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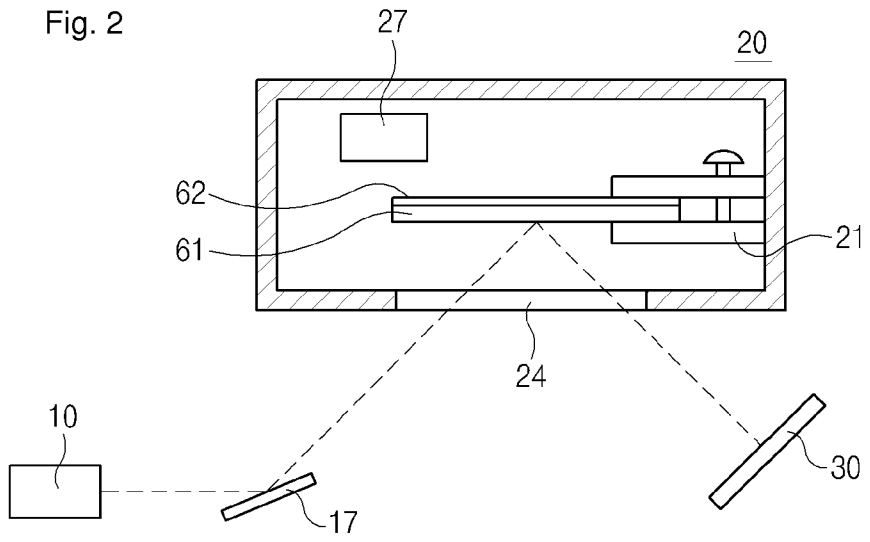
(54) **Title:** APPARATUS MEASURING STRESS OF COATING

Fig. 2



(57) **Abstract:** The present invention relates to a coating stress measurement apparatus, and more particularly, to an apparatus for determining the stress generated in a coating layer applied on a substrate during the process of drying the coating layer, by measuring the positional shift of reflected light rays. The coating stress measurement apparatus of the present invention is capable of measuring the coating stress more accurately by controlling the environmental variables such as temperature and humidity in a drying chamber which is isolated from the outside, and allows easy adjustment of the path of light rays by adopting a reflection unit or a distance adjustment unit. Furthermore, the apparatus is advantageous in that an asymmetric bending displacement distribution can be obtained by simultaneously irradiating a number of light rays over the entire area of the substrate through a light distribution unit, and measuring the respective changes of their positions. When the drying process is controlled on the basis of the information thus obtained, the generation of cracks, peeling, rumples and the like can be suppressed.

WO 2009/028896 A1

Description

APPARATUS MEASURING STRESS OF COATING

Technical Field

[1] The present invention relates to a coating stress measurement apparatus, and more particularly, to an apparatus for determining the stress generated in a coating layer applied on a substrate during the process of drying the coating layer, by measuring the positional shift of reflected light rays.

Background Art

[2] Processes of applying a coating on a substrate and drying the coating occupy essential positions in various industries, and particularly in the fields of information and telecommunication, such as in the field of semiconductor or liquid crystal displays (LCD), these processes are truly crucial.

[3] Studies on the liquid-state coating agents themselves (rheology, surface chemistry, etc.) or studies on the coating processes have been in fact carried out for long, and knowledge has been significantly accumulated in regard to the phenomena; however, not much research has been conducted in reality, on the drying process which seems apparently simple.

[4] Yet, as previously stated in the above, the process of drying a coating agent applied on a substrate is evaluated in the fields of information and telecommunication as a step so important to the extent that the drying process may dominate the overall yield in view of the characteristics of the industries which demand a high level of precision, and a good control of the process is rising as a major issue of the related art.

[5] The reason why drying of the coating solution applied on a substrate is important, is because of the phenomenon of bending as illustrated in Fig. 1. In other words, the coating solution when initially applied on a substrate 61 is in the liquid state. When the solvent evaporates from the coating layer 62 while the coating solution continues to dry, the volume of the coating layer 62 is decreased, and at a certain time point, the coating layer 62 reaches a moment of being solidified. At this time, solidification starts from the coating surface where drying occurs for the first time, and moves to the inside of the coating layer 62, finally reaching the boundary surface of the coating layer 62 and the substrate 61. However, the coating layer 62 at this boundary surface is fixed on the substrate 61 so that there is a restriction on the reduction of volume. Accordingly, the coating at this point is subjected to a tensile stress in the form of being substantially pulled toward to the edges. This state will eventually cause a situation wherein the lower part of the coating layer 62 is arbitrarily pulled up, thus causing the generation of a bending moment. As a result, even the substrate 61 is also bent upward, and there

occurs the phenomenon of bending displacement (D).

