



(51) International Patent Classification:

C23C 14/02 (2006.01) H01L 21/26 (2006.01)
C23C 14/48 (2006.01) H01L 21/687 (2006.01)
C23C 14/56 (2006.01)

(21) International Application Number:

PCT/EP2017/052884

(22) International Filing Date:

09 February 2017 (09.02.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: APPLIED MATERIALS, INC. [US/US];
3050 Bowers Avenue, Santa Clara, California 95054 (US).

(72) Inventors; and

(71) Applicants (for US only): HANIKA, Markus [DE/DE];
Reicheteile 11, 86899 Landsberg (DE). OLSON, Joseph
C. [US/US]; 5 Meeting Place Circle, Beverly, Massachu-
setts 01915 (US). KURUNCZI, Peter F. [US/US]; 2277
Massachusetts Ave #3, Cambridge, Massachusetts 02140
(US). YIM, Dong-Kil [KR/US]; 6333 Paseo Santa Maria,
Pleasanton, California 94566 (US). BENDER, Marcus
[DE/DE]; Hopfenstr. 43, 63454 Hanau (DE).

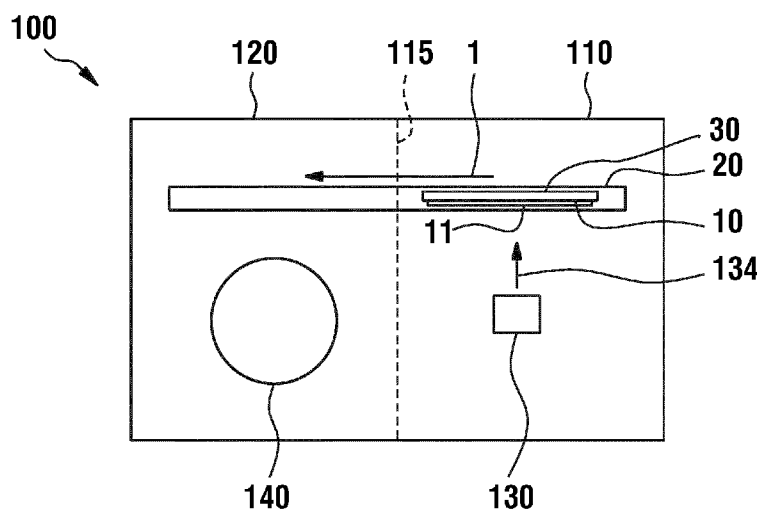
(74) Agent: ZIMMERMANN & PARTNER PATENTAN-
WÄLTE MBB; Josephspitalstr. 15, 80331 München (DE).

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

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

(54) Title: METHOD FOR VACUUM PROCESSING OF A SUBSTRATE, THIN FILM TRANSISTOR, AND APPARATUS FOR
VACUUM PROCESSING OF A SUBSTRATE

Fig. 2



(57) Abstract: A method for vacuum processing of a substrate (10) is provided. The method includes irradiating the substrate (10) or a first material layer on the substrate (10) with particles using an implantation source (130) provided in a processing region (110), and moving the substrate (10) through the processing region (110) along a transportation path (20) while the substrate (10) or the first material layer is irradiated with the particles.

Published:

— *with international search report (Art. 21(3))*

**METHOD FOR VACUUM PROCESSING OF A SUBSTRATE, THIN FILM
TRANSISTOR, AND APPARATUS FOR VACUUM PROCESSING OF A
SUBSTRATE**

5

FIELD

[0001] Embodiments of the present disclosure relate to a method for vacuum processing
10 of a substrate, a thin film transistor, and an apparatus for vacuum processing of a substrate.
Embodiments of the present disclosure particularly relate to methods and apparatuses for
physical vapor deposition, for example, sputter deposition used in the manufacture of
display devices.

15

BACKGROUND

[0002] Techniques for layer deposition on a substrate include, for example, sputter
deposition, thermal evaporation, and chemical vapor deposition (CVD). A sputter
deposition process can be used to deposit a material layer on the substrate, such as a layer
of a conductive material. Substrates provided on substrate carriers can be transported
20 through a processing system. In order to perform multiple processing measures on the
substrate, an in-line arrangement of processing modules can be used. An in-line processing
system includes a number of subsequent processing modules, wherein processing measures
are conducted in one processing module after the other. A plurality of materials such as
metals, also including oxides, nitrides or carbides thereof, may be used for deposition on a
25 substrate. Coated materials may be used in several applications and in several technical
fields. For instance, substrates for displays are often coated by a physical vapor deposition
(PVD) process such as a sputtering process, e.g., to form thin film transistors (TFTs) on the
substrate.

[0003] With development of new display technologies and a tendency towards larger
30 display sizes, there is an ongoing demand for layers or layer systems used in displays that
provide an improved performance, e.g., with respect to electrical characteristics. As an

example, thin film transistors having a channel with a higher mobility and/or having an improved threshold voltage (V_{th}) can be beneficial.

[0004] In view of the above, new methods for vacuum processing of a substrate, thin film transistors, and apparatuses for vacuum processing of a substrate, that overcome at least
5 some of the problems in the art are beneficial. Specifically, methods and apparatuses that allow for a higher charge carrier mobility and/or an improved threshold voltage (V_{th}) are beneficial.

SUMMARY

10 [0005] In light of the above, a method for vacuum processing of a substrate, a thin film transistor, and an apparatus for vacuum processing of a substrate are provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0006] According to an aspect of the present disclosure, a method for vacuum processing
15 of a substrate is provided. The method includes irradiating the substrate or a first material layer on the substrate with particles using an implantation source provided in a processing region, and moving the substrate through the processing region along a transportation path while the substrate or the first material layer is irradiated with the particles.

[0007] According to another aspect of the present disclosure, a method for vacuum
20 processing of a substrate is provided. The method includes moving an implantation source provided in a processing region with respect to a substrate provided on a transportation path, and irradiating the substrate or a first material layer on the substrate with particles provided by the implantation source while the implantation source is moved.

[0008] According to yet another aspect of the present disclosure, a thin film transistor is
25 provided. The thin film transistor includes a channel manufactured using the embodiments described herein.

[0009] According to an aspect of the present disclosure, an apparatus for vacuum processing of a substrate is provided. The apparatus includes at least one processing region

having at least one implantation source, at least one deposition region having one or more deposition sources, and a transportation path extending through the at least one processing region and the at least one deposition region. The apparatus is configured to irradiate the substrate or a first material layer on the substrate with particles provided by the at least one
5 implantation source. The apparatus is further configured to move the substrate through the processing region along the transportation path while the substrate or the first material layer is irradiated with the particles.

[0010] According to yet another aspect of the present disclosure, an apparatus for vacuum processing of a substrate is provided. The apparatus includes at least one
10 processing region having at least one implantation source, at least one deposition region having one or more deposition sources, and a transportation path extending through the at least one processing region and the at least one deposition region. The apparatus is configured to irradiate the substrate or a first material layer on the substrate with particles provided by the at least one implantation source. The apparatus is further configured to
15 move the at least one implantation source with respect to the transportation path while the substrate or the first material layer is irradiated with the particles.

[0011] Embodiments are also directed at apparatuses for carrying out the disclosed methods and include apparatus parts for performing each described method aspect. These method aspects may be performed by way of hardware components, a computer
20 programmed by appropriate software, by any combination of the two or in any other manner. Furthermore, embodiments according to the disclosure are also directed at methods for operating the described apparatus. The methods for operating the described apparatus include method aspects for carrying out every function of the apparatus.

25 BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following:

- FIG. 1 shows a flowchart of a method for vacuum processing of a substrate according to embodiments described herein;
- FIG. 2 shows a schematic view of an apparatus for vacuum processing of a substrate according to embodiments described herein;
- 5 FIG. 3 shows a schematic view of an apparatus for vacuum processing of a substrate according to further embodiments described herein;
- FIG. 4 shows a schematic cross-sectional view of an apparatus for vacuum processing of a substrate according to embodiments described herein;
- 10 FIG. 5 shows a schematic view of an apparatus for vacuum processing of a substrate according to embodiments described herein;
- 15 FIG. 6 shows a schematic view of an apparatus for vacuum processing of a substrate according to further embodiments described herein; and
- FIG. 7 shows a schematic cross-sectional view of a section of a display having a thin film transistor according to embodiments described herein.
- 20

DETAILED DESCRIPTION OF EMBODIMENTS

[0013] Reference will now be made in detail to the various embodiments of the disclosure, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. Generally, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the disclosure and is not

25

meant as a limitation of the disclosure. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

- 5 [0014] With development of new display technologies and a tendency towards larger display sizes, there is an ongoing demand for layers or layer systems used in displays that provide an improved performance, e.g., with respect to electrical characteristics. As an example, thin film transistors having a channel with a higher charge carrier mobility and/or having an improved threshold voltage (V_{th}) can be beneficial.
- 10 [0015] According to the present disclosure, an implantation source for implanting particles in a substrate or a first material layer on the substrate to change one or more material properties of the substrate or the first material layer is provided. The particles can be ions or electrically neutral atoms. As an example, particles can be implanted in the first material layer to provide a thin film transistor that has a channel with higher mobility
- 15 and/or a changed threshold voltage V_{th} . However, the present disclosure is not limited thereto, and the implantation can be used to alter other properties, such as a refractive index of the substrate or the first material layer e.g. for index matching.

