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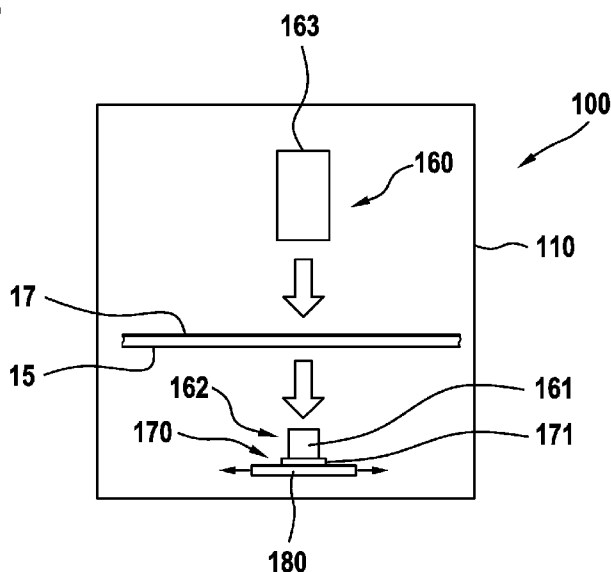
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Fig. 2



(57) Abstract: According to one aspect of the present disclosure, an apparatus for processing of a material on a substrate is provided. The apparatus includes a vacuum chamber (110) and a measuring arrangement (160) configured for measuring one or more properties of the substrate (15) and/or of the material processed on the substrate, wherein the measuring arrangement comprises a cooling device (170) with a thermoelectric cooler (171) for cooling at least one heat generating component (161) of the measuring arrangement. According to another aspect, a cooling arrangement (50) for such an apparatus is provided. The cooling arrangement includes a cooling device with a thermoelectric cooler for cooling at least one heat generating component of a measuring arrangement arranged in a vacuum chamber; and a transport device configured for moving the cooling device within the vacuum chamber.

**APPARATUS FOR PROCESSING OF A MATERIAL ON A SUBSTRATE,
COOLING ARRANGEMENT FOR A PROCESSING APPARATUS, AND
METHOD FOR MEASURING PROPERTIES OF A MATERIAL PROCESSED
ON A SUBSTRATE**

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TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to an apparatus for processing of a material on a substrate, to a cooling arrangement for an apparatus for processing of a material on a substrate, as well as to methods of measuring one or more properties of a material processed on a substrate. Embodiments of the present disclosure particularly
10 relate to an apparatus for processing a substrate and measuring one or more properties of a material processed on the substrate.

BACKGROUND

[0002] Coatings, particularly optical coatings and other materials deposited on substrates such as plastic films, can be characterized by specified spectral reflectance and transmittance values and resulting color values. Properties of the coating, particularly
15 optical properties, can be measured by a measuring arrangement which may comprise a light source and a light detector. A reliable inline measurement of transmission (T) and reflection (R) during or after production of the coatings can be an aspect that needs to be considered for the control of the deposition process and the optical quality control of the coated product. The more sophisticated part of the T/R measurement is the measurement
20 of the reflectance. The reflectance measurement can be challenging on moving plastic films since small deviations in flatness of the film cause geometrical changes in the path of the reflected beam to the detector, resulting in erroneous measurement results. In deposition apparatuses, reflectance can be measured in positions where the plastic film is in mechanical contact with guide rollers of the apparatus to ensure a flat contact of the
25 plastic film with the surface of the roller.

[0003] However, in this case, measuring may be restricted to fixed positions of the measuring arrangement. For cost reasons, the number of fixed measuring arrangements or measuring heads in roll-to-roll (R2R) sputter machines can be limited between one and

five. Even systems with five measuring arrangements do not deliver sufficient information about layer uniformity and compliance with the optical specification along the substrate width. Therefore, there is a need to provide a measuring arrangement capable of performing measurements at various positions.

5 [0004] For inline measurements, the measuring arrangement may be located in a vacuum chamber of the processing apparatus, e.g. in the vacuum chamber of a deposition or coating device. Efficient cooling of heat generating components of the measuring arrangement under vacuum conditions may be difficult, in particular when heat generating components which are located at different positions are to be cooled. For effective
10 cooling, a cooling fluid such as water may be led through flexible tubes to different positions within the vacuum chamber, where cooling may be necessary. However, the disadvantage of a cooling fluid in a vacuum environment is the risk of a leakage in the fluid circuit. If a leakage occurs, several components within the machine may be seriously affected or destroyed. Poor or ineffective cooling may negatively affect the measurement
15 quality and may even lead to defects of heat generating components of the measuring arrangement.

[0005] Therefore, there remains a need for apparatuses with which improved quality inspection of substrates and coatings on substrates can be achieved. There is also a need for improved methods of measuring properties of substrates and/or material processed on
20 the substrate, particularly suitable for processing systems with high output capacity.

SUMMARY

[0006] In light of the above, an apparatus for processing of a material on a substrate and a cooling arrangement for an apparatus for processing a material on a substrate are provided. Further, methods of measuring one or more properties of a substrate and/or a
25 material processed on the substrate are provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0007] According to one aspect of the present disclosure, an apparatus for processing of a material on a substrate is provided. The apparatus includes a vacuum chamber and a

measuring arrangement configured for measuring one or more properties of the substrate and/or of the material processed on the substrate, wherein the measuring arrangement comprises a cooling device with a thermoelectric cooler for cooling at least one heat generating component of the measuring arrangement.

5 [0008] In some embodiments, the measuring arrangement may further include a transport device configured for moving the cooling device together with or independent of the at least one heat generating component within the vacuum chamber.

10 [0009] According to a further aspect of the present disclosure, a cooling arrangement for an apparatus for processing of a material on a substrate is provided. The cooling arrangement includes a cooling device with a thermoelectric cooler for cooling at least one heat generating component of a measuring arrangement arranged in a vacuum chamber; and a transport device configured for moving the cooling device separately from or together with the at least one heat generating component within the vacuum chamber.

15 [0010] According to a further aspect of the present disclosure, a method of measuring one or more properties of a substrate and/or a material processed on a substrate in a vacuum chamber is provided. The method includes cooling, during measuring, at least one heat generating component of a measuring arrangement with a thermoelectric cooler of a cooling device, wherein the cooling device and the heat generating component are arranged at a measuring position within the vacuum chamber.

20 [0011] In some embodiments, the method further includes moving the at least one heat generating component together with the cooling device to a second measuring position or to a calibration position within the vacuum chamber.

[0012] Further aspects, advantages, and features of the present disclosure are apparent from the dependent claims, the description, and the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly

summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following. Typical embodiments are depicted in the drawings and are detailed in the description which follows.

- 5 [0014] FIG. 1 shows a schematic view of a reflection and transmission measurement of optical coatings;
- [0015] FIG. 2 shows a schematic view of a processing apparatus according to embodiments described herein;
- 10 [0016] FIG. 3 shows a schematic view of a processing apparatus according to embodiments described herein;
- [0017] FIG. 4 shows a schematic view of a processing apparatus according to embodiments described herein;
- [0018] FIG. 5 shows a schematic view of a processing apparatus according to embodiments described herein;
- 15 [0019] FIG. 6 shows another schematic view of an apparatus for processing of a material on a substrate of FIG. 5 at a measuring position and at two calibration positions within the vacuum chamber;
- [0020] FIG. 7 shows a cooling arrangement according to embodiments described herein;
- [0021] FIG. 8 shows a cooling arrangement according to embodiments described herein;
- 20 [0022] FIG. 9 shows a flow chart of a method of measuring one or more optical properties of a substrate and/or a material processed on the substrate with a processing apparatus according to embodiments described herein.

DETAILED DESCRIPTION

- 25 [0023] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in each figure. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described

as part of one embodiment can be used on or in conjunction with any other embodiment to yield yet a further embodiment. It is intended that the present disclosure includes such modifications and variations.

[0024] Within the following description of the drawings, the same reference numbers refer to the same or to similar components. Generally, only the differences with respect to the individual embodiments are described. Unless specified otherwise, the description of a part or aspect in one embodiment applies to a corresponding part or aspect in another embodiment as well.

[0025] FIG. 1 shows a schematic perspective view of a reflection and transmission measurement of optical coatings.

[0026] In deposition apparatuses, specular reflectance can be measured at positions where the substrate, e.g. a plastic film, is in mechanical contact with a roller (e.g., a guide roller) of the apparatus to ensure a flat contact of the plastic film with the surface of the roller, as will be explained in more detail below with reference to FIG. 1.

[0027] As shown in FIG. 1, a substrate 15 is carried and conveyed by a coating drum 11, a first roller 12 and/or a second roller 13 inside a vacuum chamber (not shown). The first roller 12 and the second roller 13 can be guide rollers. In a position between the first roller 12 and the second roller 13 a transmission measuring arrangement 16 is provided. The position or area between the first roller 12 and the second roller 13 may also be referred to as “free span” or “free span position”. Further, at another position where the substrate 15, e.g. a plastic film, is in mechanical contact with the second roller 13, a reflectance measuring arrangement 14 is provided.

