



**Abstract**

Biochemical assay comprising

- 5 a) a substrate (16) being capable of binding at least a target analyte and eventually other constituents contained in a biological sample,
- b) a test zone (18) on the substrate (16) for sample application,
- 10 c) a non-immobilized conjugate reagent provided in the test zone (18) for labelling the analyte, said conjugate reagent being capable of specific binding to the analyte but remaining unbound to the substrate (16),
- 15 d) a flow path (24) for transporting a washing liquid (22) through the test zone (18) and washing an excess of unbound conjugate reagent away from the test zone (18),
- e) whereby the test zone (18) is also a detection area for detecting the labelled analyte.

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**BIOCHEMICAL DEVICE****Description**

5 The invention concerns a biochemical assay and a  
process for determining at least one target analyte in  
a biochemical sample, especially glycated and total  
haemoglobin in a blood sample. The invention also  
concerns an analytical test element on the basis of  
10 such a biochemical assay.

The glycation of haemoglobin is increased in the blood  
of diabetes patients. The increase depends on the  
concentration of glucose, free to move through the  
15 erythrocyte membrane and the period of incubation of  
the protein with glucose, via a non-enzymatic reaction.  
Hence the determination of glycated haemoglobin (namely  
HbA1c) allows a retrospective estimate of the average  
glucose concentration and thus of the quality of the  
20 metabolic control of the diabetic patient. The  
disappearance of HbA1c from the blood depends on the  
lifetime of the erythrocytes (the average lifetime of  
these cells is about 120 days with a half-life of 60  
days). HbA1c is defined as haemoglobin A that has been  
25 glycated by glucose with a slow but irreversible  
reaction on the N-terminal valine residues of the  $\beta$   
chains. The HbA1c value is usually stated as a  
percentage of the total haemoglobin which requires a

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determination of the haemoglobin concentration from the same blood sample in addition to the HbA1c content.

In connection to this, it is already known to use test  
5 elements in order to provide a simple handling and rapid determination. A test element is generally understood as a carrier-bound (micro) system which enables sample preparation for an immediate analysis independent of a laboratory environment. Such test  
10 elements are usually intended to be single-use articles or disposables for near patient diagnostics in which all reagents that are necessary to carry out the test are provided on the carrier or component so that they can be used without requiring special handling.

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In this context US 6,399,293 B1 discloses a teststrip-based system comprising a sample application zone, a reagent zone containing non-immobilized signal-generating molecules, a separation zone for separating  
20 the excess signal-generating molecules that are not bound to glycated haemoglobin and a detection zone. The separation occurs by means of a positively charged membrane binding only the excess of a negatively charged signal-generating ligand in the separation  
25 zone. The total haemoglobin including the labeled HbA1c will not be bound to the membrane and thus can be transported through the different zones within the sample liquid.

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In accordance with one aspect of the present invention, there is provided a biochemical device comprising:

a) a substrate (16), i) the substrate comprising a test zone (18) on the substrate (16) for sample application, ii) the substrate being capable of non-specifically binding at the test zone (18) at least a target analyte contained in a biological sample, b) a non-immobilized conjugate reagent provided in the test zone (18) for labelling the target analyte, said conjugate reagent being capable of specific binding to the target analyte but remaining unbound to the substrate (16), c) a flow path (24) for transporting a washing liquid (22) through the test zone (18) and washing an excess of unbound conjugate reagent away from the test zone (18), d) whereby the test zone (18) is also a detection area for detecting the labelled target analyte.

In accordance with another aspect of the present invention, there is provided an analytical test element for determining the ratio of glycated to total haemoglobin in a blood sample comprising: a) a substrate (16), i) the substrate comprising a test zone (18) on the substrate (16) for sample application, ii) the substrate being capable of non-specifically binding at the test zone (18) at least haemoglobin contained in a blood sample, b) a conjugate, provided non-immobilized in the test zone (18) for labelling glycated haemoglobin, c) a flow path (24) for transporting a washing liquid (22) through the test zone (18) and washing an excess of unbound conjugate away from the test zone (18), d) whereby the test zone (18) is also a detection area for detecting the labelled and total haemoglobin.

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In accordance with yet another aspect of the present invention, there is provided a process for determining at least one target analyte in a biochemical sample, comprising the following steps: a) providing a substrate (16) comprising a finite test zone (18) and being capable of non-specifically binding at the test zone at least the target analyte and other constituents contained in the sample, b) providing a non-immobilized conjugate reagent in the test zone (18) for labelling the target analyte, said conjugate reagent being capable of specific binding to the target analyte but remaining unbound to the substrate (16), c) applying the sample in the test zone (18) of the substrate (16), d) transporting a washing liquid (22) through the test zone (18) and washing an excess of unbound conjugate reagent away from the test zone (18), e) detecting the labelled target analyte in the test zone (18).

