METHOD FOR OPERATING A SENSOR TO DIFFERENTIATE BETWEEN ANALYTES IN A SAMPLE

TECHNICAL FIELD OF THE INVENTION

The invention is in the field of sensors and methods for sensor control. The invention finds particular applicability in the field of microhotplate sensors.

BACKGROUND OF THE INVENTION

Thermally controllable microhotplate sensors for gases and vapors are known in the art. Examples of such microhotplate sensors are disclosed in U.S. Pat. Nos. 5,464,966 and 5,345,213. Such sensors typically comprise a support substrate, a heating element thermally isolated from the substrate, a conductive heat distribution plate formed above the heating element, and a layer of a chemically active material formed above the heat distribution plate. The sensors are characterized by having a low mass (on the order of about 0.2 μg) such that the temperature of the sensor can be controlled over a wide range (on the order of 20° C. to about 1200° C.) and changed very rapidly (with rise times on the order of about 1 msec). These sensors can be formed into an array, the individual sensors constituting "pixels" or elements in the sensor array.

Further details concerning the function and operation of the foregoing sensors can be found in the aforementioned U.S. Pat. Nos. 5,345,213 and 5,464,966 and in Cavicchi et al., "Fast Temperature Programmed Sensing for Micro-Hotplate Gas Sensors," *IEEE Electron Device Letters* 16(3):1–3 (1995) and in Suehle et al., "Tin Oxide Gas Sensor Fabricated Using CMOS Micro-Hotplates and in-situ processing," *IEEE Electron Device Letters* 14(3):118–120 (1993). For present purposes, it is sufficient to state that the chemically active material in such sensors interacts with a detected analyte, thus causing a change in the conductance of the chemically active material. The change in conductance of the chemically active material thus may be used to detect the presence of the analyte.

While such sensors are useful in detecting the presence or absence of a single analyte, it can be more difficult for the sensor to differentiate between two or more analytes, especially when the analytes are chemically similar. For example, when the sensor is operated with a linear temperature profile that is pulsed, i.e., cyclically varied, the conductance output profile over time of the sensor for a first analyte (for example, methanol) often is very similar to that for a second, chemically similar analyte (for example, ethanol). When the sensor is introduced to an unknown sample containing one or both of the first and second analytes, it thus can be difficult for the operator to differentiate between the first and the second analytes based on the sensor output profile obtained.

It is a general object of the invention to provide a method and apparatus for operating a sensor, such as a microhotplate and apparatus, to enhance the difference between the output profiles of the sensor when introduced to first and second analytes to thereby assist an operator in differentiating between first and second analytes in a sample of unknown composition. A further general object is to provide a method and apparatus for operating a sensor in which the detection time is minimized while still enhancing the difference in the sensor output profiles as between the first and second analytes.

SUMMARY OF THE INVENTION

It has now been found that the output profile of a microhotplate or other thermally variable sensor depends on

the temperature at which the sensor is operated, the rate of pulsing of the sensor, and other factors. It has further been found that the output profile of the sensor for one analyte may be caused to vary substantially from that for another analyte, depending upon the temperature profile applied to the sample. In accordance with the invention, an optimized temperature or other suitable input profile is determined and is applied to the sensor. The optimized input profile is an input profile, not necessarily unique, that will enhance the difference between the output profiles of the sensor as between first and second analytes present or potentially present in an unknown sample compared to a linearly ramped input temperature profile or other non-optimized profile. This optimized input profile is applied to the sensor as the sensor is introduced to an unknown sample, and the output profile of the sensor is evaluated against known sensor output profiles of the first and second analytes to thereby determine which of the analytes is present in the sample.

In accordance with a preferred embodiment of the invention, the optimized temperature profile is determined for a microhotplate sensor by modeling the output profile of the sensor for each of the first and second analytes. Any number of modeling methods may be employed in conjunction with the invention, and preferred methods include models based on neural networks or wavelet networks. The temperature profile may be modeled for any arbitrarily chosen input temperature profile. Upon modeling of the output profile, an optimized temperature profile may be calculated in accordance with conventional methods. In accordance with a highly preferred embodiment of the invention, the sensor detection time is minimized by determination of the minimum pulse duration and minimum number of pulses that will result in enhancement of the difference in the output profiles of the sensor as between the first and second analytes to a predetermined degree.

Other features and advantages of the invention will be apparent from the following drawings and description of the invention.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a microhotplate sensor as it is applied to a sample of unknown composition.

FIG. **2** is a graphical representation of a linearly ramped temperature profile as it is applied to the sensor of FIG. **1**. Such linearly ramped profile is typical of prior art sensor operation.

FIG. **2**A is a graphical representation of the conductance output profile of the sensor, shown for both methanol and ethanol, when the temperature profile shown in FIG. **2** is applied to the sensor.

FIG. **2**B is a graphical representation of the conductance output profile of the sensor for a sample of unknown composition.

FIG. **3** is a graphical representation of an optimized temperature profile as it is applied to the sensor of FIG. **1**.

FIG. **3**A is a graphical representation of the predicted and actual conductance output profiles of the sensor, shown for both methanol and ethanol, when the temperature profile shown in FIG. **3** is applied to the sensor.

FIG. **3**B is a graphical representation of the conductance output profile of the sensor for a sample of unknown composition.

FIG. **4** is a graphical representation of an optimized temperature profile, calculated for twenty pulses and $NSSD_{minimum}$=1.