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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 June 2020 (18.06.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/122944 A1

(51) International Patent Classification:
C23C 14/54 (2006.01) *G01B 11/06* (2006.01)
C23C 14/24 (2006.01)

(21) International Application Number:
PCT/US2018/065744

(22) International Filing Date:
14 December 2018 (14.12.2018)

(25) Filing Language: English

(26) Publication Language: English

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

(72) Inventor: **VINCENT, Joseph**; Flat No: A201, Vineyard Residency, 22, Heerachand Road, Cox Town, Bangalore Bangalore (IN).

(74) Agent: **PATTERSON, B. Todd** et al.; PATTERSON + SHERIDAN, LLP, 24 Greenway Plaza, Suite 1600, Houston, Texas 77046 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, 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, JO, 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).

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

(54) Title: MEASUREMENT ASSEMBLY FOR MEASURING A DEPOSITION RATE AND METHOD THEREFORE

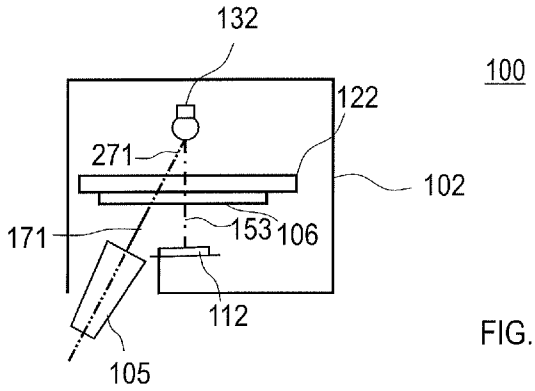


FIG. 2A

(57) Abstract: A measurement assembly for measuring a deposition rate of deposited material in a vacuum deposition chamber is described. The measurement assembly includes one or more transparent substrates providing a deposition surface and a reference surface, the deposition surface being configured to receive at least a portion of the deposited material in a vacuum chamber of the vacuum deposition apparatus and an optical measurement assembly. The optical measurement assembly includes a source of electromagnetic radiation; a first detector for a first portion of the electromagnetic radiation and providing a deposition rate signal; and a second detector for a second portion of the electromagnetic radiation and providing a reference signal.

WO 2020/122944 A1

MEASUREMENT ASSEMBLY FOR MEASURING A DEPOSITION RATE AND METHOD THEREFORE

TECHNICAL FIELD

[0001] The present disclosure relates to a measurement assembly for measuring a deposition rate of an evaporated material, an evaporation source for evaporation of material, a deposition apparatus for applying material to a substrate and a method for measuring a deposition rate of an evaporated material. The present disclosure particularly relates to a measurement assembly for measuring a deposition rate of an evaporated organic material and a method therefore. Further, the present disclosure particularly relates to devices including organic materials therein, e.g. an evaporation source and a deposition apparatus for organic material.

BACKGROUND

[0002] Organic evaporators are a tool for the production of organic light-emitting diodes (OLED). OLEDs are a special type of light-emitting diode in which the emissive layer comprises a thin-film of certain organic compounds. Organic light emitting diodes (OLEDs) are used in the manufacture of television screens, computer monitors, mobile phones, other hand-held devices, etc., for displaying information. OLEDs can also be used for general space illumination. The range of colors, brightness, and viewing angles possible with OLED displays is greater than that of traditional LCD displays because OLED pixels directly emit light and do not involve a back light. Therefore, the energy consumption of OLED displays is considerably less than that of traditional LCD displays. Further, the fact that OLEDs can be manufactured onto flexible substrates results in further applications.

[0003] The functionality of an OLED depends on the coating thickness of the organic material. This thickness has to be within a predetermined range. In the production of OLEDs, the deposition rate at which the coating with organic material is effected is

controlled to lie within a predetermined tolerance range. In other words, the deposition rate of an organic evaporator has to be controlled thoroughly in the production process.

[0004] Accordingly, for OLED applications but also for other evaporation processes, a high accuracy of the deposition rate over a comparably long time is needed. There is a plurality of measurement systems for measuring the deposition rate of evaporators available. However, these measurement systems suffer from either insufficient accuracy and/or insufficient stability over the desired time period.

[0005] For example, a Quartz Crystal microbalance (QCM) correlates the frequency of an oscillating quartz crystal with the mass of the material deposited on the QCM. Upon deposition of material on the QCM, the oscillation frequency changes. A deposition rate is determined based on the changing oscillation frequency. A QCM can be considered highly sensitive to the change in mass. Yet, saturation of the QCM and difficulties to measure reliably over a long time period results in frequent maintenance and/or long maintenance times.

[0006] Accordingly, there is a continuing demand for providing improved deposition rate measurement systems, deposition rate measurement methods, evaporators and deposition apparatuses.

SUMMARY

[0007] In view of the above, a measurement assembly for measuring a deposition rate in a vacuum deposition chamber, a deposition source, a deposition apparatus and a method for measuring a deposition rate of material to be deposited in the vacuum chamber according to the independent claims are provided. Further advantages, features, aspects and details are apparent from the dependent claims, the description and drawings.

[0008] A measurement assembly for measuring a deposition rate of deposited material in a vacuum deposition chamber is provided. The measurement assembly includes one or more transparent substrates providing a deposition surface and a reference surface, the deposition surface being configured to receive at least a portion of the deposited

material in a vacuum chamber of the vacuum deposition apparatus and an optical measurement assembly. The optical measurement assembly includes a source of electromagnetic radiation; a first detector for a first portion of the electromagnetic radiation and providing a deposition rate signal; and a second detector for a second portion of the electromagnetic radiation and providing a reference signal.

[0009] A measurement assembly for measuring a deposition rate of deposited material in a vacuum deposition chamber is provided. The measurement assembly includes a first transparent substrate having a major surface provided at a first angle relative to a material direction of the deposition material; and an optical measurement assembly. The optical measurement assembly includes a source of electromagnetic radiation at a first side of the first transparent substrate; and a first detector for at least a portion of the electromagnetic radiation at a second side of the first transparent substrate opposing the first side, wherein a radiation direction of the electromagnetic radiation is provided from the source through the first transparent substrate to the first detector, wherein the radiation direction is inclined with respect to the material direction.

[0010] A deposition source for evaporation of material is provided. The deposition source includes an evaporation crucible, wherein the evaporation crucible is configured to evaporate a material; a distribution pipe with one or more outlets provided along the length of the distribution pipe for providing evaporated material, wherein the distribution pipe is in fluid communication with the evaporation crucible; and a measurement assembly according to any of the embodiments described herein.

[0011] A method for measuring a deposition rate of a material to be deposited in a vacuum chamber is provided. The method includes depositing a portion of the material on a substrate in the vacuum chamber; guiding a further portion of the material towards a measurement assembly in the vacuum chamber for measuring a deposition rate; coating a transparent substrate in the vacuum chamber with the further portion of the material in the measurement assembly to form a layer on the transparent substrate; emitting electromagnetic radiation with a source; measuring an intensity of a portion of the electromagnetic radiation transmitted through the transparent substrate and the layer to obtain a deposition rate signal; measuring a further portion of the electromagnetic radiation to obtain a reference signal; and referencing the deposition rate signal with the reference signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] 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 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 a measurement assembly configured to measure a deposition rate signal and a reference signal according to embodiments of the present disclosure;

FIG. 2A shows a schematic view of a measurement assembly configured to continuously measure a deposition rate, particularly during operation of the deposition source, according to embodiments of the present disclosure;

FIG. 2B shows a schematic view of a measurement assembly configured to continuously measure a deposition rate, particularly during operation of the deposition source, according to embodiments of the present disclosure;

FIG. 3 shows a schematic view of a measurement assembly having a deposition compartment, a reference compartment, and an inclined transparent substrate, according to embodiments of the present disclosure;

FIG. 4 shows a schematic view of a measurement assembly having a deposition compartment configured to be evacuated independently, and elements to further improve a deposition rate element according to various embodiments of the present disclosure;

FIGS. 5A and 5B show schematic side views of an evaporation source according to embodiments described herein;

FIG. 6 shows a perspective view of an evaporation source according to embodiments described herein;

FIG. 7 shows a schematic top view of a deposition apparatus for applying material to a substrate in a vacuum chamber according to embodiments described herein; and

FIG. 8 shows a block diagram illustrating a method for measuring a deposition rate of an evaporated material according to embodiments described herein.

