Appeal decision

Appeal No. 2017-5823

Chiba, Japan

Appellant Chiba University

Osaka, Japan

Patent Attorney Saegusa and Partners.

Hyogo, Japan

Appellant KANSAI PAINT CO. LTD

Osaka, Japan

Patent Attorney Saegusa and Partners.

The case of appeal against the examiner's decision of refusal of Japanese Patent Application No. 2012-75100, entitled "Film thickness measurement method and measurement device, and film thickness change measurement method and measurement device" [the application published on Oct. 7, 2013: Japanese Unexamined Patent Application Publication No. 2013-205252] has resulted in the following appeal decision:

Conclusion

The appeal of the case was groundless.

Reason

1 History of the procedures

The patent application related to this appeal case (hereinafter, referred to as "the Present application") was made on Mar. 28, 2012. After that, an amendment regarding the scope of claims was made on Jan. 6, 2016, and, in addition, an amendment regarding the scope of claims was made on Aug. 17 of the same year. Then, a decision of refusal was made on Jan. 19, 2017, and a copy of the original of the examiner's decision was delivered on Jan. 24, 2017.

Against this, an appeal against the examiner's decision of refusal was made on Apr. 24 of the same year.

2 Summary of the examiner's decision

All the inventions according to claim 1 to claim 6 of the Present application could have been invented with ease by a person skilled in the art based on the inventions described in the following Cited Document 1 to Cited Document 3, and, therefore, the appellant should not obtain a patent for those inventions under the provisions of Article 29(2) of the Patent Act.

All the inventions according to claim 7 to claim 10 of the Present application could have been invented with ease by a person skilled in the art based on the inventions described in the following Cited Document 1 to Cited Document 4, and, therefore, the appellant should not obtain a patent for those inventions under the provisions of Article 29(2) of the Patent Act.

Cited Document 1: Japanese Unexamined Patent Application Publication No. H10-325795

Cited Document 2: Japanese Unexamined Patent Application Publication No. H9-145327

Cited Document 3: Japanese Unexamined Patent Application Publication No. H2-

297008

Cited Document 4: Japanese Unexamined Patent Application Publication No. 2006-38533

3 The Invention

The inventions according to claim 1 to claim 10 of the Present application are ones that are specified by the matters described in claim 1 to claim 10 of the scope of claims of the Present application. In particular, the invention according to claim 1 of the Present application (hereinafter, referred to as the "Invention") is as indicated below.

"[Claim 1]

A method of determining a thickness of a coated film including a pigment by irradiating the coated film with light from a light source, and detecting an intensity of interference light including reflection light from the coated film, comprising:

a branch step of branching light from the light source into reference light and incident light to the coated film;

an interference step of causing reflection light from the coated film and the reference light to interfere with each other by adjusting an optical distance of the reference light;

a detection step of detecting a plurality of intensity signals generated by the interference of the reflection light from the coated film and the reference light;

and a film thickness calculation step of calculating the thickness of the coated film from an interval between adjacent peaks of a plurality of detected intensity signals, wherein

the coated film is an ultraviolet curing resin or an electron beam curing resin, and the light from the light source is near-infrared light within a range of a wavelength of 1300 nm-2000 nm."

4 Inventions and the like described in the Cited Documents

(1) Cited Document 2

A Statements of Cited Document 2

In Cited Document 2, there are the following statements. The underlines are added by the body.

"[0001] [Field of the Invention] The present invention relates to an improved thickness measurement device for a multilayer sheet-shaped plastic, and, more particularly, provides a device useful for discontinuously or continuously (in-line) measuring the thickness of each layer of a sheet-shaped plastic formed in a multilayered manner."

"[0023] [Example] Hereinafter, description will be made in further detail by way of examples by reference to drawings, but the present invention is not restricted by the examples.

[0024] In the thickness measurement device for a multilayer sheet, the measurement principle according to a low-coherent light source of the Invention will be described by reference to a light-path diagram of FIG. 1. As the light source, a low-coherent light source 2 is used, and low-coherent light emitted therefrom is collimated by a condensing lens to be parallel light and undergoes amplitude splitting by a beam splitter 4 into two pieces of parallel light. The first piece of the divided branched light is led to a multilayer sheet 7 through a first focal point lens, and, as a result of reflection occurring on the boundary surface of each layer on that occasion, is reflected as measurement light 8. The second branched light that is the other of the divided pieces of the branched light enters into a movable mirror surface 11 by a second focal point lens to be reflected. The reflected light will be reference light 12. The measurement light 8 and the reference light 12 that have been respectively reflected return to the beam splitter 4 again to become synthesis light 13, which is led to a light-receiving element 15 through a light-receiving lens to be photoelectrically converted. Furthermore, regarding the photoelectrically converted light, a signal according to interference light is detected by a light-receiving circuit, and, further, the light undergoes processing such as envelope demodulation and is led to a calculation unit, and, here, converted into each layer thickness of the multilayer sheet.

[0025] Here, although the low-coherent light source 2 that is used as low-coherent light is not one whose center wavelength and spectral half-value width are restricted in particular, it is preferred that it be a low-coherent light source having a center wavelength and a spectral half-value width that make a coherence length be 10 μm-40 μm, because there is a case where the following problem occurs....(snip)..."

"[0029] FIG. 2 indicates a sectional view of essential parts of a device when the device is realized adopting the measurement principle of FIG. 1. Here, reference numeral 1 indicates a chassis, 3 a condensing lens to collimate coherent light emitted from the low-coherent light source 2, and 5 the first focal point lens to condense the first branched light according to the beam splitter 4."

"[0032] Reference numeral 9 indicates the second focal point lens that condenses the second branched light according to the beam splitter 4, and 10 indicates a movable mirror surface driving unit for making the movable mirror surface 11 operate and includes: a stage 25 to which the movable mirror surface 11 is attached and which uses a precision cloth roller guide and the like that guides parallel movement; and a driving motor 26 attached in a manner coupled with the stage 25. It is preferred that the driving motor 26 be a linear motor such as a linear ultrasound motor or a linear stepping motor. When the driving motor 26 is driven, the movable mirror surface 11 reciprocates as shown in the arrow in FIG. 1, and therefore the optical path length of the reference light 12 can be changed. Therefore, the speed of optical path length change of the reference light 12 can be changed by the speed to drive the driving motor 26, and thus the frequency of a signal due to interference light when the reference light 12 and the measurement light 8 interfere with each other is determined by the speed of the driving motor 26 that reciprocates the movable mirror surface 11.