More generally the use of test elements for different binding assays is well-known. For example, US 4,094,647 describes a device that comprises a material capable of transporting a solution by capillary action. Different zones on the strip contain the reagents needed to perform the binding assay and to produce a detectable signal as the analyte is transported through the zones. The binding reaction occurs between an antigen and a complementary antibody. Many variations of the method have followed. However, despite all the activity in this field, methods have been developed always in the same direction involving the use of some immobilized reagent, mostly antibody, resulting in higher effort and costs for reagents and chemistry integration, and/or involving a chromatographic run, generally requiring the need for the analyte to go through several steps in space and time to meet the reaction and detection conditions.

The object of the invention is to overcome most limitations of the prior art, and in particular to reduce the assay complexity, to minimize the necessary sample amount, to use less reagents, avoiding in particular immobilization and immunochemistry, while maintaining accuracy and reproducibility of the test with ease of handling.

The invention is based on the idea to overlap application, reaction and detection in one spot of a solid support or substrate. Correspondingly, it is suggested a biochemical assay device comprising:

- a substrate being capable of unspecifically binding at least a target analyte and eventually other species contained in a fluid sample,
- a test zone on the substrate for sample application,
- a non-immobilized conjugate reagent provided in the test zone for labelling the analyte, said conjugate reagent being capable of specific binding to the analyte but remaining unbound to the substrate,
- a flow path for transporting a washing liquid through the test zone and washing an excess of unbound conjugate reagent away from the test zone,
- whereby the test zone is also a detection area for detecting the labelled analyte.

Thereby, several advantages are achieved. The sample application, reaction and detection occur in one and the same spot or zone. Hence the analytes do not have to be transported meaning that higher reproducibility can be expected. A compact design can be achieved, with minimized reaction and sample volumes, minimized strip length and lower washing volumes. The handling is made easy and no elaborate separation steps are required.

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In a favourite embodiment an integrated reservoir contains the washing liquid and the reservoir can be fluidly connected to the flow path. According to a further improvement the reservoir is connectable to the flow path by an element rupturing a wall of the reservoir.

For a self-controlled transport it is advantageous that the flow path is a porous or capillary structure capable to transport the washing liquid by capillary forces.

Alternatively to direct sample application, a microfluidic system can be provided for transport of sample fluid to the test zone.

An adsorbing element is advantageously arranged on the flow path downstream the test zone for taking up liquid waste.

Further, it is advantageous when the substrate is a solid phase chromatographic layer. The analyte is typically a protein and the conjugate reagent is relatively small compared to proteins and is a molecule other than a protein.

Such a conjugate molecule consists of a more or less polar organic group as the signalling part and a small organic or inorganic group as the ligand part, which recognizes and binds specifically to the target

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analyte, like for example boronic acid, a chelating group, a peptide epitope or an oligonucleotide.

The conjugate reagent should have a high coefficient of  
5 partition for the washing liquid compared to the substrate. Depending on the conjugate chemical structure, the washing liquid can be an organic solvent, a mixture of water and a miscible organic solvent or just an aqueous solution, can contain a  
10 surfactant, and can be buffered at an optimal pH, so that the analyte sticks to the substrate while the binding reaction of the conjugate still occurs and the excess of unbound reagent can be removed.

15 In an advantageous embodiment the conjugate reagent is provided in dried form in the test zone before the sample application.

The invention also concerns an embodiment consisting of  
20 an analytical disposable test element, for a biochemical assay according to the invention, and a device for processing the analytical test element.

With regard to the methodology the object mentioned  
25 above is achieved by a process for determining at least one target analyte in a biochemical sample, comprising the following steps

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- providing a substrate being capable of binding at least the target analyte and eventually other constituents contained in the sample,
  - providing a non-immobilized conjugate reagent in the test zone for labelling the analyte, said conjugate reagent being capable of specific binding to the analyte but remaining unbound to the substrate,
  - applying the sample in a finite test zone of the substrate,
  - transporting a washing liquid through the test zone and washing an excess of unbound conjugate reagent away from the test zone,
  - detecting the labelled analyte in the test zone.
- 15 In a particular preferred assay, blood is used as a sample. The target analyte is haemoglobin, specifically glycated haemoglobin. The blood is haemolysed by a haemolysing reagent present preferably also in dried form in a suitable substrate, on which total
- 20 haemoglobin adsorbs. The conjugate reagent also present in dried form in the sample application zone is solubilized by the sample and binds to the glycated haemoglobin. The excess of unbound conjugate reagent is then transported away by the laterally flowing washing
- 25 liquid. Total haemoglobin and glycated haemoglobin are photometrically detected at different respective wavelengths, so that the ratio of glycated to total haemoglobin can be determined.

The invention is elucidated in more detail in the following on the basis of an embodiment shown schematically in the drawings, wherein

5 Fig. 1 shows a measuring device comprising a test element for a biochemical assay in longitudinal cross-section;

Fig. 2 shows the test element in top view;

10

Fig.3a and b show test results of a preferred assay carried out on a TLC plate of standard format.