[6] When such phenomenon of bending progresses excessively beyond a certain point, the bending will exert negative effects on the coating layer itself, and may cause ser ious problems such as the generation of cracks, peeling of the coating layer from the substrate, or the generation of rumples or distortion in the coating layer.

[7] In order to prevent such problems, it is necessary to suppress any stress generated in the entire area of the coating layer as far as possible, and to maintain the distribution of the stress uniform. However, the research on a coating stress measurement apparatus is in fact yet to be started on.

Disclosure of Invention

Technical Problem

[8] The present invention was designed in order to solve the problems as described above, and it is an object of the present invention to provide a coating stress measurement apparatus, which allows simple operation, has high precision and reproducibility, and is also capable of measurement and analysis of asymmetric bending.

Technical Solution

[9] In order to achieve the purpose as described above, the present invention provides a coating stress measurement apparatus characterized by including:

[10] a light source;

[11] a drying chamber for drying a coated substrate; and

[12] a detection unit for detecting light rays which are irradiated from the light source and then reflected at the coated substrate,

[13] wherein the drying chamber includes:

[14] a window for transmitting the light rays;

[15] a supporting unit for supporting the coated substrate; and

[16] a sensor.

[17] The apparatus of the present invention may further include a light distribution unit for distributing the light rays irradiated from the light source into 2 to 36 rays.

[18] The apparatus of the present invention preferably further includes distance adjustment units for adjusting the distances between the light source and the substrate, between the detection unit and the substrate or between the light source and the substrate, and the distance between the detection unit and the substrate.

[19] The apparatus of the present invention may further include a reflection unit for reflecting the light rays irradiated from the light source.

[20] The apparatus of the present invention preferably include thermally insulating materials in at least a part of the drying chamber except for the window.

[21] The sensor in the apparatus of the present invention preferably measures temperature,

humidity, or temperature as well as humidity.

[22] The supporting unit in the apparatus of the present invention may fix one edge of the coated substrate.

[23] The supporting unit may support at least a part of the edges of the coated substrate.

[24] The supporting unit preferably supports two or more points balanced about the center of gravity of the coated substrate.

[25] The supporting unit may be in the form of a flat plate having perforated holes.

[26] The detection unit in the apparatus of the present invention may be a photodiode.

[27] The detection unit may be a charge-coupled device camera (CCD camera).

[28] Furthermore, the light rays according to the present invention are preferably laser rays.

Advantageous Effects

[29] The coating stress measurement apparatus of the present invention is capable of measuring coating stress more accurately by controlling the environmental variables such as temperature and humidity in a drying chamber which is isolated from the outside, and allows easy adjustment of the path of light rays by adopting a reflection unit or a distance adjustment unit. Furthermore, the apparatus is advantageous in that an asymmetric bending displacement distribution can be obtained by simultaneously irradiating a number of light rays over the entire area of the substrate through a light distribution unit, and measuring the respective changes of their positions. When the drying process is controlled on the basis of the information thus obtained, the generation of cracks, peeling, rumples and the like can be suppressed.

Brief Description of the Drawings

[30] Fig. 1 is a diagram illustrating the process in which bending displacement occurs on a coated substrate as the drying process proceeds.

[31] Fig. 2 is a conceptual diagram showing an embodiment of the coating stress measurement apparatus of the present invention.

[32] Fig. 3 is a diagram illustrating the phenomenon in which bending displacement is generated when the substrate and the coating layer are bent.

[33] Fig. 4 is a graph for showing the correlation between the bending displacement and the voltage when a photodiode is used as the detection unit.

[34] Fig. 5 is a conceptual diagram showing another preferred example of the coating stress measurement apparatus of the present invention.

[35] Fig. 6 is a diagram illustrating the part A in Fig. 5 from a different angle of view.

[36] Fig. 7 is a diagram illustrating an embodiment of the supporting unit of the present invention.

[37] Fig. 8 is a diagram illustrating another embodiment of the supporting unit of the

present invention.

[38] Fig. 9 is a diagram showing the positional changes of before drying and after drying in the case of simultaneously irradiating a number of light rays to the substrate.

[39] Fig. 10 is a diagram showing the process for measuring the bending displacement in part ① of Fig. 9.

