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(54) Benævnelse: **IR SPECTROMETRY CELL WITH TEMPERATURE CONTROL MEANS**

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DESCRIPTION

Field of the invention

[0001] This invention relates to a sample cell for IR spectrophotometric analysis of a liquid sample. The sample cell comprises two substantially parallel transparent plates enclosing a cavity for holding the liquid sample and a temperature control loop for controlling a temperature of the liquid sample in the cavity. The temperature control loop comprises at least one temperature sensor for measuring a temperature in or close to the cavity, at least one heating element for increasing a temperature of the liquid sample, and control means, coupled to the temperature sensor and the heating element for controlling the heating element in dependence of the temperature in or close to the cavity.

[0002] This invention further relates to the heating element for use in such a sample cell.

Background of the invention

[0003] Such a sample cell is, e.g., known from US patent 4,415,809 in which an electro-optical apparatus for measurement of fat, protein, lactose and water or solids in milk is disclosed. In this apparatus, a milk sample is pumped into an optical measurement cell and then irradiated with light beams of different wavelengths. The cell comprises a pair of flat parallel optical windows, spaced from each other for containing the sample. The optical windows and the cavity are comprised in a large metal heating block equipped with a temperature sensor, heat resistors and a temperature control circuit.

[0004] One of the disadvantages of this setup is that the temperature control loop works too slowly. This leads, for example, to overshoot. When the temperature sensor measures a too low temperature, the heat resistors heat the heating block and the temperature increases over time. When the temperature sensor signals that the desired temperature is obtained, the heat resistors are turned off. The transfer of heat from the heat resistors, through the metal heating block, to the temperature sensor does however take some time. When the temperature at the temperature sensor is right and the heater resistors are turned off, the heat transfer through the metal heating block will not stop immediately. Even when adapting the temperature control loop in order to compensate for this overshoot, it is not possible to keep the sample at the desired temperature.

[0005] In the more recent US patent 6,667,808 the heater element is located closer to the sample cavity, which may reduce the delay between the heater and the sample cavity. However, the use of this single heat source in the larger metal block will always lead to fluctuating temperatures.

[0006] JP 2005-323509 describes a cell culture chamber which can receive a petri dish. A sheet-like circular heater H2 is provided for heating the bottom surface of the dish 33A of the plastic petri dish 33 and a sheet-like circular heater H3 for warming the lid portion 33B of the petri dish 33 are attached to the metal petri dish holder portions 32, 32. A temperature control temperature sensor (thermocouple) 34 is installed in the bottom heater H2. Temperature control can be performed by PID control of the bottom heater.

Object of the invention

[0007] It is an object of the invention to improve the temperature stability of a sample cell for IR spectrophotometric analysis of a liquid sample.

Summary of the invention

[0008] According to a first aspect of the invention, this object is achieved by providing a sample cell for IR spectrophotometric analysis of a liquid sample as defined by claim 1.

[0009] The use of the heating foil instead of the heating resistors of at least some the prior art gives at least two important advantages. A first advantage is that when the heating foil is attached to the transparent walls of the cavity itself, the source of heat is very close to the liquid to be heated. As a result, the heating of the liquid to be analyzed is much more direct than in the prior art embodiments wherein the metal housing is to be heated first. Because the heating element is closer to the position where the temperature is to be controlled, the heating effect of the liquid is much more direct and temperature fluctuations are reduced.

[0010] A further advantage of using the heat foil is that it can easily be provided in any desired shape. For example, a ring shaped heating foil may be used wherein the ring encircles that part of the transparent plate where the IR light beam is to enter (or leave) the cavity. Instead of only heating the sample cell at one or a few positions, the heating element may be designed to heat a larger surface area. This results in a more evenly distributed heat supply and increased control over the temperature of the liquid to be analyzed. Consequently, according to the invention, not only temporal, but also spatial temperature fluctuations are minimized.

