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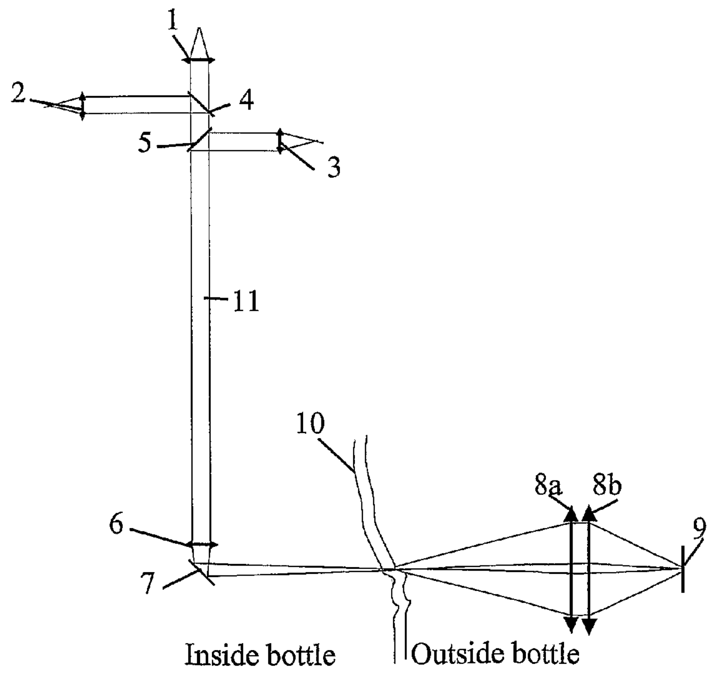
[Continued on next page]

(54) **Title:** INSTRUMENT FOR MEASURING THE THICKNESS OF A COATING ON BOTTLES



(57) **Abstract:** The present invention is related to an apparatus and a method for measuring the coating thickness deposited inside or outside a plastic container by measuring the internal transmission at two wavelengths. One wavelength is in the infrared range, i.e. longer than 750nm, and allows to subtract the absorption of the substrate while the other wavelength is shorter and chosen in a range wherein absorption by the coating is maximum and absorption by the substrate is moderate.

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INSTRUMENT FOR MEASURING THE THICKNESS OF A COATING ON BOTTLES

Field of the invention

[0001] The present invention is related to a device and a method for measuring the thickness of a carbon film or a coating deposited inside or outside plastic bottles or containers.

[0002] The aim of this coating is to produce a barrier against the penetration of oxygen from outside and the escape of CO_2 from inside the container.

[0003] More generally, the instrument built according to this invention is intended to measure the local thickness of any absorbing film deposited on a substrate.

Technological background and prior art

[0004] Plastic containers, especially PET plastic containers, are commonly used for packaging liquid food and beverages. However it is well known that the porosity of this material to common light molecules such as O_2 and CO_2 causes problems for long term conservation of the product.

[0005] It is thus essential to provide a barrier, thereby making the container tight to these molecules. This is generally obtained by extruding the bottle from a multilayer material where one of the layers serves as a barrier when it is made of a properly chosen material.

[0006] Another common way of addressing the problem is to flush a thin layer of material such as carbon or SiO_2

onto the container. Further, the most effective way of obtaining the desired tightness of the container is to deposit a carbon coating inside the bottle.

[0007] However, the final tightness depends on the thickness of the coating and on the regularity of its thickness.

[0008] One way to estimate the resulting tightness of the container is to directly measure the leak resulting from a pressurization of the container with an unwanted gas. This method is long and tedious because the leakage to be measured is very low and the unwanted gas is so common that it is difficult to separately measure the gas from the leak and the ambient gas. This is especially true for oxygen. Hence these measurements are expensive, long - several days for one bottle is not unusual- and inaccurate.

Aims of the invention

[0009] The present invention aims to provide an instrument intended to prevent the drawbacks of prior art.

[0010] Particularly, the invention aims at estimating the tightness of a container by measuring the thickness of a coating deposited on the internal or external surface of the container, using a simple, non-contact, reliable, rapid and non expensive method.

[0011] An additional goal of the invention is to measure the thickness of said coating using opto-electronics means.

[0012] An additional goal of the invention is to draw a thickness surface map of the container.

Summary of the invention

[0013] A first objet of the present invention, as recited in Claim 1, refers to an apparatus for measuring the thickness of a coating on a container such as a bottle made of a transparent substrate, said coating being located either on the external or on the internal surface of the container, characterised in that said apparatus comprises means for simultaneously measuring light transmission of an incident source beam through essentially a same point of the container, making a test sample, at a plurality of different wavelengths, preferably at two different wavelengths.

[0014] A series of preferred embodiments of the apparatus of the invention are described in the dependent Claims 2 to 20.

[0015] A second objet of the present invention relates to a method to be carried out with the afore-mentioned apparatus, for estimating the thickness of a coating deposited on a surface of a transparent bottle with a purpose of quality decision making, characterised by the following steps:

- an internal transmission measurement is recorded at essentially a same point of an uncoated reference bottle in two wavelengths, a short wavelength (SH) lower than 600 nm and a longer wavelength (IR) greater than 700 nm ;
- said internal transmission measurement is repeated for a number of points unaffected by letters or shape irregularities ;
- for each point, the absorption coefficient ratio

$$R_i = ln(Tr^{SH}{}_i)/ln(Tr^{IR}{}_i)$$

and its average

$$R = avrge(R_i)$$

are computed, wherein $Tr^{SH}{}_i$ is the internal transmission at the short wavelength (SH) at point i and $Tr^{IR}{}_i$ is the internal transmission at the longer wavelength (IR) at the same point i ; as a matter of fact, R is the ratio of the absorption coefficient per unit length of the substrate in the two utilised wavelengths ($R = A_s^{SH}/A_s^{IR}$) and is a fixed physical constant for a given substrate and a given pair of wavelengths ;

