

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).

Published:

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

METHOD OF FORMING A LIGHT EMITTING STRUCTURE AND APPARATUS THEREFOR

TECHNICAL FIELD

5 [0001] The present disclosure relates to a method and an apparatus for coating a substrate in a vacuum process chamber. In particular, the present disclosure relates to an apparatus and a method for forming at least one layer of sputtered material on a substrate for display manufacturing.

BACKGROUND

10 [0002] In many applications, deposition of thin layers on a substrate, e.g. on a glass substrate is used. Conventionally, the substrates are coated in different chambers of a coating apparatus. For some applications, the substrates are coated in a vacuum using a vapor deposition technique. Several methods are known for depositing a material on a substrate. For instance, substrates may be coated by a physical vapor deposition (PVD)
15 process, a chemical vapor deposition (CVD) process or a plasma enhanced chemical vapor deposition (PECVD) process, or the like. Usually, the process is performed in a process apparatus or process chamber where the substrate to be coated is located.

[0003] Electronic devices and particularly opto-electronic devices have shown a significant reduction in costs over the last years. Further, the pixel density in displays is
20 continuously being increased. For instance, light-emitting diode (LED) displays use an array of light emitting diodes as pixels. The high brightness of the LED displays yield an increasing demand for LED displays. In an organic light-emitting diode (OLED), the electroluminescent material is an organic compound. The potential advantages of OLEDs include thin, low-cost displays with a low driving voltage, wide viewing angle, and high
25 contrast and color gamut. However, the different layers in the OLED may be error-prone, inducing for instance cathode shorts or oxidation reducing reflection.

[0004] Accordingly, there is a continuing demand for providing methods and apparatuses for improving the properties of light emitting structures during manufacturing, in particular with respect to high quality and low cost.

SUMMARY

5 [0005] In view of the above, a method for forming a light emitting structure on a substrate and an apparatus therefor according to the independent claims are provided. Further, an electronic device including a layer which is manufactured by the method of manufacturing a layer according to embodiments described herein is provided. Further advantages, features, aspects and details are apparent from the dependent claims, the
10 description and drawings.

[0006] According to one aspect of the present disclosure, a method for forming a light emitting structure on a substrate is provided. The method includes forming a first reflective electrode portion, forming an emitter layer over the first reflective electrode portion and forming a second electrode portion over the emitter layer. Forming the first
15 reflective electrode portion includes depositing a first transparent conductive metal oxide layer, a reflective metal layer and a second metal oxide layer (especially a second transparent conductive metal oxide layer) in a process atmosphere including process gases. The method further includes setting the light absorption properties of the first reflective electrode portion to a light absorption of less than 6% of the incident light by controlling
20 the ratio of O₂ content and H₂ content of the process gas.

[0007] According to a further aspect of the present disclosure, an electronic device is provided which includes a light emitting structure which is manufactured by the method of forming a light emitting structure according to embodiments described herein.

[0008] According to a further aspect of the present disclosure, a light emitting structure is
25 provided. The light emitting structure includes a first reflective electrode portion, an emitter layer on the first reflective electrode portion and a second electrode portion on the emitter layer. The first reflective electrode portion includes a first transparent conductive metal oxide layer, a reflective metal layer and a second metal oxide layer (especially a

second transparent conductive metal oxide layer). The first reflective electrode portion has a light absorption of less than 6% of the incident light.

[0009] According to a further aspect of the present disclosure, an apparatus for depositing an electrode portion for a light emitting structure is provided. The apparatus
5 includes a vacuum chamber; and one or more indium oxide, particularly indium tin oxide (ITO), containing targets within the vacuum chamber for sputtering a transparent conductive oxide layer. The apparatus further includes a gas distribution system for providing processing gases within the vacuum chamber. Further, a controller is provided connected to the gas distribution system and configured to execute a program code,
10 wherein upon execution of the program code a method according to embodiments described herein is conducted.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the above recited features of the disclosure described herein can be understood in detail, a more particular description, briefly summarized
15 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 schematic view of an apparatus for forming a light emitting structure according to embodiments described herein;

FIG. 2 shows a flow chart illustrating a method for forming a light emitting structure
20 according to embodiments as described herein;

FIG. 3 shows a schematic view of a light emitting structure according to embodiments described herein;

FIG. 4 shows a flow chart illustrating a method for forming a light emitting structure according to embodiments as described herein; and

25 FIG. 5 shows a schematic view of a first reflective electrode portion of a light emitting structure according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0011] 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
5 components. In the following, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the disclosure and is not 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 a further embodiment. It is intended that the description includes such modifications and
10 variations.

[0012] In the present disclosure, the expression “process atmosphere” may be understood as an atmosphere inside a processing chamber, particularly inside a vacuum processing chamber of an apparatus for depositing a layer. The “process atmosphere” may have a volume which is specified by the volume inside the processing chamber.

15 [0013] In the present disclosure, the abbreviation “H₂” stands for hydrogen, in particular for gaseous hydrogen.

[0014] Further, in the present disclosure, the abbreviation “O₂” stands for oxygen, in particular for gaseous oxygen.

[0015] The term “electrode portion” may be understood as a layer sequence including
20 one or more layers. The electrode portion as used herein may be used as an electrode, in particular either as a cathode or an anode. For instance, the electrode portion as described herein may be used as a cathode or an anode in a light emitting structure, such as an LED, an OLED, or the like. According to some embodiments, a “reflective electrode portion” may be understood as an electrode portion having reflective properties, especially
25 reflective properties for incident light on the reflective electrode portion. According to some embodiments, an electrode portion being a reflective electrode portion may mean that the reflective electrode portion has a reflectivity of light of less than 100%, typically a reflectivity larger than 85%, more typically larger than 90% and even more typically larger than 95%. The same may apply for a reflective layer referred to herein. According to some

embodiments, a reflective electrode portion or a reflective layer as used herein may be understood as a layer or portion wherein the amount of reflected light is larger than the amount of transmitted light

[0016] The term “transparent conductive metal oxide layer” may be understood as a metal oxide layer having at least partly conductive and transparent properties. For instance, the metal in the transparent conductive metal oxide layer may result in a defined conductivity of the respective layer. According to some embodiments, the transparent conductive metal oxide layer may have transmitting properties for incident light, in particular for visible light. For instance, the transparent conductive metal oxide layer may have a transmission of light of less than 100%, such as typically larger than 85%, more typically larger than 90%, and even more typically larger than 95%. According to some embodiments, a layer being described as being transparent may also have reflective properties, such as by reflecting a first amount of the incident light and by transmitting a second amount of the incident light. According to embodiments described herein, a transparent layer may be understood as a layer with a low absorption. In particular, a transparent layer may be understood as a layer wherein the amount of transmitted light is larger than the amount of reflected light.