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. 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 yet a further embodiment. It is intended that the description includes such modifications and variations.

[0014] Contrary to commonly used QCM deposition rate measurement devices, embodiments of the present disclosure provide a measurement assembly for measuring a deposition rate of deposited material in a vacuum deposition chamber having a source of electromagnetic radiation. The material, for which a deposition rate is measured, is provided as a layer on a transparent substrate. The intensity of the electromagnetic radiation, for example light, changes dependent on the thickness of the layer of the material. For example, the transparent substrate can be a transparent glass. The light intensity passing through the transparent glass will decrease after deposition of a thin film on the surface, i.e. with increasing layer thickness.

[0015] Measurement assemblies according to embodiments of the present disclosure are configured to measure a deposition rate of material in a vacuum deposition chamber. A deposition process is provided in a vacuum chamber. For example, the deposition process can be an evaporation process or another physical vapor deposition process or can be a CVD process. Measurement assemblies according to embodiments of the

present disclosure can be provided and can operate in the vacuum chamber, for example, under a technical vacuum. A technical vacuum may be considered to have a pressure of 1 mbar or below, such as $1*10^{-3}$ mbar or below or $1*10^{-5}$ mbar or below.

[0016] According to some embodiments, which can be combined with other embodiments described herein, a deposition rate signal can be provided by measuring an intensity of electromagnetic radiation and a reference signal can be provided by measuring an intensity of electromagnetic radiation. The signals are generated based upon optical path lengths in the vacuum chamber. A comparison or contrast can be provided between the deposition rate signal and the reference signal to provide a highly sensitive deposition rate measurement.

[0017] According to one embodiment, a measurement assembly for measuring a deposition rate of deposited material in a vacuum deposition chamber is provided. The measurement assembly includes one or more transparent substrates providing a deposition surface and a reference surface, the deposition surface being configured to receive at least a portion of the deposited material in a vacuum chamber of the vacuum deposition apparatus. An optical measurement assembly is provided. The optical measurement assembly includes a source of electromagnetic radiation, a first detector for a first portion of electromagnetic radiation and providing a deposition rate signal, and a second detector for a second portion of the electromagnetic radiation and providing a reference signal.

[0018] According to yet further embodiments, which can be combined with other embodiments described herein, a direction of a plume of evaporated material, i.e. a main evaporation direction for the deposition rate measurement, and irradiation direction of electromagnetic radiation from the source to a detector can be angled or inclined with respect to each other. Accordingly, an in situ measurement, such as continuous measurement during deposition, can be provided in the vacuum chamber.

[0019] According to one embodiment, a measurement assembly for measuring a deposition rate in a vacuum deposition chamber is provided. The measurement assembly includes a first transparent substrate having a major service provided at a first angle relative to an evaporation direction of the evaporated material and an optical measurement assembly. The optical measurement assembly includes a source of

electromagnetic radiation at a first side of the first transparent substrate and the first detector for at least a portion of the electromagnetic radiation at a second side of the first transparent substrate opposing the first side. A radiation direction from the source through the first transparent substrate to the first detector is provided. The radiation direction is inclined with respect to the evaporation direction. For example, the angle between the radiation direction and the evaporation direction can be 10° to 120°.

[0020] FIG. 1 shows the measurement assembly 100. The measurement assembly 100 may be configured to measure a deposition rate in the vacuum deposition apparatus. The measurement assembly 100 includes a housing 102. A transparent substrate 122 is provided in the housing. A plume of deposition material 105 is guided along a main material direction 171. The plume of deposition material 105 is a portion of the material provided in the vacuum deposition chamber, for example, by a deposition source. The deposition source may, for example, deposit material on a substrate, such as a glass plate or a wafer, to generate a layer stack or device on the substrate.

[0021] The deposition material 105 guided towards the transparent substrate 122 generates a layer 106 on the transparent substrate 122. The layer thickness of the layer 106 increases over time and the increase depends on the deposition rate of the deposition source. Further, an increasing layer thickness of the layer 106 results in an increasing absorption, i.e. optical absorption of electromagnetic radiation, for example, light.

[0022] The absorption of electromagnetic radiation and/or the transmission of electromagnetic radiation, respectively, is measured with an optical measurement assembly. The optical measurement assembly includes a source 132 of electromagnetic radiation and at least a first detector 112 to detect a portion of the electromagnetic radiation emitted by the source 132. The first detector 112 can provide a deposition rate signal.

[0023] According to various embodiments, which can be combined with other embodiments described herein, the source 132 of electromagnetic radiation can be a light source. For example, the light source may admit light in an infrared wavelength range, a visible wavelength range, and/or an ultraviolet wavelength range. The light source can be a broadband light source or can be a light source emitting one or more

individual wavelengths. In some exemplary modifications, which can be combined with other embodiments described herein, a filter may be used to select one or more wavelengths or a wavelength range for the absorption and/or transmission measurement. According to some embodiments, which can be combined with other embodiments described herein, the source 132 for electromagnetic radiation, the transparent substrate 122, and the first detector 112 can provide a deposition rate measurement path or radiation direction 153 of electromagnetic radiation. The deposition rate measurement path may be modified with at least one of filters, apertures, lenses, and other optical elements.

[0024] A reference measurement path or further radiation direction 151 can be provided. The reference measurement path includes a light source. According to some embodiments, the deposition rate measurement path and the reference measurement path include the same source 132 of electromagnetic radiation. Further, the transparent substrate 122 or a similar transparent substrate and the second detector 114 are provided for the reference measurement path. The reference measurement path may be modified with the same components being at least one of filters, apertures, lenses and other optical elements, as the deposition rate measurement path. Accordingly, the reference measurement path can be provided to reference the deposition rate measurement. For example, a contrast measurement can be provided. Upon generation of the layer 106 of deposition material on the transparent substrate 122, the deposition rate measurement path changes as compared to the reference measurement path. The deposition rate can be determined.

[0025] According to some embodiments, which can be combined with other embodiments described herein, a deposition rate signal is provided by the first detector 112 and a reference signal is provided by the second detector 114. For example, the deposition rate signal can be divided by the reference signal. Fluctuations in the intensity of the source 132 of electromagnetic radiation, fluctuations of the pressure in the vacuum chamber, or other fluctuations can be reduced or compensated by referencing the deposition rate signal. An increasing layer thickness of the layer 106 results in a reduced intensity detected by the first detector 112. Due to the fact that no material layer is generated in the reference measurement path, the deposition rate can be

measured by the measurement assembly 100 while referencing the deposition rate signal with the reference signal.