- an internal transmission measurement is performed for each coated bottle made out of the same substrate material, in the two same wavelengths at a number of regularly spaced points identified by their cylindrical co-ordinates (α, h) ;
- for each said point, one computes the product of the coating thickness $E(\alpha, h)$ by the specific absorption coefficient A of the coating material at the short wavelength (SH), i.e.

$$E(\alpha, h)*A \doteq -ln(Tr^{SH}_{\alpha,h}) + ln(Tr^{IR}_{\alpha,h})*R,$$

where A is a combination of carbon absorption coefficients at the two wavelengths :

$$A = A_C^{SH} - R*A_C^{IR}.$$

These physical coefficients have to be determined independently if one wants to measure the absolute thickness of the film. They can be measured and calibrated if one has samples of the substrate covered with known thickness of carbon coating. Practically, $A_C^{SH} >> A_C^{IR}$ for any wavelength SH < 650 nm and accordingly, one can use $A = A_C^{SH}$ with an error less than 1% at any practical wavelength ;
- $E(\alpha, h)$ data are directly displayed in the form of a false colour map of the bottle ;
- alternatively, one computes the thickness average and standard deviation of all the points measured on the same bottle, i.e.

$$E = avrge[E(\alpha, h)] \text{ and } \delta E = stdev[E(\alpha, h)] ;$$

- the ratio $\delta E/E$ or the false colour map is compared to a suitable minimum threshold value and

- according to the comparison result, the bottle receives the status "test passed" or "rejected".

Short description of the drawings

[0016] FIG.1 shows the transmission ratio for a 0.5 mm thick PET bottle covered with a 50 nm carbon coating and a reference bottle of the same thickness, for clear and dark green PET respectively.

[0017] FIG.2 schematically shows the principle scheme of the optical system according to the present invention.

[0018] FIG.3 schematically shows a preferred embodiment for a source beam combination according to the present invention.

[0019] FIG.4 is a perspective illustration of a preferred overall embodiment for the apparatus of the present invention.

[0020] FIG.5A and 5B show respective elevation and perspective views for the optomechanical part of the apparatus described in FIG.4.

[0021] FIG.6A and 6B show respective cross-sectional and perspective detailed views of the detection block.

Detailed description of the invention

[0022] It is possible to map a barrier thickness in a few minutes using optical means when the barrier material and the substrate absorb light differentially. Carbon for instance is not absorbed in the infrared region of the spectrum, but more and more absorbed when shifting the test wavelength towards shorter wavelengths. It is usually possible to find a wavelength short enough at which the substrate of the bottle is sufficiently transparent to let light go through in order to measure the carbon film. It is very important to note that at least two wavelengths have to be used. Otherwise, it is not possible to separate thickness variations of the carbon film from thickness variations of the substrate, especially when the latter is coloured. It is recommended to use infrared (860 or 930 nm were the most commonly used wavelengths in our system) for substrate correction and a shorter wavelength (we commonly used 530, 460, 410 and 370 nm) for the measuring source.

[0023] It is also important to note that most beverages, in particular beer, are sensitive to light degradation, so that bottlers have a preference for deeply coloured substrate. The instrument for measuring the carbon film must take this constraint into account by providing a variety of wavelengths in the measuring source.

[0024] Hence, the short wavelength source allows to measure the cumulated thickness of the substrate and of the carbon film, while the infrared source allows to measure the substrate thickness alone. The carbon thickness is computed by subtracting the substrate thickness from the total thickness.

[0025] It is theoretically possible to deduce the carbon thickness from two measurements made at only one wavelength, but this technique has no practical application because it supposes that:

- one has a reference bottle made out of the same substrate without carbon coating ;
- the reference bottle and all the coated bottles to be measured have exactly the same substrate thickness everywhere.

[0026] This last condition is clearly impossible to fulfil since there are usually three main sources of thickness variation in the bottles from a same series:

- the blowing process induces thickness variations of at least a factor of two within a same bottle, for instance between the neck and the body ;
- the thickness variations between individual bottles are not under control inside the manufacturing process ; this yields arbitrary unavoidable variations of about 10% in thickness mapping between bottles;
- the lettering and various 3D figures which appear on the bottle surface induce thickness variations of at least 40% locally.

[0027] Hence, it is obvious that an apparatus with only one wavelength of measurement cannot practically measure the carbon thickness even when its use is limited to clear bottles.

[0028] Carbon coating deposition on a transparent medium can be detected and measured as far as the optical properties, namely bulk absorption, are markedly different for the substrate and for the film, provided that two wavelengths are utilised, a first wavelength in the infrared range and a second, shorter wavelength, suitably chosen according to its dependence on the colour of the substrate.

[0029] In the case of carbon coatings, the absorption is very low in the near infrared range (> 750 nm) and increases monotonically towards shorter wavelengths. The transmission ratio between a 0.5 mm thick PET bottle covered with a 50 nm coating of carbon and a reference bottle of the same thickness is shown in FIG.1 for clear PET and for dark green PET which are quite commonly used in beer bottling.

[0030] Both curves show the transmission ratio for a carbon coating on a PET bottle as a function of wavelength. The regular curve pertains to the clear PET ; the irregular curve representing the green PET should coincide with the former one at the higher wavelengths or where there are both regular, since it reflects only the properties of the carbon layer. The small but significant difference between both curves where they are regular is due to the fact that we used the external transmissions, which are affected by reflectivity, to compute the curves. With the correction for reflectivity, both curves would reach ordinate 1.00 for wavelengths longer than 800 nm.

[0031] One sees in these curves that the shorter the wavelength, the more sensitive the measurement to the carbon coating. For most coloured PET, the most sensitive wavelength is around 375 nm where the transmission of the coated bottle is only 46% of the transmission of the uncoated one. Some bottles however are completely opaque at this wavelength. The measurement can then be performed either at 470 nm (blue) or 530 nm (green) with progressively less sensitivity.

[0032] FIG.1 illustrates this situation for the dark green PET commonly used for bottling beer : the regions under 450 nm and between 600 and 725 nm, where the normal transmission is strongly perturbed, as shown by the continuous curve, are the spectral ranges where the green PET is essentially opaque and where no accurate measurement can be obtained.