[0028] However, the incident light beam is not only reflected on the front and back surfaces of the substrate 15, but also on the surface of the second roller 13. Since the reflectance R of metallic rollers is rather high (e.g., $R > 50\%$), a roller surface with low or reduced reflectance is beneficial. The second roller 13 has a black or blackened surface so that the surface of the second roller 13 has the low or reduced reflectance. However, the reflectance of these black or blackened surfaces suffers from insufficient low and inhomogeneous reflectance. The reliability of a measurement of the absolute reflectance is rather low.

[0029] The term “substrate” as used herein shall particularly embrace flexible substrates such as a plastic film, a web or a foil. However, the present disclosure is not limited thereto and the term “substrate” may also embrace inflexible substrates, e.g., a wafer, slices of transparent crystal such as sapphire or the like, or a glass plate. According to some embodiments, the substrate may be a transparent substrate. The term “transparent” as used herein shall particularly include the capability of a structure to transmit light with relatively low scattering, so that, for example, light transmitted therethrough can be seen in a substantially clear manner. Typically, the substrate includes polyethylene terephthalate (PET).

[0030] An apparatus for processing of a material on a substrate (also referred to as “processing apparatus” herein) may be a coating or deposition apparatus for depositing a thin material layer on a substrate, e.g. a transparent, semitransparent and/or opaque layer. The processing apparatus may include a processing chamber, in which the coated substrate is transported from a first coating region to a second coating region or from a coating region to a curing or storing region. Typically, after deposition of one or more layers on a substrate, reflection and/or transmission properties of the layer are measured, in order to characterize the quality of the layer, e.g. the layer uniformity. The transmission and/or reflection may be measured via a measuring arrangement at different positions of the coated substrate, e.g. at different positions in a width direction of the substrate. The width direction may be perpendicular to a transport direction, along which the substrate is moved through the vacuum chamber.

[0031] Typically, measuring arrangements, particularly optical measuring arrangements, include heat generating components which generate heat within the vacuum chamber, e.g. light sources, detection devices, electronic chips, sensor chips, CCD chips, gratings and/or other optical, electrical and/or opto-electronic elements. As there is no convective heat transfer through vacuum, heat generating components tend to heat up more quickly in vacuum and efficient cooling may be difficult in a vacuum chamber. Cooling in a vacuum chamber may be achieved by radiation and/or direct thermal contact of a heat generating component with a cooling device. Typical cooling devices may include heat exchangers with a circulating cooling fluid, e.g. water, in direct thermal contact with the heat generating component.

[0032] The disadvantage of cooling with a cooling fluid in a vacuum environment is the risk of a leakage in the cooling circuit. If this happens, several components within the chamber (pumps, vacuum gauges, deposition sources) may be seriously affected electrically or destroyed, e.g. by short circuits or rapid pressure variations.

5 [0033] According to embodiments described herein, the efficiency of the heat transfer away from at least one heat generation component (also referred to as “heat source” herein) is increased by using a heat pump in the form of a thermoelectric cooler. Thermoelectric coolers are available in many different variations. By applying a DC voltage to a thermoelectric cooler, one side of the element may cool down (cooling side)
10 and the other side (hot side) may heat up. The heat may be dissipated from the hot side towards a heat sink. In some embodiments, the thermoelectric cooler may include a plurality of p-type and n-type semiconductor pellets in an alternating arrangement. The semiconductor pellets may be arranged between conductor tabs provided on support structures, e.g. on ceramic substrates.

15 [0034] FIG. 2 shows an apparatus 100 for processing a material on a substrate according to embodiments described herein. The processing apparatus 100 includes a vacuum chamber 110 and a measuring arrangement 160 configured for measuring one or more properties of the substrate 15 and/or of the material 17 processed on the substrate, e.g. an optical property of a coating layer deposited on the substrate. The measuring arrangement
20 160 includes one or more heat generating components, e.g. an electronic chip for signal transport and/or signal analysis, an optical sensor chip such as a CCD chip, an optical element such as a grating. At least one of the heat generating components is cooled by a cooling device 170 including a thermoelectric cooler 171.

25 [0035] The thermoelectric cooler 171 can also be used to control the temperature of the heat generating component 161. In some embodiments, a control device for controlling the amount of cooling provided by the thermoelectric cooler 171 in dependence of a temperature of the heat generating component and/or in dependence of a temperature of the cooling device may be provided. For example, the temperature of the cooling side of the thermoelectric cooler may be controlled to remain essentially constant ($\pm 5^{\circ}\text{C}$), also
30 in the case of a varying thermal load provided by the heat generating component.

[0036] The thermoelectric cooler may be configured for providing a temperature change within seconds. For example, the thermoelectric cooler may be configured for providing a temperature decrease of 5°C within 10 seconds or less. Quick cooling may be beneficial in the case of a heat generating component including sensitive electronic elements, e.g. a sensor chip. In some implementations, the control device may be configured for keeping the temperature of the cooling side of the thermoelectric cooler essentially constant.

[0037] In some embodiments, which may be combined with other embodiments disclosed herein, the thermoelectric cooler 171 may be in direct thermal contact with the heat generating component 161. For example, the cooling side of the thermoelectric cooler 171 may be in direct mechanical contact with a heating surface of the heat generating component 161. In some embodiments, a thermocouple may be arranged between the heat generating component 161 and the thermoelectric cooler 171. The thermocouple may comprise a material with a good thermal conductivity and may be in planar contact with at least one of a heating surface of the heat generating component and the cooling side of the thermoelectric cooler.

[0038] The thermoelectric cooler 171 may include at least one Peltier element. It is noted that Peltier elements themselves may also generate some heat which needs to be transferred to a heat sink. Therefore, when using a Peltier element, the total thermal energy to be dissipated to the heat sink may be increased. For example, in some embodiments, the total heat energy which needs to be dissipated may be up to a factor of 10 higher when using a Peltier element. Surprisingly, even when considering the additional heat energy generated by the Peltier element, there is still a more effective heat transfer away from the heat generating component 161 so that cooling of the heat generation component can be improved according to embodiments described herein. In particular, temperature changes can be compensated more quickly so that the risk of damage can be reduced.

[0039] In some implementations, the thermal contact between the thermoelectric cooler and the heat generating component may be further improved by arranging a high thermal conductivity foil, e.g. a graphite foil, between the thermoelectric cooler and the heat generating component. For example, a good thermal contact may be provided by

arranging a thermocouple in thermal contact with the heat generating component, wherein a graphite foil is arranged between the cooling side of the thermoelectric cooler and the thermocouple. Graphite foils are suitable for providing an excellent thermal contact.

[0040] Optical properties of the material 17 deposited on the substrate 15 may be measured via a measuring arrangement 160 including a detector device 162, e.g. an optical detector such as a spectrometer and/or a camera. The detection device may include at least one of a spectrometer, a CCD chip, a CCD camera, a sensor chip, an electrical chip for analysis of signals, a PCB connected to a sensor chip, one or more gratings and other electric, optic, and electro-optic components. In particular, sensitive electrical chips may need to be kept at an essentially constant temperature, which may be difficult under vacuum conditions. At least one of the mentioned components may constitute the heat generating component which is cooled by the thermoelectric cooler 171 in some of the embodiments described herein.

[0041] In some embodiments, the measuring arrangement 160 may comprise a light source 163 for generating a light beam for performing reflectance and/or transmission measurements, e.g. a laser source. For a measuring arrangement 160 configured for transmittance measurements, the light source 163 may be arranged at a first main side of the substrate 15, and the heat generating component together with the cooling device may be arranged at the second main side of the substrate. For a measuring arrangement configured for reflectance measurements, the light source may be arranged at the same main side of the substrate 15 as compared to the heat generating component and the cooling device.

[0042] According to some embodiments of the present disclosure, the measuring arrangement 160 further comprises a transport device 180 configured for moving the cooling device 170 together with the at least one heat generating component 161 within the vacuum chamber 110. Thus, the measuring arrangement 160 may be configured for performing measurements at different positions of the coated substrate. For example, the transport device 180 may be configured for moving the cooling device 170 together with the heat generating component 161 in a width direction of the substrate 15 perpendicular or transverse with respect to a transport direction, in which the substrate is moved through

the vacuum chamber 110. In some embodiments, the transport device may be configured to move the cooling device 170 together with the heat generating component in at least two directions, e.g. the width direction and the transport direction. In some implementations, which may be combined with other implementations disclosed herein, the transport device 180 may be configured for moving the whole measuring arrangement 160 (including the light source 163, the detector device 162, and the cooling device 170) within the vacuum chamber 110, e.g. in a width direction of the substrate 15.

[0043] In some implementations, the transport device 180 can include a linear positioning stage. In some implementations, the transport device can include an X-Y-stage or an X-Y-Z-stage configured for a two- or three-dimensional movement of the measuring arrangement. According to some embodiments, which can be combined with other embodiments described herein, the transport device 180 can include an actuator. The actuator can be configured for performing the movement of the measuring arrangement 160 along a trajectory, e.g., a linear trajectory.