[0026] According to some embodiments, which can be combined with other embodiments described herein, the first detector 112 and the second detector 114 can be a photometer, a photoresistor, a photodiode, or a photomultiplier. According to typical embodiments, an intensity of electromagnetic radiation, for example, an intensity of light is measured by the first detector and the second detector. According to some embodiments, which can be combined with other embodiments described herein, the measurement path for the deposition rate measurement and for the reference measurement are similar or substantially symmetric, such that considerations with respect to luminance or other photometric measurement consideration resulting from the geometry may be disregarded. With respect to the sensitivity of the detectors, similar detectors having substantially the same sensitivity to the characteristic of the electromagnetic radiation can be provided. According to some embodiments, it may be considered that the intensity of the light from a known source, e.g. source 132, luminate the deposition chamber and the reference chamber. When the deposition chamber gets deposited the illumination on the chamber walls reduced due to clouding on the glass plate (source). Also due to change in surface properties of the chamber wall due to deposition, the reflectance properties also changes further change in luminance inside the chamber.

[0027] FIGS. 2A and 2B illustrate further aspects of measurement assemblies according to embodiments of the present disclosure, which may be combined with other embodiments described herein. The measurement assembly 100 shown in FIG. 2A includes a transparent substrate 122. A layer 106 is deposited on the transparent substrate during deposition rate measurement, i.e. when a plume of deposition material 105 is guided on the transparent substrate 122 along the material direction, which is the main material direction of a plume of material. The main material direction may, for example, be an evaporation direction. The material direction 171 is angled relative to a main surface of the transparent substrate 122 by a first angle. An optical measurement assembly is provided. Electromagnetic radiation, for example, light, is emitted by the source 132 on a first side of the transparent substrate 122. In FIG. 2A, the first side is the upper side of the transparent substrate 122. A first detector 112 detects at least a

portion of the electromagnetic radiation emitted by the source 132. The first detector 112 is provided on a second side of the transparent substrate 122, the second side opposing the first side. In FIG. 2A, the first side is the lower side of the transparent substrate 122. A radiation direction 153 is provided from the source 132 through the transparent substrate 122 to the first detector 112. As indicated by the direction 271 defined by the material direction 171, i.e. a main direction of a plume of deposition material 105, the material direction and the radiation direction are inclined with respect to each other. Particularly, the material direction and the radiation direction are not parallel. Accordingly, the deposition rate can be measured while material is deposited on the transparent substrate. Thus, an in-situ measurement and, particularly a continuous measurement can be provided.

[0028] According to some embodiments, which can be combined with other embodiments described herein, the first angle of the material direction 171 with respect to a major surface of the substrate can be 10° to about 90°. A second angle between the radiation direction 153 and a major surface of the substrate can be 20° to about 90°. The material direction and the radiation direction can be inclined with respect to each other by an angle of, for example, 20° to 110°.

[0029] Another implementation, which is similar to FIG. 2A is shown in FIG. 2B. In FIG. 2B, the material direction 171 may be about 90° relative to a major surface of the substrate (e.g. +- 10°) and the radiation direction 153 may be provided with a second angle being about 30° to about 60°.

[0030] FIG. 3 shows another embodiment of a measurement assembly 100. The measurement assembly 100 has the source 132 of electromagnetic radiation, for example, light source in a source compartment 302. The source compartment 302 may be provided by at least the housing 102 of the measurement assembly and a transparent substrate 122. As shown in FIG. 3, the transparent substrate 122 can be a first transparent substrate. Further, a second transparent substrate 322 can be provided. The second transparent substrate may further provide a wall of the source compartment 302. The first detector 112, configured to provide a measurement signal, can be provided in the first compartment 312, such as a measurement compartment. The second detector 114, configured to provide a reference signal, can be provided in a second compartment 314, such as a reference compartment. The first compartment can be provided by the

first transparent substrate 122 and a portion of the housing 102. The second compartment can be provided by the second transparent substrates 322 and another portion of the housing 102.

[0031] According to some embodiments, which can be combined with other embodiments described herein, a measurement path and a reference path may both be provided through a transparent substrate. The transparent substrate may be a glass plate or a plate of transparent material, i.e. a material transparent for the electromagnetic radiation. Further, the transparent substrate may be a sphere or a differently shaped transparent element. According to yet further embodiments, which can be combined with other embodiments described herein, and as shown in FIG. 3, the first transparent substrate 122 can be provided for the measurement path and a second transparent substrates 322 can be provided for the reference path. Layer 106 of the deposition material is provided on the first transparent substrate 122. No deposition occurs on the second transparent substrate 322.

[0032] Embodiments of the present disclosure include a light source and a chamber having at least two compartments, for example, a reference chamber and a deposition chamber. Two substrates being transparent for electromagnetic radiation, for example, two glass pieces, can be provided between a light source and respective detectors in the reference chamber and a deposition chamber. The two detectors, for example, two photometers can be placed appropriately in the chambers. Electromagnetic radiation, for example, light is emitted by the source 132. The light may pass through the first transparent substrate and the second transparent substrate forming, for example, inclined glass surfaces. The intensity of the light is measured and calibrated. For example, the first detector and the second detector may show the same reading of the calibration. According to some embodiments, which can be combined with other embodiments described herein, a luminances in the deposition compartment and the reference compartment may be compared. The luminance may be L= Intensity (I) / A * Cos(Z), wherein A is the area of the beam and Z indicates the angle of a projection on a detector.

[0033] Deposition material 105, e.g. a vapor plume is allowed inside the deposition chamber. The material, e.g. the vapor, gets deposited on the glass surface and reduces the Luminous intensity inside the deposition chamber. The luminous intensity is

measured using a detector, e.g. a photometer. A contrast between the measurement in the measurement chamber and the measurement in the reference chamber is calculated.

[0034] According to some embodiments, which can be combined with other embodiments described herein, the contrast C can be calculated as follows: C = 1 – Id/Ir, where Id is the measurement intensity and Ir is the reference intensity. Similarly, the contrast may be calculated as C = 1 – Ld/Lr, wherein Ld and Lr are the luminance levels of the deposition area and the reference area, respectively. The contrast is C = 0 for no contrast (no deposition) and C = 1 for maximum contrast (maximum deposition).

[0035] According to some embodiments, which can be combined with other embodiments described herein, the measurement assembly as described herein may be refreshed. If the maximum contrast is reached or before the maximum contrast is reached, which corresponds to a measured deposition intensity of zero, the layer 106 can be removed from the transparent substrate 122, i.e. a surface 123 of the transparent substrate. According to some embodiments, which can be combined with other embodiments described herein, a heater 352 can be provided. The heater 352 can heat the transparent substrate 122 to evaporate the material of the layer 106. Accordingly, the layer 106 is removed from the transparent substrate 122. The heater may be embedded in the transparent substrate or can be provided at the transparent substrate. The heater is configured to heat the transparent substrate above an evaporation temperature of the material, for which the material deposition rate is measured. According to embodiments, which can be combined with other embodiments described herein, the heater can be an electrical heater, such as resistive heater, a radiant heater, a convection heater, or any other kind of heater.

[0036] As shown in FIG. 3 the source 132, which may be provided inside the source chamber, illuminates a detector, for example, a photometer, in the deposition chamber and a detector in the reference chamber. The electromagnetic radiation, for example light, may pass through two glass plates, i.e. the first transparent substrate and the second transparent substrate. The intensity measured by the two detectors in each chamber or compartment, respectively, can be compared. Deposition on a glass plate occurs only in the deposition chamber, such that a referenced deposition rate measurement can be provided. According to some embodiments, which can be combined with other embodiments described herein, a contrast can include a ratio of

intensities of the two detectors in the two chambers. Without material being deposited on a glass plate of the measurement assembly, the contrast will be zero, i.e. the same intensity or substantially the same intensity can be measured in both chambers. This may apply initially and having no deposition. The contrast will increase as deposition occurs and may reach a maximum value. According to embodiments of the present disclosure, a deposition rate can be calibrated on the contrast. Accordingly, a deposition rate signal can be provided by the contrast, and particularly by a change in contrast measured by the measurement assembly.