[0033] It is thus essential that the intended instrument provides the choice of several short wavelengths to be combined with the measurement at a wavelength in the infrared. This allows the user to measure the carbon layer thickness on any coloured substrate.

[0034] Practically, we recommend to use the three colours of the tristimulus (red, green and blue) on top of the infrared and near ultraviolet. This allows to compute the colour of the bottle in an international scale system (such as L*, a*, b*). This is very useful since the exact colour of the bottle is part of the trademark of the beverage producer. The carbon film will alter the colour shade ; a correction can be computed and introduced in the colouring of the substrate to keep the total result of the coated bottle unchanged.

Criterion #1

[0035] It is absolutely mandatory that, for each measurement, the transmissions at the two wavelengths be measured exactly at the same point of the bottle. Otherwise, it is not sure that the PET thickness is the same for both colors and the second term in eq.(2) -see below- which is a corrective term for the short wavelength absorption of the PET substrate will be wrong. This is especially dangerous where bottles are embossed with lettering and logos. In these places, the substrate thickness varies on a very short distance and would prevent any reliable measurement of the coating thickness, inasmuch that some models of bottle are nearly completely covered with such features.

[0036] This problem is addressed in the solution of the invention by joining the two beams and focusing them with a very low numerical aperture in the near-punctual region where the measurement is to be performed.

[0037] Owing to various possible diameters of the bottles to be measured, exact focus on the wall 10 of the bottle cannot be maintained. As shown in FIG.2, one can use a small, for instance 4.5 mm, diameter parallel beam 11 entering axially into the bottle, reflected at 90° radially by a folding mirror 7 towards the wall of the bottle and focused by a focusing lens 6 at approximately 38 mm from the axis. The diameter of the measuring spot on the wall of bottles between 50 and 100 mm diameter would vary from 0.5 mm to 2.0 mm at most. The combination of the source beams is realised through dichroic beam splitters 4,5.

[0038] In FIG.2, three sources Sir 1, Sxx 2 and Ssh 3 are represented, but virtually as many sources as one wishes could be used ; in a typical preferred embodiment shown in FIG.3, five sources are used: IR (860 nm), UV (370 nm) and the three fundamental colours (RGB).

Criterion #2

[0039] It is mandatory that all or at least most of the light diffused at the bottle wall 10 by sample defects or features such as letters be collected by the detector. This is achieved by using a very large aperture for the collecting lens. In a preferred embodiment, one uses a double collecting lens : a f/1 collecting lens 8a followed by a f/1 focusing lens 8b. At the focus of this last double lens a large aperture (100 mm²) detector 9 collects all the light diffused from the bottle wall. The size of the detector and the distances are such that collection efficiency remains unchanged for bottles of diameter between 20 mm and 110 mm.

Criterion #3

[0040] The various signals from the sources have to be measured individually, while they are mixed (multiplexed) on the detector. Separation of the signals can be achieved in different ways:

- optically, by using dichroic beam splitters in the reverse way they were used for combining the source beams ;
- electronically, by modulating each source at a specific frequency and either extracting the various signals by

operating a Fourier transform of the mixed signal, either synchronously demodulating the mixed signal at each frequency, or by band-pass filtering the mixed signal.

[0041] The preferred solution is synchronous demodulation because:

- band-pass filters (optical as well as electronic filters) cannot be made as narrow as one would wish and at the same time they have a flat top shape to take care of shift of frequencies (of the filter as well as of the source). This makes the performance of band-pass filters very poor in precision photometry. Moreover dichroic separation would not work with high aperture optics at the detector ;
- synchronous demodulation makes efficient use of the information we have on the instantaneous frequency, or frequency and phase, of the signal to be detected. On the contrary, Fourier transforming a signal where, let us say, five frequencies are mixed results in making a lot of computation for determining useless information, i.e. the amplitude of the signal at frequencies where it is known there is no signal. Note however that both methods are approximately equivalent if there is no noise in the mixed signal, but this is of course never the case.

Criterion #4

[0042] It is important that the degree of polarisation in the measuring beam be as low as possible. The wall of the bottle can be considered as stretched plastic and could show some degree of birefringence. Hence, the dichroic beam splitters are utilised at low incidence angle. In a preferred embodiment, this angle is set at 15° as shown in FIG.3.

[0043] The secondary mirrors 15 facing each lateral source (R, G, B, UV) and folding the beam towards the beam splitters 16 are aluminised and bring a minimum of polarisation. If the resulting polarisation would cause a problem in very special situations, it would be necessary to correct it by the use of a retarding plate after the collimating lens in each source (or a zero order plate in the resulting beam).

[0044] In FIG.3, the axial beam is represented horizontal. The IR source is at the left, all other sources are above the parallel beam. The folding aluminised mirrors 15 are at the bottom and the dichroic beam splitters 16 are crossed at 15° incidence by the axial beam. The latter exits horizontally to the right.

[0045] For the same reason, the sources are ordinary LEDs and not laser diodes because the latter usually show a large degree of polarisation and would require careful retardation of each beam separately.

Criterion #5

[0046] For measuring the carbon coating thickness, it is important to use a robust algorithm as described hereinafter.

[0047] The latter relies on the fact that the carbon layer is transparent in the IR. This allows to measure the absorption ratio of the bottle substrate at the two wavelengths used for the measurement. This operation has to be performed for each substrate using an uncoated reference bottle. The absorption ratio R can be estimated with very high accuracy. It is used for subtracting, from the measured total absorption at wavelength SH, the part due to the bottle substrate, and to take into account its thickness variations. It is important to notice that, without this, one would not be able to separate the thickness variations of the carbon layer and those of the substrate. All the bottle features would then appear as carbon features.

Measurement algorithm

<u>*Reference Measurement*</u>

[0048] This measurement is used to characterise the optical properties of the PET. It is performed on an uncoated bottle of the same material, but not necessarily the same thickness. Its outcome is the ratio of the absorbing coefficients for the two utilised wavelength bands.

[0049] The (uncoated) reference bottle is measured and its transmission *at the same place for both wavelengths* is recorded at a certain number of "normal" points, i.e. points unaffected by letters or shape irregularities.