[0044] The actuator may be operated by a source of energy in the form of an electric current, hydraulic fluid pressure or pneumatic pressure converting the energy into motion. According to some embodiments, the actuator can be an electrical motor, a linear motor, a pneumatic actuator, a hydraulic actuator or a piezoelectric actuator.

[0045] In some embodiments, the transport device 180 may be configured to move the cooling device separately from the heat generating component within the vacuum chamber, e.g. from a first heat generating component to a second heat generating component.

[0046] Therefore, according to embodiments disclosed herein, one measuring arrangement may be moved from a first measuring position to a second measuring position and/or to a calibration position without a need to flood the vacuum chamber. Further, the at least one heat generating component can be cooled during measuring at the first and at the second measuring position. Further, if necessary, the heat generation component may also be cooled during calibration, when the measuring arrangement is arranged at the calibration position, so that equal temperature conditions may be provided

at various measuring and/or calibration positions. In some embodiments, cooling may also be provided during movement of the heat generating component. This leads to an increased measuring accuracy and to an increasing measuring speed, as there is no need to flood the vacuum chamber for changing the position of the cooling device. Further, moving of a thermoelectric cooler may be easier than moving of tubes or channels for fluid cooling, and there is no risk of fluid leakage in the vacuum chamber, as thermoelectric coolers do not need movable water hoses or tubes. Therefore, the measuring process may be simplified and accelerated, while providing an increased measuring accuracy.

[0047] According to some embodiments, which may be combined with other embodiments described herein, the transport device 180 includes an actuator configured for moving the heat generating component 161 together with the cooling device 170 to at least one of a measuring position, a reflectance calibration position and a transmission calibration position.

[0048] In some implementations, the actuator of the transport device 180 may include at least one of an electrical motor, a linear motor, a pneumatic actuator, a hydraulic actuator, and a piezoelectric actuator.

[0049] FIG. 3 shows a processing apparatus 200 according to embodiments described herein in a schematic view. The processing apparatus 200 corresponds in parts to the processing apparatus 100 shown in FIG. 2 so that reference can be made to the above explanations, whereas only the differences will be explained in the following description.

[0050] The processing apparatus 200 includes a vacuum chamber 110 and a measuring arrangement 160 for measuring an optical property of a coating layer deposited on the substrate 15, e.g. a transmission or reflection property. The measuring arrangement 160 includes a heat generating component 161 which generates heat to be dissipated via a cooling device 270 which is in direct or indirect thermal contact with the heat generating component 161.

[0051] Similar to the embodiment shown in FIG. 1, the heat generating component 161 may be a part of a detector device, e.g. at least one of a sensor chip, a grating or another electronic and/or optic component.

[0052] The cooling device 270 includes a thermoelectric cooler 171 and a heat exchanger module 271 which is in thermal contact with the thermoelectric cooler 171. In other words, the thermoelectric cooler 171 may be coupled between the at least one heat generating component 161 and the heat exchanger module 271.

5 [0053] In some embodiments, which may be combined with other embodiments described herein, the heat exchanger module 271 comprises cooling channels 272 and/or cooling tubes for a circulating cooling medium and is configured for transferring heat from a hot side of the thermoelectric cooler 171 to the cooling medium.

10 [0054] By sandwiching the thermoelectric cooler 171 between the heat generating component 161 and the heat exchanger module 271, the effectivity of the heat transfer from the heat generating component 161 to the heat exchanger module 271 can be increased. In other words, an improved heat exchange to the heat exchanger module, which may be provided as a cooling plate, can be achieved by using a heat pump in the form of a thermoelectric cooler. The thermoelectric cooler may be provided as a Peltier
15 element, wherein the heat from the hot side of the Peltier element may be dissipated to the heat exchanger module.

[0055] In order to further improve the thermal contact between the thermoelectric cooler and the heat generating component, a thermocouple 275 may be arranged therebetween. Alternatively or additionally, one or more graphite foils may be interposed between the
20 hot side of the thermoelectric cooler and the heat exchanger module and/or between the cooling side of the thermoelectric cooler and the thermocouple 275.

[0056] In order to avoid the risk of damage in case of a leakage, the heat exchanger module 271 may be configured for a gaseous cooling medium to circulate within the cooling channels 272 of the heat exchanger module. For example, the cooling medium
25 may be atmosphere, air or another cooling gas. In some implementations, the heat exchanger module may be coupled to a pump device 277 for feeding the gaseous cooling medium to the heat exchanger module. The pump device 277 is not necessarily arranged inside the vacuum chamber 110. For example, a feed-through may be provided for feeding the cooling medium through a wall of the vacuum chamber 110, where the heat
30 exchanger module 271 is arranged.

[0057] In some embodiments, a feed-through may be provided for feeding supply cables for providing a voltage, e.g. a DC-voltage, to the thermoelectric cooler 171.

[0058] In some embodiments, the cooling device 270 with the heat exchanger module 271 and the thermoelectric cooler 171 may be fixed to a transport device 180 for moving the cooling device together with the heat generating component 161 inside the vacuum chamber. Flexible tubes 278 or hoses may be provided for transporting the cooling medium from the pump device 277 to the heat exchanger device 271 and vice versa, when the cooling device is movably arranged inside the vacuum chamber 110.

[0059] If there is leakage in the gas cooling circuit, the pressure may rise within the vacuum chamber, until the electronic switches off a vacuum pump. Therefore, the risk of damage is decreased. After fixing the leakage, the vacuum pumps can be restarted again. Compared to a fluid like water, the heat transfer coefficient of a gas like air is lower. Therefore, depending on the amount of heat to be dissipated, a high gas flow may be reasonable to dissipate the heat from the hot side of the thermoelectric cooler. For example, the pump device 277 may be configured for providing a gas throughput of more than 1 liter/second.

[0060] FIG. 4 shows a processing apparatus 300 according further embodiments disclosed herein. The measuring arrangement 20 of the processing apparatus 300 includes at least one sphere structure 21, particularly an integrating sphere, located in the vacuum chamber (not shown). The sphere structure 21 may be used to allow simultaneous reflectance measurements and transmission measurements, particularly at the same position, for instance in a free span position of the substrate 15 or plastic film between two rollers. Even if the surface of the film is not flat, the reflected light is almost completely collected in the sphere structure.

[0061] The sphere structure 21 provides a uniform scattering or diffusing of light inside the sphere structure. Light incident on an inner surface of the sphere structure is equally distributed within the sphere. Directional effects of the incident light are minimized. This allows the measurement of the incident light (e.g., light reflected from or transmitted through the substrate and/or the material processed on the substrate) with a high degree of accuracy and reliability.

[0062] According to some embodiments, the sphere structure 21 is or includes an integrating sphere. An integrating sphere (or Ulbricht sphere) is an optical device including a hollow spherical cavity having at least one port, e.g. at least one entrance port and/or at least one exit port. An interior of the hollow spherical cavity can be covered with a reflective coating (e.g., a diffuse white reflective coating). The integrating sphere provides a uniform scattering or diffusing of light inside the sphere. Light incident on the inner surface is distributed equally within the sphere. Directional effects of the incident light are minimized. An integrating sphere may be thought of as a diffuser which preserves power but destroys spatial information.

[0063] The measuring arrangement 20 is arranged within the vacuum chamber. The vacuum chamber can be or include a process chamber where the substrate 15 to be coated is located. The apparatus according to embodiments described herein can be a deposition apparatus, and particularly a sputtering apparatus, a physical vapor deposition (PVD) apparatus, a chemical vapor deposition (CVD) apparatus, a plasma enhanced chemical vapor deposition (PECVD) apparatus.

[0064] As schematically shown in FIG. 4, the measuring arrangement 20 according to embodiments described herein is configured for measuring one or more optical properties of the substrate 15 and/or the material processed on the substrate 15, particularly a reflectance and/or a transmission. The term “reflectance” as used throughout the application refers to the fraction of the total radiant flux incident upon a surface that is reflected. The surface may include at least one of a surface of the material processed on the substrate, a front surface of the substrate and a back surface of the substrate. It is noted that the terms “reflectance” and “reflectivity” can be used synonymously. The term “transmission” as used throughout the application refers to a fraction of incident light (electromagnetic radiation) that passes through the substrate for instance having a material or layers processed thereon. The terms “transmission” and “transmittance” can be used synonymously.

[0065] The sphere structure 21 may have a cavity 22. According to some embodiments, the cavity 22 can be a hollow spherical cavity. In typical implementations, a surface of the cavity 22 is at least partially covered with a reflective coating (e.g., a white reflective

coating). The sphere structure 21 provides a uniform scattering or diffusing of light inside the sphere structure 21. Light incident on the surface of the cavity 22 is distributed equally within the cavity 22.

[0066] According to embodiments, which can be combined with other embodiments described herein, the sphere structure 21, and particularly the cavity 22 of the sphere structure 21, has an inner diameter of 150 mm or less, particularly of 100 mm or less, more particularly of 75 mm or less.