[0037] Further modifications of embodiments, which may be provided alternatively to each other or additionally to each other, are illustrated in FIG. 4. According to one modification, a vacuum pump 402, such as a molecular vacuum pump, can be connected to the first compartment, i.e. the deposition chamber. Accordingly, during heating of the first transparent substrate 122 with the heater 352, the deposition chamber can be evacuated such that molecules released by evaporating the layer 106 are evacuated by the vacuum pump 402.

[0038] According to the one modification, an aperture 434 can be provided in the optical path between the source 132 for electromagnetic radiation and the first detector. The aperture may define an aperture angle of the beam path of electromagnetic radiation. For example, only a light transmission through a portion of the layer 106 can be measured. Additionally, a similar aperture may be provided in the reference path to provide substantially symmetric optical arrangements.

[0039] According to one modification, a shutter 432 can be provided in the measurement chamber. The shutter 432 can be moved into the path of electromagnetic radiation as indicated by arrow 433. Particularly during heating of the first transparent substrate 122, the first detector 112 can be blocked by the shutter 432 to reduce or avoid material released from the transparent substrate to be coated on the first detector.

[0040] According to one modification, a shutter 422 can be provided to close an opening in the housing 102 of the measurement assembly. The shutter 422 can be moved as indicated by arrow 423. Accordingly, deposition material can be prevented from entering the measurement chamber.

[0041] According to one modification, an aperture or plate 424 blocking a portion of the plume of deposition material 105 can be provided. Additionally or alternatively, a chopper can be provided. The aperture or plate, and/or the chopper can be utilized to reduce the amount of material entering the deposition chamber. The reduction of material entering the deposition chamber can be beneficial to increase the time between minimum contrast and maximum contrast measured by the measurement assembly. The time periods between heating the first transparent substrate for removing the layer 106 from the transparent substrate can be increased.

[0042] Embodiments of the present disclosure allow for a reduced product maintenance cycle. Further, refreshing of the measurement assembly allows for shorter maintenance periods. Downtime of a deposition system can be reduced. Due to the optical assembly for measuring the deposition rate, the reduced number of joints and connections can be provided as compared to, for example, the revolver-based QCM deposition rate measurement. Reliability of the measurement system can be increased. Measurement assemblies according to embodiments of the present disclosure allow for a referenced measurement, for example, dividing deposition rate signal by a reference signal. A sensitive deposition rate measurement can be provided.

[0043] Embodiments of the present disclosure can be utilized for material deposition in vacuum deposition chambers. Particularly, deposition rate measurements can be used for evaporation sources and, specifically for evaporation sources for organic materials, for which highly accurate deposition rate measurements are advantageous.

[0044] FIGS. 5A and 5B show schematic side views of an evaporation source 500 according to embodiments as described herein. According to embodiments, the evaporation source 500 includes an evaporation crucible 510, wherein the evaporation crucible is configured to evaporate a material. Further, the evaporation source 500 includes a distribution pipe 520 with one or more outlets 522 provided along the length of the distribution pipe for providing evaporated material, as exemplarily shown in FIG. 5B.

[0045] According to embodiments, the distribution pipe 520 is in fluid communication with the evaporation crucible 510, for example by a vapor conduit 532, as exemplarily shown in FIG. 5B. The vapor conduit 532 can be provided to the distribution pipe 520 at

a lower end of the distribution pipe (see FIG. 5A), at a central portion of the distribution pipe or at another position between the lower end of the distribution pipe and the upper end of the distribution pipe. Further, the evaporation source 500 according to embodiments described herein includes a measurement assembly 500 according to embodiments described herein. Accordingly, an evaporation source 500 is provided for which the deposition rate can be measured with a high accuracy.

[0046] According to some embodiments, which can be combined with other embodiments described herein, the measurement assembly can be provided at an upper portion or above the distribution pipe. Accordingly, employing an evaporation source 500 according to embodiments described herein may be beneficial for high quality display manufacturing, particularly OLED manufacturing.

[0047] As exemplarily shown in FIG. 5A, According to embodiments which can be combined with other embodiments described herein, the distribution pipe 520 may be an elongated tube including a heating element 515. The evaporation crucible 510 can be a reservoir for material, e.g. organic material, to be evaporated with a heating unit 525. According to embodiments, which can be combined with other embodiments described herein, the distribution pipe 520 may provide a line source. For example, as exemplarily shown in FIG. 5B, a plurality of outlets 522, such as nozzles, can be arranged along at least one line. According to some embodiments, which can be combined with other embodiments described herein, the line source may extend essentially vertically.

[0048] According to some embodiments, which can be combined with other embodiments described herein, the length of the distribution pipe 520 may correspond to a height of a substrate onto which material is to be deposited in a deposition apparatus. Alternatively, the length of the distribution pipe 520 may be longer than the height of the substrate onto which material is to be deposited, for example at least by 10% or even 20%. Accordingly, a uniform deposition at the upper end of the substrate and/or the lower end of the substrate can be provided. For example, the length of the distribution pipe 520 can be 1.3 m or above, for example 2.5 m or above.

[0049] According to embodiments, which can be combined with other embodiments described herein, the evaporation crucible 510 may be provided at the lower end of the distribution pipe 520, as exemplarily shown in FIG. 5A. The material, e.g. an organic

material, can be evaporated in the evaporation crucible 510. The evaporated material may enter the distribution pipe 520 at the bottom of the distribution pipe and may be guided essentially sideways through the plurality of outlets 522 in the distribution pipe 520, e.g. towards an essentially vertical substrate. With exemplary reference to FIGS. 5A and 5B, the measurement assembly 100 according to embodiments described herein may be provided at an upper portion, particularly above or at an upper end, of the distribution pipe 520. A measurement outlet 550 may be provided in a top wall 524C of the distribution pipe 520.

[0050] In the present disclosure, a "measurement outlet" may be understood as an opening or aperture, through which evaporated material can be provided to a measurement device, e.g. a measurement assembly according to embodiments described herein. Further, in the present disclosure, a "measurement outlet" may be understood as an opening or aperture which is provided in a wall, particularly a top wall or a backside wall, of a distribution pipe of an evaporation source.

[0051] FIG. 6 shows a perspective view of an evaporation source 500 according to embodiments described herein. As exemplarily shown in FIG. 6, the distribution pipe 520 may be designed in a triangular shape. A triangular shape of the distribution pipe 520 may be beneficial in case two or more distribution pipes are arranged next to each other. In particular, a triangular shape of the distribution pipe 520 makes it possible to bring the outlets of neighboring distribution pipes close to each other. This allows for achieving an improved mixture of different materials from different distribution pipes, e.g. for the case of the co-evaporation of two, three or even more different materials. As exemplarily shown in FIG. 6, according to embodiments which can be combined with other embodiments described herein, the measurement assembly 100 may be provided at the distribution pipe 520, particularly at a top wall or at the upper end of a rear side of the distribution pipe.

[0052] According to embodiments, which can be combined with other embodiments described herein, the distribution pipe 520 may include walls, for example side walls 524B and a wall at the backside 524A of the distribution pipe, e.g. an end portion of the distribution pipe, which can be heated by a heating element 515. The heating element 515 may be mounted or attached to the walls of the distribution pipe 520. According to some embodiments, which can be combined with other embodiments described herein,

the evaporation source 500 may include a shield 504. The shield 504 may reduce the heat radiation towards the deposition area. Further, the shield 504 may be cooled by a cooling element 516. For example, the cooling element 516 may be mounted to the shield 504 and may include a conduit for cooling fluid.