[0050] Let us call $Tr^{SH}{}_{i}$ the internal transmission at the short wavelength *SH* at point *i*, and $Tr^{IR}{}_{i}$, the internal transmission IR at the *same* point *i*. Let us compute for each point the absorption coefficient ratio :

$$R_i = ln(Tr^{SH}{}_i)/ln(Tr^{IR}{}_i) \quad (1)$$

and their average :

$$R = avrge(R_i).$$

R is the ratio of the absorption coefficient per unit length of the substrate in the two utilised wavelengths ($R = A_s{}^{SH}/A_s{}^{IR}$) and is a fixed physical constant for a given substrate and a given pair of wavelengths.

Bottle Measurement

[0051] Each bottle made out of the same material is then measured in the two wavelengths at a number of regularly spaced points identified by their cylindrical co-ordinates (α, h).

[0052] For each point, one computes first the internal transmissions in the two wavelengths and the relative carbon coating thickness. Precisely, the result is the product of the thickness $E(\alpha, h)$ by the specific absorption coefficient A of the carbon at the wavelength SH :

$$E(\alpha,\ h)*A = -ln(Tr^{SH}_{\alpha,h}) + ln(Tr^{IR}_{\alpha,h})*R \quad (2),$$

where A is a combination of carbon absorption coefficients at the two wavelengths :

$$A = A_C^{SH} - R*A_C^{IR}.$$

These physical coefficients have to be determined independently if one wants to measure the absolute thickness of the film. They can be measured and calibrated if one has samples of the substrate covered with known thickness of carbon coating. Practically, $A_C^{SH} >> A_C^{IR}$ for any wavelength SH < 650 nm and accordingly, one can use $A = A_C^{SH}$ with an error less than 1% at any practical wavelength.

[0053] These data can be displayed directly as false colour maps of the bottle. One also computes the average and standard deviation of all the points measured on the same bottle:

$$E = avrge[E(\alpha,\ h)] \text{ and } \delta E = stdev[E(\alpha,\ h)] \quad (3).$$

[0054] It turns out that the ratio between the average and its standard deviation $E/\delta E$ is a very sensitive criterion of the overall quality of the coating. This is because this ratio characterises the inhomogeneity of the layer, i.e. its trend at showing thinner and thicker regions, the first one being liable for leaks and the second one being useless.

[0055] The internal or bulk transmission is the usual transmission, i.e. the external transmission, corrected for the reflections at both faces of the wall.

[0056] The reflectivity coefficient is different and should be measured for each wavelength.

[0057] The reflectivity coefficients of the uncoated plastic do not vary very much and average coefficients can be used without loss of accuracy. The coefficients for the coated plastic vary with the thickness and the nature of the coating and with the wavelength especially if the thickness is an appreciable fraction of the wavelength. These coefficients have to be measured on a sample of coated plastic of each category. If these corrections are not applied, i.e. if all reflectivity coefficients are set to 0, the coating thickness measurement will indicate a wrong value but the relative thickness of a bottle (its thickness map) will be roughly correct. These corrective coefficients can be calibrated if one has samples of the substrate coated with known thicknesses of carbon in the range to be measured. This calibration should be performed once for all for each substrate.

Description of a preferred embodiment of the invention

[0058] A preferred embodiment for the device of the invention is illustrated on FIG.4 showing the casing of the apparatus and on FIG.5A, 5B and 6A, 6B showing various details of the actual instrument.

[0059] The whole instrument is contained in two metallic cabinets 100 and 200. Cabinet 100 contains all the opto-mechanical parts and the proximity electronics, while cabinet 200 contains the computer and its accessories. The data acquisition card is a 8x24 bits A/D simultaneous converter clocked at 104 Kcps.

[0060] The opto-mechanical part inside cabinet 100 is shown in more details on FIG.5A and 5B. The cabinet 100 comprises a five-source system 20 and a light conducting tube 21 terminated by a lens and folding prism 22. These elements are hidden by the mobile weight 23 whose base is shaped as a cone in order to centre the mouth of the bottle 24 when the latter is lifted in the measuring area. The bottle 24 is sitting on a turntable 25, mounted on a slide mechanism 26. The latter can move the bottle upwards up to 450 mm by steps of 0.1 mm. The bottle is represented in the lower position ready to start the measurements.

[0061] The detection block 27 is shown in more details on FIG.6A and 6B. It comprises collecting lenses 28, a detector 29 and a preamplifier board. It also comprises a rotating shutter 30 that allows measuring a transmission comprised between 0% and 100% for calibration, for instance by steps of 25%. This calibration operation is done automatically before and after measuring each bottle. The number of steps in rotation and in height is programmable.

[0062] The computer analyses the data in real time and yields at the end of the measurement a chart showing the map of carbon thickness and indications for bottle and process identification, parameters of the measurements and decision about the quality of the coating.

CLAIMS

1. Apparatus for measuring the thickness of a coating on a container such as a bottle made of a transparent substrate, said coating being located either on the external or on the internal surface of the container, characterised in that said apparatus comprises means for simultaneously measuring light transmission of an incident source beam through essentially a same point of the container, making a test sample (10), at a plurality of different wavelengths, preferably at two different wavelengths.

2. Apparatus according to Claim 1, characterised in that a first one of said wavelengths is longer than 700 nm and a second one is shorter than 600 nm.

3. Apparatus according to Claim 1 or 2, characterised in that it comprises dichroic filters (4, 5, 16) through which said monochromatic beams components (1, 2, 3 ; IR, R, G, B, UV) are combined to form a single parallel test beam (11) containing all the beams of different wavelengths.

4. Apparatus according to anyone of Claims 1 to 3, characterised in that it comprises means for modulating each source beam (1, 2, 3 ; IR, R, G, B, UV) at a distinct fundamental frequency to prepare its discrimination after detection on a single detector (9).

5. Apparatus according to Claim 3 or 4, characterised in that it comprises means for focusing the single test beam (11) on or close to the test sample (10) at a relative aperture low enough for insuring that all the beams components cross the test sample (10) at the same place with a tolerance equal to 5, preferably 3, tenth of a mm maximum.