[0033] Note that, a movable mirror surface position detection element (not shown) to detect a position of the movable mirror surface 11 can be substituted by a potentiometer, a micro meter, an element such as PSD, or, when the driving motor 26 is a motor to be operated by a pulse, the number of oscillation pulses thereof. This movable mirror surface position detection element is provided in the stage 25, and detects a position when the movable mirror surface 11 reciprocates. The information on a detected position is converted into a digital signal by an A/D converter that is not shown, and led to a computer that is not shown. Also, in a case where the driving motor 26 is a motor to be operated by a pulse, it may be such that the number of oscillation pulses thereof is led to the computer directly to be information related to a position. Furthermore, if it is considered that the speed at which the movable mirror surface 11 reciprocates is constant, a traveling distance is obtained by multiplying a time during which the movable mirror surface 11 has moved by the speed, and thus it is also possible to obtain information related to a position of the movable mirror surface 11 only by calculation in a computer that is not shown. Reference numeral 14 indicates a light-receiving lens for receiving the synthesis light 13, and leading it to a light-receiving element."

"[0035] Reference numeral 16 indicates a light-receiving circuit, and, here, a signal according to interference light is processed. Reference numeral 19 indicates a holder to secure the low-coherent light source 2, and, in order to prevent degradation of the low-coherent light source 2 and light output from becoming unstable due to temperature rise, a Peltier element that is not shown is mounted on it to cool the low-coherent light source 2, and control such as automatic temperature control (ATC), automatic output control (APC) and the like is carried out by a driver that is not shown."

"[0039] The thickness of each layer of the multilayer sheet 7 will be eventually calculated by a computer. In other words, a position of the movable mirror surface 11 at the time of occurrence of interference is identified from a digital signal made by applying A/D conversion to an envelope curve signal of interference light led from the aforementioned light-receiving circuit 16 and information related to a position of the movable mirror surface 11 derived from the movable mirror surface position detection element mentioned above, and the thickness of each layer of the multilayer sheet 7 is calculated based on a result of this.

[0040] Finally, how the thickness of each layer is actually measured by a thickness measurement device for a multilayer sheet-shaped plastic according to the Invention constituted as above will be described by way of a specific example. FIG. 5 illustrates an example of the multilayer sheet 7 to be a target of measurement by a device according to the present invention, and this is a multilayer sheet 7a made up of five layers of three types and having a total thickness 300 μm. Specifically, it is constituted such that a first layer 32 and a fifth layer 36 are nylon, a second layer 33 and a fourth layer 35 are adhesive agents, and a third layer 34 is poval. When the first layer 32 side of such the multilayer sheet 7a is held in a non-contact manner by a pneumatic noncontact suppression device 6 while the multilayer sheet 7a is running, and the measurement light 8 enters, the measurement light 8 is reflected by each of boundary surfaces 37, 38, 39, 40, 41, and 42 of the multilayer sheet

7a and return to the beam splitter 4. On the other hand, the reference light 12 is reflected by the movable mirror surface 11 and returns to the beam splitter 4. On that occasion, an optical path length of the reference light 12 corresponding to each boundary surface of the multilayer sheet 7a can be varied by the movable mirror surface 11. In FIG. 6, there is indicated a relation between a peak of an envelope curve signal according to interference light by the light-receiving circuit 16 and each boundary surface of the multilayer sheet 7a when measuring the multilayer sheet of FIG. 5. The horizontal axis of FIG. 6 indicates a position of the movable mirror surface 11, and the vertical axis the magnitude of an envelope curve signal according to interference light in each boundary surface. Here, given that positions of the movable mirror surface 11 indicating each of the peaks 43, 44, 45, 46, 47, and 48 are L1, L2, L3, L4, L5, and L6, the refraction factor of the first layer 32 and the fifth layer 36 is n1, the refraction factor of the second layer 33 and the fourth layer 35 is n2, the refraction factor of the third layer 34 is n3, and the refraction factor of the air is 1, it is possible to calculate the thickness d1 of the first layer 32, the thickness d2 of the second layer 33, the thickness d3 of the third layer 34, the thickness d4 of the fourth layer 35, and the thickness d5 of the fifth layer 36 by Expressions 2-6, respectively.

[0041]

[Expression 2]

d1=(L2-L1)/n1

[Expression 3]

d2=(L3-L2)/n2

[Expression 4]

d3=(L4-L3)/n3

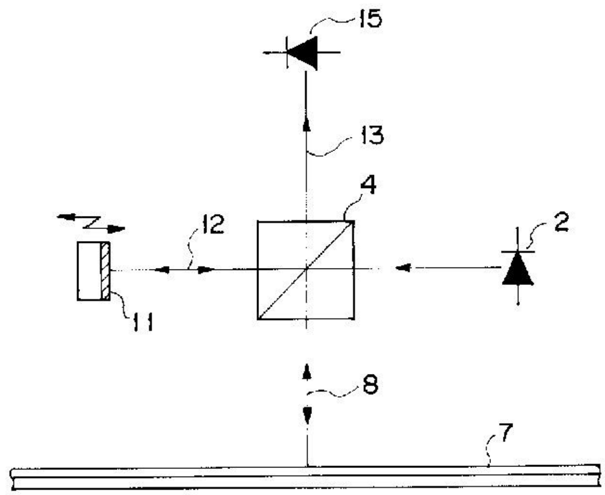
[Expression 5]

d4=(L5-L4)/n2

[Expression 6]

d5=(L6-L5)/n1"