[0017] In FIG. 1, a schematic view of an apparatus 200 for depositing one or more layers of a light emitting structure on a substrate according to embodiments described herein is shown. The layer deposition of a light emitting structure may be used for display manufacturing according to embodiments described herein. According to embodiments as described herein, the apparatus for depositing a layer for display manufacturing includes a vacuum chamber 210. In the vacuum chamber, one or more targets 220a, 220b are positioned. For instance, the targets may include one or more materials for forming a reflective electrode portion on a substrate. In some embodiments, the targets may include a material for forming a metal oxide layer on a substrate, in particular a transparent conductive oxide layer, such as indium oxide, particularly indium tin oxide (ITO). The targets are adapted for sputtering the target material (e.g. a transparent conductive metal oxide layer) on the substrate 300. The apparatus 200 further includes a gas distribution system 230 for providing a process gas to the vacuum chamber. A controller 240 is provided connected to the gas distribution system 230 and configured to execute a program

code. Upon execution of the program code, the method for forming a light emitting structure, e.g. for display manufacturing, as described herein may be conducted.

[0018] As exemplarily shown in FIG. 1, according to embodiments which can be combined with other embodiments described herein, the vacuum chamber 210 is limited by chamber walls 211 and may be connected to the gas distribution system 230 at a first gas inlet 231 for H₂ and a second gas inlet 232 for O₂. As shown in FIG.1, the first gas inlet 231 may be connected to the gas distribution system 230 via a first conduit having a first mass flow controller 234 configured for controlling an amount of H₂ provided to the process atmosphere, for example a first valve. The second gas inlet 232 may be connected to the gas distribution system 230 via a second conduit having a second mass flow controller 235 configured for controlling an amount of O₂ provided to the process atmosphere, for example a second valve.

[0019] According to embodiments which can be combined with other embodiments described herein, the gas distribution system may include a first gas source for providing H₂ and a second gas source for providing O₂. Accordingly, the apparatus as described herein may be configured for providing H₂ and O₂ independently from each other, such that the H₂ content, the O₂ content and/or the ratio of the H₂ content and the O₂ content of the process atmosphere 222 within the vacuum chamber 210 can be controlled.

[0020] According to embodiments which can be combined with other embodiments described herein, the gas distribution system may include a third gas source for providing an inert gas. The third gas source may be configured for providing the inert gas (such as Ar) to the process atmosphere separately from H₂ and/or O₂, for example through a separate third gas inlet which connects the vacuum chamber with the third gas source of the gas distribution system. According to embodiments which can be combined with other embodiments described herein, the gas distribution system may include an inert gas flow controller (not shown) configured for controlling an amount of inert gas provided to the process atmosphere. According to some embodiments, which can be combined with other embodiments described herein, the third gas source may be employed for providing an inert gas/H₂ mixture which can be provided to the process atmosphere inside the vacuum chamber through the first gas inlet. Additionally or alternatively, the third gas source may

be employed for providing an inert gas/O₂ mixture which can be provided to the process atmosphere inside the vacuum chamber through the second gas inlet.

[0021] According to embodiments which can be combined with other embodiments described herein, the gas distribution system 230 may include pumps and/or compressors
5 for providing the defined pressure of the process atmosphere inside the vacuum chamber. In particular, the gas distribution system may include pumps and/or compressors for providing the respective pressure of H₂, and/or for providing the respective pressure of O₂ and/or for providing the respective pressure of inert gas according to embodiments described herein.

10 [0022] With exemplary reference to FIG. 1, according to embodiments which can be combined with other embodiments described herein, the vacuum chamber 210 may include an outlet port 233, connected to an outlet conduit, which is in fluid connection with an outlet pump 236 for providing the vacuum in the vacuum chamber 210.

[0023] As illustrated in FIG. 1, within the vacuum chamber 210, a first deposition
15 source 223a and a second deposition source 223b may be provided. The deposition sources can, for example, be rotatable cathodes having targets of the material to be deposited on the substrate. In particular, the target may be a metal oxide containing target, in particular a transparent conductive metal oxide, and further in particular an indium tin oxide (ITO) containing target, particularly an ITO 90/10 containing target. According to embodiments
20 described herein, ITO 90/10 includes an indium oxide (In₂O₃) and a tin oxide (SnO₂) at a ratio of In₂O₃ : SnO₂ = 90:10.

[0024] According to embodiments which can be combined with other embodiments described herein, the cathodes can be rotatable cathodes with magnet assemblies 221a, 221b therein. With the apparatus as described herein, magnetron sputtering may be
25 conducted for depositing a layer for a light emitting structure. As exemplarily shown in FIG. 1, the cathodes of the first deposition source 223a and the second deposition source 223b can be connected to a power supply 250. The power supply 250 may be connected to the controller 240 such that the power supply can be controlled by the controller, as exemplarily shown in FIG. 1. Depending on the nature of the deposition process, the
30 cathodes may be connected to an AC (alternating current) power supply or a DC (direct

current) power supply. For example, sputtering from an indium oxide target, e.g. for a transparent conductive metal oxide film, may be conducted as DC sputtering. In the case of DC sputtering, the first deposition source 223a may be connected to a first DC power supply and the second deposition source 223b may be connected to a second DC power supply. For DC sputtering, the second deposition source 223b and the second deposition source 223b may have separate DC power supplies. According to embodiments which can be combined with other embodiments described herein, DC sputtering may include pulsed-DC sputtering, particularly bipolar-pulsed-DC sputtering. Accordingly, the power supply may be configured for providing pulsed-DC, particularly bipolar-pulsed-DC. In particular, the first DC power supply for the first deposition source 223a and the second DC power supply for the second deposition source 223b may be configured for providing pulsed-DC power. In FIG. 1, a horizontal arrangement of deposition sources and substrate 300 to be coated is shown. In some embodiments, which may be combined with other embodiments disclosed herein, a vertical arrangement of deposition sources and substrate 300 to be coated may be used.

[0025] With exemplary reference to FIG. 1, according to embodiments which can be combined with other embodiments described herein, a sensor 270 may be provided in the vacuum chamber 210 for measuring the composition of the process atmosphere 222. In particular, the sensor 270 may be configured for measuring the content of inert gas, H₂, O₂ and residual gas within the respective content ranges as specified herein. In some embodiments, the sensor 270 may be connected to a controller 240 for adjusting the amounts of the process gases dependent on the sensed composition in the vacuum chamber 210.