[0016] The term “implantation” as used throughout the present disclosure is to be understood in the sense that the particles are impacted into a solid, such as the substrate

20 and/or the first material layer, to alter one or more material properties of the solid, such as the elemental composition of the solid. In particular, the particles are impacted into the solid, stopping and remaining in the solid and staying there.

[0017] FIG. 1 shows a flowchart of a method for vacuum processing of a substrate according to embodiments described herein.

- 25 [0018] According to an aspect of the present disclosure, the method includes, in block 1100, irradiating the substrate or a first material layer on the substrate with particles using an implantation source provided in a processing region, and in block 1200 moving the substrate through the processing region along a transportation path while the substrate or the first material layer is irradiated with the particles. The implantation source, which can

also be referred to as “particle implantation source”, can be moving or stationary while the substrate or the first material layer is irradiated with the particles. By irradiating the substrate or the first material layer, an implantation process is conducted. In particular, the substrate or the first material layer on the substrate is irradiated with the particles for
5 implanting particles therein in order to change one or more material properties of the substrate or the first material layer, respectively. The particles can be ions or electrically neutral atoms.

[0019] According to some embodiments, which can be combined with other embodiments described herein, the one or more material properties are selected from the
10 group consisting of physical properties, electrical properties, chemical properties, and optical properties. The physical properties can for instance include the crystal structure of the solid, such as the substrate or the first material layer. The electrical properties can for instance include a charge carrier mobility. The chemical properties can for instance include an elemental composition of the solid. The optical properties can for instance include a
15 refractive index of the solid.

[0020] According to some embodiments, which can be combined with other embodiments described herein, the ions are implanted inside the solid to form a region or layer that is buried inside the solid (“buried layer”). In further implementations, the ions are implanted in (or at) a surface or surface region of the solid. The implantation depth can
20 be selected by adjusting an energy of the ions impacted on the solid. As an example, ion energies of less than 10 keV can be used for implantation at the surface of the solid, whereas ion energies of more than 10 keV can be used for implantation inside the solid to form a buried layer. In some implementations, the particles having 10 keV or less may be not just on the surface but also extend slightly into the first nm of the substrate or first
25 material layer. Yet, this is considered as an “implantation at the surface of the solid”. A penetration depth can depend on the implanted neutral or ion element.

[0021] According to some embodiments, which can be combined with other embodiments described herein, the particles are ions or electrically neutral atoms. As an example, the ions can be selected from the group including nitrogen ions, oxygen ions,
30 hydrogen ions, indium ions, and gallium ions. Likewise, the electrically neutral atoms can be selected from the group including nitrogen atoms, oxygen atoms, hydrogen atoms,

indium, and gallium atoms. However, the present disclosure is not limited thereto and other particles can be used that are suitable for altering one or more material properties of a respective material. As an example, other ions or electrically neutral atoms could be used e.g. for implantation in LTPS (p-Si) and ZnO. In the example of a thin film transistor, the particle implantation can be used in the manufacture of a channel of the thin film transistor. By implanting for instance hydrogen into a channel layer, such as a IGZO (indium gallium zinc oxide) layer, a higher mobility and a changed threshold voltage V_{th} of the thin film transistor can be provided. An example of a thin film transistor manufactured using the particle implantation of the present disclosure is further described with respect to FIG. 7.

[0022] According to some embodiments, which can be combined with other embodiments described herein, the method further includes depositing the first material layer over the substrate and/or depositing at least one second material layer over the substrate or over the first material layer after the substrate or the first material layer has been irradiated with the ions. As an example, the first material layer can be deposited before the ion implantation process using the ion implantation source is conducted. One or more material properties of the first material layer can be changed after the first material layer has been deposited on the substrate. The first material layer and the second material layer can be made of the same material or can be made of different materials. As an example, the first material layer and/or the second material layer can be a IGZO layer. The IGZO layer(s) can be used in the manufacture of a channel of a thin film transistor.

[0023] According to some embodiments, which can be combined with other embodiments described herein, a thickness of the first material layer and/or the second material layer can be in a range between 10 Å (Angstrom) and 5000 Å, specifically in a range between 20 Å and 1500 Å, and more specifically in a range between 25 Å and 1000 Å. In some implementations, a combined thickness of the first material layer and the second material layer can be in a range between 10 Å (Angstrom) and 5000 Å, specifically in a range between 20 Å and 1500 Å, and more specifically in a range between 25 Å and 1000 Å.

[0024] As an example, the first material layer includes a buried layer generated by the particles implanted in the first material layer ("single layer"). A thickness of the single first material layer can be in a range between 100 Å (Angstrom) and 2000 Å,

specifically in a range between 300 Å and 1500 Å, and more specifically in a range between 400 Å and 1000 Å. In another example, the first material layer has the particles implanted in a surface region of the first material layer and the second material layer is provided on the first material layer (“dual layer”). A thickness of each of the first material layer and the second material layer can be in a range between 10 Å (Angstrom) and 1000 Å, specifically in a range between 20 Å and 500 Å, and more specifically in a range between 25 Å and 100 Å.

[0025] In some implementations, the method further includes moving the substrate along the transportation path into a deposition region, and depositing the at least one second material layer over the substrate surface or over the first material layer after the substrate or the first material layer has been irradiated with the particles. In some implementations, the at least one second material layer includes two or more second material layers. The two or more second material layers can be made of the same or of different materials. At least one of the first material layer and the second material layer can be deposited while the substrate is stationary e.g. on the transportation path. Alternatively, at least one of the first material layer and the second material layer can be deposited while the substrate is moved along the transportation path.

[0026] The processing region and the deposition region can be regions within a vacuum chamber of a vacuum processing system. In other implementations, the processing region and the deposition region can be provided by different vacuum chambers connected to each other. The processing region and the deposition region can be separated from each other, for example, using at least one of locks, valves and separation devices, such as a gas separation shielding. The processing region and the deposition region will be further explained with reference to FIGs. 2 to 6.

[0027] According to some embodiments, the method provides a combination of a dynamic implantation process and a stationary or static deposition process. The terms “stationary” and “static” as used throughout the present disclosure can be understood in the sense that the substrate is substantially not moving with respect to the vacuum chamber and/or the deposition sources provided in the deposition region.

[0028] Specifically, the deposition process can be a static deposition process, e.g., for display processing. It should be noted that “static deposition processes”, which differ from dynamic deposition processes do not exclude any movement of the substrate as would be appreciated by a skilled person. A static deposition process can include, for example, at least one of the following: a static substrate position during deposition; an oscillating substrate position during deposition; an average substrate position that is essentially constant during deposition; a dithering substrate position during deposition; a wobbling substrate position during deposition; a deposition process for which the cathodes are provided in one vacuum chamber, i.e. a predetermined set of cathodes are provided in the vacuum chamber; a substrate position wherein the vacuum chamber has a sealed atmosphere with respect to neighboring chambers, e.g. by closing valve units separating the vacuum chamber from an adjacent chamber during deposition of the layer; or a combination thereof. A static deposition process can be understood as a deposition process with a static position, a deposition process with an essentially static position, or a deposition process with a partially static position of the substrate. In view of this, a static deposition process, in which the substrate position can in some cases be not fully without any movement during deposition, can still be distinguished from a dynamic deposition process.

[0029] According to some embodiments, which can be combined with other embodiments described herein, the implantation source, such as the ion implantation source, can be moving or stationary, for example, while the substrate and/or the first material layer is irradiated with the particles. In some implementations, the implantation source can be moving with respect to the transportation path while the substrate is transported along the transportation path. As an example, the method can further include an irradiating of the substrate or the first material layer with particles while the implantation source is moved. Specifically, both the substrate and the implantation source can be moving while the substrate or the first material layer is irradiated with the particles provided by the implantation source. Moving both the substrate and the implantation source allows for a fast implantation process.

[0030] In other implementations, the implantation source can be stationary while the substrate passes the implantation source. As an example, the implantation source can be

stationary while the substrate or the first material layer is irradiated with the particles from the implantation source. The stationary implantation source allows for a simple configuration of the apparatus.

[0031] According to a further aspect of the present disclosure, a method for vacuum processing of a substrate includes moving an implantation source provided in a processing region with respect to a substrate provided on a transportation path, and irradiating the substrate or a first material layer on the substrate with particles provided by the implantation source while the implantation source is moved. In some implementations, the method further includes depositing the first material layer over the substrate and/or depositing at least one second material layer over the substrate or over the first material layer after the substrate or the first material layer has been irradiated with the particles as described herein before.