[0067] For measuring the one or more optical properties, the measuring arrangement 20 may include a configuration with at least one light source 23 and at least one detector. A possible configuration of the at least one light source and the at least one detector is described in the following. However, other configurations are possible.

[0068] In typical implementations, the measuring arrangement 20 includes a light source 23. The light source 23 is configured for emitting light into the cavity 22 of the sphere structure 21. According to embodiments, which can be combined with other embodiments described herein, the light source 23 is configured for emitting light in the visible range of 380-780 nm and/or in the infrared range of 780 nm to 3000 nm and/or in the ultraviolet range of 200 nm to 380 nm.

[0069] According to embodiments, which can be combined with other embodiments described herein, the light source 23 is arranged such that light can be emitted into the cavity 22. The light source 23 may be arranged within the cavity 22, or attached to an inner wall or surface of the cavity 22. According to embodiments, the light source 23 can be arranged outside the sphere structure 21, wherein the wall of the sphere structure 21 can include an opening which is configured such that light emitted from the light source 23 can shine into the interior of the sphere structure 21, and particularly into the cavity 22.

[0070] According to embodiments, which can be combined with other embodiments described herein, the light source 23 may be configured as, e.g., a filament bulb, a tungsten halogen bulb, LEDs, high-power LEDs or Xe-Arc-Lamps. The light source 23 may be configured such that the light source 23 can be switched on and off for short periods of time. For the purpose of switching, the light source 23 can be connected to a control unit (not shown).

[0071] In typical embodiments, the sphere structure 21 has at least one port 26. The port 26 can be configured as entrance port and/or exit port. As an example, light reflected from or transmitted through the substrate 15 and/or the material processed on the substrate 15 can enter the sphere structure 21 through the port 26. In another example, light provided by the light source 23 can exit through the port 26, for instance for a reflectance measurement. The port 26 can be covered with a cover element, for instance a protective glass. In other examples, the port 26 can be uncovered or open.

[0072] According to embodiments, which can be combined with other embodiments described herein, the port 26 may have a diameter of 25 mm or less, particularly of 15 mm or less, more particularly of 10 mm or less. By increasing the diameter of the port 26, a larger portion of the substrate 15 may be illuminated for conducting a measurement of the at least one optical property of the substrate 15 and/or the material processed on the substrate 15.

[0073] In typical implementations, diffuse light emitted from the sphere structure 21 through the port 26 can be shone onto the substrate 15 for measurement of at least one optical property of the substrate 15 and/or the material processed on the substrate 15. By illuminating the substrate 15 with diffuse light, the light shone onto the substrate 15 is of the same intensity throughout an illuminated portion of the substrate 15. According to some embodiments, which can be combined with other embodiments described herein, the emitted diffuse light can be characterized by emitting the light at a plurality of angles, particularly with a uniform angular distribution of the intensity of the light. For example, this can be generated by diffuse reflection in the sphere structure, e.g. an integrating sphere or Ulbricht sphere, where the material in the sphere is selected for providing diffuse reflection.

[0074] As exemplarily illustrated in FIG. 4, a beam of light, which is illustrated as a solid line with arrows indicating the direction of the light, may have a position of origin P on the interior surface of the sphere structure 21 before the beam exits the port 26. The beam may be reflected from the substrate 15 and/or the material processed on the substrate, as exemplarily shown in FIG. 4, and, in case of reflectance, enter the port 26 with an angle of reflectance.

[0075] According to some embodiments, which can be combined with other embodiments described herein, the measuring arrangement 20 includes a first detector device 24 and a second detector device 27 at the sphere structure 21 configured for measuring a reflectance of the substrate 15 and/or the material processed on the substrate.

5 [0076] The first detector device 24 can be configured for receiving light entering through the port 26 (as indicated by the solid line with arrows indicating the direction of the light), and particularly light reflected from the substrate 15 and/or the material processed on the substrate 15. According to embodiments, which can be combined with other embodiments described herein, the first detector device 24 is configured and arranged such that no light
10 reflected from the inside of the sphere structure 21 is detected by the first detector device 24. For example, the first detector device 24 can be arranged such that only light entering through the port 26 of the sphere structure 21, e.g. due to reflection on the substrate 15 and/or the material processed on the substrate 15, can be detected by the first detector device 24.

15 [0077] The second detector device 27 can be configured for receiving light scattered or reflected from the interior wall of the cavity 22. As an example, the second detector device 27 can provide a reference measurement. In typical implementations, the reflectance is determined based on a first light intensity received or measured by the first detector device 24 and a second light intensity received or measured by the second
20 detector device 27. The first light intensity may include light reflected from the substrate 15 and/or the material processed on the substrate that directly reaches the first detector device 24 without being reflected in the interior of the sphere structure 21. The second light intensity may be a reference light intensity that substantially does not include such direct light reflected from the substrate 15 and/or the material processed on the substrate
25 15.

[0078] According to embodiments, which can be combined with other embodiments described herein, the first detector device 24 and/or the second detector device 27 are configured and arranged such that no direct light from the light source 23 is detected by the first detector device and/or the second detector device. For example, screening
30 arrangements (not shown) may be provided within the sphere structure 21, which prevent

light emitted by the light source 23 from directly hitting the first light detector device and/or the second light detector device. Such screening arrangements may, for example, be realized by shields, apertures or lenses, which are configured and arranged such that no direct light emitted by the light source 23 can hit the first light detector device and/or the second light detector device.

[0079] According to embodiments, the first detector device 24 comprises a first data processing or first data analysis unit 25, and the second detector device 27 comprises a second data processing or second data analysis unit 28. The data processing or data analysis units 25 and 28 can be adapted to inspect and analyze the signals of the first detector device 24 and the second detector device 27, respectively. According to some embodiments, if any characteristic of the substrate 15 and/or the material processed on the substrate is measured which is defined as non-normal, the data processing or data analysis units 25 and 28 may detect the change and trigger a reaction, such as a stop of the processing of the substrate 15.

[0080] According to some embodiments, which can be combined with other embodiments described herein, the measuring arrangement 20 includes a third detector device 29 for a transmission measurement of the substrate 15 and/or the material processed on the substrate. The third detector device 29 can be configured for measuring a transmission, particularly of the substrate 15 and/or the material processed on the substrate. In typical implementations, the third detector device 29 comprises a third data processing or data analysis unit, as it is described above with reference to the first and second detector devices.

[0081] The third detector device 29 can be configured for receiving light exiting through the port 26, and particularly light transmitted through the substrate 15 and/or the material processed on the substrate. According to embodiments, which can be combined with other embodiments described herein, the third detector device 29 is arranged outside or opposite the sphere structure 21 with a gap between the third detector device 29 and the sphere structure 21. The substrate 15 can be positioned within the gap for measuring transmission, e.g. light transmitted through the substrate 15 and/or the material processed on the substrate.

[0082] In the above example, a configuration of the measuring arrangement 20 with a light source 23, a first detector device 24, a second detector device 27, and a third detector device 29 is described. However, other configurations are possible. As an example, two sphere structures could be provided, wherein the first sphere structure can be configured for a reflectance measurement, and the second sphere structure can be configured for a transmission measurement. A first light source and a first detector could be provided at the first sphere structure for the reflectance measurement. A second detector configured for receiving light entering through a port of the sphere structure, and particularly light transmitted through the substrate and/or the material processed on the substrate, could be provided at the second sphere structure, and a second light source could be provided outside or opposite the second sphere structure with a gap between the second light source and the second sphere structure. The substrate can be positioned within the gap for measuring transmission, e.g. light transmitted through the substrate and/or the material processed on the substrate.

[0083] The measuring arrangement 20 provides an improvement of reflectance and/or transmission measurements by using the sphere structure. As an example, reflectance and/or transmission of a flexible substrate such as a plastic film can be measured for instance in a free span position. The measuring arrangement also works when the flexible substrate is not flat, for instance in a case where the flexible substrate has wrinkles.

[0084] The measuring arrangement 20 includes at least one heat generating component, wherein one or more heat generating components are cooled with a cooling device including a thermoelectric cooler. In the embodiments shown in FIG. 4, an electric chip of the first data analysis unit 25 of the first detector device 24 is cooled with a first cooling device 42, an electric chip of the second data analysis unit 28 of the second detector device 27 is cooled with a second cooling device 44, and an electric chip of the data analysis unit of the third detector device 29 is cooled with a third cooling device 46. Each of the first, second, and third cooling devices includes at least one thermoelectric cooler. In some embodiments, at least one of the first, second, and third cooling devices may include a heat exchanger module. The thermoelectric cooler may be sandwiched between the electric chip constituting the heat generating component and the heat exchanger module, as shown in FIG. 3. In some embodiments, more or less than three cooling

devices may be provided. In some embodiments, alternatively or additionally at least one of a sensor chip, a grating and another electric and/or optic component of the first, second and third detector devices may be cooled with a cooling device including a thermoelectric cooler.

5 [0085] In some embodiments, the sphere structure 21 may be cooled with a cooling device including a thermoelectric cooler.