[0026] As shown in FIG. 1, according to embodiments which can be combined with other embodiments described herein, the sensor 270, gas distribution system 230 including the first mass flow controller 234 and the second mass flow controller 235, and outlet pump 236 may be connected to a controller 240. The controller 240 may control the first mass flow controller 234, the second mass flow controller 235, the inert gas flow controller and the outlet pump 236, so that an atmosphere with a composition as described herein is created and maintained in the vacuum chamber 210. Accordingly, all constituents of a selected process atmosphere with a composition as described herein may be controlled,

especially independently from each other. In particular, the controller may be configured for controlling the gas distribution system such that the flow of H₂, the flow of O₂, and the flow of inert gas can be controlled independently from each other for establishing a process atmosphere with a selected composition as described herein. Accordingly, the composition
5 of a selected process atmosphere can be adjusted very accurately.

[0027] When the apparatus 200 for depositing a layer for a light emitting structure as described herein is used for conducting the method for forming a light emitting structure according to embodiments described herein, a substrate 300 may be disposed below the deposition sources, as exemplarily shown in FIG.1. The substrate 300 may be arranged on
10 a substrate support 310. According to embodiments which can be combined with other embodiments described herein, a substrate support device for a substrate to be coated may be disposed in the vacuum chamber. For example, the substrate support device may include conveying rolls, magnet guiding systems and further features. The substrate support device may include a substrate drive system for driving the substrate to be coated
15 in or out of the vacuum chamber 210.

[0028] Accordingly, the apparatus according to embodiments as described herein is configured for manufacturing one or more layers for a light emitting structure (such as for instance an LED, an OLED and the like) by employing the method of manufacturing a layer according to embodiments described herein.

20 [0029] FIG. 2 shows a block diagram illustrating a method for forming a light emitting structure on a substrate according to embodiments as described herein. In particular, the light emitting structure may be an OLED structure, and may in some embodiments be a top-emitting OLED structure. The method 100 includes in block 101 forming a first reflective electrode portion, forming an emitter layer on or over the first reflective
25 electrode portion and forming a second electrode portion over the emitter layer. For instance, the first reflective electrode portion, the emitter layer, and the second electrode portion may be formed by sputtering including in particular sputtering a transparent conductive metal oxide layer (e.g. from an indium oxide containing target) in a process atmosphere. In particular, the target may be an indium tin oxide (ITO) containing target or
30 an Indium Zinc oxide (IZO) containing target. According to embodiments described

herein, the first reflective electrode portion, the emitter layer, and the second electrode portion may be formed consecutively one over the other.

[0030] According to embodiments described herein, forming the first reflective electrode portion and/or the second electrode portion includes depositing a first transparent
5 conductive metal oxide layer, a reflective metal layer and a second transparent conductive metal oxide layer in a process atmosphere including process gases. According to some embodiments, the emitter layer may be an emissive electroluminescent layer, e.g. containing an organic compound. The organic compound is a compound emitting light in response to an electric current. According to some embodiments, the organic compound
10 may be an organic semiconductor. The emitter layer is arranged between the first reflective electrode portion and the second electrode portion, especially for creating a display.

[0031] According to embodiments which can be combined with other embodiments described herein, the process atmosphere includes H_2 , O_2 and an inert gas. The inert gas may be selected from the group consisting of helium, neon, argon, krypton, xenon or
15 radon. In particular, the inert gas may be argon (Ar). It can be understood that the content of the constituents of the process atmosphere according to embodiments described herein may add up to 100%. In particular, the content of H_2 , O_2 and inert gas may add up to 100% of the process atmosphere.

[0032] The method 100 according to embodiments described herein includes in block
20 102 setting the light absorption properties of the first reflective electrode portion to a light absorption of typically less than 6%, more typically less than 5%, even more typically less than 3%, and even more typically less than 2% of the incident light by controlling the ratio of O_2 content and H_2 content of the process gas. Additionally or alternatively to the absorption of the first reflective electrode portion, the absorption properties of the first
25 and/or second transparent conductive metal oxide layer may be set to be less than 6%, more typically less than 5%, even more typically less than 3%, and even more typically less than 2% of the incident light by controlling the ratio of O_2 content and H_2 content of the process gas. In particular, the absorption of the first and/or second transparent conductive layer may be less than 4% of the incident light. Additionally or alternatively to
30 the absorption properties of the first reflective electrode portion, the reflective metal layer

may have a reflectance of typically at least 95%, more typically at least 96%, and even more typically at least 98%.

[0033] For instance, the control of the O₂ content and H₂ content may be done by the gas inlets 231 and 232 as exemplarily shown in FIG. 1. According to some embodiments, the first mass flow controller 234 and the second mass flow controller 235 may control the separate gas inlets for H₂ and O₂. In some embodiments, the first mass flow controller 234 and the second mass flow controller 235 may be connected to controller 240. The controller 240 may be configured for adjusting the mass flow of the H₂ and O₂ inlet for influencing the light absorption of the first reflective electrode portion of the light emitting structure, e.g. by executing a program code, by adjusting the mass flow of H₂ and O₂, by processing results of sensor(s) within the vacuum chamber, by comparing the sensor results to a threshold value or table, by processing results of tests performed on previously manufactured light emitting structures, by comparing the test results to a threshold value or table, by monitoring the process, by giving an alert to an operator for process gas compositions not within a defined range, and the like.

[0034] According to some embodiments described herein, the light absorption of the first reflective electrode definition may be the counterpart of the sum of the transmission and the reflectance of the first reflective electrode. The light absorption as used herein may be understood as the energy introduced to the first reflective electrode by an incident light, in particular the energy of electromagnetic radiation. In some embodiments, absorbed energy of the incident light may be transformed into internal energy of the first reflective electrode (e.g. thermal energy, working energy, reactive energy or the like). According to some embodiments, the light absorption of the incident light may be understood as the amount or portion of the incident light being not reflected or transmitted by the first reflective electrode. In other words, the light absorption of the incident light may be understood as the amount or portion of the incident light staying within the first reflective electrode.

[0035] According to some embodiments described herein, setting the light absorption properties of the first reflective electrode portion to a light absorption of less than 6% of the incident light helps to increase the quality of the first reflective electrode. In some embodiments, the light absorption of less than 6% refers to the light absorption of visible

light (such as light in the range between about 380 nm and about 780 nm). In particular, the light absorption of less than 6% may refer to the light absorption of light having a wavelength of about 550 nm.