[0011] It is to be noted that to obtain the above mentioned advantages, it is not absolutely necessary that the heating foil is directly attached to the transparent plate. In principle the invention also works when there is some thermally conductive material in between the heating foil and the transparent plate. However, if there is no good reason for using additional material, the heating foil is preferably attached to the transparent plate itself. The closer the heating foil is to the cavity, the better the temperature control.

[0012] The heating foil comprises the temperature sensor. This feature has the advantage that

the temperature sensor measures temperatures at a position close to the liquid to be analyzed. The temperature measurement thus provides a more accurate indication of the relevant temperature. With the temperature sensor so close to the heating element, the temperature control loop also becomes faster and thus more accurate. As soon as the temperature starts increasing, the temperature sensor will detect this and the heating element may be turned off. As a result the overshoot in the temperature control loop is minimized.

[0013] In addition to the reduced temporal and spatial temperature fluctuations, the invention also improves the reproducibility of the sample temperature. Subsequently analyzed samples therefore have substantially the same temperature or temperature course, which is very important for reliably analyzing multiple samples.

[0014] These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

Brief description of the drawings

[0015] In the drawings:

Figure 1 schematically shows a cross section of a sample cell according to the invention,

Figure 2 shows a front view of a sample cell according to the invention,

Figure 3 shows a cross section of the sample cell of figure 2, and

Figures 4a and 4b show two examples of heating foils according to the invention.

Detailed description of the invention

[0016] Figure 1 schematically shows a cross section of a sample cell 10 according to the invention. The sample cell 10 comprises two transparent plates 11, separated by spacers 14. In, e.g., milk analysis by IR spectrophotometry the spacers usually provide a 20-40 μm (micrometer) wide cavity 17 between the two substantially parallel plates 11. The transparent plates 11 may, e.g., be made of glass, crystalline calcium fluoride (CaF_2) or transparent plastics. Also diamond may be used for producing the sample cell 10. In order to be suitable for IR spectrophotometry, the plates 11 only have to be transparent for the IR wavelengths used for the IR spectrophotometry, but it may be practical to select a material that is also transparent for visible light. If the user can look into the cavity 17, it is possible to visually inspect the analyzed liquid. If the sample cell is also used for analysis methods involving light of a different wavelength, the transparent plates 11 also have to be transparent for said different wavelengths.

[0017] A liquid supply channel 18 is provided for enabling the liquid to fill the cavity 17 between the transparent plates 11. Fresh liquid is pumped into the cavity 17 via a first part of the supply channel 18, while used liquid is pumped out of the cavity 17 via a second part of the supply channel 18. The arrows in the figure show a possible direction of flow within the sample cell. When a sample of the liquid is in the cavity 17, the sample can be analyzed, e.g., using IR photospectrometry. When fresh liquid is pumped through the supply channel 18, the cavity 17 is filled with a new sample and a new measurement can be made. In this example, a steel ring 16 is provided comprising a bypass channel 19 for the liquid. The bypass channel 19 is, e.g., ring shaped to provide a bypass from the incoming part of the supply channel 18 to the outgoing part. The bypass channel 19 is provided to prevent excessive pressures caused by the very narrow passage for the liquid in the cavity 17. The steel ring 16 may, of course, also be made of a different metal or thermally conductive material.

[0018] A first heating foil 12 with integrated temperature sensors (not visible in this figure), is attached to one of the transparent plates 11. When the temperature sensors are applied to the heating foil 12, the temperature control loop is faster and the liquid sample temperature more stable. The heat foil 12 does not cover the complete surface of the transparent plate 11 in order not to hinder the IR light beam when passing the cavity 17. In an example, a second heating foil 22 may be attached to the other transparent plate 11 for further improving the temperature control and increasing the reproducibility of the sample temperature. According to the claimed invention, the second heating foil 22 is however not attached to the transparent plate 11 itself but rather it is attached to a thermally conductive material, being in the example shown in this figure the steel ring 16. If the second heating foil 22 was applied between the transparent plate 11 and the steel ring 16, also some sealing would have to be provided for the bypass channel 19.