[FIG. 1]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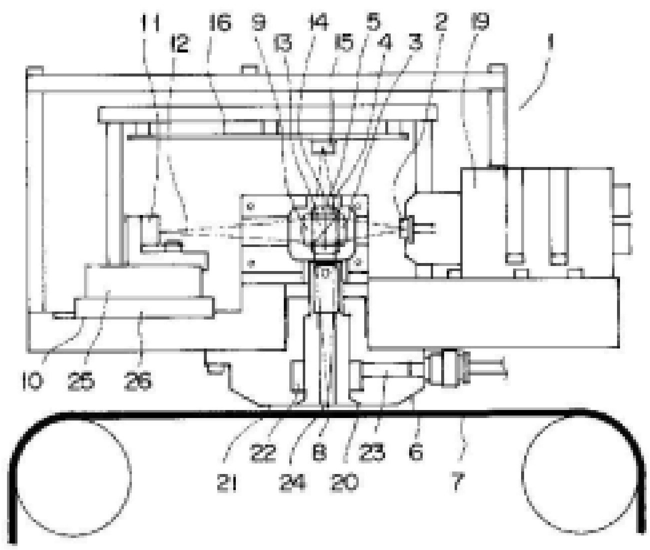
[FIG. 2]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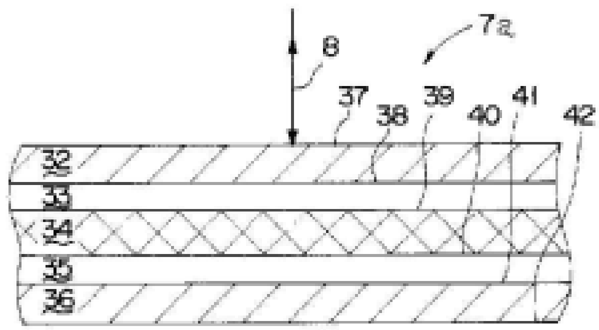
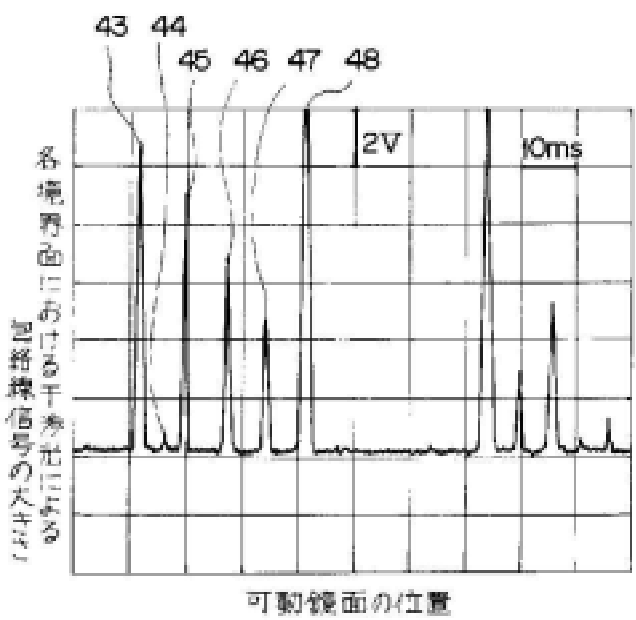
[FIG. 5]



[FIG. 6]



各境界面における干渉光による包絡線信号の大きさ　Magnitude of an envelope curve signal according to interference light in each boundary surface

可動鏡面の位置　　Position of movable mirror surface

B The invention described in Cited Document 2

(A) In Cited Document 2, there is described a thickness measurement device for a multilayer sheet that measures the thickness of each layer of a sheet-shaped plastic formed in a multilayer manner ([0001], [0024]).

(B) In the thickness measurement device of a multilayer sheet described in Cited Document 2, low-coherent light emitted from the low-coherent light source 2 is collimated by the condensing lens 3 to become parallel light, and undergoes amplitude splitting by the beam splitter 4 into the first branched light and the second branched light that are two pieces of parallel light ([0024], [0029], FIG. 1, FIG. 2).

(C) The first branched light is led to the multilayer sheet 7(7a) that is a measurement target through the first focal point lens 5, and becomes the measurement light 8 by being reflected by the boundary surfaces 37-42 of respective layers (the first layer 32 constituted of nylon, the second layer 33 constituted of adhesive agent, the third layer 34 constituted of poval, the fourth layer 35 constituted of an adhesive agent, the fifth layer 36 constituted of nylon) of the multilayer sheet 7(7a) ([0024], [0029], [0040], FIG. 1, FIG. 2, FIG. 5).

(D) The second branched light is incident on the movable mirror surface 11 through the second focal point lens 9 and is reflected to become the reference light 12, and, at this time, the movable mirror surface 11 reciprocates and changes the optical path length of the reference light 12 corresponding to each of the boundary surfaces 37-42 of the multilayer sheet 7(7a) ([0024], [0032], [0040], FIG. 1, FIG. 2, FIG. 5).

(E) The measurement light 8 and the reference light 12 reflected respectively return to the beam splitter 4 to become the synthesis light 13, and then the synthesis light 13 is led to the light-receiving element 15 through a light-receiving lens 14 to be photoelectrically converted. Then, a signal according to interference light between the reference light 12 and the measurement light 8 is detected by the light-receiving circuit 16, led to the calculation unit via processing such as envelope demodulation, and, based on a position of the movable mirror surface 11 at the time of occurrence of interference identified from an envelope curve signal of interference light and a signal related to a position of the movable mirror surface 11, the thickness of each layer of the multilayer sheet 7 is calculated ([0024],

[0032], [0033], [0035], [0039], FIG. 1, FIG. 2).

(F) Specifically, given that positions of the movable mirror surface 11 when envelope curve signals according to interference light at each boundary surface 37 to 42 of the multilayer sheet 7(7a) show peaks 43 to 48 are L1 to L6, and the refraction factors of the first layer 32 to the fifth layer 36 are n1, n2, n3, n2, and n1, respectively, the thicknesses d1 to d5 of the first layer 32 to the fifth layer 36 are calculated using relational expressions of d1=(L2-L1)/n1, d2=(L3-L2)/n2, d3=(L4-L3)/n3, d4=(L5-L4)/n2, and d5=(L6-L5)/n1 ([0040], [0041], FIG. 6).

(G) When the above matters are summarized, the following invention (hereinafter, referred to as "Cited Invention") is described in Cited Document 2 as a measurement method of the thickness of each layer of the multilayer sheet 7a that is performed by a thickness measurement device for multilayer sheets.

"A measurement method of a thickness of each layer of the multilayer sheet 7a, comprising:

a step of collimating by the condensing lens 3 low-coherent light emitted from the low-coherent light source 2 to make the low-coherent light be parallel light, and amplitude-splitting the parallel light by the beam splitter 4 into first branched light and second branched light that are two pieces of parallel light;

a step of leading the first branched light to the multilayer sheet 7a through the first focal point lens 5, and making the first branched light be reflected by the boundary surfaces 37 to 42 of the first layer 32 to the fifth layer 36 of the multilayer sheet 7a to be the measurement light 8;

a step of making the second branched light be incident on the movable mirror surface 11 through the second focal point lens 9, and reflected to be the reference light 12, and causing the movable mirror surface 11 be reciprocated to make an optical path length of the reference light 12 corresponding to each of the boundary surfaces 37 to 42 of the multilayer sheet 7a be changed; and

a step of returning the measurement light 8 and the reference light 12 to the beam splitter 4 to generate the synthesis light 13, leading the synthesis light 13 to the light-receiving element 15 through the light-receiving lens 14 to be photoelectrically converted, detecting a signal according to interference light between the reference light 12 and the measurement light 8 by the light-receiving circuit 16, leading the signal to a calculation unit after carrying out processing such as envelope demodulation, and, based on a position of the movable mirror surface 11 at the time of occurrence of interference identified from an envelope curve signal of interference light and a signal related to a position of the movable mirror surface 11, calculating a thickness of each layer of the multilayer sheet 7, wherein, given that positions of the movable mirror surface 11 when envelope curve signals according to interference light at each of the boundary surfaces 37 to 42 of the multilayer sheet 7a indicate peaks 43 to 48 are L1 to L6, and refraction factors of the first layer 32 to the fifth layer 36 are respectively n1, n2, n3, n2, and n1, thicknesses d1 to d5 of the first layer 32 to the fifth layer 36 are calculated using relational expressions of d1=(L2-L1)/n1, d2=(L3-L2)/n2, d3=(L4-L3)/n3, d4=(L5-L4)/n2, and d5=(L6-L5)/n1."