[0036] In particular, reducing and/or minimizing the absorption to a value of less than 5 6% according to embodiments described herein is done by optimizing and tuning the ratio of the H₂ and the O₂ content in the process gas of the deposition process. Oxygen has an impact on crystallinity during the transparent conductive metal oxide layer process and helps to reduce the absorption of the transparent conductive metal oxide layer. A comparatively high hydrogen content (i.e. a higher content than described in some 10 embodiments herein) makes the transparent conductive metal oxide layer more amorphous. Increasing the amorphous properties of the second transparent conductive metal oxide layer is not beneficial for a low absorption rate of the incident light.

[0037] According to some embodiments, the ratio of H₂ and O₂ in the process gas has an influence on the surface roughness of the single layers. In particular, the lower absorption 15 of the second transparent conductive metal oxide layer allows using a thinner reflective metal layer between the first transparent conductive metal oxide layer and the second transparent conductive metal oxide layer, especially compared to metal layer thicknesses as used in known light emitting structures. A thinner reflective metal layer can be deposited having a lower surface roughness. The lower surface roughness compared to known light 20 emitting structures result in a higher reflection of the first reflective electrode portion.

[0038] According to some embodiments described herein, the light emitting structure formed by the method according to embodiments described herein, may be a top emitting structure, in particular a top emitting OLED structure. FIG. 3 shows an example of a light emitting structure 500 according to embodiments described herein. In the light emitting 25 structures 500, a substrate 501 is used. For instance, in top emitting OLED structures, a substrate having a low transparency or being not transparent is used. In some applications, a reflective or opaque substrate may be used. The range of substrates that can be used for a top emitting OLED is large. The substrates may range from glass or plastic substrates to metallic foils or even silicon substrates such as silicon wafers or the like.

[0039] On the substrate 501 of the light emitting structure 500, a first reflective electrode portion 400 may be formed. In some embodiments, the first reflective electrode portion 400 may be used as an anode. On or over the first reflective electrode, an emitter layer 502 is formed. In particular, the emitter layer (or emissive layer) may include an organic compound (such as organic semiconductors) that emits light in response to an electric current. In some embodiments, the light emitting structure according to embodiments described herein may include a conductive layer 503 formed next to the emitter layer 502 (e.g. being formed as a bilayer structure with the emitter layer).

[0040] The light emitting structure 500 according to some embodiments described herein and as shown in FIG. 3 includes a second electrode portion 504 over or on the emitter layer 502. According to some embodiments, the second electrode portion 504 may be used as a cathode. In some embodiments, the light emitting structure 500 includes a sealing layer 505 over the second electrode portion. For instance, the sealing layer may be a transparent material, such as a glass sealing layer.

[0041] In some embodiments, the first reflective electrode may be the electrode being nearer to the substrate than the second electrode of the light emitting structure. According to some embodiments, the first reflective electrode may be the electrode on or directly adjacent to the substrate.

[0042] According to some embodiments, and in particular in the case that a top emitting OLED is used as the light emitting structure, the anode being formed on the substrate as a first electrode is beneficially a reflective anode. Having a reflective anode, such as the first reflective electrode portion in a light emitting structure (in particular a top emitting structure) helps to concentrate and direct the incident light in the right direction. Reducing the absorption of the transparent conductive metal oxide layer(s) and the reflectance of the reflective metal layer increases the efficiency of the light emitting structure and yields more light being emitted from the light emitting structure.

[0043] In FIG. 3, the light emitted from the light emitting structure 500 is shown as arrow 506. It can exemplarily be seen in FIG. 3 that the light emitted from the light emitting structure 500 leaves the light emitting structure 500 in a direction away from the substrate 501.

[0044] According to some embodiments, setting the light absorption of the first and/or second transparent conductive metal oxide layer of the first reflective electrode portion to less than 6%, more typically less than 5%, even more typically less than 3%, and even more typically less than 2% is dependent on the ratio of the O₂ content and H₂ content of the process gases. As mentioned above, the ratio of the O₂ content and H₂ content of the process gases is adjusted for reducing the light absorption, and in particular for minimizing the light absorption of the first reflective electrode portion. For instance, the O₂ content and H₂ content of the process gases may be set to a range between a H₂ content of typically less than 2%. According to some embodiments, the O₂ content is adjusted to a value of typically between 1% and about 5% (or typically less than 5%) in the process atmosphere. According to some embodiments, which may be combined with other embodiments described herein, the H₂ content may be controlled to be typically between about 0.01% and about 3%, more typically between 0.01 % and about 2%, and even more typically between about 0.1% and about 1.5%. According to some embodiments, which may be combined with other embodiments described herein, the O₂ content is controlled to a value of typically between 0.5% and about 6%, more typically between about 1% and about 5%, and even more typically between about 1.5% and about 4%. In one embodiment, the O₂ content is about 2.5% and the H₂ content is 0 %. According to some embodiments, the ratio between H₂ and O₂ content may be adapted to the respective application. In one embodiment, the O₂ content is reduced when reducing the H₂ content. According to some embodiments, the absorption can be reduced when less H₂ and higher O₂ is used. In some embodiments, the H₂ content may be increased by up to about 20%.

[0045] Fig. 4 shows a flow chart of a method 100 for forming a light emitting structure according to some embodiments described herein. The method 100 may have the same features as described with respect to FIG. 2, especially with regard to blocks 101 and 102. The method 100 of FIG. 4 includes in block 103 setting the light absorption properties of the first reflective electrode layer to a light absorption of less than 6% of the incident light by controlling the ratio of O₂ content and H₂ content of the process gas by providing a defined flow of H₂ and O₂ to the process gases. For instance, the method may include an oxygen flow of typically between about 1 sccm and about 10 sccm, more typically between about 2 sccm and about 10 sccm, and even more typically between about 2 sccm and about

8 sccm, especially during deposition of the transparent conductive metal oxide layer. The values of the flow rate of oxygen may lead to a low absorption of the transparent conductive metal oxide layer. According to some embodiments, a flow rate of up to 10 sccm oxygen may be used for improving the resistance of the reflective electrode, e.g. by
5 the higher crystallinity of the transparent conductive metal oxide.

[0046] According to some embodiments, which may be combined with other embodiments described herein, the light emitting structure (or parts of the light emitting structure such as the first reflective electrode portion) may be subjected to an increased temperature (increased compared to ambient temperature) for annealing purposes. For
10 instance, the light emitting structure, or parts of the light emitting structure may be subjected to a temperature of typically about 150°C to about 300°C, more typically to about 200°C to about 280°C, and even more typically to about 200°C and about 260°C. In one example, the light emitting structure according to embodiments described herein or parts of the light emitting structure according to embodiments described herein is heated to
15 a temperature of about 200°C, 230°C, or 260°C.