[0032] According to some embodiments, which can be combined with other embodiments described herein, moving the implantation source includes a moving in at least one of a first direction parallel to the transportation path and a second direction perpendicular to the transportation path. As an example, the first direction can be a horizontal direction and/or the second direction can be a vertical direction. The implantation source, such as the ion implantation source or linear ion implantation source, can be vertically and/or horizontally scanned over the substrate surface to implant the particles into the substrate or the first material layer. The moving of the implantation source in the first direction and the second direction can improve an efficiency of the implantation process.

[0033] The term “vertical direction” is understood to distinguish over “horizontal direction”. That is, the “vertical direction” relates to a substantially vertical movement of the implantation source, wherein a deviation of a few degrees, e.g. up to 10° or even up to 30°, from an exact vertical direction or vertical movement is still considered as a “substantially vertical direction” or a “substantially vertical movement”. The vertical direction can be substantially parallel to the force of gravity. Likewise, the “horizontal direction” relates to a substantially horizontal movement of the ion implantation source, wherein a deviation of a few degrees, e.g. up to 10° or even up to 30°, from an exact

horizontal direction or horizontal movement is still considered as a “substantially horizontal direction” or a “substantially horizontal movement”.

[0034] In some embodiments, the implantation source is moved sequentially or simultaneously in the first direction and the second direction. The implantation source can move along a continuous or discontinuous movement path in a plane spanned by the first direction and the second direction. As an example, the implantation source can move along a continuous movement path, when the implantation source is moved simultaneously in the first direction and the second direction. The implantation source can move along a discontinuous movement path, when the implantation source is moved sequentially in the first direction and the second direction.

[0035] According to some embodiments, which can be combined with other embodiments described herein, an operation of the implantation source is based on a position of the substrate on the transportation path. Specifically, an on/off-mode of the implantation source can be triggered by a movement and/or position of the substrate. As an example, the implantation source can be switched on when the substrate enters the processing region. The implantation source can be switched off when the substrate leaves the processing region and, for example, enters the deposition region. In some implementations, the implantation source can be repeatedly switched on and off while the substrate moves through the processing region.

[0036] In some implementations, the substrate is moving or stationary while the substrate or the first material layer is irradiated with the particles. As an example, the method further includes moving the substrate along the transportation path while the substrate or the first material layer is irradiated with the particles. Specifically, both the implantation source and the substrate can be moving during the particle implantation process. Moving both the implantation source and the substrate can shorten a process time of the particle implantation process. A throughput of the apparatus can be improved.

[0037] In other examples, the substrate is stationarily positioned on the transportation path while the implantation source moves with respect to the transportation path to irradiate the substrate or the first material layer with the particles. Keeping the substrate stationary allows for a flexible selection of the process time of the particle implantation

process. Specifically, the process time can be selected such that a predetermined amount of particles is implanted in the substrate or the first material layer e.g. per unit volume of the solid.

[0038] According to some embodiments, which can be combined with other
5 embodiments described herein, a moving speed of the substrate along the transportation path and/or a moving speed of the implantation source is substantially constant during at least one of the irradiation with particles and the deposition of the first material layer and/or the at least one second material layer. According to further embodiments, which can be combined with other embodiments described herein, a moving speed of the substrate
10 along the transportation path and/or a moving speed of the implantation source can be varied or changed (i.e., a non-uniform moving speed can be provided) during at least one of the irradiation with particles and the deposition of the first material layer and/or the at least one second material layer. As an example, the moving speed of the substrate along the transportation path and/or the moving speed of the implantation source can be varied or
15 changed during the irradiation with particles for providing local implantation concentration changes in the solid.

[0039] In some embodiments, the second material layer is deposited over the substrate or over the first material layer while the substrate is stationary. Specifically, the deposition process can be a stationary or static deposition process. In further embodiments, the second
20 material layer is deposited over the substrate or over the first material layer while the substrate is moved through the deposition region along the transportation path. Specifically, the deposition process can be a dynamic deposition process.

[0040] When reference is made to the term “over”, i.e. one layer being over the other, it is understood that, starting from the substrate, a first material layer is deposited over the
25 substrate, and the second material layer, deposited after the first material layer, is thus over the first layer and over the substrate. In other words, the term “over” is used to define an order of layers, layer stacks, and/or films wherein the starting point is the substrate. This is irrespective of whether the layer stack is considered upside down or not.

[0041] The term “over” shall embrace embodiments where one or more further material
30 layers are provided between the substrate and the first material layer and/or the first

material layer and the second material layer. In other words, the first material layer is not directly disposed on the substrate and/or the second material layer is not directly disposed on the first material layer. However, the present disclosure is not limited thereto and the term “over” shall embrace embodiments where no further layers are provided between the substrate and the first material layer and/or the first material layer and the second material layer. In other words, the first material layer can be disposed directly on the substrate and can be in direct contact with the substrate. The second material layer can be disposed directly on the first material layer and can be in direct contact with the first material layer.

[0042] According to some embodiments, which can be combined with other embodiments described herein, at least one of the first material layer and the second material layer can be a conductive layer. As an example, the first material layer can be a first conductive layer and the second material layer can be a second conductive layer. As an example, the material of the first material layer and/or the second material layer is selected from the group consisting of IGZO, a metal, a metal alloy, titanium, aluminum, indium tin oxide (ITO), and any combination thereof.

[0043] According to some embodiments, which can be combined with other embodiments described herein, the substrate is transported along the transportation path in a substantially vertical orientation. As an example, the substrate or the first material layer is irradiated with the particles while the substrate is in a substantially vertical orientation. As used throughout the present disclosure, “substantially vertical” is understood particularly when referring to the substrate orientation, to allow for a deviation from the vertical direction or orientation of $\pm 20^\circ$ or below, e.g. of $\pm 10^\circ$ or below. This deviation can be provided for example because a substrate support with some deviation from the vertical orientation might result in a more stable substrate position. Yet, the substrate orientation, e.g., during the implantation process and/or the deposition process is considered substantially vertical, which is considered different from the horizontal substrate orientation.

[0044] The term “substrate” as used herein shall embrace substrates which are typically used for display manufacturing. The substrates can be large area substrates. For example, substrates as described herein shall embrace substrates which are typically used for an LCD (Liquid Crystal Display), a PDP (Plasma Display Panel), and the like. For instance, a

large area substrate can be GEN 4.5, which corresponds to about 0.67 m² substrates (0.73 x 0.92m), GEN 5, which corresponds to about 1.4 m² substrates (1.1 m x 1.3 m), GEN 6, which corresponds to about 2.8 m² substrates (1.85 m x 1.5 m), GEN 7.5, which corresponds to about 4.29 m² substrates (1.95 m x 2.2 m), GEN 8.5, which corresponds to about 5.7m² substrates (2.2 m x 2.5 m), or even GEN 10, which corresponds to about 8.7 m² substrates (2.85 m x 3.05 m). Even larger generations such as GEN 11 and GEN 12 and corresponding substrate areas can similarly be implemented.

[0045] The term “substrate” as used herein shall particularly embrace substantially inflexible substrates, e.g., a wafer, slices of transparent crystal such as sapphire or the like, or a glass plate. In particular, the substrates can be glass substrates and/or transparent substrates. However, the present disclosure is not limited thereto and the term “substrate” may also embrace flexible substrates such as a web or a foil. The term “substantially inflexible” is understood to distinguish over “flexible”. Specifically, a substantially inflexible substrate can have a certain degree of flexibility, e.g. a glass plate having a thickness of 0.5 mm or below, wherein the flexibility of the substantially inflexible substrate is small in comparison to the flexible substrates.

[0046] According to embodiments described herein, the method for vacuum processing of a substrate can be conducted using computer programs, software, computer software products and the interrelated controllers, which can have a CPU, a memory, a user interface, and input and output devices being in communication with the corresponding components of the apparatus.

[0047] FIG. 2 shows a schematic view of an apparatus 100 for vacuum processing of a substrate 10 according to embodiments described herein.

[0048] According to an aspect of the present disclosure, the apparatus 100 includes at least one processing region 110 having at least one implantation source, such as at least one linear ion implantation source 130, at least one deposition region 120 having one or more deposition sources 140, and a transportation path 20 extending through the at least one processing region 110 and the at least one deposition region 120. The apparatus 100 can be configured to perform the method for vacuum processing of a substrate according to the embodiments described herein. In the following, the at least one linear ion implantation

source 130 is exemplarily described. However, it is to be understood that the present disclosure is not limited thereto and that other geometries or types of implantation sources can be used.

[0049] The apparatus 100 can include a substrate carrier 30 configured to support the substrate 10. The substrate carrier 30 having the substrate 10 positioned thereon can be transported along the transportation path 20. The substrate carrier 30 can include a plate or a frame configured for supporting the substrate 10, for example, using a support surface provided by the plate or frame. Optionally, the substrate carrier 30 can include one or more holding devices (not shown) configured for holding the substrate 10 at the plate or frame. The one or more holding devices can include at least one of mechanical and/or magnetic clamps.