(2) Cited Document 1

A Statements of Cited Document 1

In Cited Document 1, there are the following statements. The underlines are added by the body.

"[0002]

[Conventional Art] A method of measuring optical characteristics of a measuring object (medium) such as a refraction factor n (= a phase refraction factor np), double refraction, and a thickness in a non-contact manner is one of the most fundamental technologies in the field of optics. As a representative one, there is an ellipsometer ...(omitted) .... This is a method in which a medium (thin film) to be a measurement target is irradiated with light from an oblique direction, attention is paid mainly to a difference between phase changes of P-polarized light and S-polarized light of reflection light, and, by observing a state of polarization on the occasion when light is reflected at a surface of the medium, the refraction factor n and the thickness t of a substrate and a thin film deposited on its surface are measured.

[0003] Also, there are reflection factor analysis methods to measure film thickness, a refraction factor n, and an absorption coefficient of a medium using a reflection factor, and such methods are disclosed in Japanese Unexamined Patent Application Publication No. S64-75902, Japanese Unexamined Patent Application Publication No. S63-128210, Japanese Unexamined Patent Application Publication No. H3-17505, and the like. The reflection factor analysis methods disclosed in Japanese Unexamined Patent Application Publication No. S64-75902 and Japanese Unexamined Patent Application Publication No. S63-128210 are methods that measure a reflected light intensity change that comes with an incidence angle change of light; that is, the incidence angle dependence characteristics of reflected light intensity, and obtain characteristics of a thin film using incidence angles of three extreme values thereof....(snip)..."

"[0005] In addition, in evaluation of a cure state or a cure degree of various kinds of hardening resin (ultraviolet curing, thermal hardening, catalyst curing, electron beam curing, and the like) and coated films, currently, the gel fraction (when solvent extraction is carried out to a measurement sample by methyl ethyl ketone and the like, a ratio of weight changes between the initial weight and the weight after the solvent extraction) is the most common index. However, this evaluation method is a destructive test, and a long time is required for preparation and evaluation of a sample.

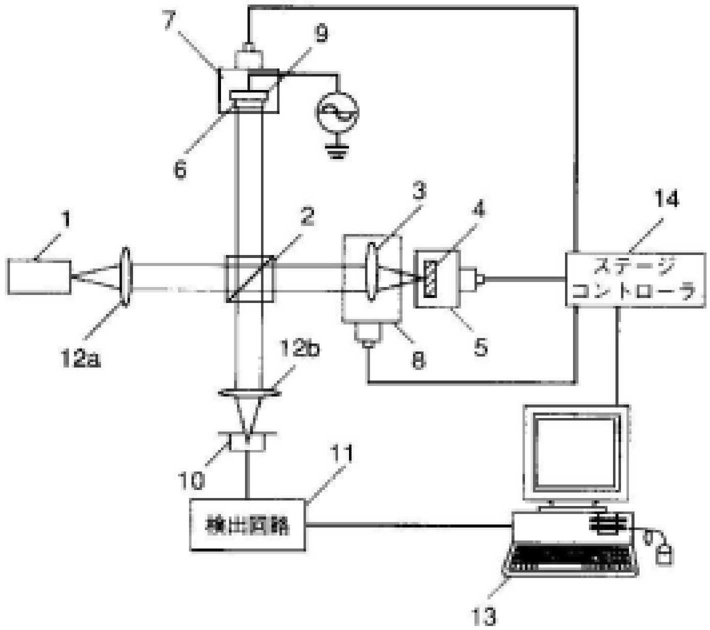
[0006] [Problems to be solved by the invention] In light of such situation, there are proposed here methods based on an interference optical system using a low coherence light source, the methods including: a method of measuring a phase refraction factor np and a thickness t of a medium simultaneously and precisely by focused beam irradiation; a method of measuring double refraction of a medium precisely without requiring polarization control such as a polarizer/analyzer, and a polarization rotator and the like; a method of measuring a phase refraction factor np and a group refraction factor ng simultaneously and precisely; and a method of evaluating hardenability or a cure degree of resin using such methods."

"[0099] FIG. 1 is a basic system configuration diagram according to an embodiment of the Invention for simultaneously measuring a phase refraction factor and a thickness, and for simultaneously measuring a phase refraction factor and a group refraction factor. Here, the route of light in the present system configuration will be described, first. Light emitted from the light source 1 is collimated by the lens 12a, and is led to the demultiplexing/multiplexing means 2 that carries out demultiplexing and multiplexing of light from the light source 1. The light source 1 is divided into two pieces by the demultiplexing/multiplexing means 2, and one of that light goes straight ahead and is condensed onto the measuring object 4 held and mounted on the driving means 5 by the condensing lens 3 held and mounted on the driving means 8. On the other hand, the other of the light moves in a vertical direction from the demultiplexing/multiplexing means 2, and is radiated onto the reference light mirror 6 that is held and mounted on the driving means 7 and is secured to the vibrator 9. To the vibrator 9, vibration of a frequency f and a predetermined amplitude is imparted, and reflection light (reference light) from the reference light mirror 6 is phase-modulated. Reflection light (signal light) from the measuring object 4 is incident on the light-receiving element 10 through the condensing lens 3, the demultiplexing/multiplexing means 2, and the lens 12b. Reflection light (reference light) from the reference light mirror 6 is incident on the light-receiving element 10 through the demultiplexing/multiplexing means 2, and the lens 12b. A detection signal of the light-receiving element 10 is converted into a digital signal by the detection circuit 11, and the data thereof are processed in the PC 13. Note that the driving means 5, 7, 8 are controlled by a signal from the PC 13 via the stage controller 14.