[0086] According to some embodiments of the present disclosure, the processing apparatus 300 includes a transport device 129 configured for moving the measuring arrangement 20 in the vacuum chamber. As an example, the transport device 129 is
10 configured for moving at least the sphere structure 21, the first detector device 24, the second detector device 27, and the third detector device 29 within the vacuum chamber 110. In some implementations, the transport device can include a linear positioning stage. As an example, the transport device 129 can be configured for moving the sphere structure 21 and the first, second and third detector devices between at least three
15 positions 30, 31 and 32, which are illustrated in FIG. 5. A first position 30 can be the transmission calibration position, a second position 31 can be a measuring position, and a third position 32 can be the reflectance calibration position. The at least three positions 30, 31 and 32 can be free span positions. As an example, the transmission calibration position can be an open position. The measuring position can be a free span position,
20 particularly between two guide rollers. Typically, more than one measuring positions are provided, for instance at least five, and particularly 6, 7, 8, 9 or 10. According to some embodiments, a reflectance reference element 33 can be provided at the reflectance calibration position. The reflectance reference element 33 can provide a known reflection standard. As an example, the reflectance reference element 33 can include or be Silicon
25 (Si).

[0087] A single transport device with an actuator may be provided for moving the measuring arrangement 20 (including the sphere structure and all detector devices) inside the vacuum chamber. In some embodiments more than one transport devices are provided, e.g. a first transport device for moving the sphere structure, in some cases together with
30 the first and second detector devices, and a second transport device for moving the third

detector device 29. The transport devices may be configured for moving the cooling devices together with the detector devices and/or the sphere structure, respectively.

[0088] FIG. 5 and FIG. 6 show schematic views of an apparatus for processing of a material on a substrate 15 according to embodiments described herein. The substrate 15 to be processed is placed in a vacuum chamber 110. One or more measuring arrangements according to the embodiments described herein are provided in the vacuum chamber 110. The measuring arrangement is configured to be moveable in the vacuum chamber 110, particularly between at least three positions 30, 31 and 32.

[0089] According to some embodiments, which can be combined with other embodiments described herein, the vacuum chamber 110 can have a flange for connecting a vacuum system, such as a vacuum pump or the like, for evacuating the vacuum chamber 110.

[0090] According to some embodiments, which can be combined with other embodiments described herein, the vacuum chamber may be a chamber selected from the group consisting of: a buffer chamber, a heating chamber, a transfer chamber, a cycle-time-adjusting chamber, a deposition chamber, a processing chamber or the like. According to embodiments, which can be combined with other embodiments described herein, the vacuum chamber may be a processing chamber. According to the present disclosure, a “processing chamber” may be understood as a chamber in which a processing device for processing a substrate is arranged. The processing device may be understood as any device used for processing a substrate. For example, the processing device may include a deposition source for depositing a layer onto the substrate. Accordingly, the vacuum chamber or processing chamber including the deposition source may also be referred to as a deposition chamber. The deposition chamber may be a chemical vapor deposition (CVD) chamber or a physical vapor deposition (PVD) chamber.

[0091] According to some embodiments, which can be combined with other embodiments described herein, the processing apparatus may be configured for deposition of material selected from the group consisting of: low index materials, such as SiO₂,

MgF, mid index material, such as SiN, Al₂O₃, AlN, ITO, IZO, SiO_xNy, AlO_xNy and high index materials, such as Nb₂O₅, TiO₂, TaO₂, or other high index materials.

[0092] According to typical embodiments, which can be combined with other embodiments described herein, the processing apparatus includes at least one load-lock chamber for guiding the substrate 15 in and/or out of the processing apparatus, and particularly in and/or out of the vacuum chamber 110. The at least one load-lock chamber can be configured for changing the interior pressure from atmospheric pressure to vacuum, e.g. to a pressure of 10 mbar or below, or vice versa. According to embodiments, an entry load-lock chamber including an entry port and an exit load-lock chamber including an exit port are provided (not shown).

[0093] As an example, a calibration of a transmission measurement and a reflectance measurement can be carried out in a free span position. The sphere structure, the first detector (reflectance sensor) and the second detector (transmission sensor) can be mounted on a moveable linear positioning stage for a synchronous movement. For transmission calibration, the detectors (sensors) are moved to the transmission calibration position for a 100%-calibration together with a cooling device configured for cooling the respective detector. The transmission calibration position can be an open position. For reflection calibration, the detectors (sensors) are moved to the reflectance calibration position, where a known reflection standard (e.g., Si) is provided, together with the cooling device configured for cooling the respective detector. Typically, the detectors can be moved to calibration positions with the transport device, which may also be referred to as a drive mechanism. In some embodiments, the measuring positions can be changed, for instance during a production run.

[0094] As explained above, according to some embodiments, the processing apparatus can utilize two reference positions outside the substrate. In one position, the reflectance can be calibrated by a known reference, for example a calibrated Al-mirror or a polished Si-surface, and the transmittance can be calibrated in the other position with nothing between the sphere structure 21 and the third detector device 29. The reflectance and transmission calibration can be repeated periodically in the calibration positions outside

the substrate 15, for instance to compensate drift. This may be an aspect in long coating runs lasting for instance several hours.

[0095] FIG. 7 shows a cooling arrangement 50 for a processing apparatus according to embodiments described herein. The cooling arrangement 50 includes a cooling device 52 and a transport device 54. The cooling device 52 includes a thermoelectric cooler 55, e.g. a Peltier module, and is configured for cooling at least one heat generating component 56 of a measuring arrangement arranged in a vacuum chamber.

[0096] The transport device 54 is configured for moving the cooling device together with the heat generating component 56 within the vacuum chamber. In some embodiments, the transport device may be configured for moving the cooling device independently from the heat generating component 56 within the vacuum chamber, e.g. from a first heat generating component to a second heat generating component.

[0097] The heat generating component 56 may be an electrical, optical, or optoelectronic component of a measuring arrangement for measuring an optical property of a material processed on a substrate. In some embodiments, the heat generating component 56 is at least a part of a detector device, a data analysis unit of a detector device or of a sphere structure, e.g. a sensor chip or an electric chip for analyzing a sensor signal.

[0098] The measuring arrangement may include further features described in the present disclosure, which are not repeated here. The cooling device 52 may include further features described in the present disclosure, which are not repeated here. The transport device 54 may include further features described in the present disclosure which are not repeated here. The vacuum chamber (not shown) may include further features of the present disclosure which are not repeated here.

[0099] FIG. 8 shows a cooling arrangement 60 for a processing apparatus according to embodiments described herein. The cooling arrangement 60 includes a cooling device and a transport device 54. The cooling device includes a thermoelectric cooler 55, e.g. a Peltier module, and is configured for cooling at least one heat generating component 56 of a measuring arrangement arranged in a vacuum chamber, wherein the heat generating component 56 may also be a part of the cooling arrangement 60. The cooling device

further includes a heat exchanger module 62 for transferring heat from a hot side of the thermoelectric cooler 55 to a cooling medium, particularly to a gaseous cooling medium.

[00100] The transport device 54 is configured for moving the cooling device together with the heat generating component 56 within the vacuum chamber. In some
5 embodiments, the transport device may be configured for moving the cooling device independently from the heat generating component 56 within the vacuum chamber, e.g. from a first heat generating component to a second heat generating component.

[00101] In some embodiments, which may be combined with other embodiments described herein, the heat exchanger module 62 comprises cooling channels 272 for a
10 circulating cooling medium and is configured for transferring heat from a hot side of the thermoelectric cooler 55 to the cooling medium. By sandwiching the thermoelectric cooler 55 between the heat generating component 56 and the heat exchanger module 62, the effectivity of the heat transfer from the heat generating component 56 to the heat exchanger module 62 can be increased. The thermoelectric cooler 55 may be provided as
15 a Peltier element, wherein the heat from the hot side of the Peltier element may be dissipated to the heat exchanger module 62.

[00102] In some embodiments, a thermocouple 275 may be arranged between the heat generating component 56 and the thermoelectric cooler 55. Alternatively or
20 additionally, one or more graphite foils 63 may be interposed between the hot side of the thermoelectric cooler 55 and the heat exchanger module 62 and/or between the cooling side of the thermoelectric cooler 55 and the thermocouple 275.

[00103] The heat exchanger module 62 may be configured for a gaseous cooling medium to circulate within the cooling channels 272. For example, the cooling medium may be atmosphere, air or another cooling gas. In some implementations, the heat
25 exchanger module 62 may be coupled to a pump device 277 for feeding the gaseous cooling medium to the heat exchanger module. In some embodiments, a feed-through may be provided for feeding supply cables for providing a voltage, e.g. a D.C. voltage, to the thermoelectric cooler 171. Flexible connections, e.g. flexible tubes 278 or hoses, may be provided for feeding the cooling medium from the pump device 277 to the movably
30 arranged heat exchanger module 62.

[00104] The measuring arrangement may include further features described in the present disclosure, which are not repeated here. The cooling device may include further features described in the present disclosure, particularly with reference to the embodiment shown in FIG. 3, which are not repeated here. The transport device 54 may include further features described in the present disclosure which are not repeated here.