The measuring device 10 shown in fig. 1 allows a  
15 disposable strip-shaped test element 12 to be processed for determining total haemoglobin and HbA1c values of a blood sample in a single-use test. As further illustrated in fig. 2, the test element 12 essentially comprises a carrier 14, a substrate 16 with a test zone  
20 18 formed therein, a reservoir 20 containing a washing liquid 22 and a flow path 24 for the transport of washing liquid through the test zone.

The carrier 14 is formed as an elongated thin strip of  
25 a plastic or metal foil, with a central part where a thin layer of chromatographic material, analogous to a TLC plate, is layered as the substrate 16. The substrate 16 has a microporous structure 26 serving as

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the flow path 24 essentially parallel to the longitudinal axis of the strip 14.

The reservoir 20 is a deformable blister which has a  
5 bottom wall 28 that can be ruptured or punctured by an  
integrated barb 30 so that the washing liquid 22 is  
forced out of the created hole into a soft compressible  
adsorbing material 32 bordered by a soft compressible  
U-frame 34. Mechanical actuation can be accomplished by  
10 a pressing block 36 for puncturing the blister and a  
pressing cylinder 38 to push the liquid 22 out.

The adsorbing material 32 overlaps the upstream end of  
the substrate 16 to enable liquid transfer into the  
15 microporous structure 26. An adsorbing element 40 is  
arranged downstream the test zone 18 for taking up the  
liquid waste.

As only schematically illustrated in fig. 2, the linear  
20 liquid transport system described so far could be part  
of a more complex microfluidic system. Instead of  
direct sample spotting, the sample fluid can reach the  
test zone from the side through the channel 41 after  
prior processing. For example haemolysis of blood and  
25 eventually also the binding reaction with the conjugate  
can take place in zone(s) different from the adsorbing  
and detection area 18. In this case, care should be  
preferably taken to avoid excess of sample spreading  
outside the test zone 18. Microfluidic flow control

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should be used to deliver preferably a given amount at the given location.

In order to carry out a photometrical measurement, a  
5 detector 42 is located in the device 10 in  
correspondence of the test zone 18 of the test element  
12. For precise alignment, the housing 44 of the device  
10 can have a guide way 46 which allows sliding the  
test element 12 in and out.

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In one example, to perform a test, a small sample  
volume ( $\mu\text{l}$ ) of a blood sample to be analysed is  
delivered to the test zone 18. Fresh capillary blood or  
whole blood can be used. Release of haemoglobin from  
15 the erythrocytes is obtained by action of a haemolysing  
reagent with which the substrate is impregnated.

The glycated haemoglobin, made accessible in this way,  
can be selectively labelled by reaction with a non-  
20 immobilized conjugate reagent present in the test zone  
18. The conjugate is composed of phenylboronic acid  
linked to an organic dye with maximum absorbance at a  
wavelength  $> 600$  nm. This selectively binds to the  
sugar residue of glycated haemoglobin and thus makes it  
25 detectable and distinguishable. In order to ensure that  
the reaction is quantitative, an excess of conjugate  
relative to the expected amount of glycated haemoglobin  
is used. Therefore it is important that the excess or  
fraction of conjugate reagent, which is not bound to

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glycated haemoglobin, is separated after sample application from the test zone 18.

The separation mechanism according to the invention is based upon the principle of immobilizing the analyte(s) in the test zone 18, by simple adsorption whereas the unbound conjugate is removed with the aid of the washing liquid 22. To make this possible, the analyte and the conjugate must belong to different chemical classes. If the analyte is a protein, the conjugate must be something other than a protein. Preferably this is instead a relatively small organic molecule more or less polar.

As outlined above, the non-glycated haemoglobin and the complex of glycated haemoglobin with boronic acid-dye conjugate stick on the TLC substrate firmly under particular washing conditions, while the excess of unbound conjugate is transported away with the mobile washing phase.

It is important for an optimal separating effect that the conjugate has a high coefficient of partition for the washing liquid 22 compared to the substrate 16. Particular attention must be paid to the pH value. This influences, on one hand, the reaction between target analyte and conjugate and, on the other hand, can determine how strongly the analyte adsorbs on the

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substrate and the affinity of the free conjugate for the mobile phase.

At a given time after sample application, the flow of the washing fluid can be actuated by means of the mechanism 36, 38, so that the liquid is transported through the adsorbing material 32 and the microporous structure 26, passing the test zone 18 and taking up excess conjugate eventually into the waste 40.

10

In one working **example** (figure 3) a commercial aluminium oxide TLC plate was used as substrate, phenylboronic acid linked to an organic dye of low-polarity (max. absorbance at ca. 650 nm, emission at ca. 670 nm) as conjugate reagent (MW <700 Dalton), and a buffer phosphate/EDTA at pH preferably  $\geq 7$ , most preferably  $\geq 9$ , containing approximately 1% tetradecyltrimethylammonium bromide (TTAB), as mobile phase. TTAB was used also as haemolysing reagent.