[0047] FIG. 5 shows an embodiment of a first reflective electrode portion 400 according to embodiments described herein. The first reflective electrode portion 400 includes a first (transparent) conductive metal oxide layer 401, a reflective metal layer 402, and a second transparent conductive metal oxide layer 403.

20 [0048] According to some embodiments, the absorption of the first and/or second transparent conductive layer is less than typically 7%, more typically less than 5%, even more typically less than 3%, and even more typically less than 2% of the incident light. In particular, the absorption of the first and/or second transparent conductive layer is less than 4% of the incident light. The reflective metal layer may have a reflectance of typically at
25 least 95%, more typically at least 96%, and even more typically at least 98%. According to some embodiments, the reflectance of the reflective metal layer may be influenced by the sputtering power for depositing the reflective metal layer. For instance, the depositing of the reflective metal layer may be performed with a sputter power of typically between 4 KW and 15 kW, more typically between 5 kW and 15 kW, and even more typically

between 6kW and 12 kW. According to some embodiments, a higher power may contribute to a lower absorption.

[0049] In FIG. 5, the arrow indicates the incident light 410 on the first reflective electrode portion 400. In particular, the incident light 410 may come from the emitter layer of the light emitting structure. As can be seen in the example of FIG. 5, the incident light 410 is partly reflected by the second transparent metal oxide layer 403 as first reflected light 411. The size of the arrows is an indication for the amount of the light. For instance, a small amount of the incident light 410 is reflected by the second transparent conductive metal oxide layer 403. A large (or the larger) amount of the incident light 410 is transmitted through the second transparent metal oxide layer 403 as transmitted light 412. The transmitted light 412 hits the reflective metal layer 402 and is reflected as second reflected light 413. As can be seen in FIG. 5, the size of the incident light 410 and sum of the size of the first reflected light 411 and the second reflected light 413 is approximately the same. The absorption of the first reflective electrode portion 400 is approximately 0% in the example shown in FIG. 5.

[0050] FIG. 5 shows that the second transparent metal oxide layer 403 has partly reflective properties and partly transmitting properties to the incident light. In particular, the second transparent metal oxide layer 403 has mainly transmitting properties, with a small reflective portion.

[0051] According to some embodiments, which may be combined with other embodiments described herein, the reflective metal layer 402 may have a thickness 420 of between typically about 700 Å and about 1500 Å, more typically between about 700 Å and about 1200 Å, and even more typically between about 800 Å and about 1000 Å. In one example, the layer thickness of the reflective metal layer 402 may be chosen small compared to known light emitting structures. For instance, the thickness 420 of the reflective metal layer 402 may be between 700 Å and 1000 Å. In one embodiment, the thickness of the reflective metal layer may be less than 850 Å. In one embodiment, the reflective metal layer according to embodiments described herein can provide a reflectance of larger than 94% at a thickness of about 850 Å. The lower thickness of the reflective metal layer according to embodiments described herein compared to metal layers of known

structures is possible in particular due to the improved reflective properties in view of the above discussed ratio of the process gases.

[0052] In some embodiments, the reflective metal layer in a light emitting structure according to embodiments described herein may include a metal alloy. In particular, the
5 metal in the reflective metal layer of the first electrode portion may be Ag, and/or an alloy including Ag, such as Ag containing Ta, Al, Pd, Au, Cu, Ti, Cr, Mo, Ni, Nb, Ru and the like. In some embodiments, the metal includes an amount between about 0.1 wt% to about 3wt% of an alloy metal.

[0053] According to some embodiments, the transparent conductive metal oxide layer
10 may be chosen from the group consisting of: indium tin oxide (ITO), Indium Zinc oxide (IZO), fluorine tin oxide (FTO), aluminum doped zinc oxide (AZO), and antimony tin oxide (ATO). Alternatively, in some embodiments, the transparent conductive metal oxide layer may be replaced by a conductive polymer, metal grids, carbon nanotubes, graphene, nanowire meshes, ultra-thin metal films and the like.

15 [0054] According to some embodiments, the layers of the first reflective electrode portion, such as the first and/or second transparent metal oxide layer and/or the reflective metal layer may have a defined roughness. For instance, the roughness may be smaller than in known light emitting structures, e.g. by the smaller thickness of the reflective metal layer (which is – for instance – possible due to the increased reflectivity of the reflective
20 metal layer by controlling the ratio of the H₂ and O₂ content in the process gas). In some embodiments, the roughness $R_{\max}$ of the reflective metal layer is less than the roughness of the first and/or second transparent metal oxide layer, in particular the second transparent metal oxide layer. For instance, the roughness $R_{\max}$ of the reflective metal layer of the first reflective electrode may typically be less than 2 nm, more typically less than 1.5 nm.
25 According to some embodiments, adding an alloy to the metal of the reflective metal layer may have a beneficial effect on the surface roughness, such as a decreasing surface roughness of the reflective metal layer.

[0055] In some embodiments, a good coverage of the reflective metal layer with a layer of a transparent metal oxide layer may increase the beneficial reflective properties between
30 the reflective metal layer and the transparent metal oxide layer. In particular, a good

coverage of the reflective metal layer may prevent oxidizing of the metal, which may be the cause for some defects and, especially, for a reduced reflection of the reflective metal layer.

[0056] According to embodiments which can be combined with other embodiments
5 described herein, the content of inert gas which is in the process atmosphere may be from a range between a lower limit of 85%, particularly a lower limit of 90%, more particularly a lower limit of 95%, and an upper limit of 97%, particularly an upper limit of 98.0%, more particularly an upper limit of 99%. By sputtering a transparent metal oxide layer (especially from an indium oxide containing target) in a process atmosphere in which the
10 content of inert gas in the process atmosphere has been selected from a range between a lower limit and an upper limit as described herein, the quality of the transparent conductive oxide layer can be ensured. In particular, by providing a process atmosphere with inert gas as described herein, the risk of flammability and explosion of H_2 in the process atmosphere can be reduced or even eliminated.