[00105] Figure 9 shows a flow chart of a method 1000 for measuring one or more properties of a substrate and/or a material processed on the substrate in a vacuum chamber according to embodiments described herein.

[00106] In block 1010, the method includes cooling, during measuring, at least one heat generating component of a measuring arrangement with a thermoelectric cooler of a cooling device, wherein the cooling device and the heat generating component are arranged at a measuring position within the vacuum chamber.

[00107] In some embodiments, the method further comprises, in block 1020, moving the at least one heat generating component together with the cooling device to a second measuring position or to a calibration position within the vacuum chamber.

[00108] The method 1000 may be performed with a processing apparatus of any of the embodiments described herein, which includes a vacuum chamber and a measuring arrangement located in the vacuum chamber. The measuring arrangement includes a heat generating component which is cooled by a cooling device including a thermoelectric cooler.

[00109] Measuring may include measuring one or more optical properties of a coating layer deposited on the substrate, e.g. the transmittance and/or the reflectance. The measuring arrangement may include at least one sphere structure located in the vacuum chamber.

[00110] In some embodiments, the method 1000 may include moving the measuring arrangement with the cooling device to a first calibration position in the vacuum chamber, particularly to a reflectance calibration position, and calibrating the measuring arrangement. In typical implementations, the method 1000 may include moving the measuring arrangement with the cooling device to a second calibration

position in the vacuum chamber, particularly to a transmission calibration position, and calibrating the measuring arrangement.

[00111] According to some embodiments, which can be combined with other embodiments described herein, at least one of the calibration at the first calibration position and the calibration at the second calibration position are periodically or a-periodically repeated. As an example, the calibration can be repeated in predetermined time intervals, after a processing cycle, during a processing cycle, and the like. The reflectance and transmission calibration can be repeated periodically in the calibration positions, for instance to compensate drift. This may be an aspect in long coating runs lasting for instance several hours.

[00112] According to embodiments described herein, the method for measuring one or more optical properties of the substrate and/or the material processed on a substrate can be conducted via computer programs, software, computer software products and the interrelated controllers, which can have a CPU, a memory, a user interface, and input and output devices being in communication with the corresponding components of the apparatus for processing a large area substrate.

[00113] The present disclosure may use sphere structures within a vacuum chamber for reflectance and/or transmission measurements, for instance in a free span position of a substrate such as a plastic film between two rollers. According to some embodiments, reflectance and transmission measurements can be performed at the same position. Even if the surface of the film is not flat, the reflected light is almost completely collected in the sphere structure. According to some embodiments, to allow measurements on any selected position along the substrate width, the measuring arrangement of the apparatus can be installed on a linear positioning stage, for instance driven by a motor. In combination with a detector for transmittance, the apparatus according to embodiments described herein allows reflection and transmission measurements at pre-defined positions of the material processed on the substrate, for instance a coated film. Particularly the reflectance measurement is insensitive to changes (wrinkles) of the substrate plane (e.g., +/-5mm).

[00114] In embodiments, transmission and reflection measurements can be performed at the same position, for instance with only one linear positioning stage having for instance two coupled axes. Using the sphere structure provides an improved reflectance measurement accuracy. The apparatus can for instance be used for inspection of optical layer systems, such as antireflection, invisible ITO, window films, and the like. An optical quality control for the customer over a total web width can be possible. According to some embodiments, the apparatus and particularly the measuring arrangement has electromagnetic interference (EMI) compatibility and can tolerate strong electrical fields for instance induced by sputter deposition sources (DC, MF, RF).

[00115] In some embodiments, at least during measuring, a temperature of at least one heat generating component is controlled to remain essentially constant, e.g. within a range of $\pm 5^{\circ}\text{C}$ of a target temperature. A controller for controlling one or more thermoelectric coolers which are thermally coupled to one or more heat generating components may be provided for that reason.

[00116] While the foregoing is directed to embodiments of the disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. An apparatus for processing of a material on a substrate, comprising:

a vacuum chamber (110); and

5 a measuring arrangement (20, 160) configured for measuring one or more properties of the substrate (15) and/or of the material processed on the substrate, wherein the measuring arrangement comprises a cooling device (52, 170, 270) with a thermoelectric cooler (55, 171) for cooling at least one heat generating component (56, 161) of the measuring arrangement.
- 10 2. The apparatus of claim 1, wherein the measuring arrangement (20, 160) further comprises a transport device (54, 129, 180) configured for moving the cooling device separately from or together with the at least one heat generating component within the vacuum chamber (110).
- 15 3. The apparatus of claim 2, wherein the transport device includes an actuator configured for moving the heat generating component together with the cooling device to at least one of a measuring position (31), a reflectance calibration position (32) and a transmission calibration position (30).
- 20 4. The apparatus of claim 3, wherein the actuator comprises at least one of an electrical motor, a linear motor, a pneumatic actuator, a hydraulic actuator, and a piezoelectric actuator.
5. The apparatus of any of claims 1 to 4, wherein the measuring arrangement comprises a detector device (24, 27, 29, 162), and the heat generating component is a part of the detector device.
- 25 6. The apparatus of claim 5, wherein the heat generating component comprises at least one of a spectrometer device, a camera device, a CCD camera, an electrical chip, a sensor chip and a grating.

7. The apparatus of any of claims 1 to 6, wherein the thermoelectric cooler (55, 171) comprises a Peltier module thermally coupled to the at least one heat generating component.
8. The apparatus of any of claims 1 to 7, wherein the cooling device comprises a heat
5 exchanger module (62, 271), wherein the thermoelectric cooler is coupled between the at least one heat generating component and the heat exchanger module.
9. The apparatus of claim 8, wherein the heat exchanger module (62, 271) comprises cooling channels (272) and/or cooling tubes for a circulating cooling medium and is configured for transferring heat from a hot side of the thermoelectric cooler to the cooling medium.
10. The apparatus of claim 8 or 9, wherein the heat exchanger module (62, 271) is coupled to
10 a pump device (277) configured for feeding a gaseous cooling medium, particularly cooling air, through the heat exchanger module.
11. The apparatus of any of claims 1 to 10, wherein the measuring arrangement is configured for measuring an optical property of the substrate and/or of the material processed on the
15 substrate, particularly at least one of a reflectance and a transmission.
12. The apparatus of any of claims 1 to 11, wherein the measuring arrangement comprises at least one sphere structure (21), particularly an integrating sphere, located in the vacuum chamber (110).
13. A cooling arrangement (50, 60) for an apparatus of any of claims 1 to 12, comprising:
20 a cooling device comprising a thermoelectric cooler (55) for cooling at least one heat generating component (56) of a measuring arrangement arranged in a vacuum chamber; and
a transport device (54) configured for moving the cooling device separately from or together with the at least one heat generating component (56) within the vacuum chamber.

14. The cooling arrangement of claim 13, wherein the cooling device further comprises a heat exchanger module (62) for transferring heat from a hot side of the thermoelectric cooler (55) to a cooling medium, particularly to a gaseous cooling medium.

15. A method of measuring one or more properties of a substrate and/or a material processed on a substrate in a vacuum chamber, the method comprising:

cooling, during measuring, at least one heat generating component of a measuring arrangement with a thermoelectric cooler of a cooling device, wherein the cooling device and the heat generating component are arranged at a measuring position within the vacuum chamber.

