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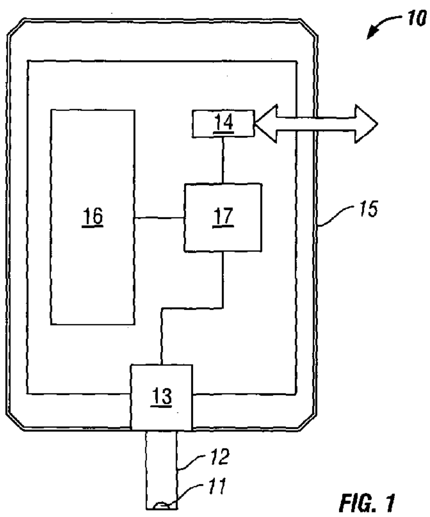

FIG. 1

(57) Abstract: A device(10) for monitoring the glucose concentration of a blood sample or other temperature-dependent properties of an external sample(11), the device comprising a temperature sensor (14) for measuring the absolute internal temperature within or adjacent to the device(10) and a processor(17) for estimating the temperature of the external sample(11) from the measured absolute internal temperature. Also disclosed is a method of operation of the device.

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ESTIMATING AMBIENT TEMPERATURE FROM INTERNAL TEMPERATURE SENSOR, IN PARTICULAR FOR BLOOD GLUCOSE MEASUREMENT

The present invention relates to monitoring devices and more particularly but not exclusively to devices for monitoring the concentration of glucose in a blood sample.

It is often necessary to accurately measure the concentration of glucose in a blood sample. Such a procedure is particularly important in the treatment of diabetes where inaccurate measurements can have potentially fatal consequences. Commercially available blood glucose meters estimate the blood glucose concentration through exploitation of the electrical properties of blood. A typical blood glucose monitoring device comprises a housing which encloses components used to measure the electrical properties of the blood sample. A socket is provided in the housing for receiving a strip to which a blood sample is applied. The strip comprises a plurality of conducting tracks which an incomplete electrical circuit. The user applies a sample of blood to the strip to bridge a gap between the conductive tracks and complete the electrical circuit, thereby enabling measurement of one or more electrical properties of the blood sample.

The electrical properties of the circuit are extremely sensitive to temperature in the vicinity of the blood sample. Consequently, accurate blood glucose measurements can only be obtained if the absolute temperature in the vicinity of the blood sample is known to an accuracy of 2 degrees Celsius. One known device uses an assumed temperature value but a disadvantage of this is that the actual temperature may be considerably different. Another known device comprises a temperature sensor disposed within housing. A disadvantage of this arrangement is that the heat generated by the components within the housing can significantly increase the measured temperature.

We have now devised an improved method and device for monitoring an external sample.

In accordance with the present invention there is provided a method for estimating the external ambient temperature outside a substantially enclosed device, wherein the method comprises measuring the absolute internal temperature within or adjacent to the device, and estimating the external temperature from the measured absolute internal temperature.

Preferably, the method further comprises calculating the level of heat generated within the device and using the result in the estimation of the external temperature from the measured absolute internal temperature.

Preferably, the calculation of the heat generated within the device comprises ascertaining modes of operation of at least one heat source within the unit and using a-priori knowledge of power output of the at least one heat source for a given mode of operation to calculate the heat generated within the device.

Preferably, the estimation of the external temperature from the measured absolute internal temperature accounts for the thermal conductivity of the device.

Preferably, the estimation of the external temperature comprises execution of an algorithmic procedure relating the external temperature to the measured absolute internal temperature.

Alternatively, or in addition thereto, the estimation of the external temperature comprises or further comprises consultation of a database, wherein the database comprises a list of possible absolute internal temperatures with corresponding external temperatures.

In accordance with the present invention there is also provided a method of measuring blood glucose concentration, the method comprising measuring the electrical properties of a blood sample, estimating the temperature of the blood sample, and calculating the glucose concentration of the blood sample from the electrical properties and the temperature, wherein estimation of the temperature of the blood sample comprises measuring the absolute internal temperature within or adjacent to the device, and estimating the external temperature from the measured absolute internal temperature.

In accordance with the present invention there is also provided a device for monitoring temperature-dependent properties of an external sample, wherein the device comprises a temperature sensor for measuring the absolute internal temperature within or adjacent to the device, and means for estimating the temperature of the external sample from the measured absolute internal temperature.