[0207] Light of linear polarization, or light of unpolarization or random polarization can be used as the light source 1 in simultaneous measurement of a refraction factor and a thickness and in simultaneous measurement of a phase refraction factor and a group refraction factor. Similarly, light of unpolarization or random polarization can be used in double refraction measurement and in measurement of double refraction and thickness. As a specific example of the light source 1, it is possible to use any light source having a coherence length of 30 μm or less, such as: a super luminescent diode (SLD); ones in which spectral diffraction of light from a white light source (a halogen lamp or a xenon lamp) is applied only to a specific wavelength region by a monochrome meter; and a laser diode (LD), a light emitting diode, and the like to be driven by an injection current equal to or less than a threshold. In addition, no particular limitation is imposed on the wavelength of the light source 1, and it is possible to use any one having a coherence length of 30 μm or less ranging from ultraviolet light to infrared light. Therefore, it is also possible to measure wavelength characteristics (wavelength dispersion) of a measuring object (medium) by performing scanning of a light wavelength from a short wavelength to a long wavelength using the light source 1 by a combination of a white light source and a monochrome meter. Furthermore, it is also possible to measure wavelength characteristics (wavelength dispersion) by, as with ones using light made by performing spectral diffraction to a white light source by a monochrome meter as the light source 1, using in combination a plurality of laser diodes and the like having different oscillation center wavelengths. Note that, from the aspect of stable measurement, it is desired that the output of the light source 1 be stable without fluctuation, and match the sensitivity of a light-receiving element that makes a signal light from a measuring object and reference light from a reference light mirror be multiplexed and interfere with each other to carry out detection."

"[0210] The measuring object 4 is glass (quartz glass, soda lime glass, borosilicate glass, lead glass, or the like, for example), a polymer (PMMA, PC, polybutylene terephthalate, polybutylene terephthalate, methyl methacrylate, epoxy resin, polyphloro acrylate, silicon resin, melamine resin, ultraviolet curing resin, electron beam curing resin, catalyst curing resin, thermal hardening resin, or the like, for example), a crystalline material (lithium niobate, lithium tantalate, sapphire, KDP, ADP, calcite, or the like, for example), a liquid material in a transparent container, and a body tissue (for example, cornea, crystalline lens, nail, or the like) and so on. Here, the front face and rear face of the measuring object 4 are not necessarily mirror surfaces, and it is possible to perform measurement even if one or both are rough surfaces. In addition, the measuring object 4 is not limited to glass, polymers, and crystalline materials mentioned above, and it may be a multilayer film of these. Furthermore, the measuring object 4 only has to be a medium that does not absorb light entirely, and, even in a case of a scattering medium such as one in which scatterers interpose within media, measurement can be performed by extracting only reflected going-straight light (signal light). Yet further, the measuring object 4 is not necessarily a parallel plate, and even a medium having inclination or curvature in the front face or rear face can be measured."

[FIG. 1]



検出回路　　Detection circuit

ステージコントローラ　　Stage controller

B Matters described in Cited Document 1

(A) In Cited Document 1, there is described a method of measuring a phase refraction factor and a thickness of a medium simultaneously and precisely by focused beam irradiation based on an interference optical system using a low coherence light source ([0006]).

(B) There is no limitation in the wavelength of the light source, and it is possible to use any light source having a coherence length of 30 μm or less ranging from ultraviolet light to infrared light ([0207]).

(C) A measuring object includes ultraviolet curing resin or electron beam curing resin, the front face and rear face of a measuring object may be a rough surface, and even a scattering medium such as one in which scatterers interpose within media can be measured by extracting only reflected going-straight light ([0210]).

(D) The method described in Cited Document 1 has been made in light of drawbacks of ellipsometers and reflection factor analysis methods that are prior art for measuring the thickness of a thin film, and drawbacks of evaluation of a cure state or a cure degree of various kinds of curing resin including ultraviolet curing resin and electron beam curing resin and a coated film thereof ([0002], [0003], [0005]), and, therefore, it is obvious that a thin film or a coated film is assumed to be a measuring object.

(E) When the above matters are summarized, there is described the following matter in Cited Document 1.

"It is possible to measure the thickness of a measuring object using an interference optical system using a low coherence light source, and, on this occasion, regarding the wavelength of the light source, all light sources having a coherence length of 30 μm or less ranging from ultraviolet light to infrared light can be used, a measuring object may be a thin film or a coated film of ultraviolet curing resin or electron beam curing resin, the front face and rear face thereof may be rough surfaces, and, further, even scattering medium in which scatterers interpose within media can be measured by extracting only reflected going-straight light."

(F) Note that, specifically, the interference optical system mentioned here is a well-known Michelson interferometer ([0099], FIG. 1).

(3) Cited Document 3

A Statements of Cited Document 3

There are the following statements in Cited Document 3. The underlines are added by the body.

"(Industrial Application Field)

The present invention relates to an optical measurement method of a thickness of an opaque thin film.

(Conventional Art and Problems to be solved by the Invention)

The optical interferometry and the infrared absorption spectrometry are cited as representative thickness measurement methods of an optics system relating to a transparent thin film. The former uses a phenomenon that, in an optically transparent thin film, interference occurs between the front surface and rear surface of the thin film, and calculates a thickness from a relational expression between an interference fringe thereof and thickness. The latter uses infrared ray absorbing characteristics peculiar to a thin film material, and obtains a thickness from relation between a thickness and absorbancy, a so-called calibration curve. Wavelength bands to be utilized by these are different from each other. The former utilizes a transparent wavelength band that does not have characteristic absorption. The latter cannot conduct precise measurement if an interference phenomenon peculiar to an optical thin film is not removed. In this way, interferometry and absorptiometry have a front-back relation.

Incidentally, in a thin film including light scattering particles, such as an opaque film or a coating film including a pigment and the like, both optical interferometry and infrared absorption spectrometry have a limit of application. Besides usual particles that cause absorption and reflection of incident light, such as a pigment in a coated film, the light scattering particles include: ones that absorb visible and infrared incident light and do not diffuse incident beams so much, such as carbon particles within a coated film; and ones that reflect incident light, and diffuse incident light in a macroscopic manner in a state close to diffuse reflection, such as metal particles. In a thin film including such light scattering particles, an interference phenomenon is less likely to occur, due to scattering and attenuation of light beams and degradation of coherence that comes with light scattering phenomenon caused by particles within a sample. In addition, such attenuation due to light scattering is different from attenuation due to infrared ray absorbing characteristics, and thus an infrared absorption spectrum is also distorted. Moreover, when the scattering phenomenon becomes intense, interference fringes will not be observed. On the other hand, absorbancy is not proportional to a thickness, and, further, can present a reverse phenomenon. In other words, the Beer-Lambert law fails. For this reason, if these problems are not solved, neither methods can be applied to thickness measurement of an opaque sample and a coating film, and thus the application ranges cannot be expanded.