[0053] FIG. 7 shows a schematic top view of a deposition apparatus 700 for applying material to a substrate 733 in a vacuum chamber 710 according to embodiments described herein. According to embodiments which can be combined with other embodiments described herein, the evaporation source 500 as described herein may be provided in the vacuum chamber 710, for example on a track, e.g. a linear guide 720. The track or the linear guide 720 may be configured for a translational movement of the evaporation source 500. Accordingly, according to embodiments which can be combined with other embodiments described herein, a drive for the translational movement can be provided for the evaporation source 500, at the track and/or the linear guide 720, within the vacuum chamber 710. According to embodiments which can be combined with other embodiments described herein, a first valve 705, for example a gate valve, may be provided which allows for a vacuum seal to an adjacent vacuum chamber (not shown in FIG. 7). The first valve can be opened for transport of the substrate 733 or a mask 732 into the vacuum chamber 710 or out of the vacuum chamber 710.

[0054] According to some embodiments, which can be combined with other embodiments described herein, a further vacuum chamber, such as maintenance vacuum chamber 711 may be provided adjacent to the vacuum chamber 710, as exemplarily shown in FIG. 7. Accordingly, the vacuum chamber 710 and the maintenance vacuum chamber 711 may be connected with a second valve 707.

[0055] As exemplarily shown in FIG. 7, two substrates may be supported on respective transportation tracks within the vacuum chamber 710. Further, two tracks for providing masks thereon can be provided. Accordingly, during coating the substrate 733 can be masked by respective masks. For example, the mask may be provided in a mask frame 731 to hold the mask 732 in a predetermined position.

[0056] According to some embodiments, which can be combined with other embodiments described herein, the substrate 733 may be supported by a substrate

support 726, which can connect to an alignment unit 712. The alignment unit 712 may adjust the position of the substrate 733 with respect to the mask 732. As exemplarily shown in FIG. 7 the substrate support 726 may be connected to the alignment unit 712. Accordingly, the substrate may be moved relative to the mask 732 in order to provide for a proper alignment between the substrate and the mask during deposition of the material which may be beneficial for high quality display manufacturing. Alternatively or additionally, the mask 732 and/or the mask frame 731 holding the mask 732 can be connected to the alignment unit 712. Accordingly, either the mask 732 can be positioned relative to the substrate 733 or the mask 732 and the substrate 733 can both be positioned relative to each other.

[0057] As shown in FIG. 7, the linear guide 720 may provide a direction of the translational movement of the evaporation source 500. A mask 732 may be provided on both sides of the evaporation source 500. The masks may extend essentially parallel to the direction of the translational movement. Further, the substrates at the opposing sides of the evaporation source 500 can also extend essentially parallel to the direction of the translational movement. As exemplarily shown in FIG. 7, the evaporation source 500 provided in the vacuum chamber 710 of the deposition apparatus 700 may include a support 702 which may be configured for the translational movement along the linear guide 720. For example, the support 702 may support three evaporation crucibles and three distribution pipes 520 provided over the evaporation crucible 510. Accordingly, the vapor generated in the evaporation crucible can move upwardly and out of the one or more outlets of the distribution pipe.

[0058] In FIG. 8 a block diagram illustrating a method for measuring a deposition rate of an evaporated material according to embodiments described herein is shown. According to embodiments, the method 800 for measuring a deposition rate of a material may include evaporating 802 a material, for example an organic material. As indicated by box 804 a portion of the material is deposited on a substrate in the vacuum chamber and a further portion of the material is guided towards a measurement assembly in the vacuum chamber for measuring a deposition rate. A transparent substrate in the vacuum chamber is coated with the further portion of the material in the measurement assembly to form a layer on the transparent substrate. As illustrated by box 806, electromagnetic radiation is emitted with a source and an intensity of a portion

of the electromagnetic radiation transmitted through the transparent substrate and the layer is measured to obtain a deposition rate signal. A further portion of the electromagnetic radiation is measured to obtain a reference signal. As indicated by box 808 the deposition rate signal is referenced with the reference signal.

[0059] Accordingly, the measurement assembly for measuring a deposition rate of deposited material in a vacuum chamber, an evaporation source, and a deposition apparatus are provided. Advantageously, a deposition rate signal can be referenced with a reference signal, particularly based on electromagnetic radiation from the same source. A highly sensitive deposition rate signal can be provided by a comparison. Further, the number of maintenance cycles can be reduced and the time period for maintenance can be reduced.

[0060] While the foregoing is directed to embodiments, other and further embodiments may be devised without departing from the basic scope, and the scope is determined by the claims that follow.

[0061] In particular, this written description uses examples to disclose the disclosure, including the best mode, and also to enable any person skilled in the art to practice the described subject-matter, including making and using any devices or systems and performing any incorporated methods. While various specific embodiments have been disclosed in the foregoing, mutually non-exclusive features of the embodiments described above may be combined with each other. The patentable scope is defined by the claims, and other examples are intended to be within the scope of the claims if the claims have structural elements that do not differ from the literal language of the claims, or if the claims include equivalent structural elements with insubstantial differences from the literal language of the claims.

CLAIMS

1. A measurement assembly (100) for measuring a deposition rate of deposited material in a vacuum deposition chamber, comprising:

one or more transparent substrates providing a deposition surface and a reference surface, the deposition surface being configured to receive at least a portion of the deposited material in a vacuum chamber of the vacuum deposition apparatus;

an optical measurement assembly, comprising:

a source of electromagnetic radiation;

a first detector for a first portion of the electromagnetic radiation and providing a deposition rate signal; and

a second detector for a second portion of the electromagnetic radiation and providing a reference signal.

2. The measurement assembly according to claim 1, further comprising:

a housing for the measurement assembly, the housing providing a source compartment for the source, a deposition compartment for the first detector, and a reference compartment for the second detector.

3. The measurement assembly according to claim 2, wherein the one or more transparent substrates separate the source compartment from the deposition compartment and the reference compartment.

4. A measurement assembly (100) for measuring a deposition rate in a vacuum deposition chamber, comprising:

a first transparent substrate having a major surface provided at a first angle relative to a material direction of the deposition material; and

an optical measurement assembly, comprising:,

a source of electromagnetic radiation at a first side of the first transparent substrate; and

a first detector for at least a portion of the electromagnetic radiation at a second side of the first transparent substrate opposing the first side, wherein a radiation direction of the electromagnetic radiation is provided from the source through the first transparent substrate to the first detector;

wherein the radiation direction is inclined with respect to the material direction.

5. The measurement assembly (100) according to claim 4, wherein the first angle is about 10° to about 90°.

6. The measurement assembly according to any of claims 4 to 5, wherein the radiation direction is angled at a second angle relative to the major surface of the first transparent substrate, the second angle being different from the first angle and being about 20° to about 90°.

7. The measurement assembly according to any of claims 4 to 6, further comprising:

a heater, particularly at or in the transparent substrate.

8. The measurement assembly according to any of claims 4 to 7, further comprising

a second transparent substrate; and

a second detector, wherein electromagnetic radiation is provided from the source through the second transparent substrate to the second detector

9. The measurement assembly (100) according to any of claims 4 to 8, wherein a first optical arrangement having the source, the first transparent substrate and first detector is symmetrically arranged with respect to a second optical arrangement having the source, the second transparent substrate and second detector

10. The measurement assembly (100) according to any of claims 4 to 9, further comprising:

a housing for the first detector, the housing having an opening defining the material direction.

11. The measurement assembly (100) according to any of claims 4 to 10, wherein the housing provides a first compartment having the first detector for deposition measurement and a second compartment for the second detector for reference measurement.