6. Apparatus according to anyone of Claims 3 to 5, characterised in that it comprises a large relative aperture lens (8a, 8b) to collect said single test beam (11) that has passed through the sample (10) and to direct said single test beam (11) therefrom to a large area detector (9).

7. Apparatus according to anyone of Claims 3 to 6, characterised in that it comprises means for discriminating the signal of each source from the other ones after detection and measuring said signal according to its modulation frequency.

8. Apparatus according to Claim 7, characterised in that said means comprise an electronic band-pass filter centred on each source frequency.

9. Apparatus according to Claim 7, characterised in that said means comprise Fourier transform of the composite signal.

10. Apparatus according to Claim 7, characterised in that said means comprise synchronous detection of each signal, i.e. multiplicating the composite signal by the modulating signal and low pass filtering.

11. Apparatus according to Claim 10, characterised in that said means are digital or comprise analogue lock-in amplifiers.

12. Apparatus according to anyone of the preceding Claims, characterised in that the coated container is a clear or coloured plastic, preferably a PET, bottle with a carbon coating inside or outside the bottle.

13. Apparatus according to Claim 12, characterised in that it comprises means (25, 26) for rotating around the bottle and transporting the bottle along its axis respectively so that to scan the point where the test beam (11) crosses the bottle wall (10) in order to cover the whole surface except the bottom of the bottle.

14. Apparatus according to Claim 12 or 13, characterised in that it comprises means for removing the bottle completely from the test beam (11), so that the 100% transmission point can be calibrated.

15. Apparatus according to Claim 14, characterised in that it comprises a shutter (30) for calibrating the 0% transmission point.

16. Apparatus according to anyone of Claims 13 to 15, characterised in that a computer, a sequencer or a programmable automate is provided to automatically control all operations and movements.

17. Apparatus according to Claim 16, characterised in that it comprises a data processing algorithm implemented in the computer and means for displaying on a screen and/or printing out a resulting map of the carbon coating thickness at the surface of the bottle.

18. Apparatus according to Claim 17, characterised in that the data processing algorithm comprises means for comparing criteria on the average thickness and its relative variations, preferably its standard deviation, to prefixed limit values in order to discriminate automatically deficient coatings.

19. Apparatus according to anyone of the preceding Claims, characterised in that the sources are light emitting diodes (LED).

20. Apparatus according to anyone of the preceding Claims, characterised in that it comprises means for computing the colour of the container in an international standard system such as (L*, a*, b*) by use of the transmission values measured in the R, G, B colours.

21. Method to be carried out with the apparatus according to anyone of the Claims 1 to 20, for estimating the thickness of a coating deposited on a surface of a transparent bottle with a purpose of quality decision making, characterised by the following steps :

- an internal transmission measurement is recorded at essentially a same point of an uncoated reference bottle in two wavelengths, a short wavelength (SH) lower than 600 nm and a longer wavelength (IR) greater than 700 nm ;
- said internal transmission measurement is repeated for a number of points unaffected by letters or shape irregularities ;
- for each point, the absorption coefficient ratio

$$R_i = ln(Tr^{SH}{}_i)/ln(Tr^{IR}{}_i)$$

and its average

$$R = avrge(R_i)$$

are computed, wherein $Tr^{SH}{}_i$ is the internal transmission at the short wavelength (SH) at point i and $Tr^{IR}{}_i$ is the internal transmission at the longer wavelength (IR) at the same point i ;
- an internal transmission measurement is performed for each coated bottle made out of the same substrate material, in the two same wavelengths at a number of regularly spaced points identified by their cylindrical co-ordinates (α, h) ;
- for each said point, one computes the product of the coating thickness $E(\alpha, h)$ by the specific absorption coefficient A of the coating material at the short wavelength (SH), i.e.

$$E(\alpha, h)*A = -ln(Tr^{SH}{}_{\alpha,h}) + ln(Tr^{IR}{}_{\alpha,h})*R ;$$

- $E(\alpha, h)$ data are directly displayed in the form of a false colour map of the bottle ;
- alternatively, one computes the thickness average and standard deviation of all the points measured on the same bottle, i.e.

$$E = avrge[E(\alpha, h)] \text{ and } \delta E = stdev[E(\alpha, h)] ;$$

- the ratio $\delta E/E$ or the false colour map is compared to a suitable minimum threshold value and
- according to the comparison result, the bottle receives the status "test passed" or "rejected".

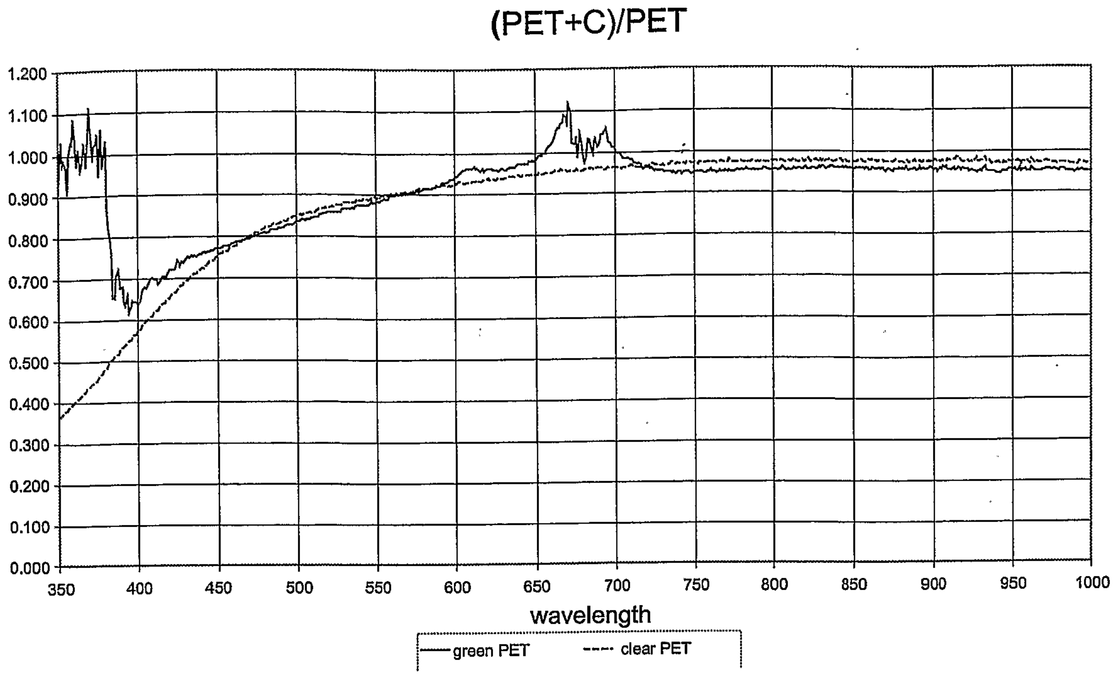
(PET+C)/PET
1.200
1.100
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
wavelength
green PET
clear PET