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Two controls were run in parallel with the HbA1c test (blood sample containing 10% glycated haemoglobin plus non-immobilized conjugate) in the center, namely blood sample without conjugate on the left, and conjugate without blood on the right. The two images in fig. 3a were taken at different wavelengths, i.e. 540 nm and 665 nm, by using a CCD camera as detector and a set of filters for the illumination source and the camera objective. The three absorbance traces showing relative

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absorbance  $a$  over separation length  $d$  in fig. 3b refer to the three spotted samples, aligned in the same order, with the solid line representing 540 nm and the dotted line 665 nm respectively. From here it is clear

5 that total haemoglobin with or without conjugate (absorbing at 540 nm) is strongly adsorbed on the substrate while the non-immobilized and unbound conjugate (detected at 665 nm) is transported away from the application spot under these washing conditions.

10 Only when reaction between conjugate and glycated haemoglobin occurs (spot in the middle) absorbance at 665 nm proportional to the percentage of HbA1c present can be detected in the application zone.

15 In principle, known methods, i.e. absorbance, reflection or fluorescence can be conducted to determine haemoglobin remaining in the test zone 18. In the method according to the invention both total and glycated haemoglobin have to be detected. Use is made

20 of the fact that the boronic acid conjugate has an absorption maximum at a wavelength which is outside of the range in which haemoglobin absorbs. The ratio of glycated to total haemoglobin can then be determined by measuring the reflectance of the test zone 18 at

25 different wavelengths for example at 540 nm (for the total amount of haemoglobin) and 665 nm (for the dye, which is bound via boronic acid to glycated haemoglobin).

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The mechanism by which the analyte of interest sticks while the excess of unbound non-immobilized conjugate reagent is removed from the reaction/detection area under particular washing conditions, can be generalized to most assays in which the analyte is a protein, preferably an abundant protein, and the labelled ligand is a non-protein that is something other than an antibody. Preferably this is instead a relatively small organic molecule more or less polar, or a small peptide epitope, or even an oligonucleotide for nucleic acid binding proteins. The substrate can be other than aluminium oxide, like for example silica, reversed phase or other chromatographic material, so that the protein analyte can be firmly adsorbed by electrostatic or hydrophilic interactions, hydrogen bonding, hydrophobic interactions, or combinations thereof. The mobile phase can be a buffer at such pH that the analyte sticks on the solid phase but that the reaction still occurs. It can contain a detergent other than TTAB at any optimal concentration. It can contain acids or bases. It can contain an organic solvent or can be a simple mixture of a miscible organic solvent and water. Pre-spotted samples at known concentration could also be present on the same test strip for direct calibration. If all this is considered, then this method can be used to determine the presence and quantity of antibodies and ligand-binding proteins in a biological fluid, such as blood, urine, milk or in a cell extract, either human tissue or other organisms

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including bacteria, whenever specific suitable ligands are known and can be derivatized with signal-generating molecules, if not already self-signaling.

5 It is eventually also possible to use different signals for different ligands so that different analytes can be targeted at the same time on the same spots, or for introducing internal calibration standards. For better sensitivity fluorescence detection would be the method  
10 of choice. More specific examples of assays that could be performed by this method involve different classes of ligand-binding proteins. Besides immunoglobulines, can be mentioned: DNA and RNA binding proteins, lipid-binding proteins (e.g.  $\beta$ -lactoglobulin, serum retinol-  
15 binding protein, urinary  $\alpha$ 2-globuline, fatty acid binding proteins), lectins, serum albumins, pheromone-binding proteins, odor-binding proteins, immunosuppressant-binding proteins.

## Claims:

1. Biochemical device comprising:
  - a) a substrate (16),
    - i) the substrate comprising a test zone (18) on the substrate (16) for sample application,
    - ii) the substrate being capable of non-specifically binding at the test zone (18) at least a target analyte contained in a biological sample,
  - b) a non-immobilized conjugate reagent provided in the test zone (18) for labelling the target analyte, said conjugate reagent being capable of specific binding to the target analyte but remaining unbound to the substrate (16),
  - c) a flow path (24) for transporting a washing liquid (22) through the test zone (18) and washing an excess of unbound conjugate reagent away from the test zone (18),
  - d) whereby the test zone (18) is also a detection area for detecting the labelled target analyte.
2. Biochemical device according to claim 1, characterized in that a reservoir (20) contains the washing liquid (22) and the reservoir (20) can be fluidly connected to the flow path (24).
3. Biochemical device according to claim 2, characterized in that the reservoir (20) is connectable to the flow path (24) by an element (30) rupturing a wall (28) of the reservoir (20).