[0050] In some implementations, the substrate carrier 30 includes, or is, an electrostatic chuck (E-chuck). The E-chuck can have a supporting surface for supporting the substrate thereon. In one embodiment, the E-chuck includes a dielectric body having electrodes embedded therein. The dielectric body can be fabricated from a dielectric material, preferably a high thermal conductivity dielectric material such as pyrolytic boron nitride, aluminum nitride, silicon nitride, alumina or an equivalent material; or the dielectric body may be fabricated from a very thin but less thermally-conductive material such as polyimide. The electrodes may be coupled to a power source which provides power to the electrodes to control a chucking force. The chucking force is an electrostatic force acting on the substrate to fix the substrate on the supporting surface.

[0051] According to some embodiments, which can be combined with other embodiments described herein, the implantation source can be configured to emit a beam of energetic particles (e.g. ions or electrically neutral particles) as indicated with reference numeral 134. The implantation source can be configured to provide ions or electrically neutral atoms. The ions can be selected from the group including nitrogen ions, oxygen ions, hydrogen ions, indium ions and gallium ions. Likewise, the electrically neutral atoms can be selected from the group including nitrogen atoms, oxygen atoms, hydrogen atoms, indium atoms and gallium atoms. The particles, such as the ions, are implanted in the substrate 10, a surface 11 of the substrate, or the first material layer on the substrate 10, to

change one or more material properties of the material into which the particles are implanted.

[0052] The implantation source can include an ion source configured to generate ions and an accelerator configured for accelerating the ions provided by the ion source. The ion source can be configured to provide an inductively coupled plasma (ICP). As an example, the ion source can include a coil electrically connected to a power supply, such as a radiofrequency (RF) power supply. A current can be applied to the coil and a plasma can be generated by excitation of a process gas inside the ion source. In further implementations, the ion source can be configured to provide a charged coupled plasma (CCP) using a plate.

[0053] According to some embodiments, the implantation source can be configured for implantation of the ions generated by the ion source in the substrate or the first material layer. In other embodiments, the implantation source is configured to electrically neutralize the generated ions, e.g. after the acceleration of the ions, for implantation of electrically neutral particles in the substrate or the first material layer. As an example, the implantation source further includes a neutralizing device for electrically neutralizing the accelerated ions. In particular, a material can be ionized to be able to be accelerated, wherein a PFG (plasma flood gun) can be provided between the ion source and the substrate to neutralize the “ion” beam.

[0054] The accelerator can be configured to accelerate the ions provided by the ion source to a predetermined energy for impact of the ions or the neutralized particles on the solid, such as the substrate or the first material layer. As an example, the implantation source, and particularly the accelerator, can be configured to provide the particles and/or the ions with an energy of at least 1 keV, specifically at least 10 keV, and more specifically at least 100 keV for impingement on the substrate or the first material layer. In some embodiments, the implantation source, and particularly the accelerator, can be configured to provide the particles and/or the ions with an energy in a range between 1 and 1000 keV, specifically between 1 and 500 keV, and more specifically between 3 and 300 keV.

[0055] In some implementations, the accelerator includes one or more lenses. The one or more lenses can be selected from the group consisting of electrostatic lenses, magnetic

lenses, and electromagnetic lenses. The one or more lenses can be configured for at least one of accelerating the ions towards the substrate/first material layer and focusing the ion beam onto the substrate/first material layer. Optionally, the ions can be neutralized after acceleration and an optional focusing for implantation of electrically neutral particles in the substrate or the first material layer.

[0056] In some implementations, the implantation source is a linear implantation source, such as a vertical linear implantation source. The term “linear” can be understood in the sense that the linear implantation source 130 has a major dimension and a minor dimension defining an emission area of the particles or ions (e.g., a substantially rectangular area), wherein the minor dimension is less than the major dimension. For example, the minor dimension can be less than 10%, specifically less than 5% and more specifically less than 1% of the major dimension. The major dimension can extend substantially vertically. In other words, the at least one linear ion implantation source 130 can be a vertical linear implantation source. According to some embodiments, a beam width of the particles or ions provided by the at least one linear ion implantation source 130, e.g., the emission area, can be in a range of between 1mm to 3000mm, specifically in a range of between 30mm to 2100mm, and more specifically less than 50mm. The beam width can be defined perpendicular to the linear extension of the at least one linear implantation source.

[0057] In some implementations, the linear implantation source can have one or more outlets or particle sources (e.g., ion sources) arranged along a vertical line, e.g., in the major dimension, configured to provide the particles and/or the emission area. As an example, one continuous outlet or particle source can be provided. In other examples, a plurality of outlets or particle sources can be arranged along a line. For instance, the linear implantation source can consist of multiple point sources closely aligned next to each other along the line.

[0058] In some implementations, the apparatus 100 is configured to move the substrate 10 through the at least one processing region 110 along the transportation path 20 while the substrate 10 or the first material layer is irradiated with the particles. As an example, the apparatus 100 is configured to provide a combination of a dynamic implantation process and a static deposition process. The apparatus 100 can be configured to irradiate the substrate 10 or the first material layer on the substrate 10 with particles (indicated with

reference numeral 134) provided by the at least one linear implantation source while the substrate 10 passes the at least one linear implantation source. As an example, the substrate 10 or the first material layer is irradiated during the transportation of the substrate 10 or substrate carrier 30 along the transportation path 20, for example, in a direction towards the at least one deposition region 120 (the transport direction 1). According to some embodiments, the apparatus 100 is configured to deposit at least one second material layer over the substrate or over the first material layer while the substrate 10 is stationary in the at least one deposition region 120.

[0059] The term “processing region” can be understood as a space or area where the substrate 10 can be provided or positioned so that the substrate 10 can be irradiated with the particles provided by the linear implantation source. The term “deposition region” can be understood as a space or area where the substrate 10 can be provided or positioned so that the substrate 10 can be coated with a material provided by the one or more deposition sources 140.

[0060] According to some embodiments, which can be combined with other embodiments described herein, the apparatus 100 can include one or more vacuum chambers. The at least one processing region 110 and the at least one deposition region 120 can be provided by the same (one single) vacuum chamber. The vacuum chamber can be divided in two or more portions or areas providing the at least one processing region 110 and the at least one deposition region 120. The vacuum chamber can be divided using one or more separation devices 115, for example, a gas separation shielding. In other implementations, no separating device is provided between the at least one processing region 110 and the at least one deposition region 120. The at least one processing region 110 and the at least one deposition region 120 can be provided in the vacuum chamber without any separation therebetween. In yet further implementations, the at least one process region 110 and the at least one deposition region 120 can be provided by different vacuum chambers connected to each other, for example, using a gate and/or a valve. According to the embodiments described herein, the at least one processing region 110 and the at least one deposition region 120 are connected to each other vacuum-wise, so that the substrate 10 stays within the vacuum environment during the transfer from the at least one processing region 110 to the at least one deposition region 120, or vice versa.

[0061] According to some embodiments, which can be combined with other embodiments described herein, the at least one processing region 110 includes two or more processing regions each having one or more implantation sources. Alternatively or additionally, the at least one deposition region 120 includes two or more deposition regions each having one or more deposition sources. Specifically, the apparatus can have multiple processing regions and/or multiple deposition regions for conducting multiple implantation processes and multiple deposition processes, respectively.

[0062] The term “vacuum” as used throughout the present disclosure can be understood as a space that is substantially devoid of matter, e.g., a space from which all or most of the air or gas has been removed, except for process gases that are used in a deposition process, such as a sputter deposition process. As an example, the term “vacuum” can be understood in the sense of a technical vacuum having a vacuum pressure of less than, for example, 10 mbar. One or more vacuum pumps, such as turbo pumps and/or cryo-pumps, can be connected to the one or more vacuum chambers providing the at least one processing region 110 and the at least one deposition region 120 for generation of the vacuum.

[0063] The term “transportation path” as used throughout the present disclosure can be understood as a path along which the substrate 10 or the substrate carrier 30 having the substrate 10 positioned thereon can be moved or conveyed, for example, through the at least one processing region 110 and the at least one deposition region 120. As an example, the transportation path can be a linear transportation path. The transportation path 20 can define a transport direction 1 for the substrate 10 or the substrate carrier 30 through the at least one processing region 110 and the at least one deposition region 120. The transportation path 20 can be a unidirectional transportation path or can be a bidirectional transportation path.

[0064] The apparatus 100 can have at least two transportation paths, such as the transportation path 20 and another transportation path (not shown). The at least two transportation paths can be provided so that a first substrate carrier having a first substrate positioned thereon may overtake a second substrate on a second substrate carrier, for example, when the second substrate is being coated. The at least two transportation paths can extend substantially parallel to each other, for example, in the transport direction 1 of the substrate 10 or substrate carrier 30. In some implementations, the at least two

transportation paths can be displaced with respect to each other in the direction perpendicular to the transport direction 1 of the substrate carrier. The term “substantially parallel” relates to a substantially parallel orientation e.g. of direction(s) and/or path(s), wherein a deviation of a few degrees, e.g. up to 10° or even up to 15°, from an exact parallel orientation is still considered as “substantially parallel”.