An object of the present invention is to provide an optical measurement method of an opaque thin film." (Page 1, lower right column, line 13 to page 2, upper right column, line 11)

"Interferometry is a measurement method that can be applied to a transparent sample inherently." (page 3, upper left column, line 2 to line 3)

"It is possible to calculate the thickness d of the sample 1 from a relational expression between an interference fringe and the sample thickness d if the refraction factor n of the sample is known in advance." (page 3, upper right column, line 11 to line 13)

"Next, application of the interferometry in the case of a thin film including light scattering particles, such as an opaque film or a coating film including a pigment and the like, will be described. In samples of these, interference phenomenon is less likely to occur, due to scattering and attenuation of a light beam and degradation of coherence that come with light scattering phenomenon by particles within a sample. Such attenuation due to light scattering (hereinafter, referred to as Scattering & Attenuation) is different from attenuation due to infrared ray absorbing characteristics (hereinafter, referred to as Absorption & Attenuation). In addition, also in a black paint film including carbon particles that are absorbers of visible light and infrared light, a transmitted light quantity It attenuates significantly in a similar fashion and thus an interference effect degrades.

It is necessary to take a wavelength of light into consideration in order to expand application of the interferometry to such an opaque sample.

Light scattering intensity is dependent on a relation between a scattering particle diameter a and a light wavelength λ. When a wavelength becomes large compared with a particle diameter, more scattering is caused in the front of the particle 1' than in the back (this is called the Mie effect) as shown in FIG. 4. That is, the longer a wavelength, the less the influence of scattering. Accordingly, from the viewpoint of a light scattering effect, it is preferred to use near-infrared light or infrared light rather than visible light. From the practical viewpoint, it is preferred to use a semiconductor laser of a wavelength of 1.3 μm band, or 1.5 μm band that is used in optical communication (however, when a long wavelength is used, accuracy of thickness measurement falls with respect to a sample having a thinner film thickness, and thus compromise is required according to application)." (page 3, lower left column, line 5 to lower right column, line 11)

B Matters described in Cited Document 3

According to the statements of the aforementioned A of Cited Document 3, there is described the following matter in Cited Document 3.

"When applying the optical interferometry that is a thickness measurement method that can be inherently applied to a transparent sample to a thin film including light scattering particles such as a coating film including a pigment and the like, it is preferred to use near-infrared light or infrared light rather than visible light by making use of a fact that, when a wavelength is large, the longer the wavelength, the less the influence of scattering, due to the Mie effect in which more light is scattered in the front of a particle rather than in the back, and, from the practical viewpoint, it is preferred to use light of a wavelength of 1.3 μm band or 1.5 μm band."

5 Comparison

(1) Comparison

When the Invention and Cited Invention are compared, it is as indicated below.

A "Thickness measurement method of each layer of the multilayer sheet 7a" and "thickness measurement method" of Cited Invention and "method of determining a thickness of a coated film" and "film thickness measurement method" of the Invention are common in a point of "thickness measurement method," and "the multilayer sheet 7a" of Cited Invention and "coated film" of the Invention are common in a point of a "measuring object" to be a target of thickness measurement. Therefore, "thickness measurement method of each layer of the multilayer sheet 7a" and "thickness measurement method" of Cited Invention and "method of determining a thickness of a coated film" and "film thickness measurement method" of the Invention are common in a point of being "a method of measuring a thickness of a measuring object" and "thickness measurement method."

B "The low-coherent light source 2" of Cited Invention corresponds to "light source" of the Invention, and thus "low-coherent light emitted from the low-coherent light source 2" of Cited Invention corresponds to "light from the light source" of the Invention.

C "First branched light" in "a step of collimating by the condensing lens 3 low-coherent light emitted from the low-coherent light source 2 to make the low-coherent light be parallel light, and amplitude-splitting the parallel light by the beam splitter 4 into first branched light and second branched light that are two pieces of parallel light" of Cited Invention is one to be "led to the multilayer sheet 7a through the first focal point lens 5," and, therefore, in light of the aforementioned A, it is common to "incident light to the coated film" of the Invention in a point of being "incident light to a measuring object."

D "Second branched light" in "a step of collimating by the condensing lens 3 low-coherent light emitted from the low-coherent light source 2 to make the low-coherent light be parallel light, and amplitude-splitting the parallel light by the beam splitter 4 into first branched light and second branched light that are two pieces of parallel light" of Cited Invention is one to be "made to be incident on the movable mirror surface 11 through the second focal point lens 9, and reflected to be the reference light 12," and, therefore, corresponds to "reference light" of the Invention.

E In light of the aforementioned C and D, "a step of collimating by the condensing lens 3 low-coherent light emitted from the low-coherent light source 2 to make the low-coherent light be parallel light, and amplitude-splitting the parallel light by the beam splitter 4 into first branched light and second branched light that are two pieces of parallel light" of Cited Invention and "a branch step of branching light from the light source into reference light and incident light to the coated film" of the Invention are common in a point of being "a branch step of branching light from a light source into reference light and incident light to a measuring object."

F Since "optical path length" of Cited Invention corresponds to "optical distance" of the

Invention, "making the second branched light be incident on the movable mirror surface 11 through the second focal point lens 9, and reflected to be the reference light 12, and causing the movable mirror surface 11 be reciprocated" "to make an optical path length of the reference light 12 be changed" in Cited Invention corresponds to "adjusting an optical distance of the reference light" in the Invention in light of D mentioned above.

G In light of the aforementioned C, "the measurement light 8" generated by "leading the first branched light to the multilayer sheet 7a through the first focal point lens 5, and making the first branched light be reflected by the boundary surfaces 37 to 42 of the first layer 32 to the fifth layer 36 of the multilayer sheet 7a" of Cited Invention and "the reflection light from the coated film" of the Invention are common in a point of being "reflection light from a measuring object."

H It is obvious that "returning the measurement light 8 and the reference light 12 to the beam splitter 4 to generate the synthesis light 13, leading the synthesis light 13 to the light-receiving element 15 through the light-receiving lens 14 to be photoelectrically converted, detecting a signal according to interference light between the reference light 12 and the measurement light 8 by the light-receiving circuit 16" in Cited Invention makes "the reference light 12" and "the measurement light 8" interfere with each other as a presupposition thereof, and, therefore, it is common to "causing the reflection light from the coated film and the reference light to interfere with each other" in the Invention in a point of "causing reflection light from a measuring object and reference light to interfere with each other."