4. Biochemical device according to one of the claims 1 to 3, characterized in that the flow path (24) is a porous or capillary structure (26) of the substrate (16) for capillary transport of the washing liquid (22).
5. Biochemical device according to one of the claims 1 to 4, characterized in that a microfluidic system (42) is provided for transport of sample fluid to the test zone (18).
6. Biochemical device according to one of the claims 1 to 5, characterized in that an adsorbing element (40) is arranged on the flow path (24) downstream the test zone (18) for taking up liquid (22) waste.
7. Biochemical device according to one of the claims 1 to 6, characterized in that the substrate (16) is a solid phase chromatographic layer on a polymer or metal support (14).
8. Biochemical device according to one of the claims 1 to 7, characterized in that the substrate (16) consists of aluminium oxide or silica or a reversed-phase material.
9. Biochemical device according to one of the claims 1 to 8, characterized in that the analyte is a protein.
10. Biochemical device according to one of the claims 1 to 9, characterized in that the conjugate reagent is relatively small compared to proteins and is a non-protein that is polar or non-polar.

11. Biochemical device according to one of the claims 1 to 10, characterized in that the conjugate reagent is a labelled organic or inorganic molecule or peptide epitope or oligonucleotide.
12. Biochemical device according to one of the claims 1 to 11, characterized in that the conjugate reagent contains a boronic acid dye.
13. Biochemical device according to one of the claims 1 to 12, characterized in that the conjugate reagent is provided in dried form in the test zone (18).
14. Biochemical device according to one of the claims 1 to 13, characterized in that the sample is blood, and an analyte is haemoglobin.
15. Biochemical device according to claim 14, wherein the sample blood is whole blood.
16. Biochemical device according to claim 14 or 15, characterized in that the haemoglobin is glycosylated haemoglobin.
17. Biochemical device according to one of the claims 1 to 16, characterized in that the substrate (16) is impregnated with a haemolysing agent.
18. Biochemical device according to claim 17, characterized in that the haemolysing agent is tetradecyltrimethylammonium bromide.
19. Biochemical device according to one of the claims 1 to 16, characterized in that the conjugate reagent has a high coefficient of partition for the washing liquid (22) compared to the substrate (16).

20. Biochemical device according to one of the claims 1 to 17, characterized in that the washing liquid (22) is an organic solvent or a mixture of water and a miscible organic solvent.
21. Biochemical device according to one of the claims 1 to 18, characterized in that the washing liquid (22) is a buffer at such pH that the analyte sticks to the substrate (16) and the binding reaction of the conjugate still occurs.
22. Biochemical device according to one of the claims 1 to 19, characterized in that the washing liquid (22) contains a surfactant.
23. Analytical test element comprising a biochemical device as claimed in any one of claims 1 to 22.
24. Analytical test element according to claim 23, that is disposable.
25. Analytical test element for determining the ratio of glycated to total haemoglobin in a blood sample comprising:
  - a) a substrate (16),
    - i) the substrate comprising a test zone (18) on the substrate (16) for sample application,
    - ii) the substrate being capable of non-specifically binding at the test zone (18) at least haemoglobin contained in a blood sample,
  - b) a conjugate, provided non-immobilized in the test zone (18) for labelling glycated haemoglobin,

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- c) a flow path (24) for transporting a washing liquid (22) through the test zone (18) and washing an excess of unbound conjugate away from the test zone (18),
  - d) whereby the test zone (18) is also a detection area for detecting the labelled and total haemoglobin.
26. Analytical test element according to claim 25, wherein the conjugate is a boronic acid dye.
27. Process for determining at least one target analyte in a biochemical sample, comprising the following steps:
- a) providing a substrate (16) comprising a finite test zone (18) and being capable of non-specifically binding at the test zone at least the target analyte and other constituents contained in the sample,
  - b) providing a non-immobilized conjugate reagent in the test zone (18) for labelling the target analyte, said conjugate reagent being capable of specific binding to the target analyte but remaining unbound to the substrate (16),
  - c) applying the sample in the test zone (18) of the substrate (16),
  - d) transporting a washing liquid (22) through the test zone (18) and washing an excess of unbound conjugate reagent away from the test zone (18),
  - e) detecting the labelled target analyte in the test zone (18).

28. Process according to claim 27, characterized in that blood is used as a sample and non-glycated haemoglobin and glycated haemoglobin are adsorbed on the substrate (16), the conjugate reagent being bound to the glycated haemoglobin.
29. Process according to claim 28, characterized in that the blood is whole blood.
30. Process according to any one of claims 27 or 29, characterized in that total haemoglobin and glycated haemoglobin are photometrically detected at different respective wavelengths and that the ratio of glycated to total haemoglobin is determined.