12. The measurement assembly (100) according to any of claims 4 to 11, wherein at least one of the first transparent substrate and the second transparent substrate is a glass plate.

13. A deposition source (500) for evaporation of material, comprising:

an evaporation crucible (510), wherein the evaporation crucible is configured to evaporate a material;

a distribution pipe (520) with one or more outlets (522) provided along the length of the distribution pipe for providing evaporated material, wherein the distribution pipe (520) is in fluid communication with the evaporation crucible (510); and

a measurement assembly (100) according to any of claims 1 to 12.

14. The deposition source (500) according to claim 13, wherein the measurement outlet (550) and the measurement assembly (500) are arranged at an end of the distribution pipe (520), particularly at a top wall (524C) of the distribution pipe (520).

15. A deposition apparatus (700) for applying material to a substrate (733) in a vacuum chamber (710) at a deposition rate, comprising at least one deposition source (500) according to any of claims 13 to 14.

16. A method (400) for measuring a deposition rate of a material to be deposited in a vacuum chamber, comprising:

depositing a portion of the material on a substrate in the vacuum chamber;

guiding a further portion of the material towards a measurement assembly in the vacuum chamber for measuring a deposition rate;

coating a transparent substrate in the vacuum chamber with the further portion of the material in the measurement assembly to form a layer on the transparent substrate;

emitting electromagnetic radiation with a source;

measuring an intensity of a portion of the electromagnetic radiation transmitted through the transparent substrate and the layer to obtain a deposition rate signal;

measuring a further portion of the electromagnetic radiation to obtain a reference signal; and

referencing the deposition rate signal with the reference signal.

17. The method of claim 16, wherein the vacuum chamber has a deposition compartment and a reference compartment and the vacuum in the deposition compartment is similar to a vacuum in the reference compartment.