[0019] Although the second heating foil 22 is not attached to the transparent plate directly, it still takes advantage of the inventive idea behind the invention. The diameter of the bypass channel 19 is much bigger than the diameter of the cavity 17. Most of the cold liquid runs through the bypass channel 19. The second heating foil 22 is provided at an excellent position for heating the liquid in the bypass channel 19.

[0020] Additional layers 15 of isolating and/or thermally conductive material may be provided. For example, the sample cell 10 may be embedded in a large block of steel that forms a thermal buffer for further stabilizing the temperature at the cavity 17.

[0021] Figure 2 shows a front view of a sample cell 10 according to the invention. In this perspective view some of the features described above, with reference to figure 1, are shown again. Figure 2 shows a ring shaped heating foil 22 and the transparent passage for the IR light beam. An incoming IR light beam passes through the ring of the heating foil 22, a first transparent plate 11, the cavity and a second transparent plate 11 before it reaches a detector (not shown). The heating foil 22 is coupled to an electric power source via a connection strip 13. The connection strip 13 preferably is an integral part of the heating foil 22. Also the

temperature sensors and the control circuit for controlling the heating means in dependence of the measured temperature may be integrated in the heating foil 22. Alternatively, the control circuit may be provided separately with an electrical connection to the heating foil 22. If multiple heating foils 12, 22 are used also multiple connection strips 13 may be provided.

[0022] Figure 3 shows a cross section of the sample cell 1 0 of figure 2. The features shown in this figure have already been discussed above with reference to the previous figures.

[0023] Figures 4a and 4b show two examples of heating foils 12, 32 according to the invention. In figure 4a, the heating foil 12 is ring shaped. In figure 4b, the heating foil 32 is rectangular. Also other shapes may be used. For obtaining the advantages of the current invention, two aspects are important. First, the heating foil 12, 32 must leave open some space for the IR beam to be able to pass through the cavity 17, towards the detector. In addition, the heating foil 12, 32 should cover a significant part of the cavity 17 in order to maximize the heating effect on the liquid inside the cavity 17 and to improve the control over the temperature of different samples. A connection strip 13 may couple the heating foil 12, 32 to a temperature control circuit and/or a power source provided separate from the sample cell 10 itself. The heating foil 12, 32 and the connection strip 13 may, e.g., be made from standard flexible plastic substrates, such as polyimide.

[0024] When an electric current runs through the heating foil 12, 32, the electrical resistance of electrical wiring 42 and/or specific heating elements in the heating foil 12, 32 will cause local heating near the foil surface. In addition to electrical wiring 42, at least one of the heating foils 12, 32 comprises one or more temperature sensors 41. For optimal control over the liquid temperature, at least one temperature sensor is provided close to the liquid inlet of the cavity.

[0025] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims.

REFERENCES CITED IN THE DESCRIPTION

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- US6667808B [0005]
- JP2005323509A [0006]

Claims

1. En prøvecelle (10) til IR spektrofotometrisk analyse af en væskeprøve, hvilken prøvecelle (10) omfatter:
   - to i det væsentlige parallelle, transparente plader (11) omgivende et hulrum (17) til at indeholde væskeprøven,
   - en væskeforsyningskanal (18) omfattende en første del til at pumpe ny væske ind i hulrummet (17) og en anden del til at pumpe væske ud af hulrummet (17),
   - et termisk ledende materiale (16) omfattende en omløbskanal (19), der tilvejebringer et omløb fra den første del af forsyningskanalen (18) til den anden del af forsyningskanalen (18), og
   - en temperaturstyrekreds til kontrol af en temperatur af væskeprøven i hulrummet (17), hvilken temperaturstyrekreds omfatter:
     - mindst en temperatursensor (41) til måling af en temperatur i eller nær ved hulrummet (17),
     - mindst et varmeelement (12, 22, 32) til øgning af en temperatur af væskeprøven, og
     - kontrolmidler, koblet til temperatursensoren (41) og varmeelementet (12, 22, 32) til kontrol af varmeelementet (12,22,32) afhængigt af temperaturen i eller nær ved hulrummet (17), hvor
     - varmeelementet (12,22,32) omfatter
       - en første varmefolie (12, 32) som er vedhæftet eller termisk koblet til den første af de transparente plader (11) på en sådan måde, at IR lysstrålen tillades at passere gennem de transparente plader (11) og hulrummet (17) uden at blive forhindret heri af varmefolien (12, 32), hvor den første varmefolie (12, 32) omfatter temperatursensoreren (41), og
       - en anden varmefolie (22) som er vedhæftet til det termisk ledende materiale til opvarmning af væsken i omløbskanalen (19).