Application number / numéro de demande: 2524574

Figures: 3a

Pages: 2

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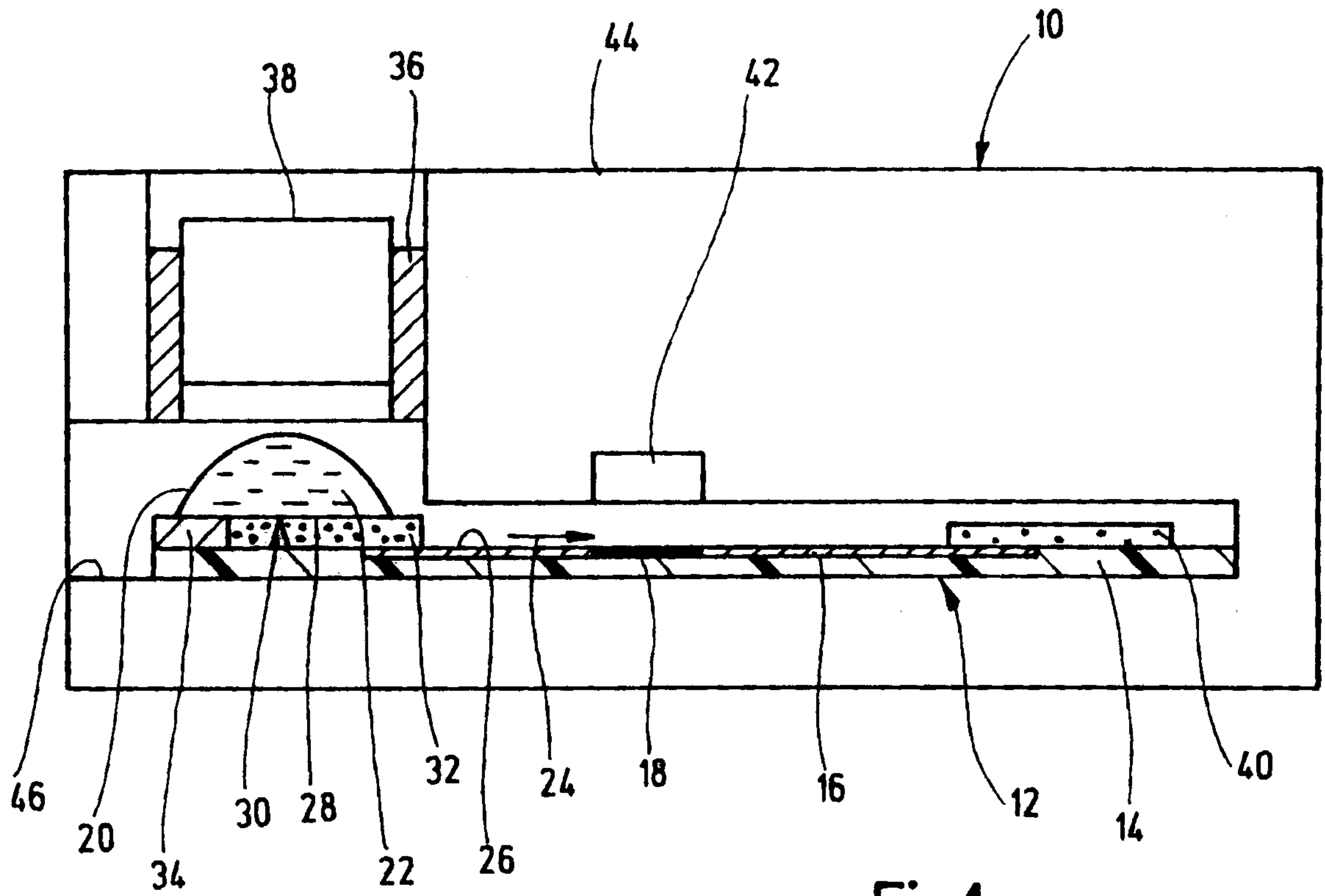