Preferably, the device further comprises at least one heat source and means for calculating the heat generated by the at least one heat source, the result of the calculation being used in the calculation of the external temperature from the measured absolute internal temperature.

Preferably, the means for calculating the heat generated by the at least one heat source comprises means for ascertaining modes of operation of the at least one heat source and uses a-priori knowledge of power output of the at least one heat source for a given mode of operation to calculate the heat generated.

Preferably, the estimation of the external temperature from the measured absolute internal temperature accounts for the thermal conductivity of the device.

Preferably, the means for estimating the temperature of the external sample comprises an algorithmic procedure relating the external temperature to the measured absolute internal temperature.

Preferably, the means for estimating the temperature of the external sample comprises or further comprises a database, wherein the database comprises a list of possible absolute internal temperatures with corresponding external temperatures.

Preferably, the external sample is a blood sample and the device comprises means for measuring blood glucose concentration.

An embodiment of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of the device according to the third embodiment of the present invention, wherein the device is connected to an external sample; and

Figure 2 is a schematic plot showing:

The normalised difference between the internal temperature θ_i at time t and the internal temperature at t=0 (denoted by $\Delta\theta_i(t)$) ;

The normalised rate of change of the internal temperature difference $\Delta\theta_i(t)$ (denoted by $\frac{d(\Delta\theta_i(t))}{dt}$).

Referring to Figure 1 of the drawings, there is illustrated a device 10 for monitoring properties of an external blood sample 11 in accordance with the present invention. A connecting strip 12 is coupled to the device 10 via a socket 13. The connecting strip 12 comprises several conducting tracks (not shown) arranged an incomplete electrical circuit (not shown). The application of the external blood sample 11 to the connecting strip 12 completes the electrical circuit (not shown), thereby enabling measurement of the electrical properties of the blood sample 11.

The device 10 comprises a microprocessor 17 for calculating the blood glucose concentration from the electrical properties of the blood sample 11 and a temperature sensor 14 for measuring the absolute internal temperature. The microprocessor 17 and temperature sensor 14 are substantially enclosed by housing 15. The microprocessor 17 acts as a heat source; this may be the only heat source or may be supplemented by additional heat sources such as a screen 16.

In use, the heat output from the microprocessor 17 and possible other heat sources 16 gives rise to a time dependent absolute internal temperature Θ_i. The rate of change of the absolute internal temperature Θ_i with time may be approximately described by a first order differential equation. From this relationship, the difference between the internal temperature θ_i at time t and the internal temperature θ_i at t=0 is found to be:

$$\Delta\theta_i(t) = \theta_d^{\infty}\left(1 - e^{-\frac{t}{\tau}}\right)$$

Where θ_d^{∞} is the final (t $\rightarrow\infty$) steady state difference between the internal temperature θ_i and external temperature θ_e and the time constant τ has possible dependence on variables such as the heat generated by heat sources 14, 16 within the device 10 and the thermal conductivity of the walls of the device 10 (illustrated schematically by the arrow in Figure 1). Both θ_d^{∞} and the time constant τ are constant for any given mode of operation and device design (wall material, wall thickness etc) and may be determined empirically.

Referring to Figure 2 of the drawings, there is illustrated a schematic plot of the normalised difference between the internal temperature θ_i at time t and the internal temperature θ_i at t=0 ($\Delta\theta_i(t)$), and the normalised rate of change of the internal temperature difference $\frac{d(\Delta\theta_i(t))}{dt}$.

In order to accurately determine the blood glucose concentration from the electrical properties of the blood sample 11, the temperature in the vicinity of the measurement must be known to an accuracy of 2 degrees Celsius. The temperature sensor 14 is contained within the walls of the device 10 so only the absolute internal temperature is directly measurable. Therefore the temperature in the vicinity of the measurement (i.e. the temperature of the external blood sample) $\theta_e(t)$ must be calculated from the absolute internal temperature $\theta_i(t)$ using the relationship:

$$\theta_e(t) = \theta_i(t) - \theta_d(t)$$

Where $\theta_d(t)$ is the difference between the internal and external temperatures; this must be calculated from $\Delta\theta_i(t)$. If the device has not recently been in use then the initial internal temperature $\theta_i(t=0)$ is equivalent to the external temperature θ_e. In this case the difference between the internal and external temperatures $\theta_d(t)$ is simply equivalent to $\Delta\theta_i(t)$ and may therefore be found directly from the plot shown in Figure 2. However, if the device is cooling from previous use and is subsequently switched on then the situation is more complex. In this case, calculation of $\theta_d(t)$ demands that the internal temperature θ_i is measured at least twice within some time interval and the rate of change of internal temperature with time $\frac{d(\Delta\theta_i(t))}{dt}$ is calculated. This enables the device 10 or the user (not shown) to consult a plot such as that shown in Figure 2 in order to find an equivalent value for t such that the relationship $\theta_d(t) = \Delta\theta_i(t_{equiv})$ may be employed and hence the external temperature $\theta_e(t)$ calculated.

In both cases, once the external temperature $\theta_e(t)$ has been estimated, it is combined with measurements of the electrical properties of the blood sample 11 in order to calculate the blood glucose concentration.

From the foregoing therefore, it is evident that the present invention provides for a simple yet effective means of monitoring the temperature-dependent properties of an external sample.

CLAIMS

1. A method for estimating the external ambient temperature outside a substantially enclosed device, wherein the method comprises measuring the absolute internal temperature within or adjacent to the device, and estimating the external temperature from the measured absolute internal temperature.

2. A method according to claim 1, wherein the method further comprises calculating the level of heat generated within the device and using the result in the estimation of the external temperature from the measured absolute internal temperature.

3. A method according to claim 2, wherein the calculation of the heat generated within the device comprises ascertaining modes of operation of at least one heat source within the unit and using a-priori knowledge of power output of the at least one heat source for a given mode of operation to calculate the heat generated within the device.

4. A method according to any preceding claim, wherein the estimation of the external temperature from the measured absolute internal temperature accounts for the thermal conductivity of the device.

5. A method according to any of the preceding claims, wherein the estimation of the external temperature comprises execution of an algorithmic procedure relating the external temperature to the measured absolute internal temperature.

6. A method according to any of the preceding claims, wherein the estimation of the external temperature comprises or further comprises consultation of a database, wherein the database comprises a list of possible absolute internal temperatures with corresponding external temperatures.

7. A method of measuring blood glucose concentration, the method comprising measuring the electrical properties of a blood sample, estimating the temperature of the blood sample, and calculating the glucose concentration of the blood sample from the electrical properties and the temperature, wherein estimation of the temperature of the blood sample comprises measuring the absolute internal temperature within or adjacent to the device, and estimating the external temperature from the measured absolute internal temperature.

8. A device for monitoring temperature-dependent properties of an external sample, wherein the device comprises a temperature sensor for measuring the absolute internal temperature within or adjacent to the device, and means for estimating the temperature of the external sample from the measured absolute internal temperature.

9. A device according to claim 8, wherein the device further comprises at least one heat source and means for calculating the heat generated by the at least one heat source, the result of the calculation being used in the calculation of the external temperature from the measured absolute internal temperature.

10. A device according to claim 9, wherein the means for calculating the heat generated by the at least one heat source comprises means for ascertaining modes of operation of the at least one heat source and uses a-priori knowledge of power output of the at least one heat source for a given mode of operation to calculate the heat generated.

11. A device according to any of claims 8 to 10, wherein the estimation of the external temperature from the measured absolute internal temperature accounts for the thermal conductivity of the device.

12. A device according to any of claims 8 to 11, wherein the means for estimating the temperature of the external sample comprises an

algorithmic procedure relating the external temperature to the measured absolute internal temperature.

13. A device according to any of claims 8 to 12, wherein the means for estimating the temperature of the external sample comprises or further comprises a database, wherein the database comprises a list of possible absolute internal temperatures with corresponding external temperatures.

14. A device according to any of claims 8 to 13, wherein the external sample is a blood sample and the device comprises means for measuring blood glucose concentration.