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Fig. 1

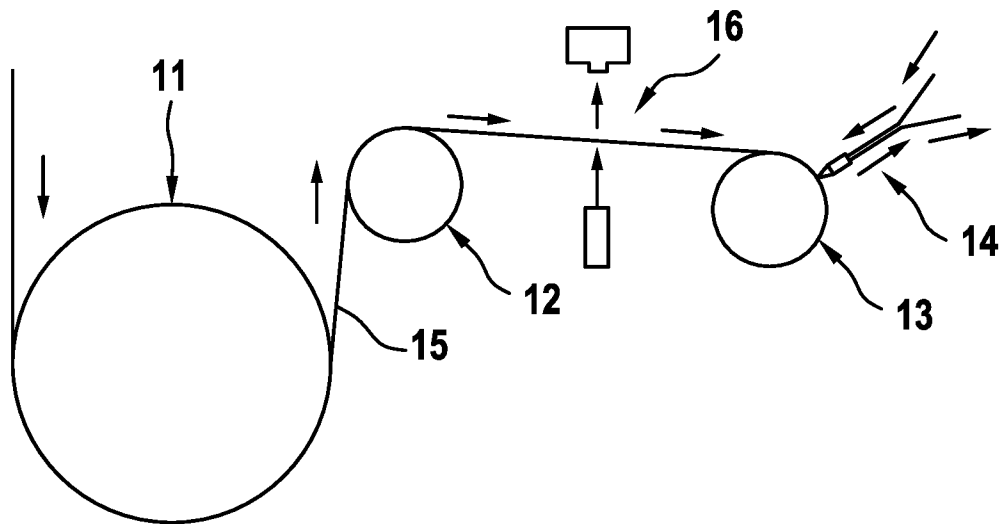


Fig. 2

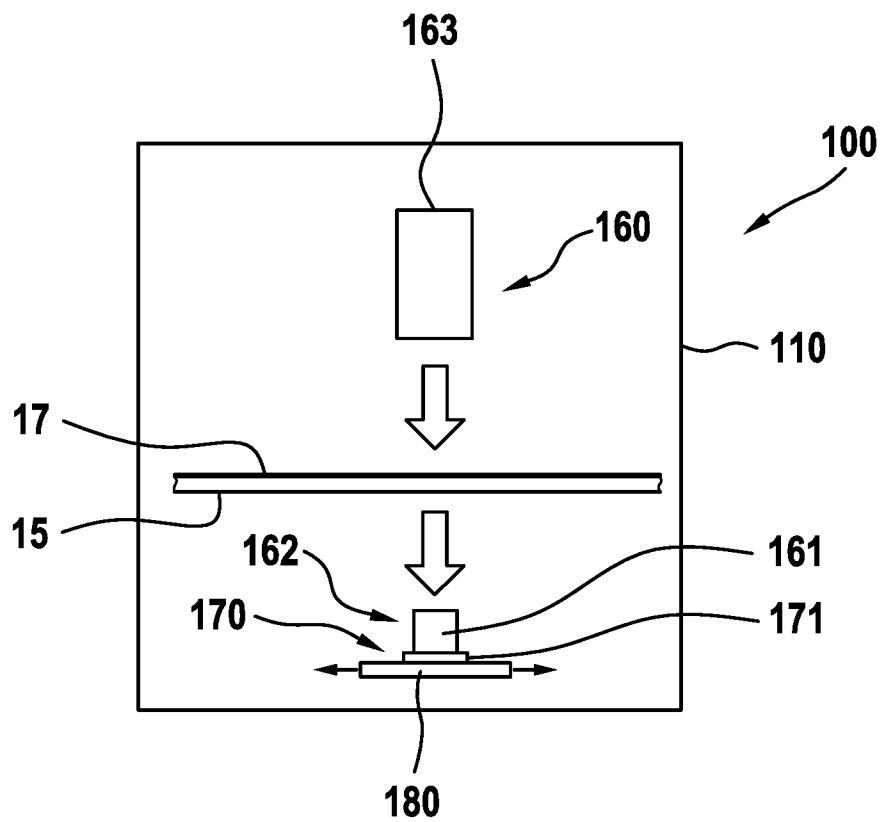


Fig. 3

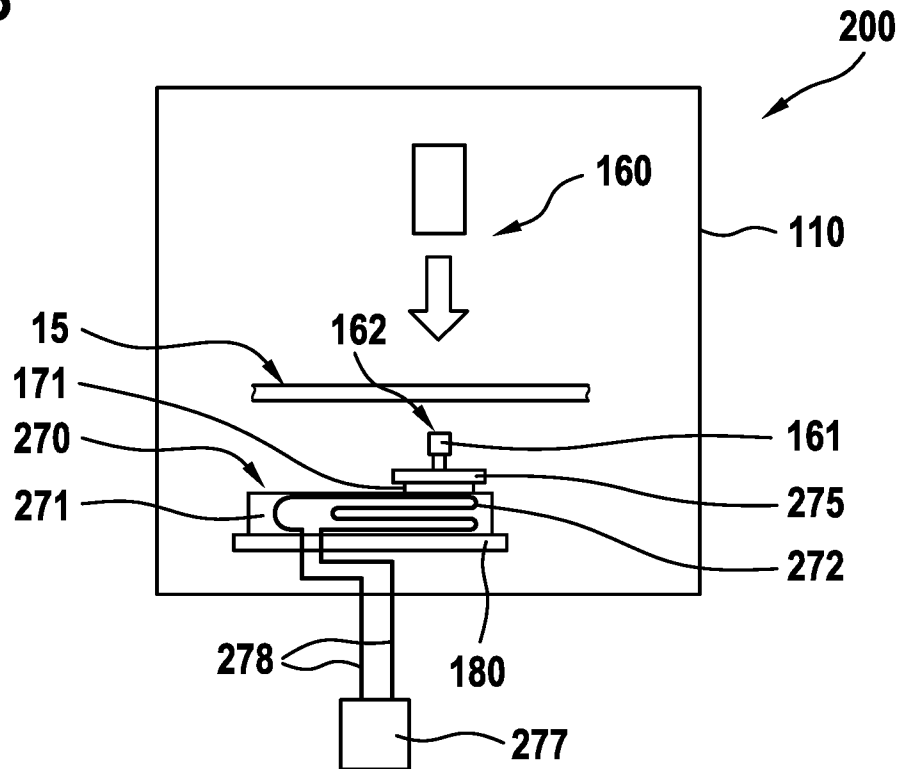


Fig. 4

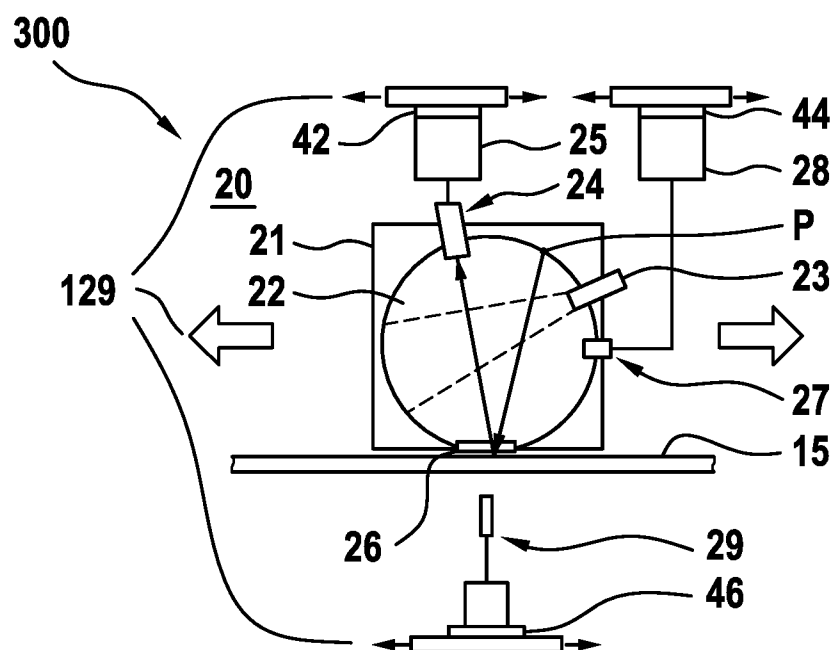


Fig. 5

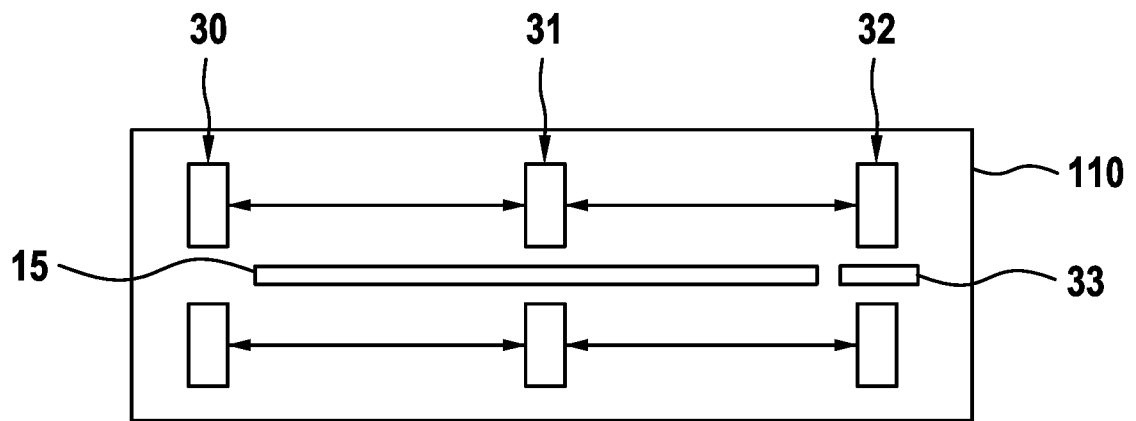
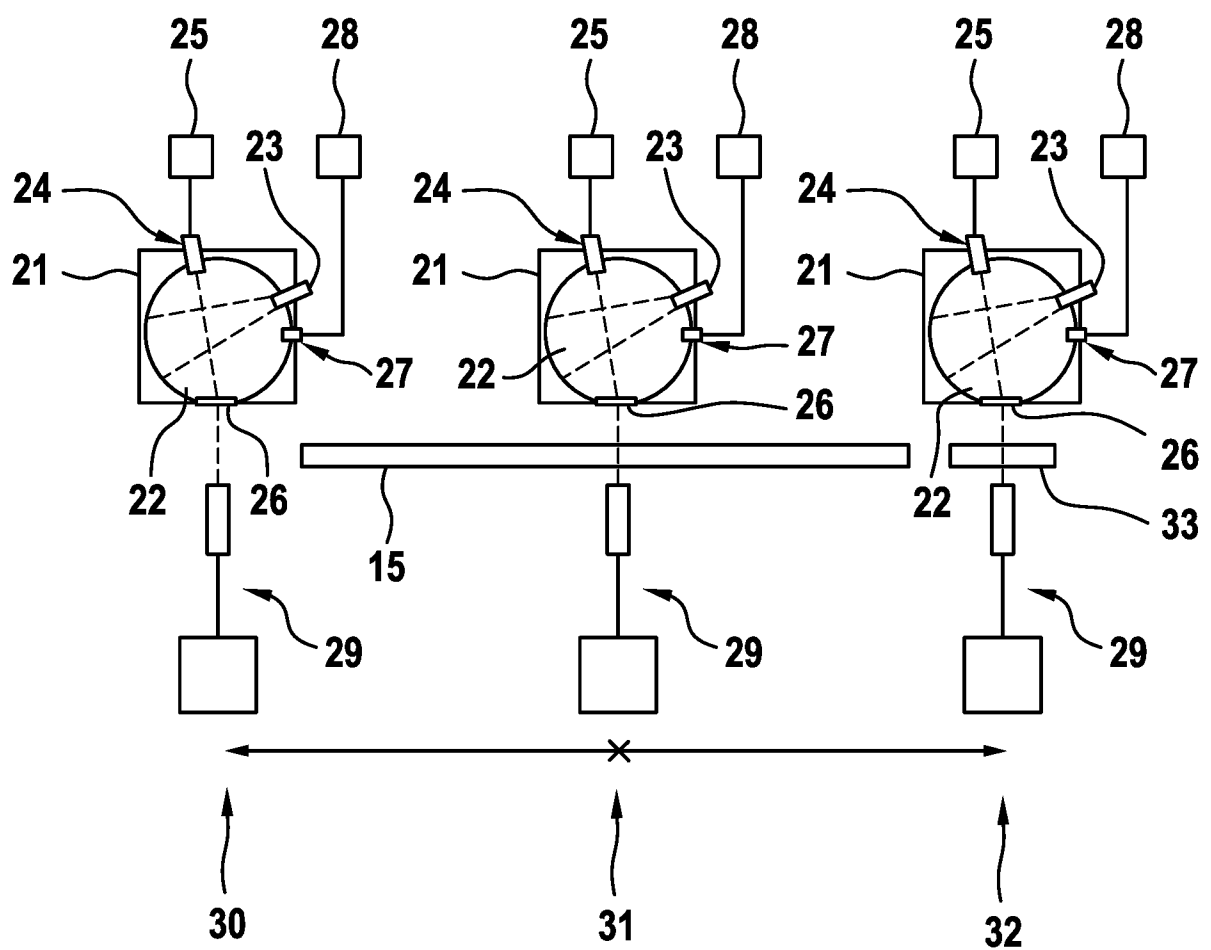


Fig. 6



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Fig. 7

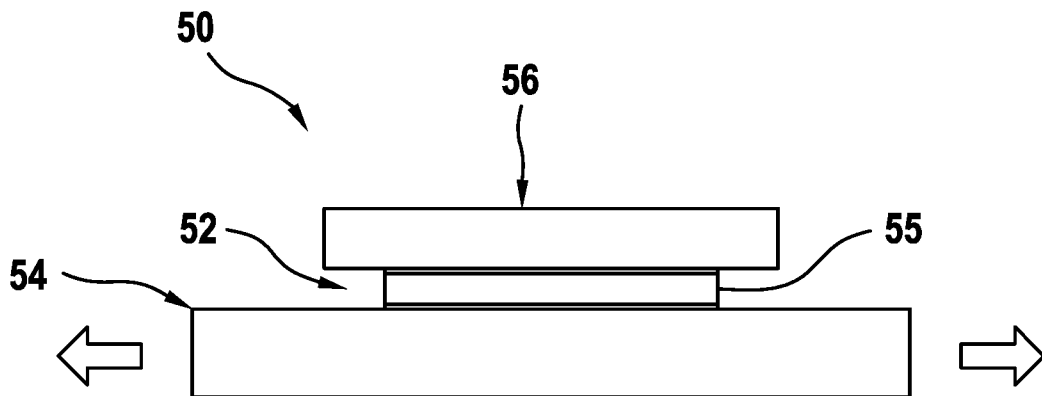
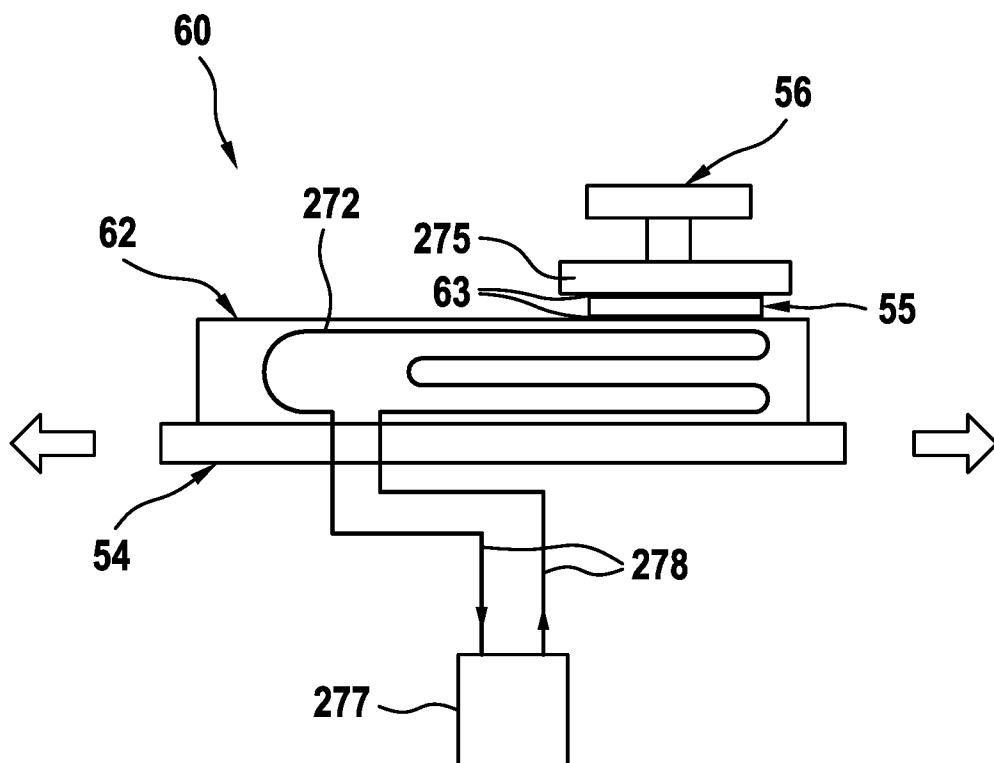
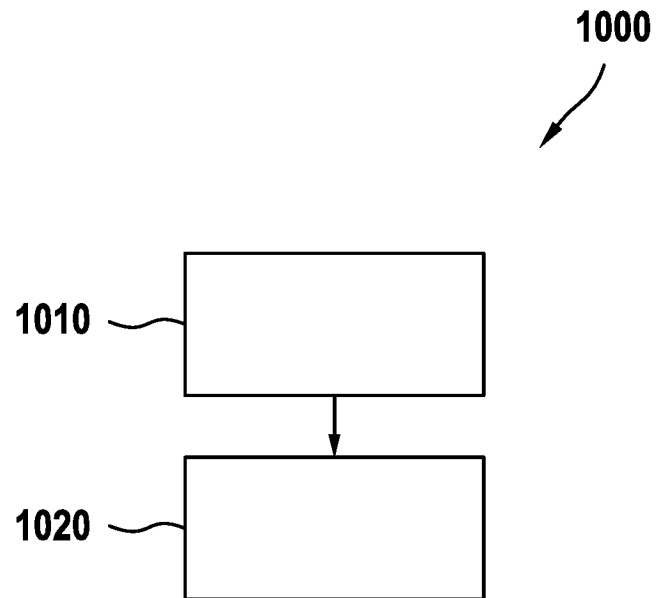


Fig. 8



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Fig. 9



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/075006

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01N21/84 C23C14/54 G01B11/06
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)

G01N C23C G01B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/192964 A1 (LOTZ HANS-GEORG [DE] ET AL) 31 August 2006 (2006-08-31)	1, 15
Y	the whole document	2-14
A	US 2005/237539 A1 (GERMANENKO IGOR N [US] ET AL) 27 October 2005 (2005-10-27) paragraph [0045]	1-15
Y	US 6 447 652 B1 (AMANO SHUNJI [JP] ET AL) 10 September 2002 (2002-09-10) column 6, line 60 - column 7, line 9	2-11, 13, 14
Y	US 2012/314219 A1 (MARGRAF JOERG [DE] ET AL) 13 December 2012 (2012-12-13) paragraphs [0037] - [0038]	12



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

14 June 2016

Date of mailing of the international search report

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Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/075006

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