Fig.1

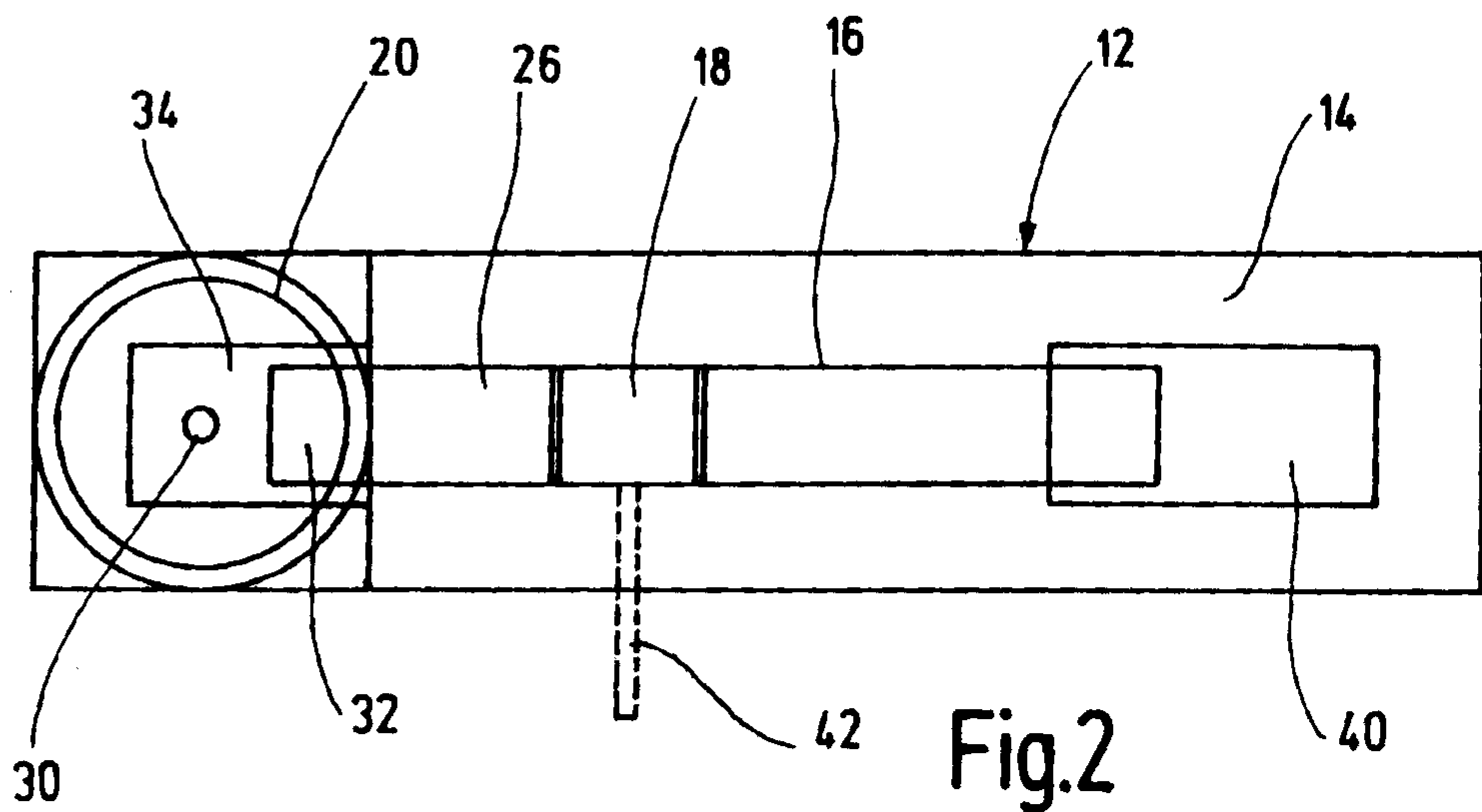


Fig.2

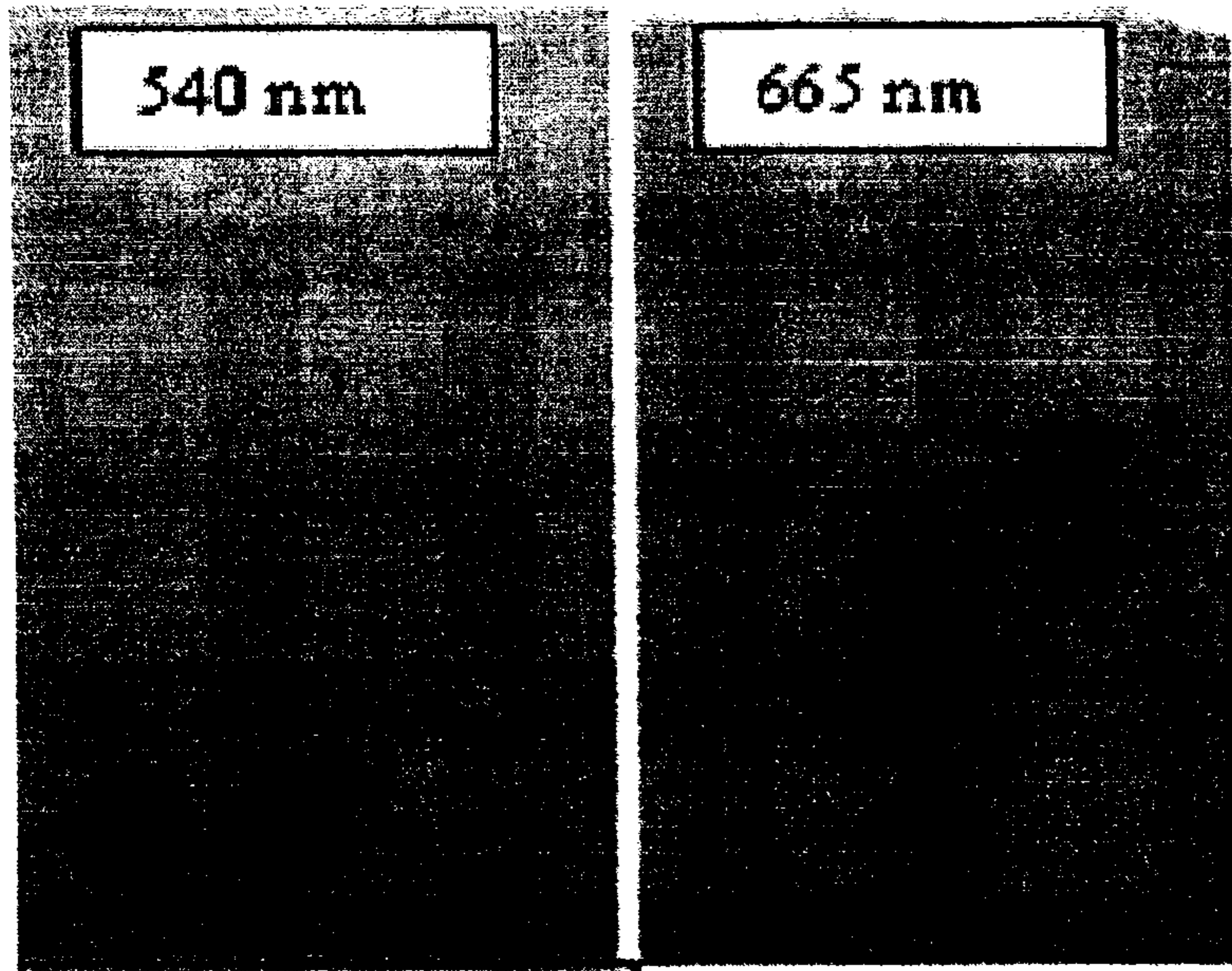