[40] Fig. 11 is a diagram illustrating the variables for the measurement of curvature and stress.

Best Mode for Carrying Out the Invention

[41] Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the attached drawings. First, it should be noted that upon assigning reference numerals to each of the components in the drawings, identical components were assigned with identical numerals as far as possible, although the components appear in different drawings. Also, in the following description, a number of specific embodiments involving specific components are illustrated, and it will be apparent to those having ordinary skill in the art that such specific embodiments have been provided to help in general understanding of the present invention, and the present invention can be carried out even without such specific embodiments. Furthermore, in describing the present invention, wherever it is judged that detailed illustration of a known function or constitution that is related to the present invention may rather render the gist of the invention unnecessarily ambiguous, the detailed illustration will be omitted.

[42] Fig. 2 is a schematic diagram showing an embodiment of the coating stress measurement apparatus of the present invention, and the principle of measurement of this apparatus may be described as follows with reference to this diagram.

[43] First, light rays irradiated from a light source 10 are reflected at a coated substrate 61 inside the drying chamber 20, and are detected by a detection unit 30.

[44] The coated substrate 61 is subjected to bending due to stress as the drying of the coating proceeds as illustrated in Fig. 3, and thereby the position of the light rays detected by the detection unit 30 is changed.

[45] In the case of using a photodiode as the detection unit 30, the positional change is immediately manifested as a change in the voltage, and this change can be converted to the bending displacement value and stress value, which are desired to be obtained in the present invention, by means of a preliminarily prepared correlation curve as shown in Fig. 4.

[46] The above-described steps will be described in more detail.

[47] The light rays detected by the detection unit 30 are irradiated from the light source 10, and are reflected at the substrate 61 where the bending displacement is intended to

be measured. In this case, the light rays are not particularly limited in type as long as the light rays have excellent properties of rectilinear propagation, and laser light is more preferred from the viewpoint of stability.

[48] It is preferable that the light rays pass through an appropriate reflection unit 17 before reaching the coated substrate 61. When such reflection unit 17 is introduced, the path of light rays can be more easily modified, and thereby the accuracy of measurement can also be enhanced.

[49] Meanwhile, the substrate 61 for reflecting the light rays is fixed onto a supporting unit 21 inside the drying chamber 20.

[50] The supporting unit 21 as depicted in Fig. 2 is illustrated, as an example, in the form of a cantilever which fixes one edge of the substrate 61. However, the type of the supporting unit 21 is not particularly limited as long as it takes a form which is capable of fixing the substrate 61.

[51] It is preferable that the drying chamber 20 be isolated from the outside so that the influence of an environmental variable such as temperature or humidity exerted on the drying process, and furthermore bending displacement, can be accurately observed. In this case, it is preferable that the part of the drying chamber 20, which corresponds to the path of the light rays, be formed into a window 24 so that the light rays irradiated from the light source 10 can be reflected at the substrate 61.

[52] Furthermore, the drying chamber 20 preferably includes a sensor 27 so as to control the environmental variables to be constantly maintained. Moreover, it is preferable that the drying chamber 20 includes thermally insulating materials in at least some parts of the chamber except for the window 24, for more precise temperature control.

[53] The light rays reflected at the coated substrate 61 are detected by the detection unit 30, and as illustrated in Fig. 3, the position of reflection and angle of reflection are changed as the drying process proceeds, thereby the position at which the light rays are received at the detection unit 30, changing along therewith.

[54] If a photodiode is used as this detection unit 30, the positional change is manifested as a change in the voltage in a real-time mode. When these changes are fitted into a correlation curve preliminarily prepared as shown in Fig. 4, the bending displacement ("D" in Fig. 1) can be directly obtained therefrom. This bending displacement may be converted to the stress (σ) inside the coating layer 62 by a correlation equation such as, for example, the following equation 1.

[55] MathFigure 1

[Math.1]

$$\sigma = \frac{DE_s t_s^3}{3t_c L^2 (t_s + t_c)(1 - \nu_s)}$$

[56] wherein E: elastic modulus,

[57] t: thickness,

[58] L: length,

[59] ν: Poisson's ratio,

[60] subscript s: substrate, and

[61] subscript c: coating layer.

[62]

[63] Fig. 5 is a schematic diagram showing another embodiment of the coating stress measurement apparatus of the present invention.

[64] The embodiment shown in Fig. 2 is a case which is suitably used when the substrate 61 is basically bent in a generally circular shape so that symmetry about a certain point is obtained, and the degree of this bending is linearly interpreted along the direction of length.