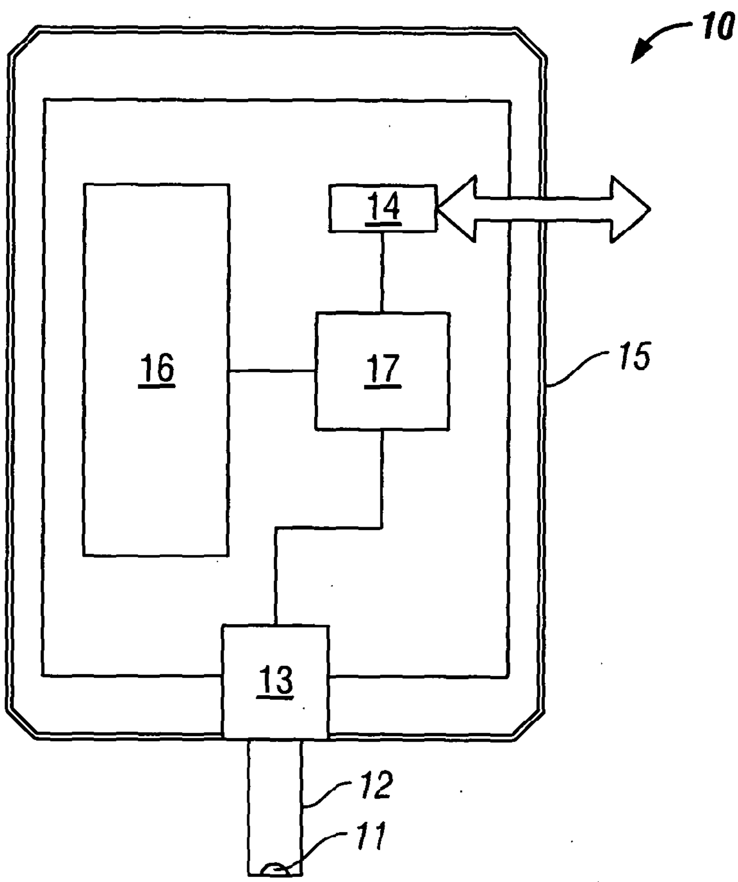
10
14
16
17
15
13
12
11

FIG. 1

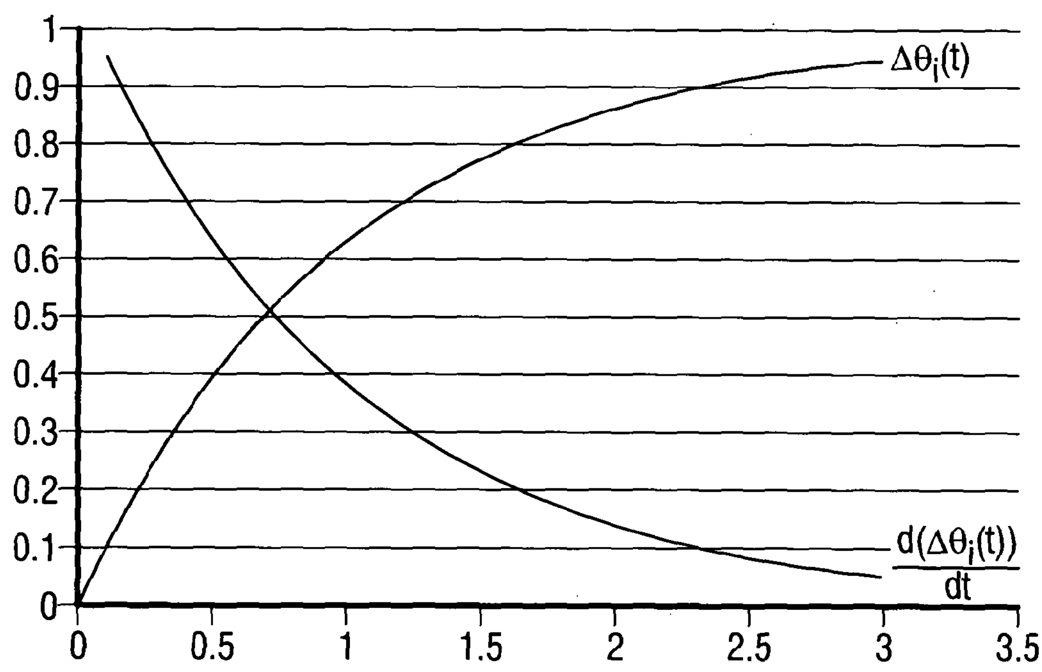
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3
3.5
Δθi(t)
d(Δθi(t))/dt

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/145 A61B5/1495 G01N27/327 G01K7/42
ADD.

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)
A61B G01N G01K

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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