Fig.3a

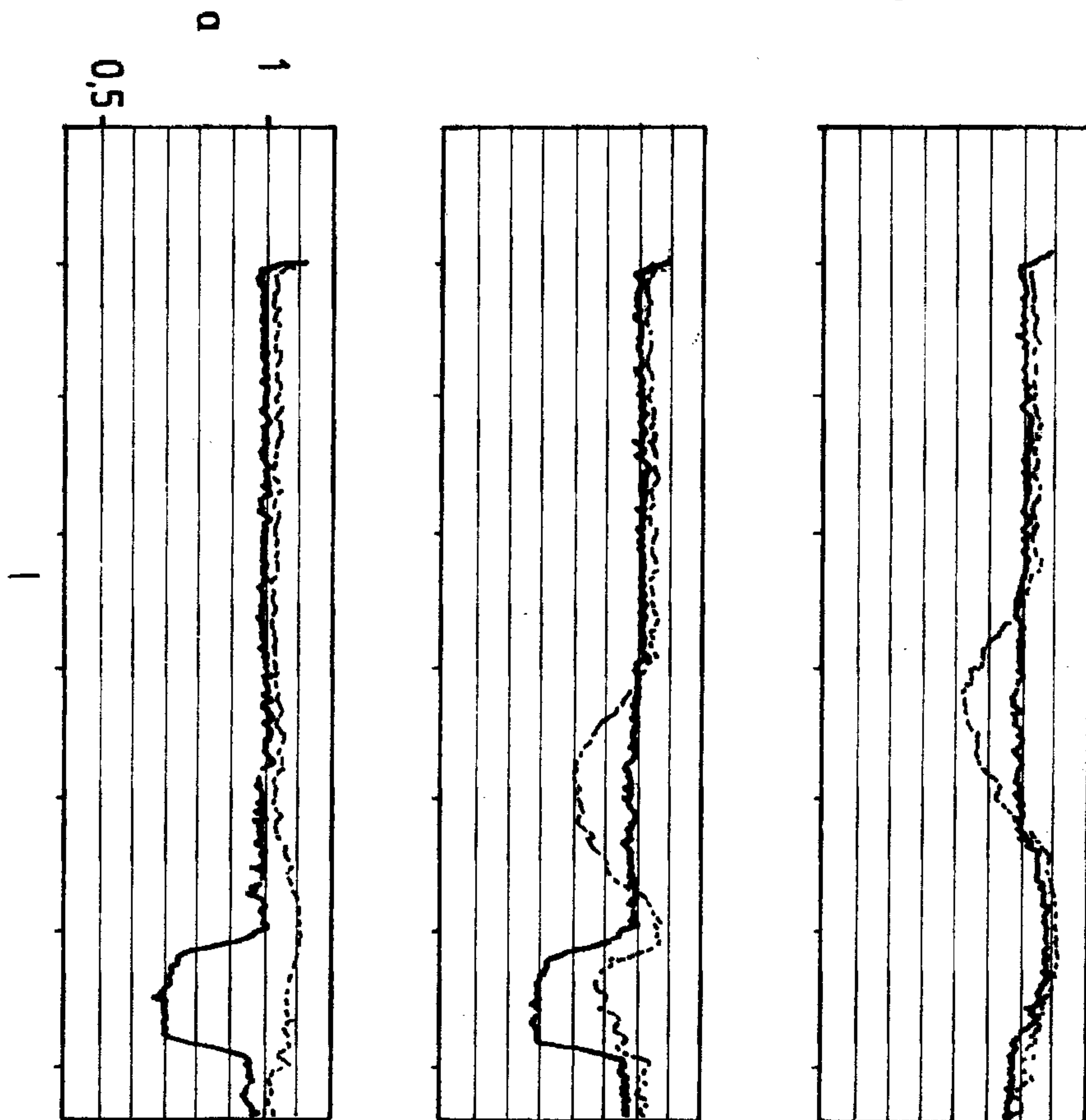


Fig.3b