[65] However, in this case, it is inevitably likely to have a disparity in the bending displacement between the one edge fixed to the cantilever and the free edge on the opposite side, and there is an inherent limitation that a higher-dimensional analysis is difficult.

[66] However, such limitation can be easily overcome by applying the embodiment illustrated in Fig. 5. The light source 10 shown in Fig. 5 irradiates a plurality of light rays by means of a light distribution means installed in the light source, and these light rays are distributed again by a light distribution unit 15 which is installed outside the light source 10 so that a number of light rays are simultaneously irradiated onto the substrate 61.

[67] The number of light rays distributed as described above is preferably from 2 to 36, and if the number exceeds 36, the distance between the light rays may be so small that interference of adjacent light rays would occur, which is undesirable.

[68] Fig. 6 is a conceptual diagram illustrating the part A in Fig. 5 from a different angle of view. In this case, nine light rays simultaneously reach the substrate 61 as shown in Fig. 7.

[69] In this case, it is necessary that the supporting unit 21 be in a form capable of supporting the entire edge areas of the substrate 61 evenly, rather than in the cantilever form which supports only one side of the substrate 61 as shown in the previous embodiment. As for this supporting form, there may be mentioned, as an example, a form supporting at least two parts in the edges of the substrate 61, more preferably two or more points that are balanced about the center of gravity of the substrate 61, as illustrated in Fig. 7.

[70] Alternatively, as shown in Fig. 8, the supporting unit may also be in a form supporting almost the entire area of the substrate 61, but having perforated holes 22

formed in those areas where the light rays from the light source 10 reach.

[71] Meanwhile, in Fig. 7 and Fig. 8, the space deep in the right side of the supporting unit 21 provides a space for the operation of a transport arm which lifts up the substrate 61 upon the transport of the substrate 61.

[72] Fig. 9 illustrates the case where 25 light rays in total are irradiated onto the substrate 61, and it can be seen that there occurs a shift in the position of the respective light rays irradiated at the positions marked in the diagram on the left side (marked in red), which indicates the substrate before drying, to the positions marked in blue in the diagram on the right side after drying.

[73] Such changes in the position are preferably detected by a detection unit 30, which may be a charge-coupled device camera (CCD camera).

[74] Figs. 10 and 11 show an example of determining the stress on the basis of the part indicated by "①" in the diagram on the right side of Fig. 9.

[75] In Fig. 10, δd1 (= d1' - d1) and δd2 (= d2' - d2) are determined, and then the curvature (κ) is determined by the following equation 2. This curvature is then inserted into the following equation 3 to determine the stress (σ).

[76] MathFigure 2

[Math.2]

$$\kappa = \frac{1}{R} = \frac{\cos(\alpha)}{2L}\left(\frac{\delta d}{d}\right)$$

[77] wherein κ represents the curvature; and R represents the radius.

[78] MathFigure 3

[Math.3]

$$\sigma_f = \frac{\kappa M_s h_s^2}{6h_f}$$

[79] wherein M_s represents the modulus of the substrate; h_s represents the thickness of the substrate; and h_f represents the thickness of the coating layer.

[80] When the curvature and the stress determined for the respective points are calculated, and the values obtained in the directions of "①" (horizontal axis) and "②" (vertical axis) are compared, information on the stress distribution over the entire area of the coating layer can be obtained.

[81] The above-described equations 2 and 3 suggest an exemplary method for analyzing the case where bending does not occur uniformly over the entire area of the substrate 61, and there may be present a number of analytic methods in addition to the afore-

mentioned method.

[82] The coating stress measurement apparatus of the present invention preferably further includes distance adjustment units (not depicted) for adjusting the distance between the light source 10 and the substrate 61, between the detection unit 30 and the substrate 61, or between the light source 10 and the substrate 61, and the distance between the detection unit 30 and the substrate 61.

[83] The mode in which the lower part of the substrate 61 is irradiated with light rays, and the position of the reflected light is detected, should respond very sensitively to the degree of bending of the substrate 61. Since this sensitivity is determined by the positions of the substrate 61, the light rays and the detection unit 30, the apparatuses for determining the sensitivity should be able to freely move to different positions in accordance with the sample and experimental conditions, so that the optimum experimental results are obtained.

[84] As in the case of introducing a reflection unit 15 for modifying the path of the light rays, when the distance adjustment units are introduced, sharp light rays can be likewise irradiated to the detection unit 30 so that more accurate measurement is made possible.