FIG.1

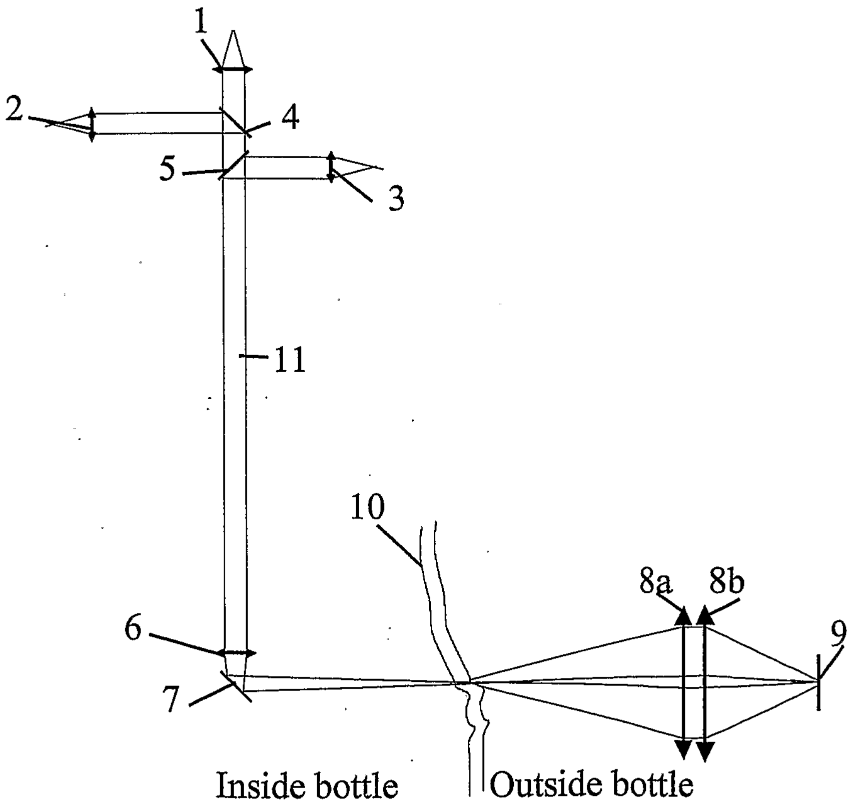
1
2
3
4
5
11
10
6
7
8a
8b
9
Inside bottle
Outside bottle