15 [0057] According to embodiments which can be combined with other embodiments described herein, the process atmosphere consists of H_2 , O_2 , an inert gas and a residual gas. The content of H_2 , O_2 and inert gas in the process atmosphere consisting of H_2 , O_2 and inert gas may be selected from a range between a respective lower limit and a respective upper limit as described herein. The residual gas may be any impurity or any contaminant
20 in the process atmosphere. In the process atmosphere consisting of H_2 , O_2 , inert gas and a residual gas, the content of residual gas may be from 0.0% to 1.0% of the process atmosphere. According to embodiments which can be combined with other embodiments described herein, the content of residual gas is 0.0% of the process atmosphere. It may be understood that the content of the constituents of the process atmosphere according to
25 embodiments described herein may add up to 100%. In particular, the content of H_2 , O_2 , inert gas and residual gas may add up to 100% of the process atmosphere in the case that residual gas is present in the process atmosphere or in the case that the process atmosphere contains no residual gas, i.e. the content of the residual gas is 0.0%.

[0058] According to embodiments which can be combined with other embodiments
30 described herein, the total pressure of the process atmosphere may be from a range

- between a lower limit of 0.2 Pa, particularly a lower limit of 0.3 Pa, more particularly a lower limit of 0.4 Pa, and an upper limit of 0.6 Pa, particularly an upper limit of 0.7 Pa, more particularly an upper limit of 0.8 Pa. In particular, the total pressure of the process atmosphere may be 0.3 Pa. By sputtering a transparent conductive metal oxide layer
- 5 (especially from an indium oxide containing target) in a process atmosphere in which the total pressure of the process atmosphere has been selected from a range between a lower limit to an upper limit as described herein, the degree of amorphous structure of the oxide layer may be adjusted. In particular, by increasing the total pressure of the process atmosphere, the degree of amorphous structure in the oxide layer may be increased.
- 10 [0059] According to embodiments which can be combined with other embodiments described herein, all constituent gases of the process atmosphere may be mixed prior to establishing the process atmosphere in the vacuum chamber. Accordingly, prior to sputtering or during sputtering the transparent conductive oxide layer, all constituent gases of the process atmosphere may be supplied to the vacuum chamber through the same gas
- 15 showers. In particular, depending on the selected composition of the process atmosphere as described herein, H₂, O₂ and inert gas may be supplied to the vacuum chamber through the same gas showers. For example, the gaseous constituents of a selected process atmosphere may be mixed in a mixing unit before the gaseous constituents of the selected process gas are provided into the vacuum chamber via the gas showers. Accordingly, according to
- 20 some embodiments which can be combined with other embodiments describe herein, the apparatus for depositing a layer may include a mixing unit for mixing the gaseous constituents of the selected process gas before the gaseous constituents of the selected process gas are provided into the vacuum chamber via the gas showers. Accordingly, a very homogenous process atmosphere can be established in the vacuum chamber.
- 25 [0060] According to embodiments, after layer deposition an annealing procedure may be performed, for example in a temperature range from 200°C to 260°C.
- [0061] According to embodiments which can be combined with other embodiments described herein, H₂ may be provided to the process atmosphere in an inert gas/H₂ mixture. By providing H₂ to the process atmosphere in an inert gas/H₂ mixture, the risk of
- 30 flammability and explosion of H₂ in the gas distribution system can be reduced or even

eliminated. According to embodiments which can be combined with other embodiments described herein, O₂ is provided to the process atmosphere in an inert gas/O₂ mixture.

[0062] According to embodiments which can be combined with other embodiments described herein, the method of manufacturing a light emitting structure, especially for display manufacturing, may further include patterning the deposited layer(s), for example by etching, in particular wet chemical etching. Further, the method of manufacturing a layer according to embodiments described herein may include annealing the layer, for example after patterning.

[0063] According to embodiments described herein, the light emitting structure manufactured by the method for forming a light emitting structure according to embodiments described herein may be employed in an electronic device, particularly in an opto-electronic device. Accordingly, by providing an electronic device with a light emitting structure according to embodiments described herein, the quality of the electronic device can be improved. In particular, it will be understood that the method for forming a light emitting structure, e.g. for display manufacturing, and an apparatus therefore according to embodiments described herein provide for tuning TFT display properties during manufacturing, in particular with respect to high quality and low cost.

[0064] While the foregoing is directed to embodiments, other and further embodiments 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 forming a light emitting structure (500) on a substrate (501), comprising:
- forming a first reflective electrode portion (400), forming an emitter layer (502)
5 over the first reflective electrode portion and forming a second electrode portion (504) over the emitter layer (502);
 - wherein forming the first reflective electrode portion (400) comprises depositing a first transparent conductive metal oxide layer (401), a reflective metal layer (402)
10 and a second transparent conductive metal oxide layer (403) in a process atmosphere including process gases;
 - setting the light absorption properties of the first reflective electrode portion (400) to a light absorption of less than 6% of the incident light by controlling the ratio of O₂ content and H₂ content of the process gas.
- 15 2. The method according to claim 1, wherein the thickness of the reflective metal layer (402) of the first reflective electrode (400) is between 700 Å and 1000 Å and has more than 93% reflection rate of the incident light.
3. The method according to any of the preceding claims, wherein setting the light
20 absorption of the first reflective electrode portion (400) to a light absorption of less than 6% comprises setting the light absorption of the first transparent conductive metal oxide layer (401) and/or second transparent conductive metal oxide layer (403) of the first reflective electrode portion (400) to less than 6% dependent on the ratio of the O₂ content and H₂ content of the process gases.

25

4. The method according to any of the preceding claims, wherein the light emitting structure (500) is a top emitting structure, in particular a top emitting OLED structure.

5. The method according to any of the preceding claims, wherein the first reflective electrode portion (400) is arranged nearer to the substrate (501) than the second electrode portion (504).

6. The method according to any of the preceding claims, wherein the first reflective electrode portion (400) is an anode.

10

7. The method according to any of the preceding claims, wherein setting the light absorption of the first reflective electrode portion (400) by controlling the H₂ and O₂ content comprises controlling a H₂ content to less than 2% and an O₂ content to between 1% and about 5% in the process atmosphere.

15

8. The method according to any of the preceding claims, wherein the metal in the first reflective electrode portion (400) is Ag or an Ag alloy, in particular Ag-Ta or Ag-Al.

9. The method according to any of the preceding claims, wherein the transparent conductive metal oxide in the first reflective electrode portion (400) is at least one of ITO and IZO.

10. The method according to any of the preceding claims, wherein setting the absorption of the first reflective electrode portion (400) by controlling the ratio of H₂ content and O₂ content comprises reducing the O₂ content, when reducing the H₂ content.