[85] As an example for these distance adjustment units, a type of adjusting the height of the drying chamber 20 may be mentioned.

[86] Preferred embodiments of the present invention have been thus far illustrated and explained, but the present invention is not limited to the specific examples described above, and any person having ordinary skill in the art would understand that various modifications can be made without departing from the gist of the present invention. Therefore, the scope of the present invention should not be construed to be limited to the above examples, and the scope should be defined by the following claims as well as equivalents to the claims.

[87]

Claims

[1] A coating stress measurement apparatus comprising:
a light source;
a drying chamber for drying a coated substrate; and
a detection unit for detecting light rays which are irradiated from the light source and then reflected at the coated substrate,
wherein the drying chamber includes:
a window for transmitting the light rays;
a supporting unit for supporting the coated substrate; and
a sensor.

[2] The coating stress measurement apparatus according to claim 1, further comprising a light distribution unit for distributing the light rays irradiated from the light source into 2 to 36 rays.

[3] The coating stress measurement apparatus according to claim 1 or 2, further comprising distance adjustment units for adjusting the distance between the light source and the substrate, the distance between the detection unit and the substrate, or the distance between the light source and the substrate, and between the detection unit and the substrate.

[4] The coating stress measurement apparatus according to claim 1 or 2, further comprising a reflection unit for reflecting the light rays irradiated from the light source.

[5] The coating stress measurement apparatus according to claim 1 or 2, comprising thermally insulating materials in at least a part of the drying chamber except for the window.

[6] The coating stress measurement apparatus according to claim 1 or 2, wherein the sensor measures temperature, humidity, or temperature and humidity.

[7] The coating stress measurement apparatus according to claim 1 or 2, wherein the supporting unit fixes one edge of the coated substrate.

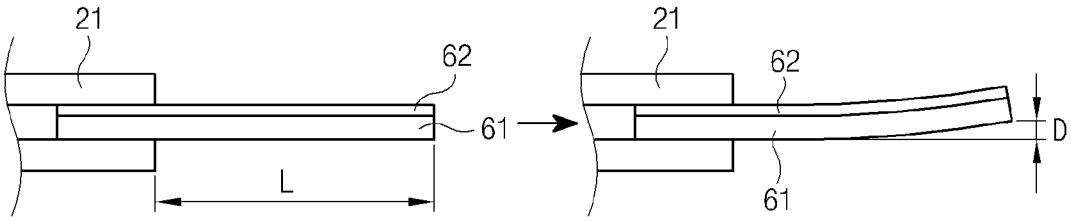
[8] The coating stress measurement apparatus according to claim 1 or 2, wherein the supporting unit supports at least a part of the edges of the coated substrate.

[9] The coating stress measurement apparatus according to claim 1 or 2, wherein the supporting unit is in the form of a flat plate including perforated holes.

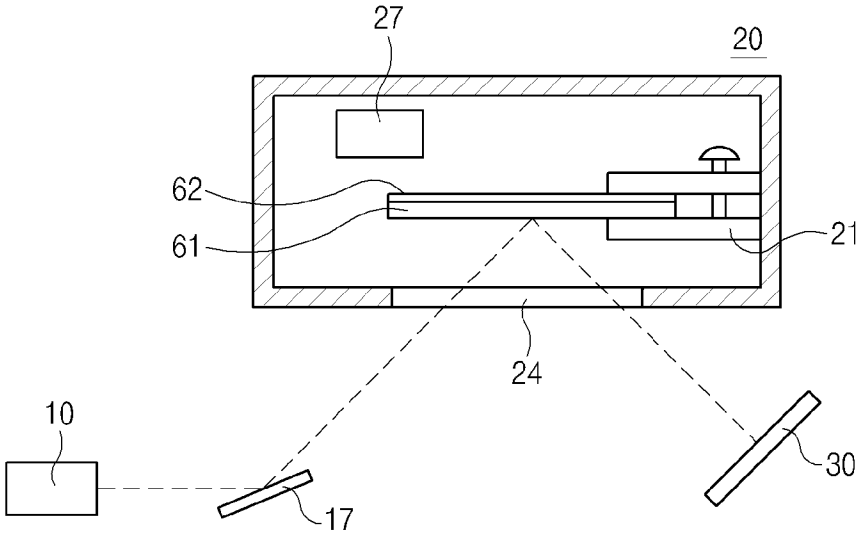
[10] The coating stress measurement apparatus according to claim 1 or 2, wherein the detection unit is a photodiode.