[0065] The transportation path(s) can be provided by respective tracks. As an example, the transportation path 20 can be provided by a track and the other transportation path can be provided by another track. As used throughout the present disclosure, the term “track” can be defined as a space or device that accommodates or supports the substrate carrier, which can be an E-chuck. As an example, the track can accommodate or support the substrate carrier mechanically (using, for example, rollers), contactlessly (using, for example, magnetic fields and respective magnetic forces), or using a combination thereof.

[0066] FIG. 3 shows a schematic view of an apparatus 200 for vacuum processing of a substrate 10 according to further embodiments described herein. The apparatus 200 can be configured to perform the method for vacuum processing of a substrate according to some embodiments described herein.

[0067] According to some embodiments, which can be combined with other embodiments described herein, the apparatus 200 is configured to move the at least one implantation source with respect to the transportation path while the substrate 10 or the first material layer is irradiated with the particles. As an example, the apparatus 200 includes a drive configured to move the at least one implantation source, such as the at least one linear ion implantation source 130, with respect to the transportation path 20. In some implementations, the drive can be configured to move the at least one implantation source, such as the at least one linear ion implantation source 130, substantially parallel and/or substantially perpendicular to the transportation path 20. As an example, the drive can be configured to move the at least one implantation source in at least one of a first direction (indicated with reference numeral 2) parallel to the transportation path 20 and a second direction perpendicular to the transportation path. As an example, the first direction can be a horizontal direction and/or the second direction can be a vertical direction. The term “vertical direction” is understood to distinguish over “horizontal direction”. That is, the “vertical direction” relates to a substantially vertical movement of the implantation

source, wherein a deviation of a few degrees, e.g. up to 10° or even up to 30°, from an exact vertical direction or vertical movement is still considered as a “substantially vertical direction” or a “substantially vertical movement”. The vertical direction can be substantially parallel to the force of gravity.

5 [0068] The apparatus 200 can include a track 132 in the at least one processing region 110. The track 132 can be configured to movably support the at least one implantation source. The track 132 can be substantially parallel to the transportation path 20. The drive can be configured to move the at least one implantation source along the track 132 in the first direction. As an example, the drive can be configured to move the at least one
10 implantation source back and forth along the track 132. In some embodiments, the drive is configured to move the at least one implantation source substantially perpendicular to the track 132, for example, in the second direction which can be the vertical direction. The movements in the first direction and the second direction can include bidirectional movements in the first direction and the second direction. As an example, the movement of
15 the implantation source can include back and forth movements in the first direction (as indicated with the double-ended arrow in FIG. 3) and/or back and forth movements in the second direction.

[0069] In some embodiments, the drive is configured to move the at least one implantation source sequentially or simultaneously in the first direction and the second
20 direction. The at least one implantation source can move along a continuous or discontinuous movement path in a plane spanned by the first direction and the second direction. The plane can be a substantially vertically oriented plane. As an example, the at least one implantation source can move along a continuous movement path, when the at least one implantation source is moved simultaneously in the first direction and the second
25 direction. The at least one implantation source can move along a discontinuous movement path, when the at least one implantation source is moved sequentially in the first direction and the second direction.

[0070] According to some embodiments, which can be combined with other embodiments described herein, the apparatus 200 can be configured to conduct the
30 implantation process with the substrate 10 being stationary or moving. As an example, the apparatus 200 can be configured to irradiate the substrate 10 or the first material layer on

the substrate 10 with particles provided by the at least one implantation source while the substrate 10 passes the at least one implantation source or while the substrate 10 is stationary on the transportation path 20. Specifically, both the at least one implantation source and the substrate 10 can be moving during the implantation process. In other examples, the substrate 10 is stationarily positioned on the transportation path 20 while the at least one implantation source moves with respect to the transportation path 20 to irradiate the substrate 10 or the first material layer with the ions.

[0071] FIG. 4 shows a schematic cross-sectional view of an apparatus for vacuum processing of a substrate 10 according to embodiments described herein. The at least one implantation source, such as the at least one linear ion implantation source 130, is provided on the track 132. The at least one implantation source provides particles, such as ions (indicated with reference numeral 134), for irradiation of the substrate 10 that is supported on the substrate carrier 30. The apparatus can include the drive configured to move the at least one implantation source along the track 132 in the first direction. Additionally or alternatively, the drive is configured to move the at least one implantation source in the second direction, wherein the second direction can be the vertical direction 3.

[0072] According to some embodiments, which can be combined with other embodiments described herein, the apparatus for vacuum processing can include a magnetic levitation system (not shown) configured for a contactless levitation of the substrate carrier 30 in, for example, the vertical orientation. The substrate carrier 30 can be an E-chuck. The term “contactless levitation” as used throughout the present disclosure can be understood in the sense that a weight of the substrate carrier 30 is not carried or held by a mechanical contact or mechanical forces, but is carried or held by a magnetic force. Specifically, the substrate carrier 30 is held in a levitating or floating state using magnetic forces instead of mechanical forces. As an example, the magnetic levitation system has no mechanical devices, such as rollers, that support the weight of the substrate carrier 30. In some implementations, there can be no mechanical contact between the substrate carrier 30 and the apparatus for vacuum processing at all. The contactless levitation is beneficial in that no particles are generated due to a mechanical contact between the substrate carrier 30 and sections of the apparatus for vacuum processing, such as rollers. Accordingly, a purity

of the layers deposited on the substrate 10 can be improved, in particular since a particle generation is minimized or even avoided.

[0073] The magnetic force provided by the magnetic levitation system is sufficient to hold the substrate carrier 30 having the substrate 10 positioned thereon in the floating state.

5 Specifically, the magnetic force can be equal to a total weight of the substrate carrier 30. The total weight of the substrate carrier 30 can include at least a weight of the (empty) substrate carrier 30 and a weight of the substrate 10. As an example, a magnetic field generated by the magnetic levitation system is selected such that the magnetic force is equal to the total weight of the substrate carrier 30 in order to keep the substrate carrier 30
10 in the suspended or levitating state.

[0074] FIG. 5 shows a schematic view of an apparatus 500 for vacuum processing of a substrate 10 according to embodiments described herein.

[0075] The apparatus 500 includes a plurality of regions, such as a first deposition region 508, at least one processing region 510, and a second deposition region 520. The plurality
15 of regions can be provided in one vacuum chamber. Alternatively, the plurality of regions can be provided in different vacuum chambers connected to each other. As an example, each vacuum chamber can provide one region. Specifically, a first vacuum chamber can provide the first deposition region 508, a second vacuum chamber can provide the at least one processing region 510, and a third vacuum chamber can provide the second deposition
20 region 520. In some implementations, the first vacuum chamber and the third vacuum chamber can be referred to as “deposition chambers”. The second vacuum chamber can be referred to as “processing chamber” or “implantation chamber”. Further vacuum chambers or regions, such as a loading chamber and an unloading chamber, can be provided adjacent to the regions shown in the example of FIG. 5.

25 [0076] The vacuum chambers or regions can be separated from adjacent regions by a valve having a valve housing 504 and a valve unit 505. After a substrate carrier 30 with the substrate 10 thereon is, as indicated by arrow 1, inserted in a region, such as the at least one processing region 510, the valve unit 505 can be closed. The atmosphere in the regions can be individually controlled by generating a technical vacuum, for example, with
30 vacuum pumps connected to the regions and/or by inserting one or more process gases, for

example, in the first deposition region 508 and/or the second deposition region 520. A transportation path 20, such as a linear transportation path, can be provided in order to transport the substrate carrier 30, having the substrate 10 thereon, into, through and out of the regions. The transportation path 20 can extend at least in part through the first deposition region 508, the at least one processing region 510, and the second deposition region 520.

[0077] The apparatus 500 includes the at least one implantation source, such as the at least one linear ion implantation source 130, in the at least one processing region 510. The at least one implantation source can be configured according to the embodiments described herein. Within the deposition regions, such as the first deposition region 508 and the second deposition region 520, one or more deposition sources are provided. As an example, a first deposition source 540 can be provided in the first deposition region 508. A second deposition source 550 can be provided in the second deposition region 520. A deposition source of the one or more deposition sources can include one or more cathodes and one or more anodes. As an example, the first deposition source 540 can include a first cathode 542 and a first anode 544. The second deposition source 550 can include a second cathode 552 and a second anode 554. For example, the one or more cathodes can be rotatable cathodes having the sputter targets of the material to be deposited on the substrate 10. The one or more cathodes can have a magnet assembly therein, and magnetron sputtering can be conducted for depositing of the layers.

[0078] The one or more cathodes and the one or more anodes can be electrically connected to a DC power supply. The one or more cathodes are connected to the DC power supply together with the one or more anodes for collecting electrons during sputtering. According to yet further embodiments, which can be combined with other embodiments described herein, at least one of the one or more cathodes can have a corresponding, individual DC power supply. Specifically, the first deposition source 540 can have a first DC power supply 546 and the second deposition source 550 can have a second DC power supply 556.