11. The method according to any of the preceding claims, wherein depositing the first transparent conductive metal oxide layer (401) and the second transparent conductive metal oxide layer (403) comprises depositing the first transparent conductive metal oxide layer (401) and the second transparent conductive metal oxide layer (403) in a sputter process.

12. The method according to claim 11, wherein the sputter process is performed with a power of between 4 kW and 9 kW.

10

13. A light emitting structure (500) comprising:

- A first reflective electrode portion (400), an emitter layer (502) on the first reflective electrode portion and a second electrode portion (504) on the emitter layer;
- 15 - wherein the first reflective electrode portion (400) comprises a first transparent conductive metal oxide layer (401), a reflective metal layer (402) and a second transparent conductive metal oxide layer (403);
- wherein the first reflective electrode portion (400) has a light absorption of less than 6% of the incident light.

20

14. The light emitting structure (500) according to claim 13, further comprising at least one of:

- the thickness of the reflective metal layer (402) of the first reflective electrode portion (400) is between 700 Å and 1000 Å and has more than 93% reflection rate of the incident light;

25

- at least one of the first transparent conductive metal oxide layer (401) and the second transparent conductive metal oxide layer (403) has an absorption rate of 93% to 100% of the incident light;
- the roughness of the first reflective electrode portion (400) being less than 2 nm;
- 5 - the O₂ content in the first reflective electrode portion (400) being between about 1% and about 5%; and
- the H₂ content in the first reflective electrode portion being between 0% and 3%.

15. Apparatus for depositing an electrode portion for a light emitting structure, comprising:

10 a vacuum chamber (210);

one or more indium oxide, particularly indium tin oxide (ITO), containing targets (220a, 220b) within the vacuum chamber (210) for sputtering a transparent conductive oxide layer (401; 403);

15 a gas distribution system (230) for providing processing gases within the vacuum chamber (210); and

a controller (240) connected to the gas distribution system (230) and configured to execute a program code, wherein upon execution of the program code a method according to any of claims 1 to 12 is conducted.

