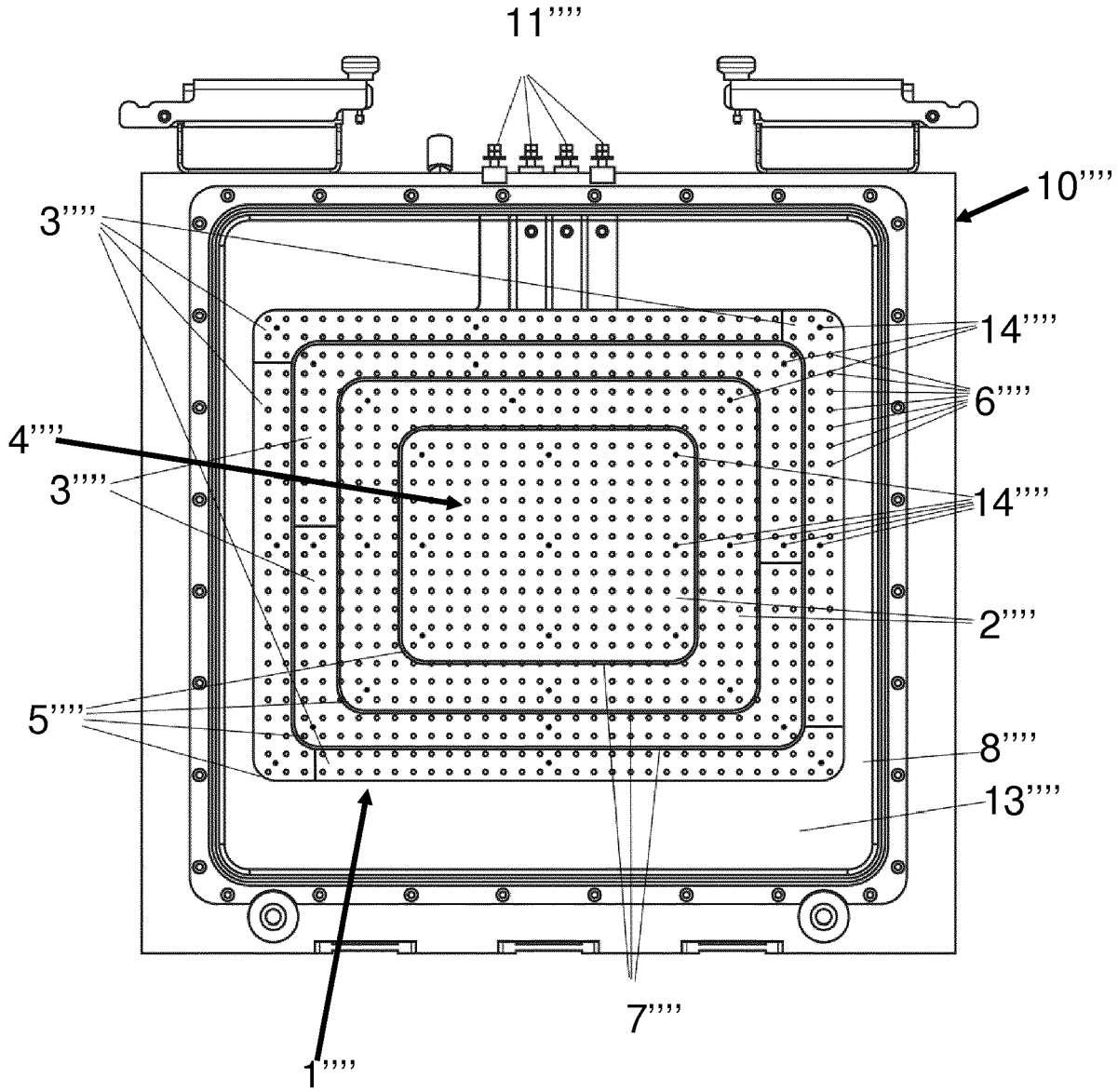


Fig. 4



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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 5395

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2015/090599 A1 (HANDER JONATHAN [US] ET AL) 2 April 2015 (2015-04-02) * abstract; figures 1, 3, 4 * * paragraph [0029] - paragraph [0031] * -----	1-4,6-8, 12-15	INV. C25D17/00 C25D17/12 C25D17/10
X	US 7 682 498 B1 (MAYER STEVEN T [US] ET AL) 23 March 2010 (2010-03-23) * abstract; figure 12 * * column 19, lines 21-34 * * column 20, lines 8-24 * -----	1,2,8, 12,14,15	

TECHNICAL FIELDS SEARCHED (IPC)

C25D

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
The Hague	22 February 2017	Telias, Gabriela

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 16 18 5395

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

2-4(completely); 1, 6-8, 12-15(partially)

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 16 18 5395

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 2-4(completely); 1, 6-8, 12-15(partially)

   A segmented anode

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2. claims: 5(completely); 1, 6-8, 12-15(partially)

   An anode comprising through-holes

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3. claims: 9-11(completely); 1, 12-15(partially)

   A module comprising a segmented anode and a carrier.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 18 5395

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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22-02-2017

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US 2015090599 A1	02-04-2015	TW 201520377 A	01-06-2015
		US 2015090599 A1	02-04-2015
		WO 2015050593 A1	09-04-2015
US 7682498 B1	23-03-2010	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82