I In light of the abovementioned F to H, "a step of leading the first branched light to the multilayer sheet 7a through the first focal point lens 5, and making the first branched light be reflected by the boundary surfaces 37 to 42 of the first layer 32 to the fifth layer 36 of the multilayer sheet 7a to be the measurement light 8" and "a step of making the second branched light be incident on the movable mirror surface 11 through the second focal point lens 9, and reflected to be the reference light 12, and causing the movable mirror surface 11 be reciprocated to make an optical path length of the reference light 12 corresponding to each of the boundary surfaces 37 to 42 of the multilayer sheet 7a be changed" of Cited Invention and "returning the measurement light 8 and the reference light 12 to the beam splitter 4 to generate the synthesis light 13, leading the synthesis light 13 to the light-receiving element 15 through the light-receiving lens 14 to be photoelectrically converted, detecting a signal according to interference light between the reference light 12 and the measurement light 8 by the light-receiving circuit 16" in Cited Invention are common to "an interference step of causing reflection light from the coated film and the reference light to interfere with each other by adjusting an optical distance of the reference light" of the Invention in a point of being "an interference step of causing reflection light from a measuring object and reference light to interfere with each other by adjusting an optical distance of the reference light."

J "A step of returning the measurement light 8 and the reference light 12 to the beam splitter 4 to generate the synthesis light 13, leading the synthesis light 13 to the light-receiving element 15 through the light-receiving lens 14 to be photoelectrically converted, detecting a signal according to interference light between the reference light 12 and the measurement light 8 by the light-receiving circuit 16, leading the signal to a calculation unit after carrying out processing such as envelope demodulation, and, based on a position of the movable mirror surface 11 at the time of occurrence of interference identified from an envelope curve signal of interference light and a signal related to a position of the movable mirror surface 11, calculating a thickness of each layer of the multilayer sheet 7" of Cited Invention uses "L1 to L6" that are "positions of the movable mirror surface 11 when envelope curve signals according to interference light at each of the boundary surfaces 37 to 42 of the multilayer sheet 7a indicate peaks 43 to 48," and obviously a plurality of intensity signals according to interference between "the reference light 12" and "the measurement light 8" are detected. Therefore, this step is common to "a detection step of detecting a plurality of intensity signals generated by the interference of the reflection light from the coated film and the reference light" of the Invention in a point of being "a detection step of detecting a plurality of intensity signals according to interference between reflection light from a measuring object and reference light."

K All of "L2-L1," "L3-L2," "L4-L3," "L5-L4," and "L6-L5" in "a step wherein, given that positions of the movable mirror surface 11 when envelope curve signals according to interference light at each of the boundary surfaces 37 to 42 of the multilayer sheet 7a indicate peaks 43 to 48 are L1 to L6, and refraction factors of the first layer 32 to the fifth layer 36 are respectively n1, n2, n3, n2, and n1, thicknesses d1 to d5 of the first layer 32 to the fifth layer 36 are calculated using relational expressions of d1=(L2-L1)/n1, d2=(L3-L2)/n2, d3=(L4-L3)/n3, d4=(L5-L4)/n2, and d5=(L6-L5)/n1" of Cited Invention correspond to "an interval between adjacent peaks of a plurality of detected intensity signals" of the Invention. Therefore, this "step" of Cited Invention and "a film thickness calculation step of calculating the thickness of the coated film from an interval between adjacent peaks of a plurality of detected intensity signals" of the Invention are common in a point of being "a thickness calculation step of calculating thickness of a measuring object by an interval between adjacent peaks of a plurality of intensity signals having been detected."

L Cited Invention is an invention that "detects a signal according to interference light between" light made in such a way that "low-coherent light emitted from the low-coherent light source 2" is "led to the multilayer sheet 7a through the first focal point lens 5, and making the light be reflected by the boundary surfaces 37 to 42 of the first layer 32 to the fifth layer 36 of the multilayer sheet 7a to be the measurement light 8" and "the reference light 12" to "calculate a thickness of each layer of the multilayer sheet 7," and the Invention is one that "irradiates the coated film including a pigment with light from a light source, and detects an intensity of interference light including reflection light from the coated film." Therefore, in light of the aforementioned A to K, the two are common in a point of "irradiating a measuring object with light from a light source, and detecting intensity of interference light including reflection light from the measuring object to measure the thickness of the measuring object."

(2) Corresponding features and different features

When the results of the comparison of the above (1) are summarized, the corresponding features and the different features between the Invention and Cited Invention are as indicated below.

A Corresponding features

"A method of measuring a thickness of a measuring object by irradiating the measuring object with light from a light source, and detecting intensity of interference light including reflection light from the measuring object, comprising:

a branch step of branching light from the light source into reference light and incident light to the measuring object;

an interference step of causing reflection light from the measuring object and the reference light to interfere with each other by adjusting an optical distance of the reference light;

a detection step of detecting a plurality of intensity signals generated by the interference of the reflection light from the measuring object and the reference light; and

a thickness calculation step of calculating the thickness of the measuring object from an interval between adjacent peaks of a plurality of detected intensity signals."

B Different features

(A) Different feature 1

A point that, the Invention is one in which a "measuring object" is "a coated film including a pigment" and "ultraviolet curing resin or electron beam curing resin," and is one that measures "the film thickness" thereof, whereas, Cited Invention is one in which a "measuring object" is "the multilayer sheet 7a," and is one that measures "a thickness of each layer" thereof, and therefore, "the reference light 12" whose "optical path length is made to be changed" (this corresponds to "reference light" whose "optical distance is adjusted" of the Invention) is also supposed to "correspond to each of the boundary surfaces 37 to 42 of the multilayer sheet 7a."

(B) Different feature 2

A point that, in the Invention, "light from a light source" is "near-infrared light within a range of wavelength of 1300 nm-2000 nm," whereas, in Cited Invention, "light from a light source" is "low-coherent light emitted from the low-coherent light source 2," and its wavelength is not specified.

6 Judgment regarding the different features

(1) Regarding the different feature 1

Cited Invention is a measurement method of the thickness of each layer of the multilayer sheet 7a that is performed by a thickness measurement device for multilayer sheets described in Cited Document 2 (4(1)B(G) mentioned above). Here, as is obvious from the statement of [0024] of Cited Document 2, the thickness measurement device described in Cited Document 2 is a device for measuring the thickness of each layer of a multilayer sheet using interference according to a low-coherent light source, and, therefore, Cited Invention is a method of measuring the thickness of each layer of a multilayer sheet using interference according to a low-coherent light source, after all. Also, as is obvious when statements of [0024] and FIG. 1 of Cited Document 2 are referred to, an optical system of the thickness measurement device described in Cited Document 2 is constituted by a well-known Michelson interferometer.

On the other hand, in Cited Document 1, there is described that the thickness of a coated film of ultraviolet curing resin or electron beam curing resin can be measured using an interference optical system that uses a low-coherent light source, and, in addition, the front face and rear face of the coated film may be rough surfaces, and, further, scatterers may be interposed within that (4(2)B(E) mentioned above). Furthermore, the interference optical system mentioned here is specifically a well-known Michelson interferometer, (4(2)B(F) mentioned above), and thus this is the same as the optical system of the thickness measurement device described in Cited Document 2.