2. En prøvecelle (10) ifølge krav 1, hvor det termisk ledende materiale forefindes som en ring (16) af termisk ledende materiale omfattende omløbskanalen (19).

3. En prøvecelle (10) ifølge krav 1, hvor det termisk ledende materiale er et metal eller stål.

4. En prøvecelle (10) ifølge krav 1, hvor omløbskanalen (19) er ringformet.

5. En prøvecelle (10) ifølge krav 1, hvor den første varmefolie (12) og/eller den anden varmefolie (22) er ringformet.

6. Brug af en prøvecelle (10) ifølge krav 1 til at øge en temperatur af en væskeprøve i hulrummet (17) og opvarme væsken i omløbskanalen (19).

DRAWINGS

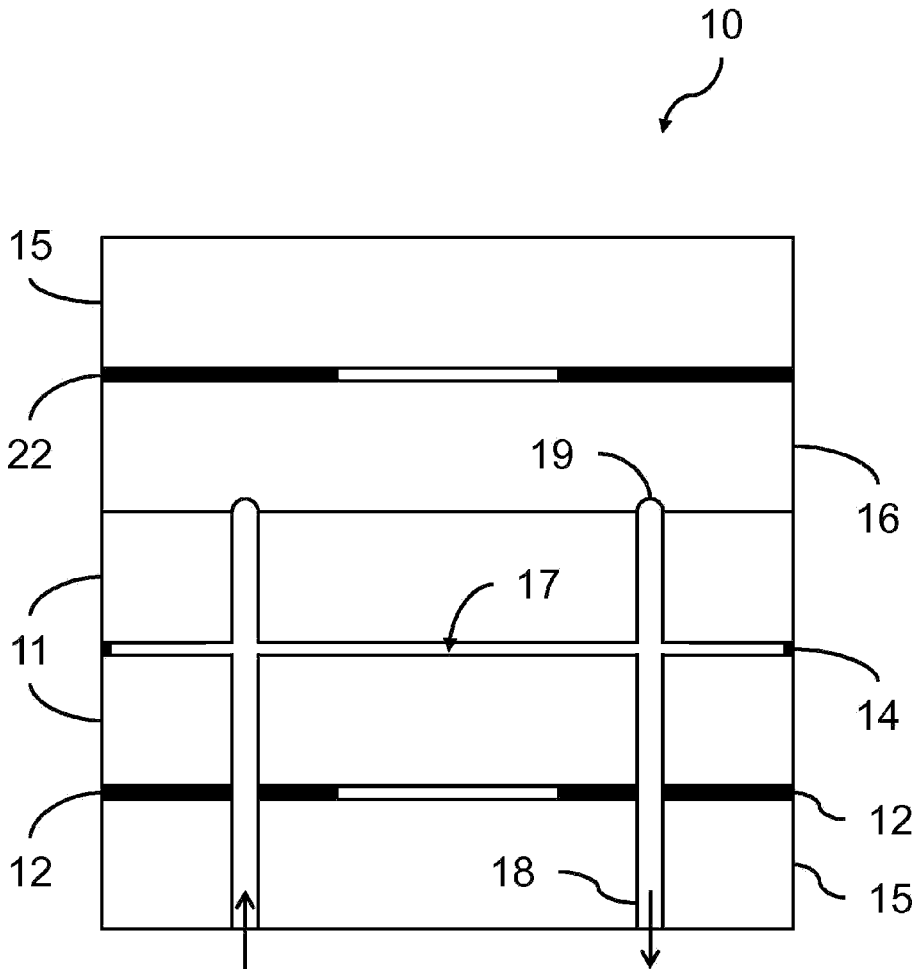


Fig. 1

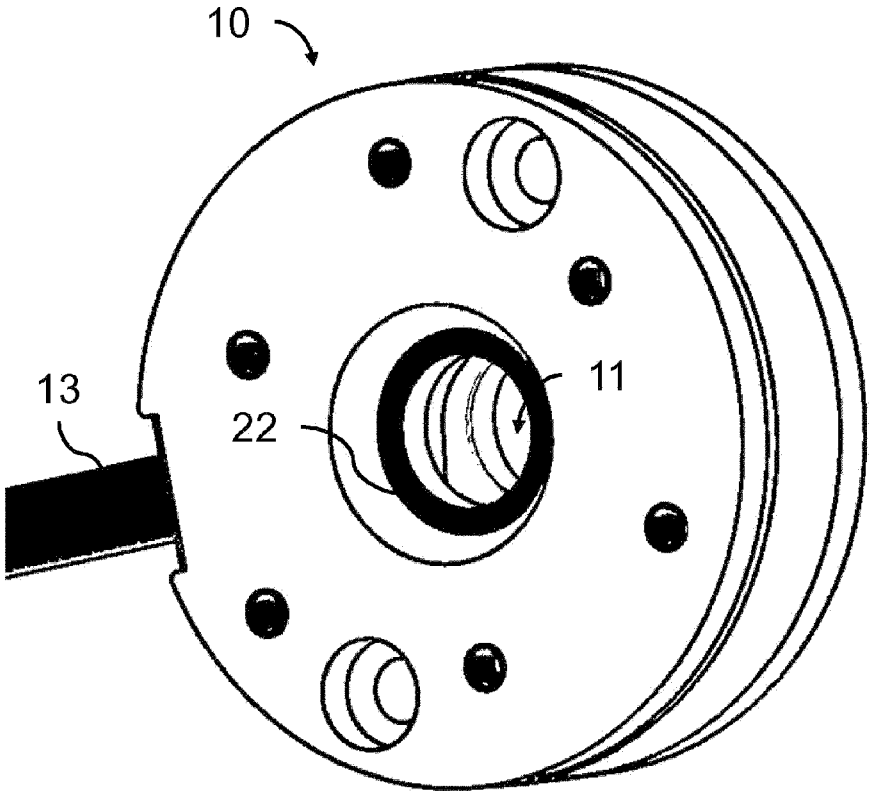


Fig. 2

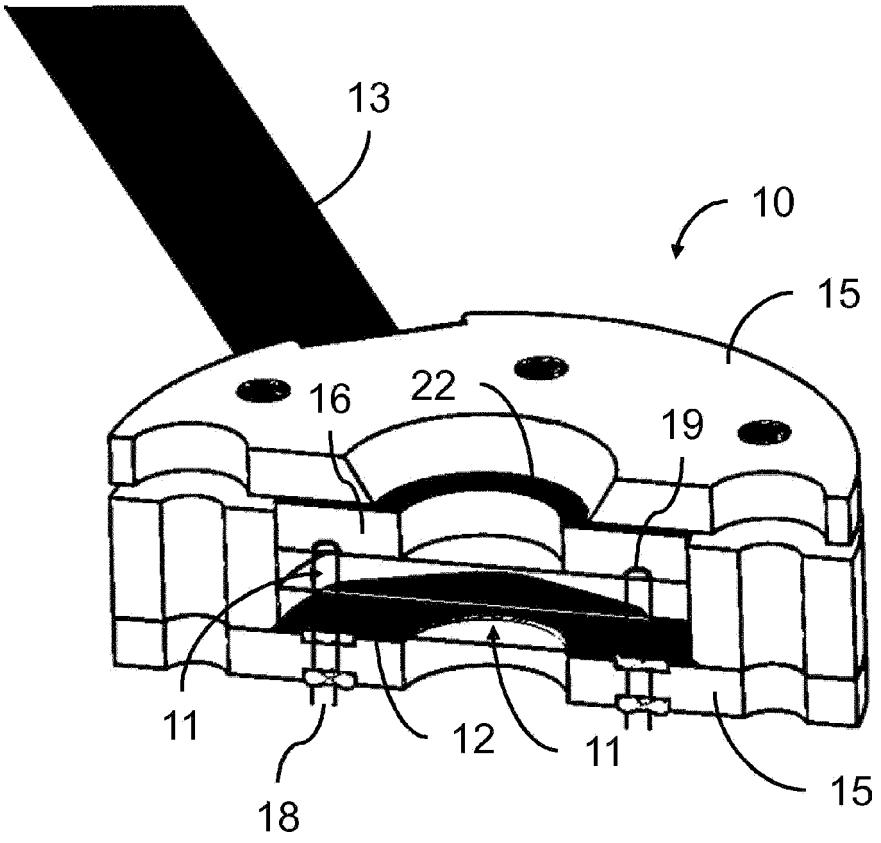


Fig. 3

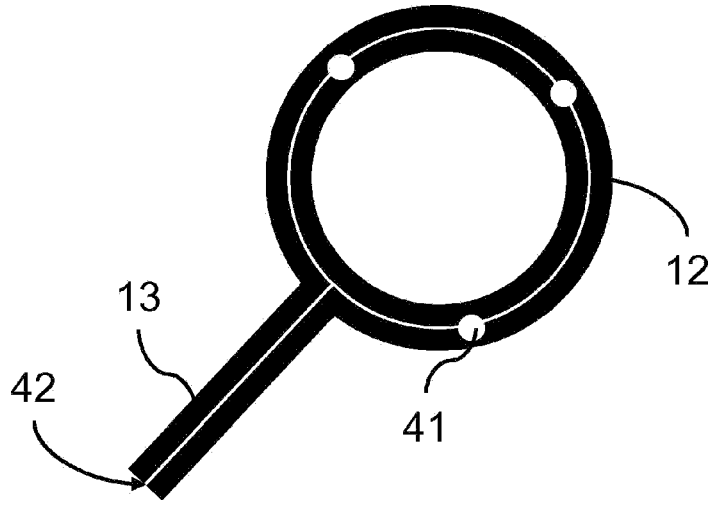


Fig. 4a

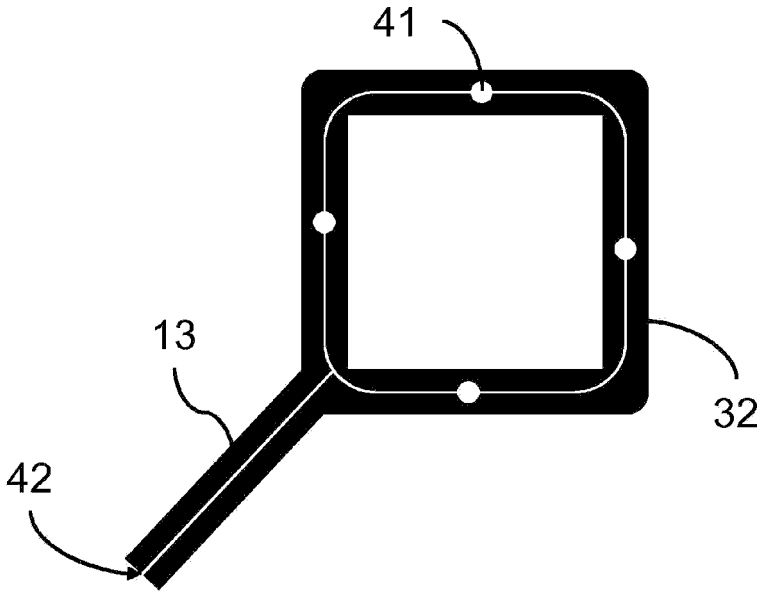


Fig. 4b