[11] The coating stress measurement apparatus according to claim 1 or 2, wherein the detection unit is a charge-coupled device camera (CCD camera).

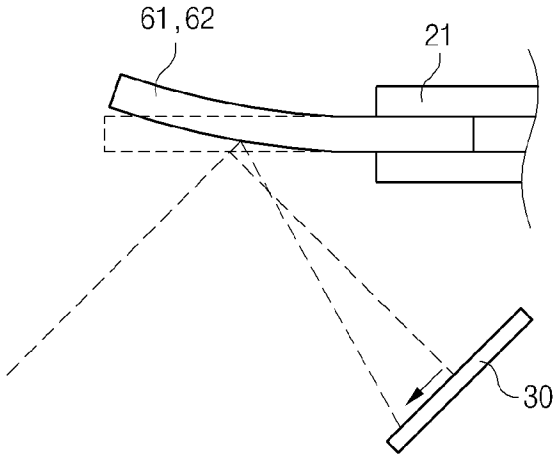
[Fig. 1]



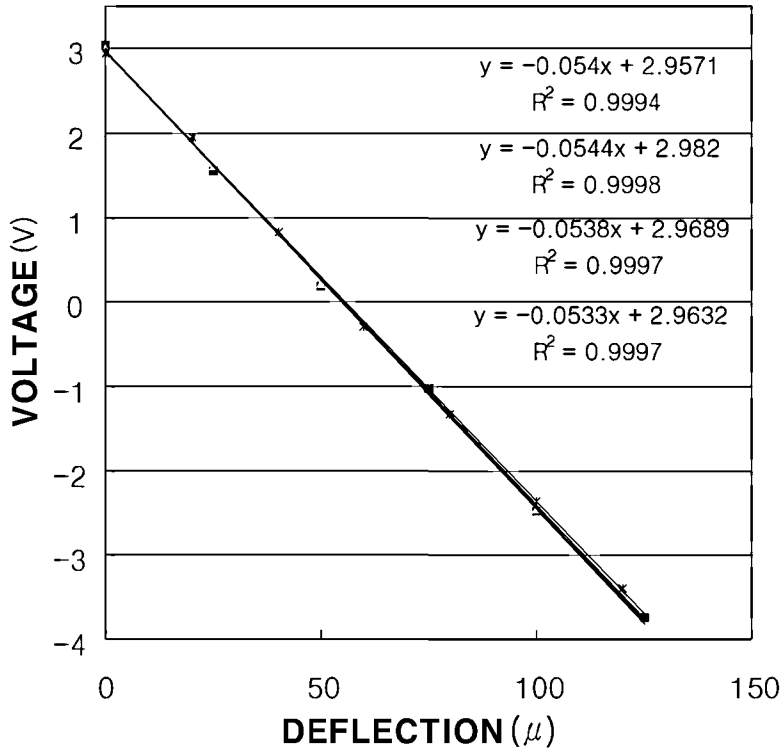
[Fig. 2]



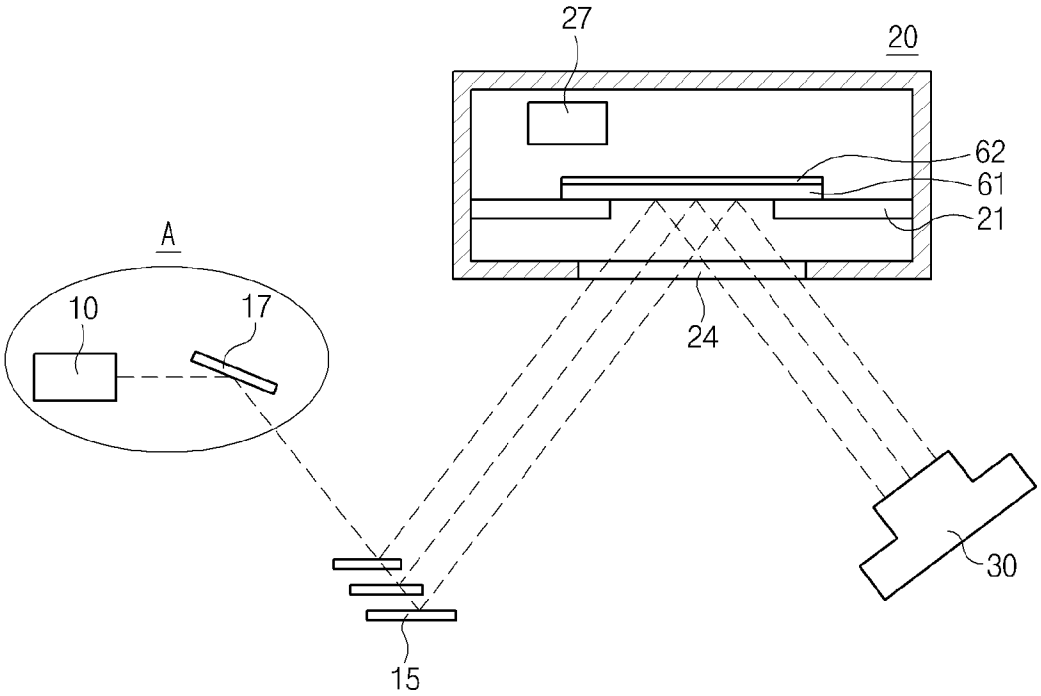
[Fig. 3]