[0079] As used herein, “magnetron sputtering” refers to sputtering performed using a magnetron or magnet assembly, i.e., a unit capable of generating a magnetic field. Such a magnet assembly consists of one or more permanent magnets. These permanent magnets

can be arranged within a rotatable sputter target or coupled to a planar sputter target in a manner such that the free electrons are trapped within the generated magnetic field generated below the rotatable target surface. Such a magnet assembly may also be arranged coupled to a planar cathode. According to some embodiments described herein, sputtering
5 can be conducted as DC (direct current) sputtering. However, other sputtering methods such as MF (middle frequency) sputtering, RF (radio frequency) sputtering, or pulse sputtering can also be applied.

[0080] FIG. 5 shows the deposition regions having one deposition source including one cathode and one anode. Particularly for applications for large area deposition, an array of
10 deposition sources can be provided within at least one of the regions, such as the first deposition region 508 and the second deposition region 520.

[0081] In some implementations, the first material layer, such as a first IGZO layer, is deposited on the substrate 10 in the first deposition region 508 using the first deposition source 540. The substrate 10 having the first material layer deposited thereon is transported
15 from the first deposition region 508 into the at least one processing region 510 having the at least one implantation source, such as the at least one linear ion implantation source 130. The at least one implantation source can be stationary. Specifically, the at least one implantation source can provide the particles while the substrate 10 on the substrate carrier 30 passes the implantation source. As an example, the first material layer on the substrate
20 10 can be irradiated with the particles for implantation of the particles into the first material layer while the substrate carrier 30 is transported along the transportation path 20 through the at least one processing region 510. The implantation process can change one or more material properties, such as electrical and/or optical properties, of the first material layer. Having completed the implantation process, the substrate 10 can be transferred into
25 the second deposition region 520 for deposition of a second material layer, for example, a second IGZO layer, over the substrate 10.

[0082] FIG. 6 shows a schematic view of an apparatus 600 for vacuum processing of a substrate according to embodiments described herein. The apparatus 600 is similar to the apparatus 500 described above with reference to FIG. 5, the difference being that the at
30 least one implantation source, such as the at least one linear ion implantation source 130, is movable with respect to the transportation path 20 (indicated with reference numeral “2”).

The movable implantation source can be configured as described with reference to, for example, FIGs. 1, 3 and 4.

[0083] FIG. 7 shows a schematic cross-sectional view of a section of a display having a thin film transistor 400 according to further embodiments described herein. The TFT according to the embodiments described herein can, for example, be used in display devices, such as liquid crystal displays (LCDs) and/or organic light emitting diode (OLED) displays.

[0084] The display includes a substrate 410, for example, a glass substrate. A gate electrode 420 is formed on or over the substrate 410. The gate electrode 420 can be deposited using a PVD process. As an example, the gate electrode 420 can include a metal. The metal can be selected from the group including Cr, Cu, Mo, Ti, and any combination thereof. The metal can also be a metal stack including two or more of the metals selected from the group including Cr, Cu, Mo, Ti, and any combination thereof. A gate insulator 430 is formed at least over the gate electrode 420, e.g., by a PECVD process. As an example, the gate insulator 430 can include at least one of SiN_x and SiO_y . The gate insulator can have at least two sub-layers, e.g., at least one SiN_x layer and at least one SiO_y layer.

[0085] A channel layer 440 is formed on or over the gate insulator 430. The channel layer is the active (semiconducting) layer. The material of the channel layer 440 can be selected from the group consisting of ZnON, LTPS (p-Si), IGZO, and a-Si. The channel layer 440 (also referred to as "channel") can be manufactured using the embodiments of the present disclosure. As an example, the channel layer 440 can be made of IGZO. IGZO electric properties react strongly to hydrogen, oxygen and other atoms. By implanting e.g. hydrogen into the IGZO layer (e.g. the first material layer) an implantation region 442 having an increased content of the implanted ions is formed. A dual layer active channel can be generated, leading to higher mobility and a changed V_{th} . Depending on beam energy this layer can be a buried layer inside a thick IGZO film (i.e., a thick first material layer) or can be provided as a surface modification of a first IGZO layer (the first material layer) which is coated with a second IGZO layer (the second material layer) after the particle treatment, such as the ion beam treatment.

[0086] According to some embodiments, the channel includes the first material layer having the buried layer generated by the particles implanted in the first material layer. In further embodiments, the channel includes the first material layer having the particles implanted in a surface region of the first material layer and the second material layer on the first material layer. A thickness of the buried layer and/or the surface region having the ions implanted can be 100 Å or more, specifically 200 Å or more, and specifically 500 Å or more. As an example, the thickness of the buried layer and/or the surface region can be in a range between 50 Å and 500 Å, and more specifically in a range between 100 Å and 200 Å. A THK profile can be broad. As an example, in a case in which oxygen is implanted into IGZO, a 100 Å median penetration depth with a spread of +/- 100 Å can be provided (the implanted layer from surface down to 200 Å with a maximal oxygen content at approximately 100 Å).

[0087] An etch stopper 470, e.g., of SiO_x, is formed on the channel layer 440, e.g., by a PECVD process. A source electrode 450 and a drain electrode 460 are formed on the channel layer 440, e.g., by a PVD process. The source electrode 450 and the drain electrode 460 can be made of a metal. The metal can be selected from the group including Cr, Cu, Mo, Ti, and any combination thereof. The metal can also be a metal stack including two or more of the metals selected from the group including Al, Ti, Cr, Cu, Mo, and any combination thereof. A passivation layer 480 is formed at least over the source electrode 450 and the drain electrode 460. The passivation layer 480 can, for example, be formed by a PECVD process. A pixel electrode (not shown) can be provided in contact with the drain electrode 460. The pixel electrode can be made of indium tin oxide (ITO).

[0088] The present disclosure uses an ion implantation source for implanting ions in a substrate or a first material layer on the substrate to change one or more material properties of the substrate or the first material layer. As an example, ions can be implanted in the first material layer to provide a channel of a thin film transistor that has a higher mobility and/or a changed threshold voltage V_{th}. An improvement of a display TFT performance by modification of the IGZO channel by an ion beam treatment to enhance a mobility and/or other TFT properties can be achieved.

[0089] While the foregoing is directed to embodiments of the disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. Method for vacuum processing of a substrate, comprising:

irradiating the substrate or a first material layer on the substrate with particles using
5 an implantation source provided in a processing region; and

moving the substrate through the processing region along a transportation path
while the substrate or the first material layer is irradiated with the particles.
2. The method of claim 1, wherein the implantation source is moving or stationary
10 while the substrate or the first material layer is irradiated with the particles.
3. Method for vacuum processing of a substrate, comprising:

moving an implantation source provided in a processing region with respect to a
substrate provided on a transportation path; and
15 irradiating the substrate or a first material layer on the substrate with particles
provided by the implantation source while the implantation source is moved.
4. The method of claim 3, wherein the substrate is moving along the transportation
path or is stationary on the transportation path while the substrate or the first material layer
20 is irradiated with the particles.
5. The method of any one of claims 1 to 4, wherein the particles are selected from the
group consisting of ions, electrically neutral atoms, nitrogen, oxygen, hydrogen, gallium,
indium, and any combination thereof.

6. The method of any one of claims 1 to 5, wherein the substrate or the first material layer on the substrate is irradiated with the particles to change one or more material properties of the substrate or the first material layer, respectively.

5

7. The method of claim 6, wherein the one or more material properties are selected from the group consisting of physical properties, electrical properties, chemical properties, and optical properties.

10 8. The method of any one of claims 1 to 7, further including at least one of:

depositing the first material layer over the substrate; and

depositing at least one second material layer over the substrate or over the first material layer after the substrate or the first material layer has been irradiated with the particles.

15

9. The method of claim 8, wherein at least one of the first material layer and the second material layer is deposited while the substrate is stationary or while the substrate is moved along the transportation path.

20 10. A thin film transistor, including a channel manufactured using the method of any one of claims 1 to 9.

11. The thin film transistor of claim 10, wherein the channel includes:

the first material layer including a buried layer generated by the particles implanted in the first material layer; or

the first material layer having the particles implanted in a surface region of the first material layer and the second material layer on the first material layer.

5

12. An apparatus for vacuum processing of a substrate, comprising:

at least one processing region having at least one implantation source;

at least one deposition region having one or more deposition sources; and

10 a transportation path extending through the at least one processing region and the at least one deposition region,

wherein the apparatus is configured to irradiate the substrate or the first material layer on the substrate with particles provided by the at least one implantation source,

wherein the apparatus is configured to:

15 move the substrate through the processing region along the transportation path while the substrate or a first material layer is irradiated with the particles; or

move the at least one implantation source with respect to the transportation path while the substrate or a first material layer is irradiated with the particles.

13. The apparatus of claim 12,

20 wherein the implantation source is an ion implantation source or a linear ion implantation source configured to generate ions for implantation of the ions in the substrate or the first material layer, or

wherein the implantation source is configured to generate ions and is further configured to electrically neutralize the generated ions for implantation of electrically neutral particles in the substrate or the first material layer.