In this way, in Cited Document 1, there is described that a thickness of a coated film including scatterers interposing within ultraviolet curing resin or electron beam curing resin can be measured using the same measurement principle as that of Cited Invention (interference according to a low-coherent light source) and the same optical system (Michelson interferometer), and, therefore, it can be said that a person skilled in the art coming into contact with Cited Document 1 has motivation to make, in Cited Invention, a coated film including scatterers interposing within ultraviolet curing resin or electron beam curing resin be a measuring object instead of "the multilayer sheet 7a."

As a result of doing so, it is natural that a measured value becomes the film thickness of a coated film including scatterers interposing within ultraviolet curing resin or electron beam curing resin, instead of "the thickness each layer of the multilayer sheet 7a." Furthermore, the reason that "the reference light 12" whose "optical path length is made to be changed" is supposed to "correspond to each of the boundary surfaces 37 to 42 of the multilayer sheet 7a" in Cited Invention is that "the thickness of each layer of the multilayer sheet 7a" is made to be a measured variable, and, in a case where the film thickness of a coated film; that is, the thickness of a single layer, is made to be a measured variable, it is natural that "the reference light 12" whose "optical path length is made to be changed" becomes to correspond to a boundary surface (front face and rear face) of a single layer (coated film).

Moreover, it is well-known for a person skilled in the art that a coated film having scatterers interposing within the film includes a coated film including a pigment as one kind thereof, as described in Cited Document 3 that "a thin film including light scattering particles such as an opaque film, or a coating film including a pigment and the like" (page 2, upper left column, line 9 to line 11), for example. Accordingly, to limit a measuring object, from a coated film having scatterers interposing within ultraviolet curing resin or electron beam curing resin, to a coated film including a pigment that is a kind of the scatterers is nothing but an act a person skilled in the art could perform as appropriate.

As described above, the constitution of the Invention concerning the different feature 1 could be conceived of by a person skilled in the art with ease based on the matters described in Cited Document 1.

(2) Regarding the different feature 2

As described in Cited Document 2 that "the low-coherent light source 2 is not one whose center wavelength and spectral half-value width are restricted in particular" ([0025]), and in Cited Document 1 that, regarding the wavelength of a light source, all wavelengths having a coherence length of 30 μm or less ranging from ultraviolet light to infrared light can be used (4(2)B(E) mentioned above), it is possible to perform thickness measurement using interference according to a low-coherent light source by light of any wavelength from ultraviolet light to infrared light. Accordingly, the wavelength of "low-coherent light emitted from the low-coherent light source 2" of Cited Invention can be selected essentially by a person skilled in the art as needed.

In addition, in Cited Document 3, there is described that, when applying the optical interferometry that is a thickness measurement method that can be inherently applied to a transparent sample to a coating film including a pigment and the like, it is preferred to use light of wavelength of 1.3 μm band or 1.5 μm band from a practical viewpoint (4(3)B mentioned above). Therefore, it could be conceived of by a person skilled in the art with ease to make, on the occasion that a coated film having scatterers interposing within ultraviolet curing resin or electron beam curing resin is made to be a measuring object instead of "the multilayer sheet 7a" in Cited Invention, in conjunction with this, use light of a wavelength of 1.3 μm (= 1300 nm) band or 1.5 μm (= 1500 nm) band as "low-coherent light emitted from the low-coherent light source 2" of Cited Invention based on the matters described in Cited Document 3.

As a result, it is obvious that Cited Invention comes to have the constitution of the Invention concerning the different feature 2.

7 Appellant's allegation

(1) The appellant alleges that although the thickness of an opaque thin film is optically measured in the invention of Cited Document 3, a thin film to be a measurement target is not ultraviolet curing resin or electron beam curing resin involving a curing process of a coated film (the written amendment dated May 19, 2017 (hereinafter, simply referred to as "Written amendment"), page 3, line 3 to line 5).

However, as mentioned above in 6(1), it could be conceived of by a person skilled in the art with ease to make, in Cited Invention, a coated film having scatterers interposing within ultraviolet curing resin or electron beam curing resin be a measuring object based on the matters described in Cited Document 1.

Therefore, the appellant's allegation is improper.

(2) The appellant alleges that, while stating that, in a case where measurement of a film thickness is required in order to examine process of coated film formation of a ultraviolet curing coating material that is reactive-cured by ultraviolet light irradiation, the wavelength range of measurement light of 1300 nm to 2000 nm used in the Invention has a particular effect that a negative effect is not given to the curing process of a coating material (Written amendment, page 2, line 5 to line 2 from the bottom), such particular effect of the Invention cannot be obtained by the invention of Cited Document 3, and cannot be acquired also by the inventions according to Cited Document 1, Cited Document 2, and Cited Document 4 (Written amendment, page 3, line 6 to line 7).

However, there is no statement or indication about the effect alleged by the appellant in the description of the Present application, and thus it shall not be taken into consideration.

Even if there is such effect, it is just an obvious effect derived from using light of a wavelength 1.3 μm band or 1.5 μm band as "low-coherent light emitted from the low-coherent light source 2" of Cited Invention, and it cannot be said to be special.

Accordingly, the appellant's allegation cannot be employed.

(3) The appellant alleges that the finding of Examiner's decision that it is a well-known art to use near-infrared light or infrared light rather than visible light when a coating film or the like including a pigment and the like is optically measured is an error, because it is only based on Cited Document 3.

However, as 6(2) mentioned above, as "low-coherent light emitted from the low-coherent light source 2" of Cited Invention, it could be conceived of by a person skilled in the art with ease to make use of light of a wavelength of 1.3 μm (= 1300 nm) band or 1.5 μm (=1500 nm) band based on the matters described in Cited Document 3. Whether or not it is a well-known art to use near-infrared light or infrared light rather than visible light when optically measuring a coating film and the like including a pigment and the like does not influence this finding.

Accordingly, the appellant's allegation is improper.

8 Closing

As mentioned above, the Invention could have been invented with ease by a person skilled in the art based on the inventions described in Cited Document 1 to Cited Document 3, and, therefore, the appellant should not obtain a patent for that under the provisions of Article 29(2) of the Patent Act.

Accordingly, without examining the inventions according to other claims, the Present application should be rejected.

Therefore, the appeal decision shall be made as described in the conclusion.

Dec. 4, 2017

Chief administrative judge: SHIMIZU, Minoru

Administrative judge: KOBAYASHI, Norifumi

Administrative judge: SUHARA, Hiromitsu