FIG.2

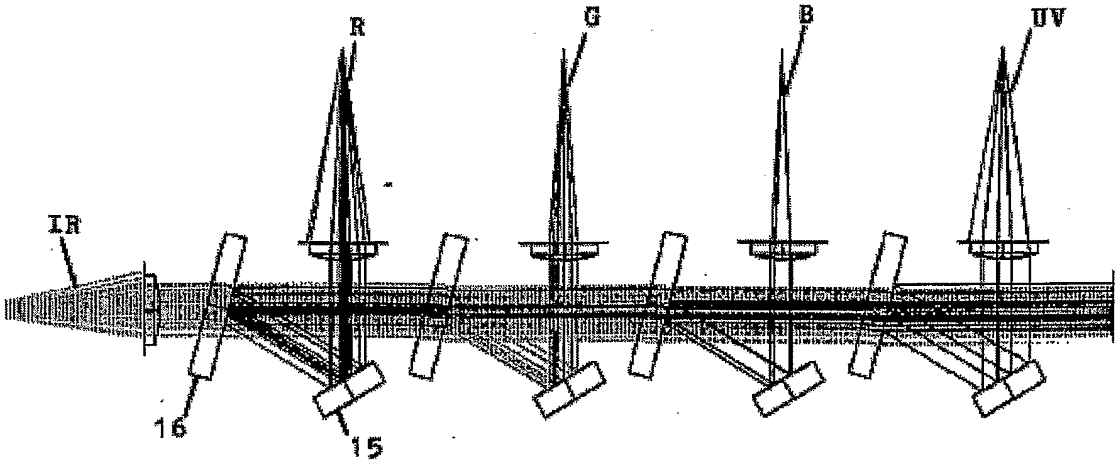

FIG.3

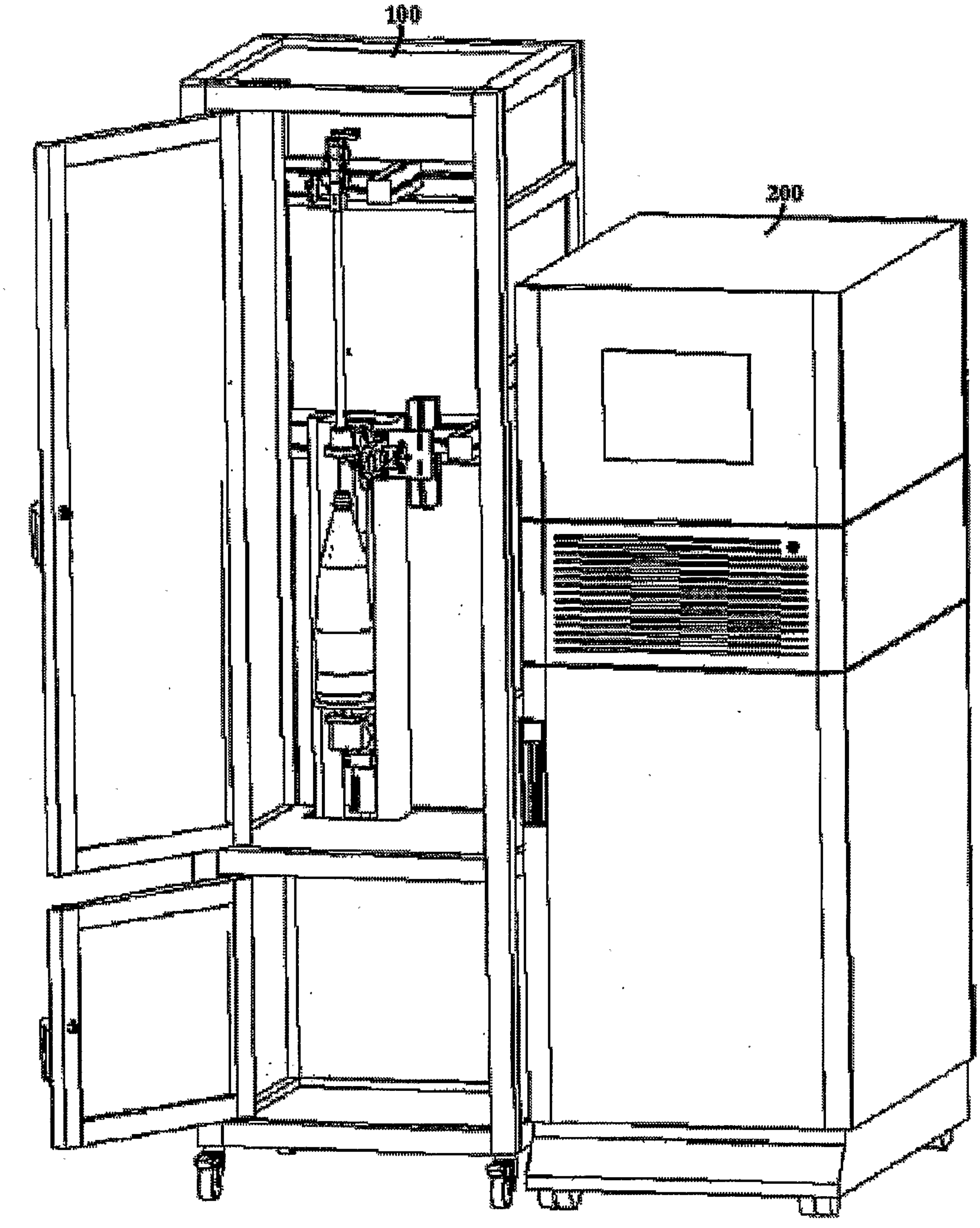

FIG. 4

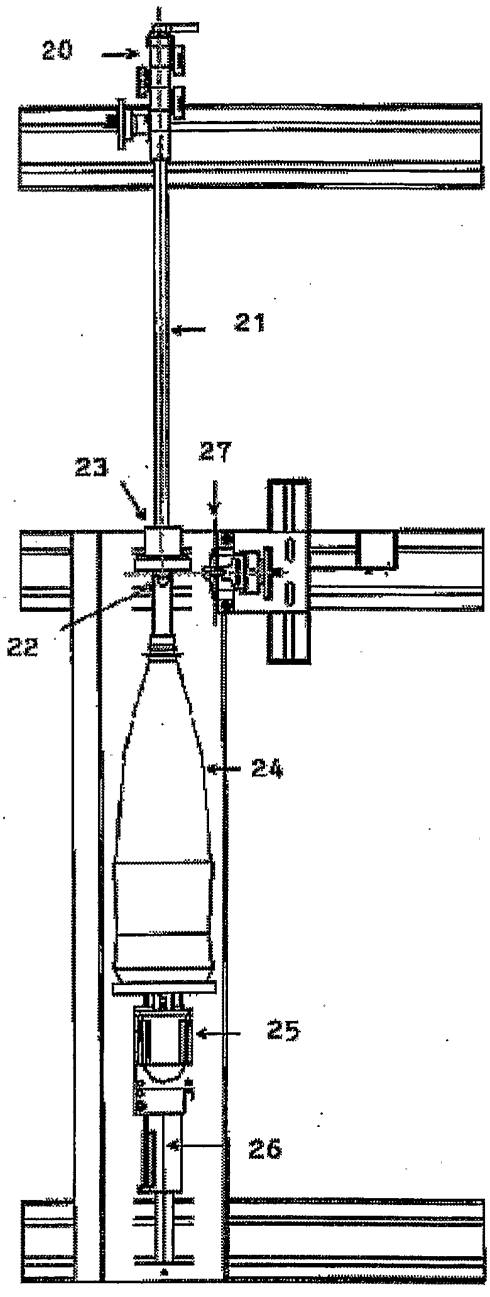

FIG. 5A

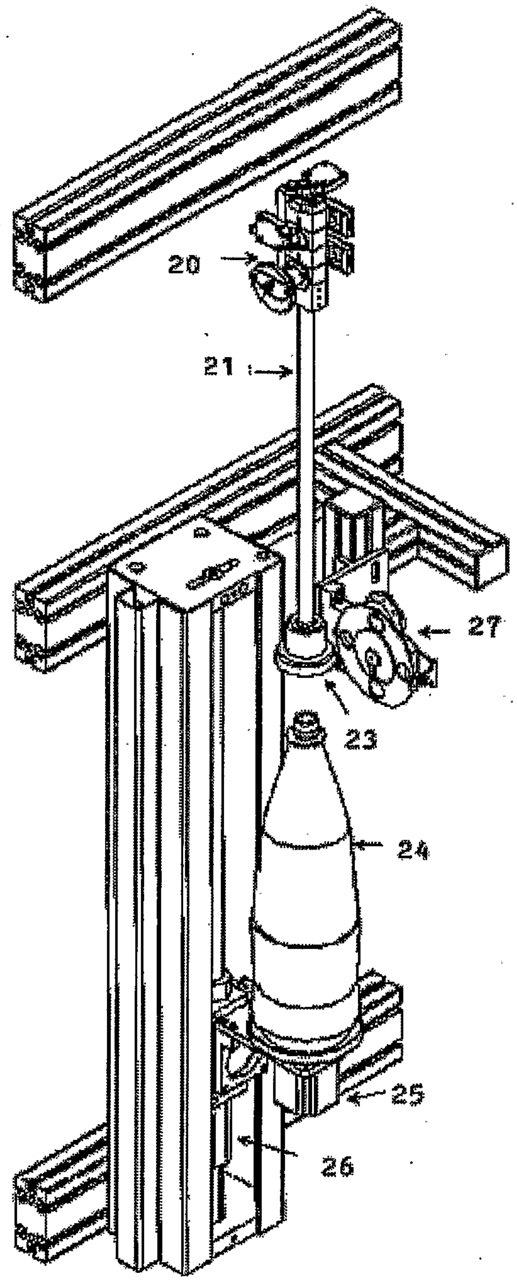

FIG. 5B

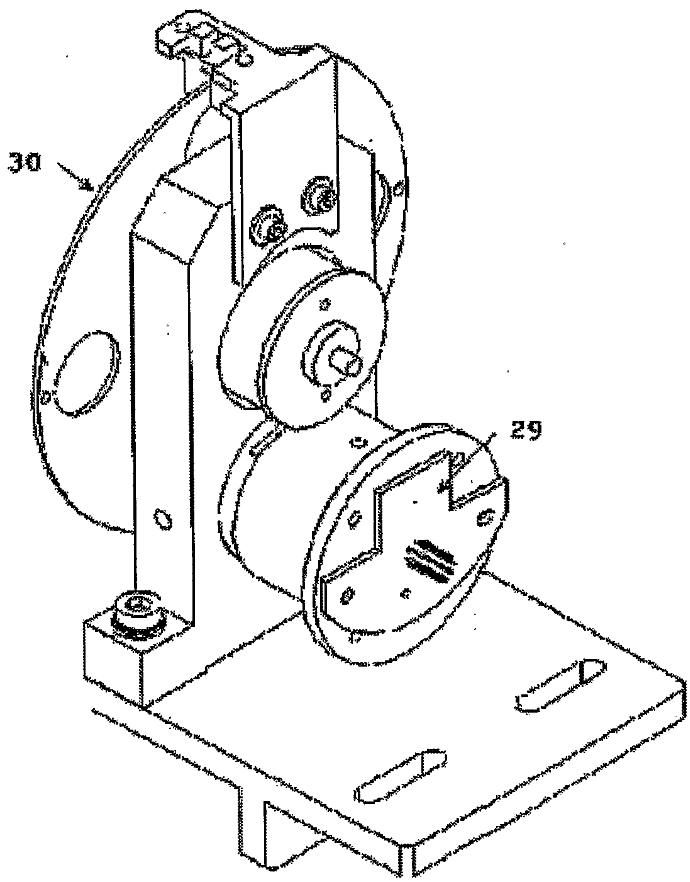

FIG. 6B

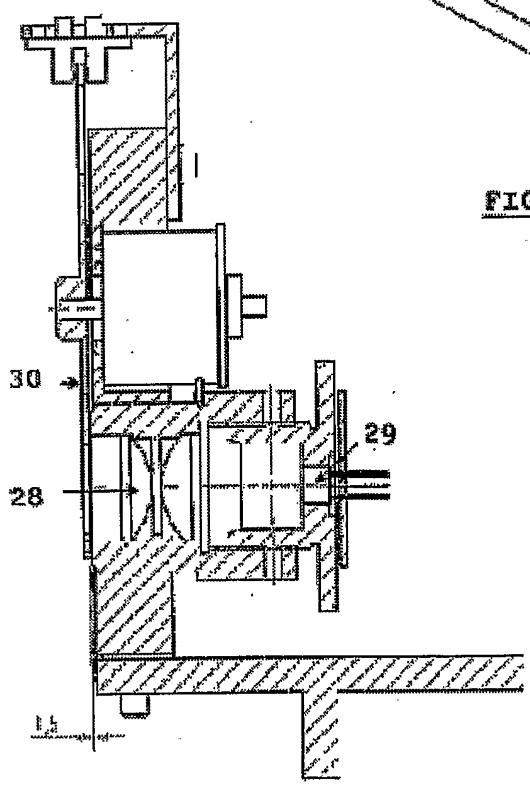

Fig. 6A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/BE2005/000050

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01B11/06 G01N21/90

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 7 G01B G01N

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 practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 737 237 A (ZURASKY J,US) 5 June 1973 (1973-06-05)	1-20
A	column 2, line 16 - column 3, line 2 abstract; figures 1,3	21
X	US 4 243 882 A (YASUJIMA ET AL) 6 January 1981 (1981-01-06)	1-20
A	column 1, line 51 - column 2, line 53 column 4, line 31 - column 6, line 4 abstract	21
X	US 4 808 824 A (SINNAR ET AL) 28 February 1989 (1989-02-28)	1-20
A	column 2, line 42 - column 4, line 65 column 5, line 41 - column 6, line 50 abstract; figures 1,3,4	21

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 July 2005	23/08/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Passier, M

INTERNATIONAL SEARCH REPORT

International Application No
PCT/BE2005/000050

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 619 330 A (EHEMANN, JR. ET AL) 8 April 1997 (1997-04-08) column 2, line 65 - column 3, line 6 abstract; figures 1,2,5 -----	1-20 21
A	US 2004/065841 A1 (DARR RICHARD C ET AL) 8 April 2004 (2004-04-08) paragraphs '0019!, '0020! paragraph '0026! - paragraph '0032! paragraph '0049! - paragraph '0053! abstract; claims 1-20; figures 1,2 -----	1-21

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INTERNATIONAL SEARCH REPORT

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