- 5 14. The apparatus of claim 12 or 13, wherein the implantation source includes:
- an ion source configured to provide ions; and
- an accelerator configured for accelerating the ions provided by the ion source.

15. The apparatus of claim 14, wherein the implantation source further includes a
- 10 neutralizing device for electrically neutralizing the accelerated ions.

Fig. 1

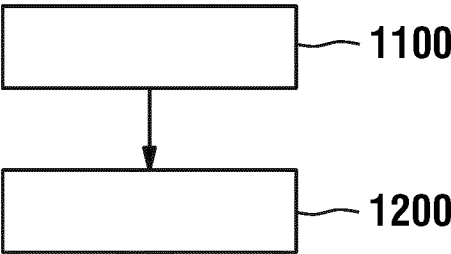
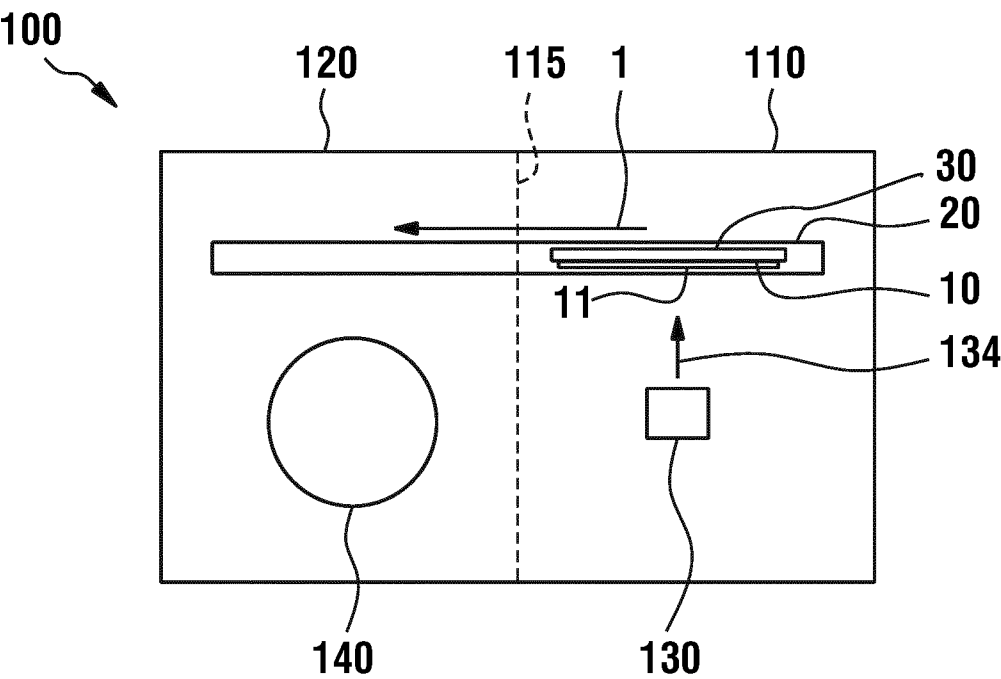


Fig. 2



2 / 5

Fig. 3

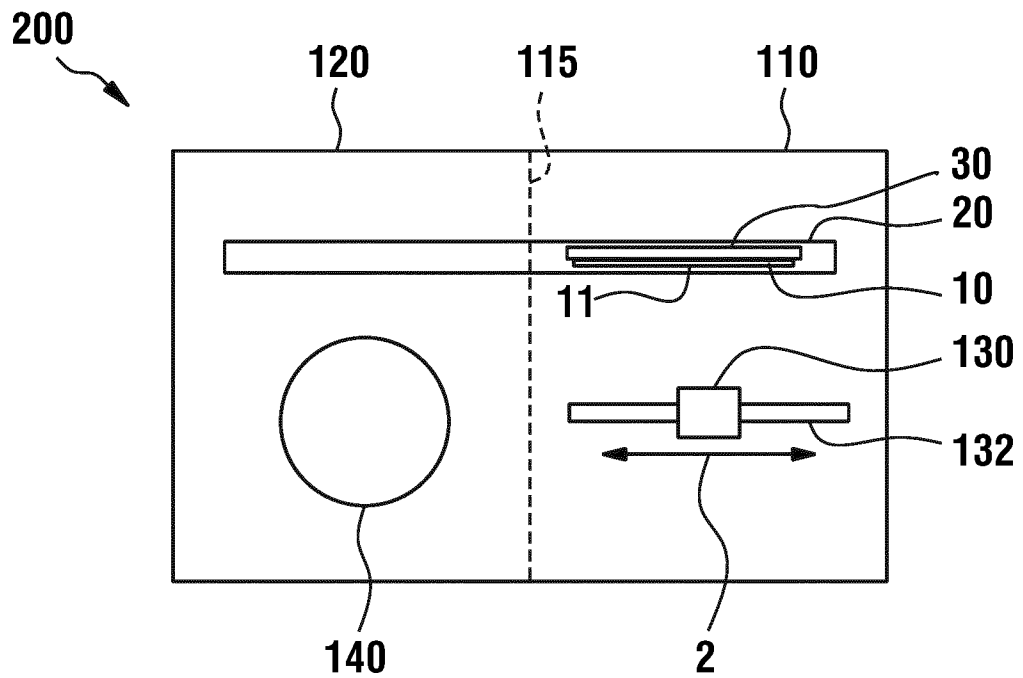
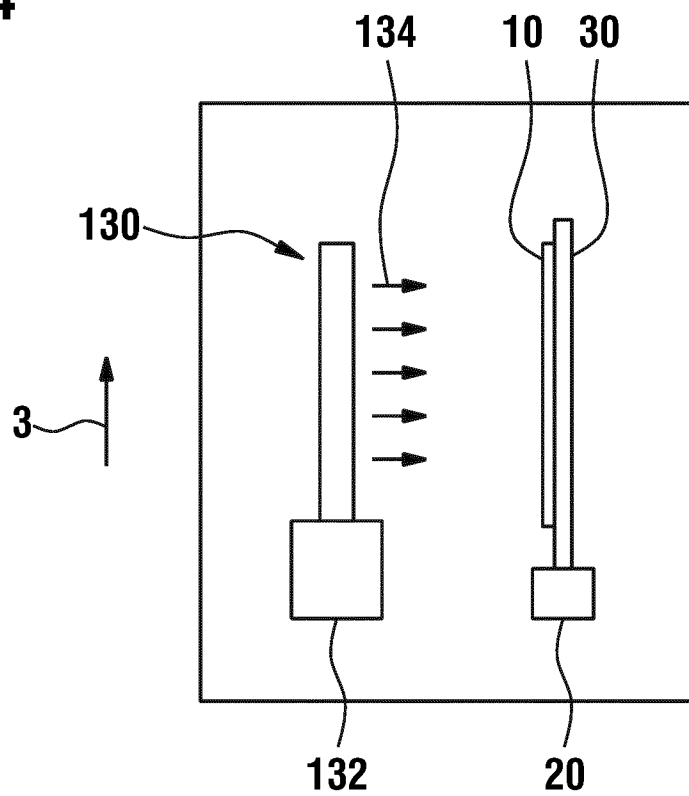
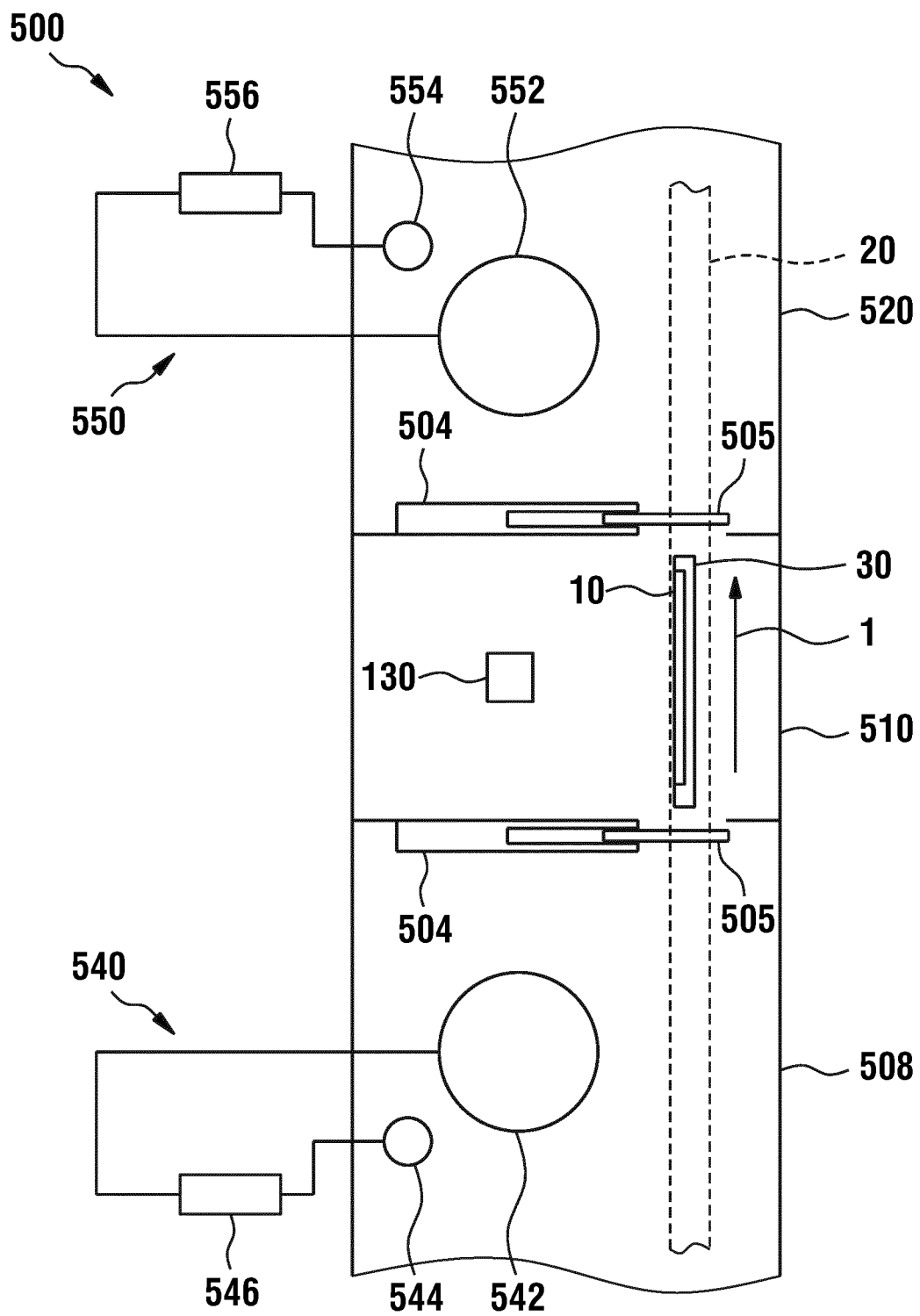