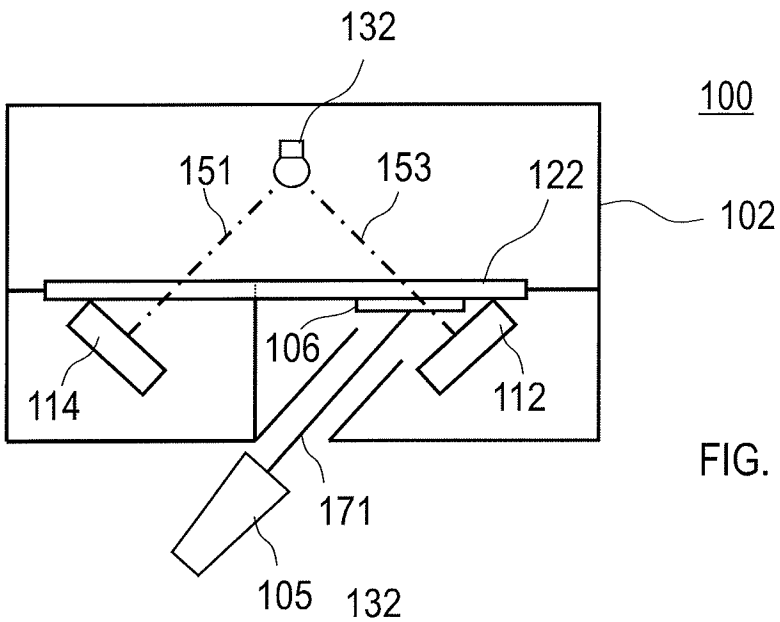


FIG. 1

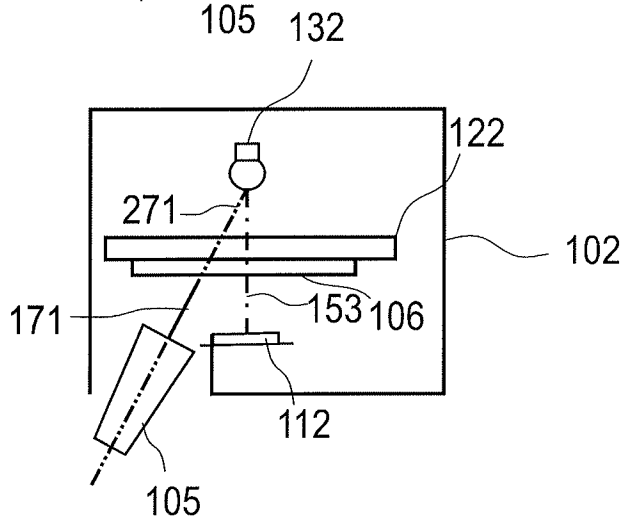


FIG. 2A

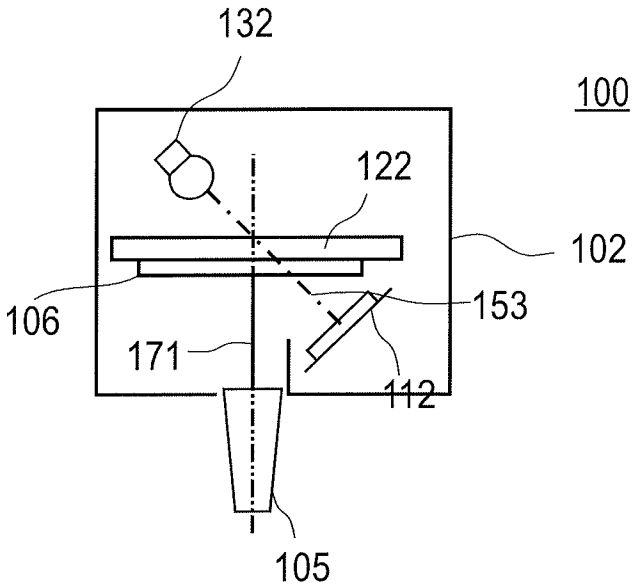


FIG. 2B

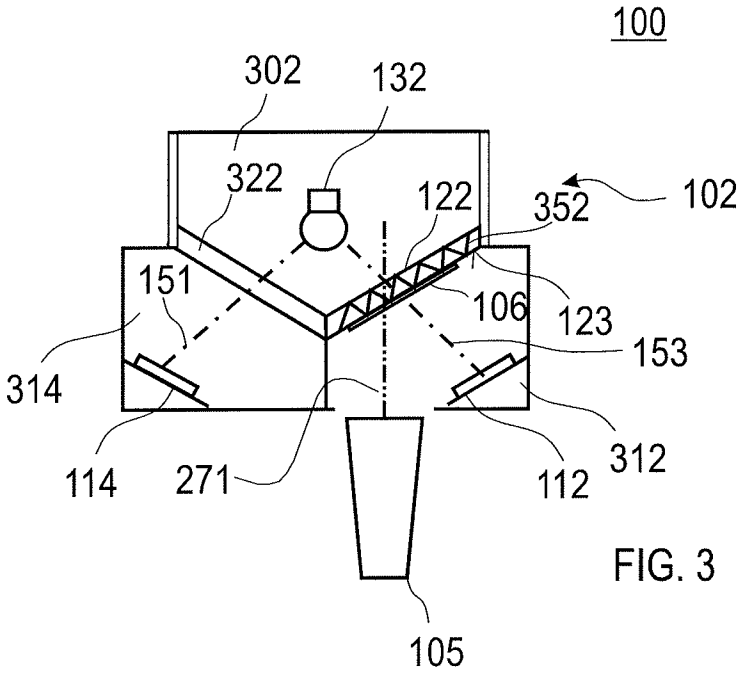

100
302
132
322
122
352
102
151
106
123
153
314
114
271
112
312
105

FIG. 3

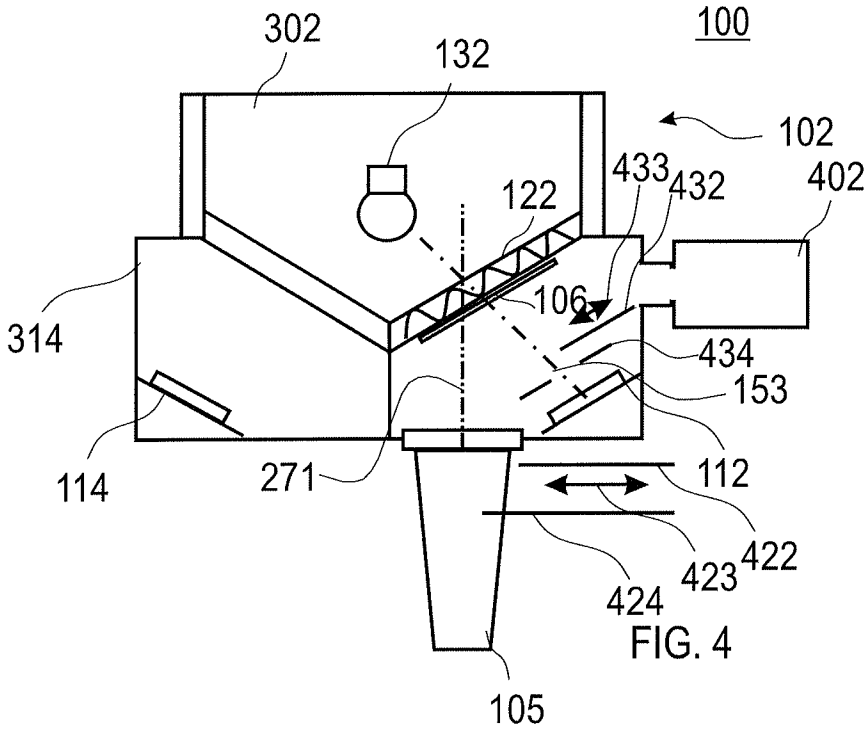

100
302
132
102
433
432
402
122
106
314
434
153
114
271
112
422
423
424
105

FIG. 4

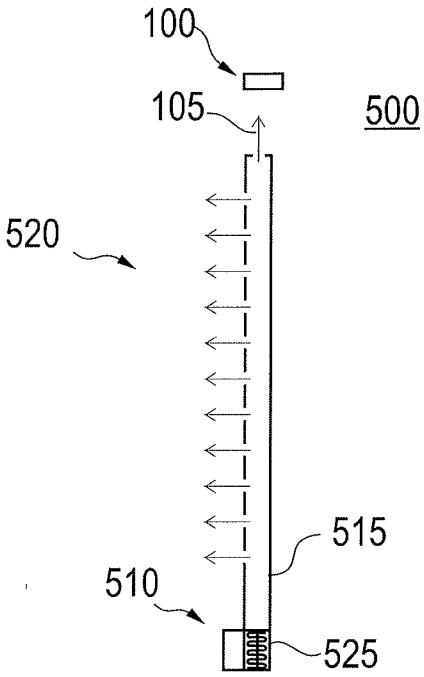

100
105
500
520
515
510
525

FIG. 5A

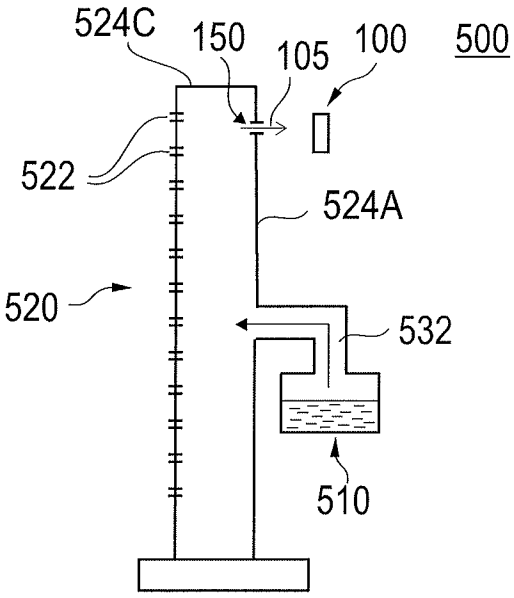

524C
150
105
100
500
522
524A
520
532
510

FIG. 5B

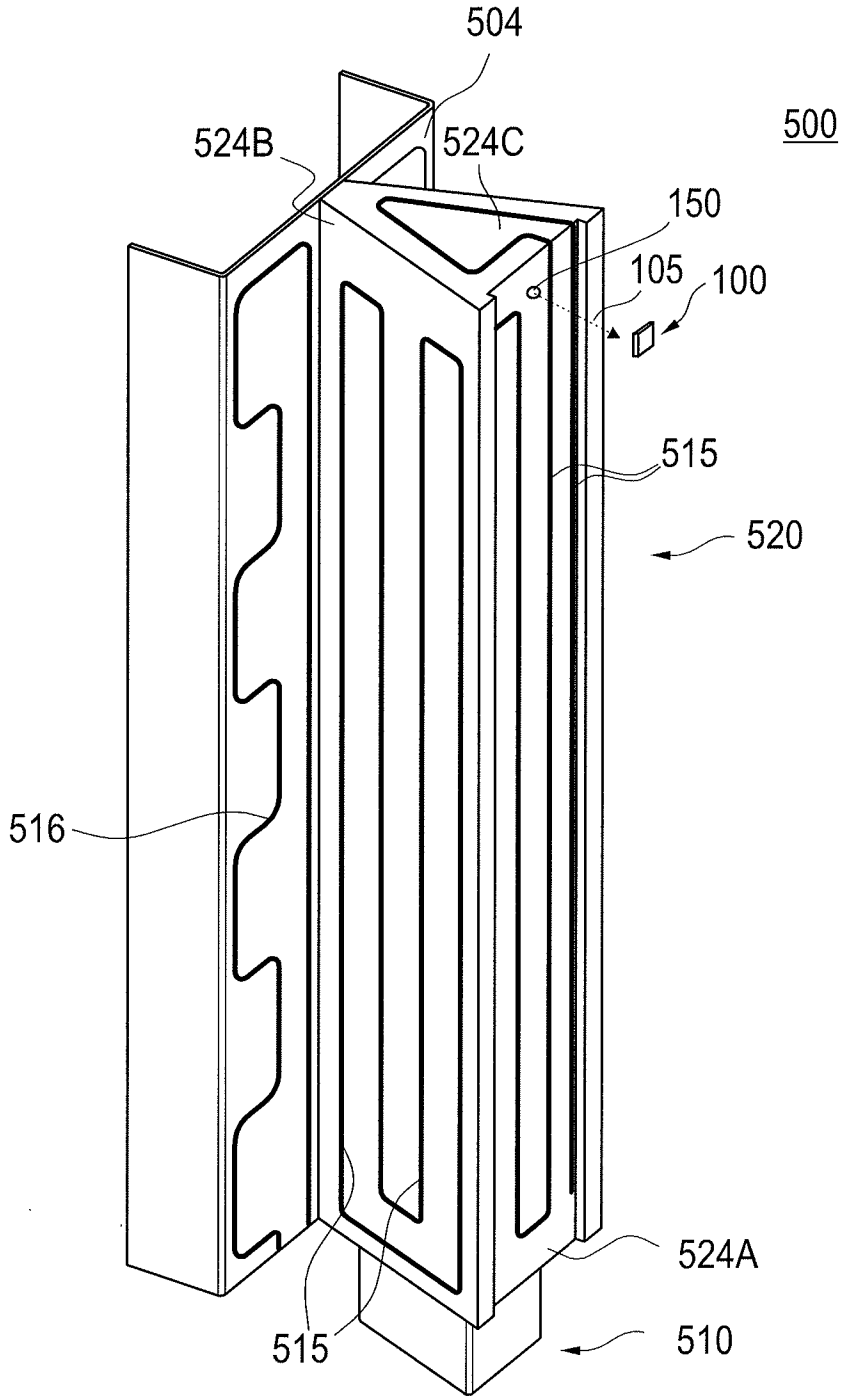


FIG. 6

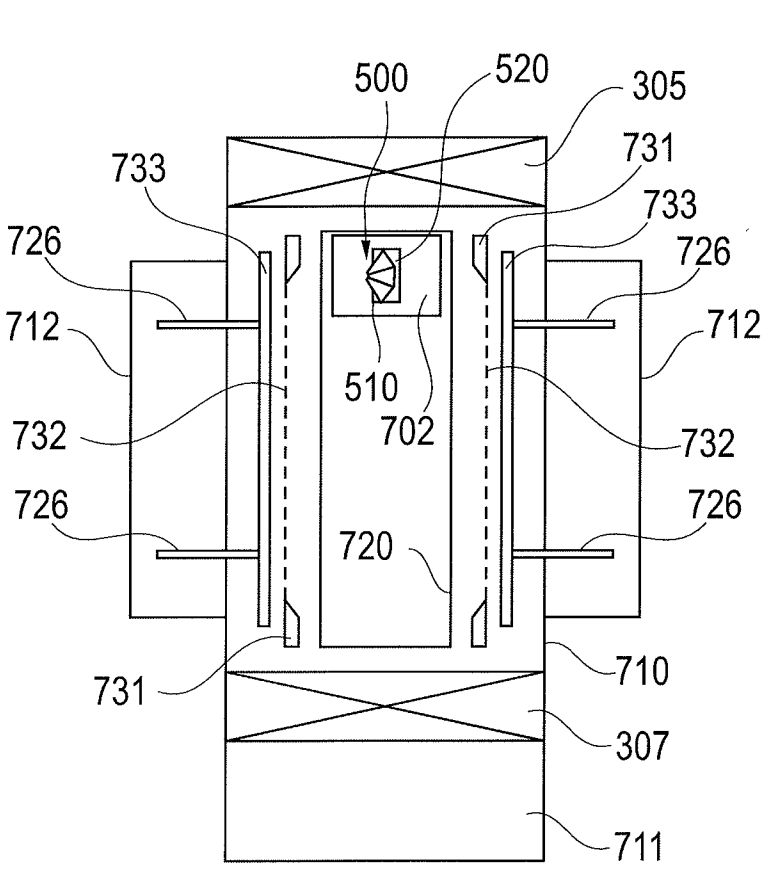

700
500
520
305
731
733
733
726
726
712
712
510
702
732
732
726
726
720
710
731
307
711

FIG. 7

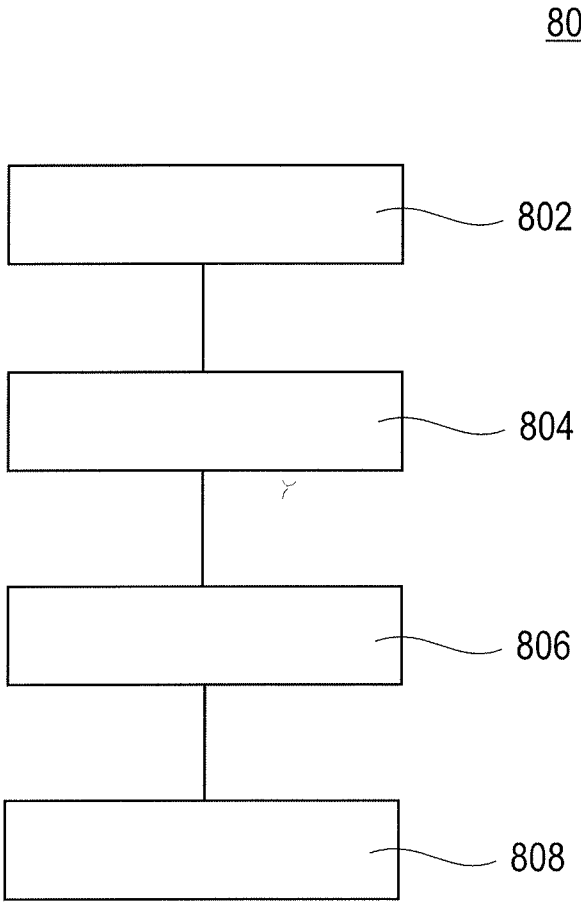


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/065744

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 14
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claim 14 is regarded to be not clear because it refers to claim 13, which does not comply with PCT Rule 6.4(a).

3. ☒ Claims Nos.: 7-13, 15
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/065744

A. CLASSIFICATION OF SUBJECT MATTER

C23C 14/54(2006.01)i, C23C 14/24(2006.01)i, G01B 11/06(2006.01)i

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 14/54; B05C 11/00; B05C 19/04; B05D 1/00; C23C 14/04; C23C 16/00; C23C 16/44; C23C 16/52; C23C 14/24; G01B 11/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: deposition rate, transparent substrate, reference surface, second detector, source, reference signal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002-0068126 A1 (GREZES-BESSET, CATHERINE) 06 June 2002 See paragraphs [0048]-[0058]; claims 1-2; and figure 1.	4-6