20

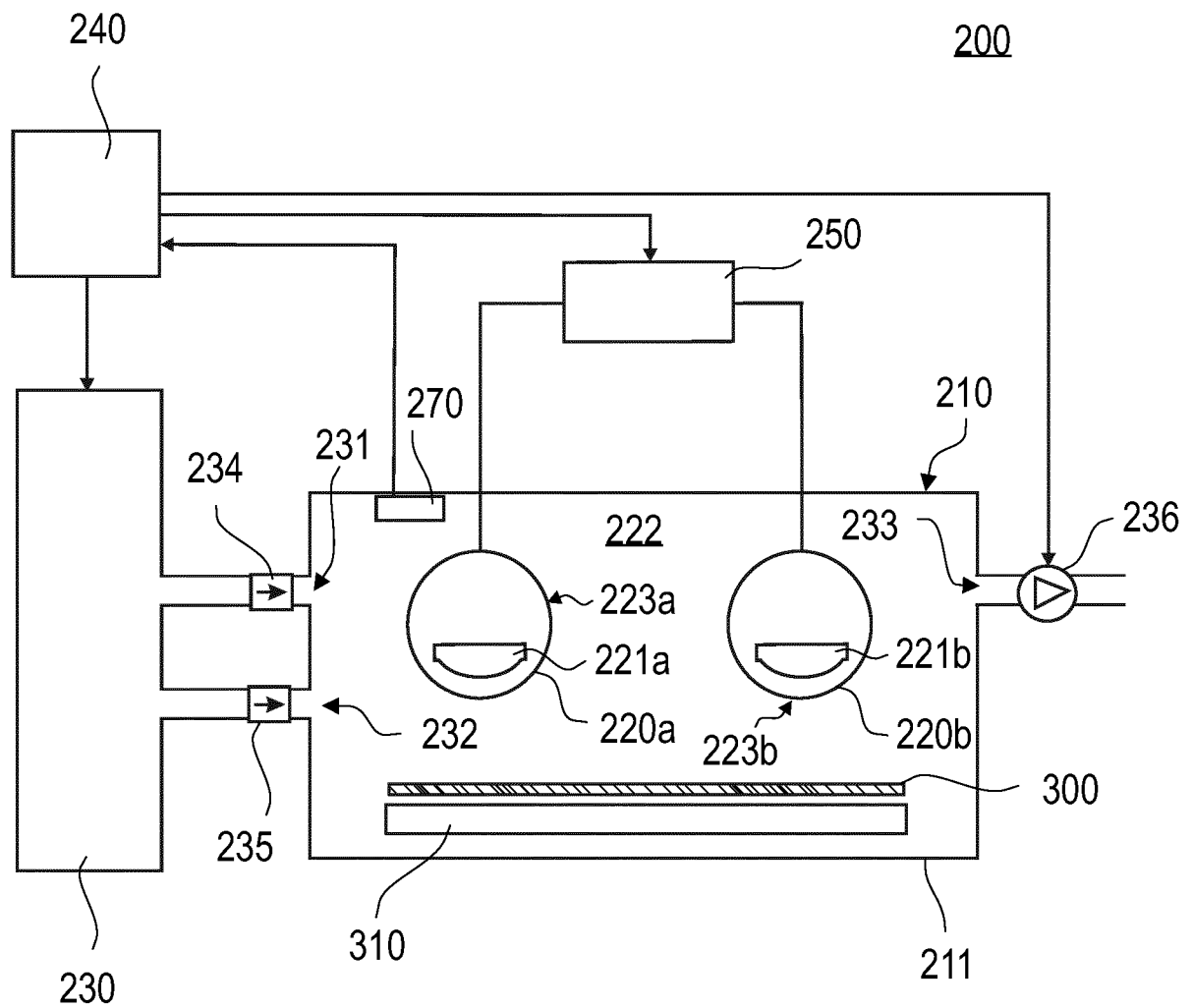


FIG. 1

100

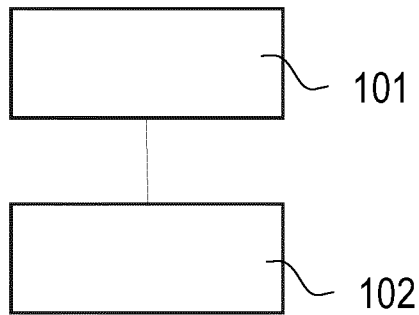


FIG. 2

100

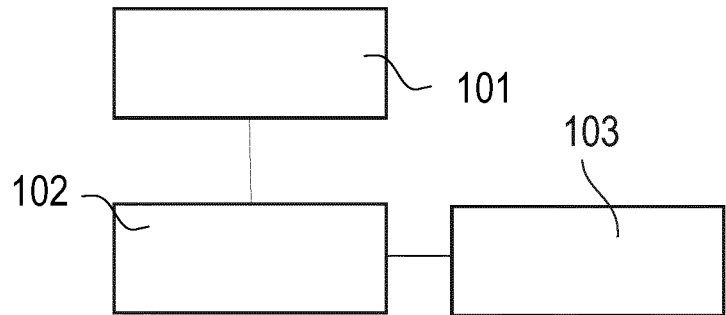


FIG. 4

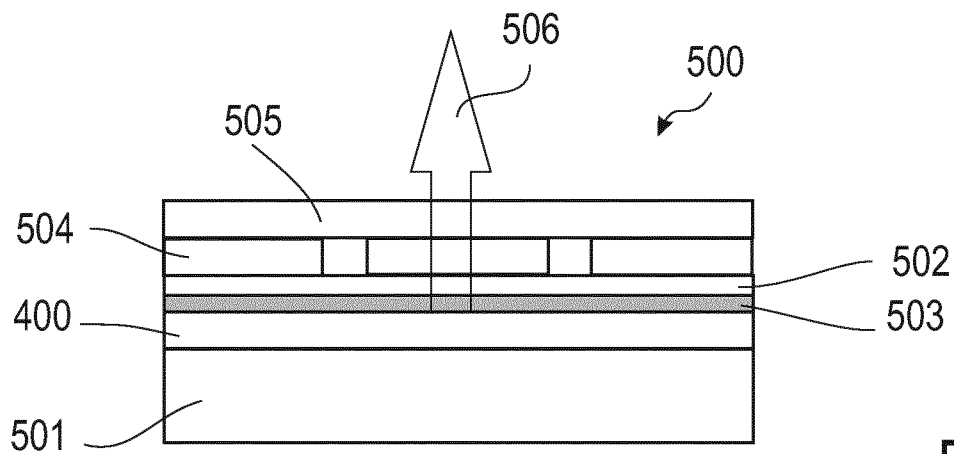


FIG. 3

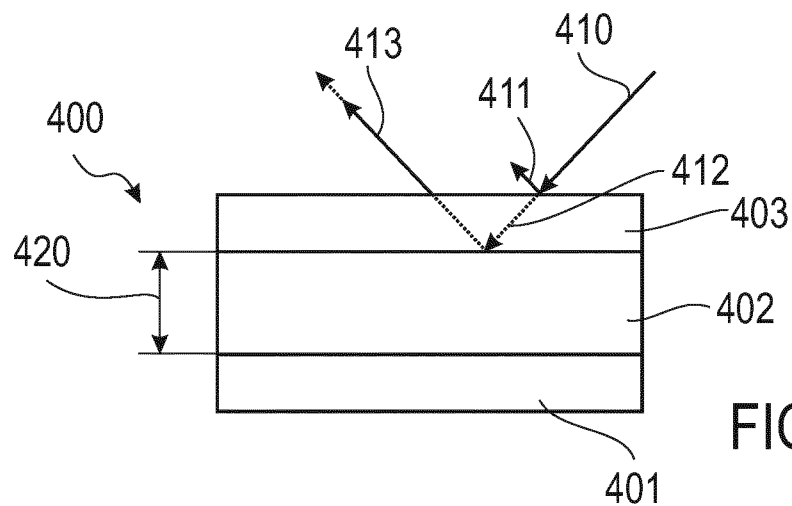


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065826

A. CLASSIFICATION OF SUBJECT MATTER		
INV.	C23C14/08	C23C14/18 C23C14/00 C23C14/35 H01L51/52
	H01L33/40	
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	CN 103 928 635 A (SHANGHAI EVERDISPLAY OPTRONICS CO LTD) 16 July 2014 (2014-07-16)	13
Y	the whole document	1-12, 14
X	EP 2 360 290 A1 (APPLIED MATERIALS INC [US]) 24 August 2011 (2011-08-24)	15
Y	paragraph [0039]; figure 1 paragraph [0036] paragraphs [0037], [0038], [0040] paragraph [0044]	1, 3-11, 14
Y	US 2015/099101 A1 (BAKER BRAIN [US] ET AL) 9 April 2015 (2015-04-09) paragraph [0017]	12
	- / - -	
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
24 March 2017		10/04/2017
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 Kudelka, Stephan

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065826

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/326189 A1 (LEE JOON-GU [KR] ET AL) 27 December 2012 (2012-12-27) paragraph [0021] -----	2
A	KIM ET AL: "Effects of hydrogen gas on properties of tin-doped indium oxide films deposited by radio frequency magnetron sputtering method", THIN SOLID FILMS, ELSEVIER, AMSTERDAM, NL, vol. 515, no. 17, 5 May 2007 (2007-05-05), pages 6949-6952, XP022062458, ISSN: 0040-6090, DOI: 10.1016/J.TSF.2007.02.056 paragraph [0003]; figure 3 -----	1-15
A	GUILLÃ N C ET AL: "TCO/metal/TCO structures for energy and flexible electronics", THIN SOLID FILMS, vol. 520, no. 1, 30 November 2011 (2011-11-30), pages 1-17, XP028313238, ISSN: 0040-6090, DOI: 10.1016/J.TSF.2011.06.091 [retrieved on 2011-06-30] page 13, paragraph 4.1 -----	1
A	US 2011/194181 A1 (TAKAHASHI HIROHISA [JP] ET AL) 11 August 2011 (2011-08-11) claims 1,2 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/065826

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
CN 103928635	A	16-07-2014	NONE	
EP 2360290	A1	24-08-2011	EP 2360290 A1	24-08-2011
			TW 201127977 A	16-08-2011
			US 2011192716 A1	11-08-2011
			WO 2011098538 A1	18-08-2011
US 2015099101	A1	09-04-2015	CN 104516586 A	15-04-2015
			TW 201520853 A	01-06-2015
			US 2015099101 A1	09-04-2015
US 2012326189	A1	27-12-2012	CN 102842684 A	26-12-2012
			KR 20130000218 A	02-01-2013
			TW 201303081 A	16-01-2013
			US 2012326189 A1	27-12-2012
US 2011194181	A1	11-08-2011	CN 102159971 A	17-08-2011
			DE 112009002574 T5	19-01-2012
			KR 20110059632 A	02-06-2011
			TW 201022463 A	16-06-2010
			US 2011194181 A1	11-08-2011
			WO 2010044265 A1	22-04-2010