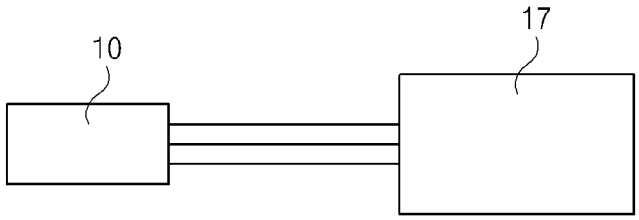
[Fig. 4]



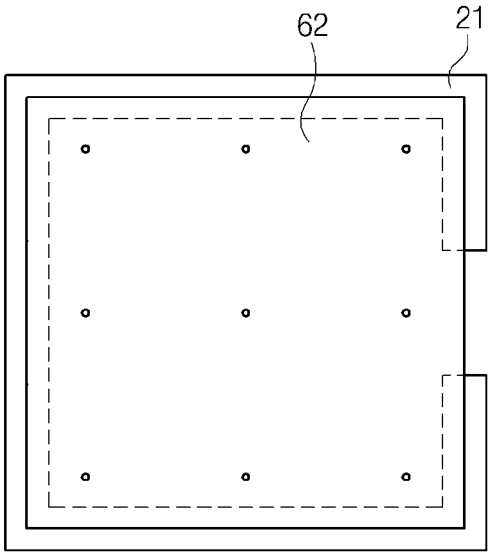
[Fig. 5]



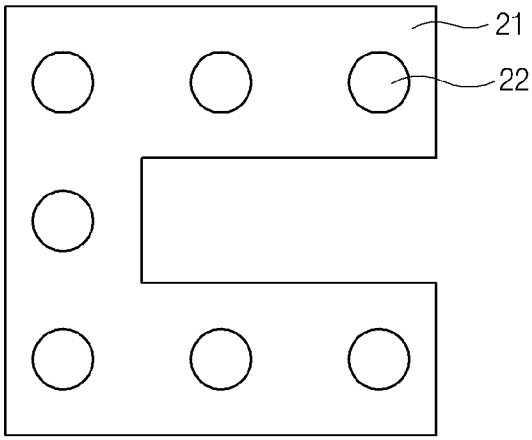
[Fig. 6]



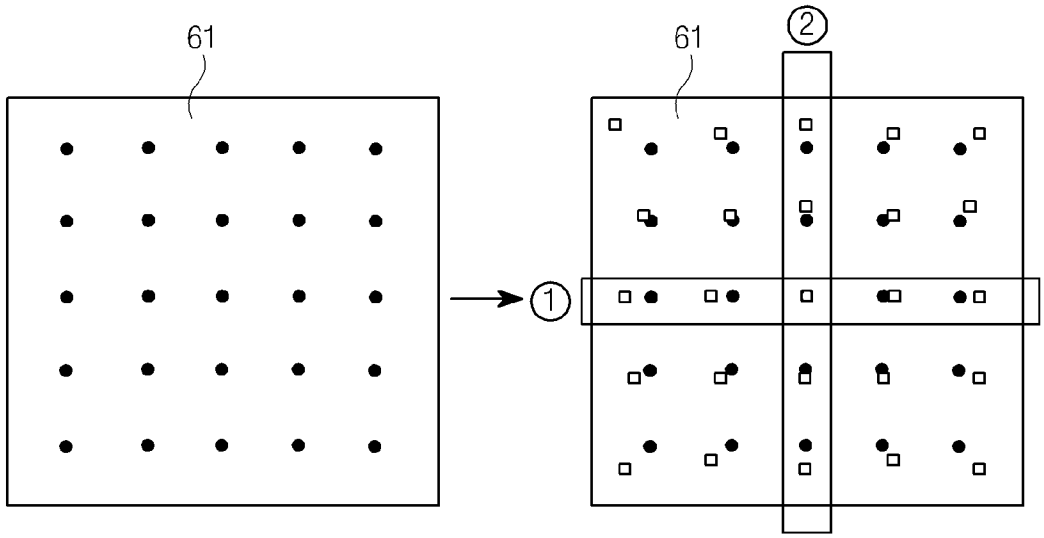
[Fig. 7]