A		1-3,16-17
A	US 2002-0139666 A1 (HSUEH et al.) 03 October 2002 See paragraphs [0022]-[0033]; and figures 1-4.	1-6,16-17
A	US 2003-0140858 A1 (MARCUS et al.) 31 July 2003 See paragraphs [0050]-[0060]; and figure 7.	1-6,16-17
A	US 2006-0185588 A1 (NOZAWA et al.) 24 August 2006 See paragraphs [0025]-[0056]; and figures 1-3.	1-6,16-17
A	WO 03-048415 A1 (INFINEON TECHNOLOGIES SC300 GMBH & CO. KG et al.) 12 June 2003 See page 9, line 29 - page 14, line 16; and figures 1-3.	1-6,16-17

☐ 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
23 August 2019 (23.08.2019)	**23 August 2019 (23.08.2019)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
KIM, Jin Ho
Telephone No. +82-42-481-8699

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2018/065744

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002-0068126 A1	06/06/2002	AU 2378002 A	27/05/2002
		EP 1409763 A1	21/04/2004
		EP 1409763 B1	28/09/2011
		FR 2816714 A1	17/05/2002
		FR 2816714 B1	10/10/2003
		US 6620249 B2	16/09/2003
		WO 02-40737 A1	23/05/2002
US 2002-0139666 A1	03/10/2002	US 6547939 B2	15/04/2003
US 2003-0140858 A1	31/07/2003	CN 1279208 C	11/10/2006
		CN 1382827 A	04/12/2002
		EP 1251571 A2	23/10/2002
		EP 1251571 A3	19/09/2007
		JP 2002-373782 A	26/12/2002
		KR 10-2002-0082128 A	30/10/2002
		TW 546987 B	11/08/2003
		US 2002-0187253 A1	12/12/2002
		US 6558735 B2	06/05/2003
		US 6682600 B2	27/01/2004
US 2006-0185588 A1	24/08/2006	JP 2006-176831 A	06/07/2006
		KR 10-0832385 B1	26/05/2008
		KR 10-2006-0072089 A	27/06/2006
WO 03-048415 A1	12/06/2003	EP 1318211 A1	11/06/2003
		EP 1318211 B1	27/08/2008
		TW 200410309 A	16/06/2004
		TW I244685 B	01/12/2005
		US 2004-0253824 A1	16/12/2004