Fig. 4



3 / 5

Fig. 5



4 / 5

Fig. 6

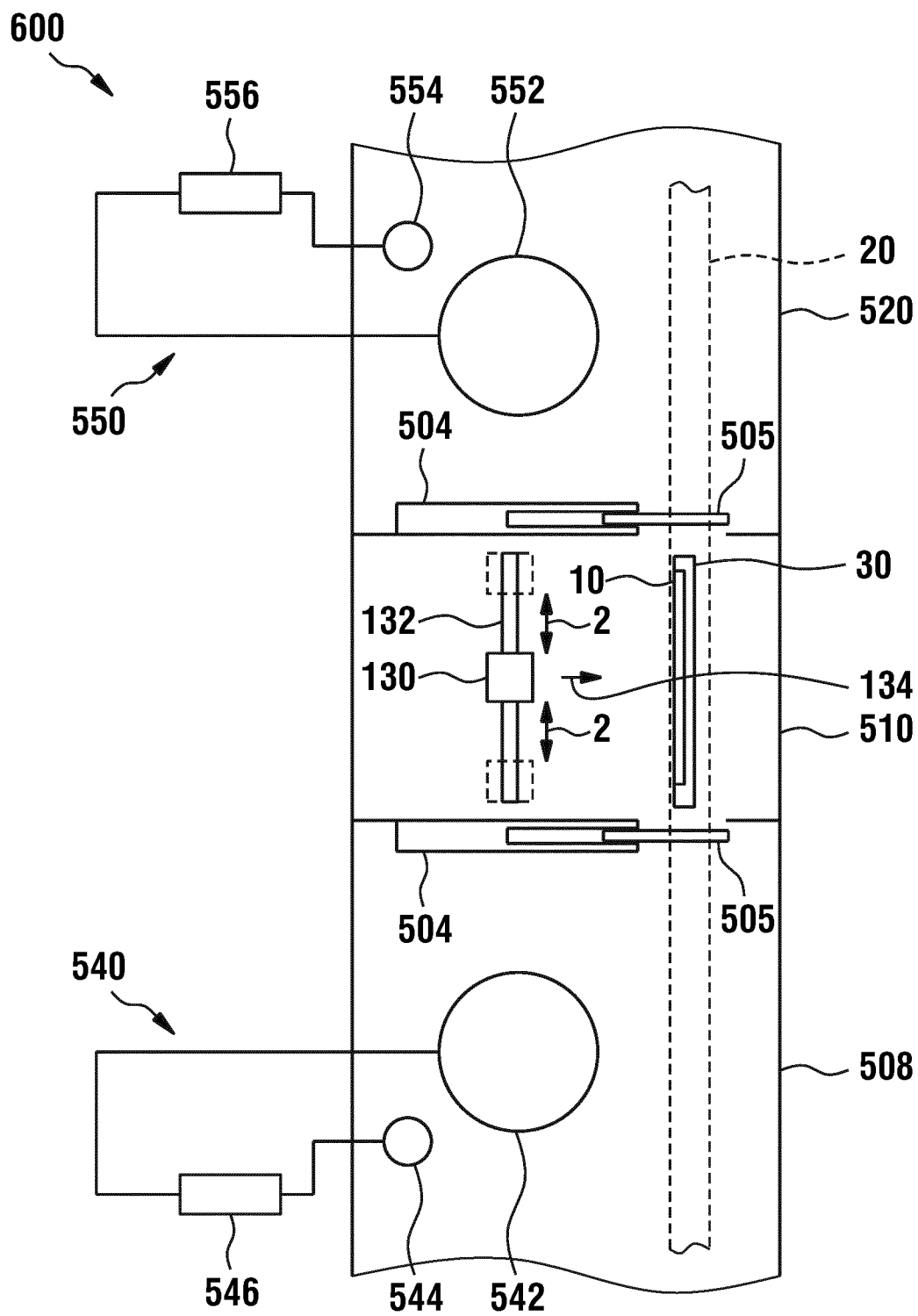
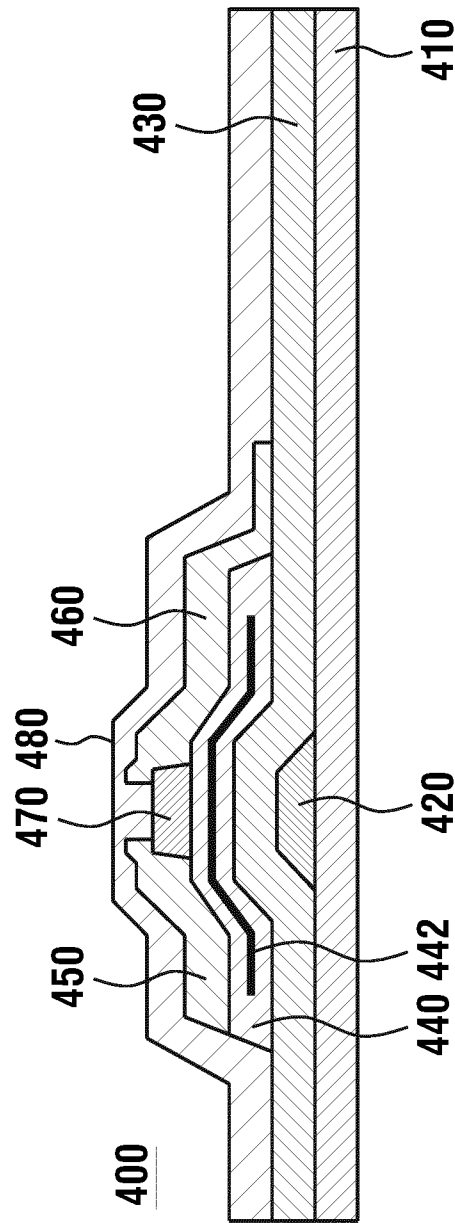


Fig. 7



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/052884

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C14/02 C23C14/48 C23C14/56 H01L21/26 H01L21/687
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C23C H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/330787 A1 (SFERLAZZO PIERO [US]) 30 December 2010 (2010-12-30) page 2, paragraphs 14,15 - page 3, paragraphs 29,35,36 page 4, paragraph 39 - page 6, paragraphs 56,57	1,2,5-14
X	US 2009/098306 A1 (DRUZ BORIS [US] ET AL) 16 April 2009 (2009-04-16) page 2, paragraphs 15,16 - page 5, paragraph 72	1-7,10, 12-15
X	US 2002/134668 A1 (WAN ZHIMIN [US] ET AL) 26 September 2002 (2002-09-26) page 2, paragraphs 10,11	1,2,5-7, 10,12-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

6 November 2017

Date of mailing of the international search report

13/11/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Boussard, Nadège

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/052884

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010330787 A1	30-12-2010	US 2010330787 A1 WO 2008021501 A2	30-12-2010 21-02-2008
US 2009098306 A1	16-04-2009	US 2009098306 A1 US 2016071708 A1	16-04-2009 10-03-2016
US 2002134668 A1	26-09-2002	NONE	