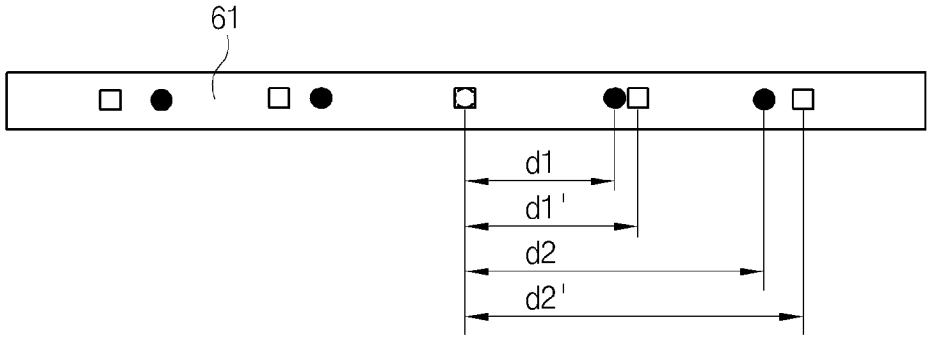
[Fig. 8]



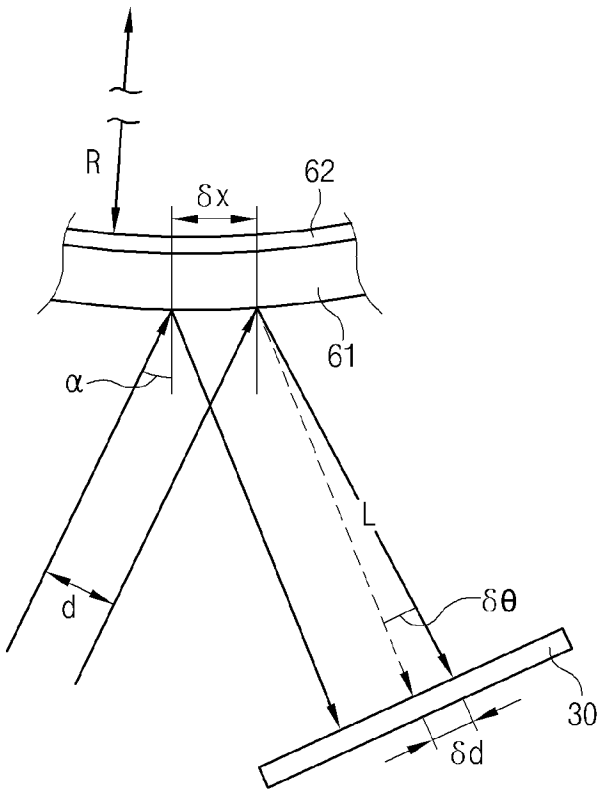
[Fig. 9]



[Fig. 10]



[Fig. 11]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2008/005073

A. CLASSIFICATION OF SUBJECT MATTER

G01N 21/89(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)

IPC 8 : G01N 21/00, 25/00

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 since 1975

Japanese Utility models and applications for Utility models since 1975

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

eKIPASS(KIPO internal) "light", "dry", "detect","measure", "plate", "window"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,096,559 A (THUNDAT et al.) 1 August 2000	1, 6-8
Y	See Abstract, Fig. 1	2-4, 11
Y	JP 3-56846 A (NEC CO.) 12 March 1991 See Abstract, Fig. 1	1, 6-8
Y	US 6,753,188 B2 (PERKINS et al.) 22 June 2004 See Abstract, Fig. 4, 5	2-4, 11
A	KR 10-1999-022912 A (KIRIN HOLDINGS CO.) 25 March 1999 See Page 9, 17, Fig. 1	5, 9, 10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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