SENSOR HAVING A MICRO-BRIDGE HEATER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to integrated device sensors. More specifically, the present invention relates to sensors having a bridge structure in which an electrical resistance changes in response to ambient conditions. The sensor may be used for flow sensing, humidity sensing, infrared ray sensing, or gas sensing.

2. Discussion of the Background

In recent years, flow measuring such as hygrometry and gas measurement has been performed by utilizing a phenomenon which makes the electric properties of a conductive film used as a sensing portion of a sensor change with changing humidity or density of the gas. For example, a change of humidity in the atmosphere may be expressed as a change of the heat conductivity rate of a conductive film. Therefore, an apparatus utilizing this phenomenon can detect the change of humidity or other changes by measuring a resistance change of the heater which is made of a film having known properties. This change in resistance corresponds to a temperature change of the heater. The heater is heated by applying an electric current intermittently or continuously to the conductive film.

In order to have a low thermal time constant and to stabilize the performance of the heater, the heating portion is separated from a supporting substrate such as a silicon substrate by suspending the heating portion of the substrate in a bridge-like manner. Due to the small size and bridge-like construction, the heater is commonly referred to as a micro-bridge heater.

The micro-bridge heater includes a substrate, a first insulating film formed on the substrate, a conductive film made of a selected material formed on the first insulating film, and a second insulating film formed on the conductive film. These three films form the heating portion of the heater. One or both ends of the heating structure are fixed on the substrate and a center portion of the heating structure is separated from the substrate due to a depression which is formed in the substrate.

An exemplary conventional method of fabricating a micro-bridge heater made of thin films is disclosed in Japanese Laid-Open Patent Application No. 57-94641 which is incorporated herein by reference. The structure of this conventional micro-bridge heater is explained referring to FIGS. 1–3. FIG. 1 illustrates a top view of the micro-bridge heater, FIG. 2 illustrates a cross-sectional view at line X–X' of FIG. 1, and FIG. 3 shows a cross-sectional view at line Y–Y' of FIG. 1.

The conventional device of FIGS. **1–3** is an integrated semiconductor device including a semiconductor substrate **1** made of a material such as silicon having a depression **10** formed therein, as shown in FIGS. **2** and **3**. There is a first insulating film **2** formed on the semiconductor body **1**, a foundation metal film **3** formed thereon, a conductive film **4** formed on the foundation metal film **3**, and a second insulating film **5** formed on the conductive film **4**. These four films form a heating portion bridging the depression **10**. Parts of these films are removed selectively, for example by etching, which results in the structure illustrated in FIGS. **1–3**. The conductive film **4** has electrical current applied thereto and generates heat.

The conductive film **4** is a platinum film which is 5,000 angstroms thick, and a silicon dioxide (SiO_2) film having a thickness of 1.4 microns is used as the first insulating film **2**. The foundation metal film **3** is made of a metal such as molybdenum, titanium or chromium, has a thickness of 400 angstroms, and functions to increase adhesivity between the first insulating film **2** and the conductive film **4**. The second insulating film **5** is made of silicon dioxide (SiO_2) and has a thickness of about 3,000 angstroms. Both ends of the heating portion **7** are fixed on the semiconductor body **1**. These ends are formed as electrode pads **8**. When the conventional micro-bridge heater described above is used as a humidity sensor, electric power, for example 10 mW, is applied to the electrode pads **8** of the heating portion **7** in the form of pulses. The pulses having a minimum duration of 50 milliseconds to 100 milliseconds are applied every fixed cycle such as 1 second to 1 minute in the case of a humidity sensor and then the voltage across the pads **8** is measured. The measured voltage is typically several millivolts and this voltage is amplified by a suitable amplifier (not illustrated).

A problem exists in that the pulses of the electrical power cause thermal stress due to the rise in temperature of the heating portion to about 400° C. and a subsequent falling towards an ambient temperature. Because this thermal stress occurs intermittently, cracks are generated at the heating portion **7** at an interface between the conductive film **4** and the first insulating film **2**, and between the conductive film **4** and the second insulating film **5**. This may cause separation of the films depending on the circumstances. When silicon nitride is used as the insulating films **2** or **5**, crack production increases. This is because a silicon nitride film has a high internal stress and thermal expansion problems. Furthermore, warp caused by repeated expansion and contraction of the films also produces cracks due to thermal stress.

The thermal stress and cracks are not only caused by heat generated by the micro-bridge heater itself but also by changes in ambient temperature. A temperature increase at a location where the micro-bridge heater is located has detrimental effects similar to the thermal stress due to heat generation by the micro-bridge heater, and therefore cracks and thermal stress may occur even if electric power is not applied to the heater.

The thickness of the second insulating film **5** of the micro-bridge heater shown in FIG. **1** is as thin as 3,000 angstroms. The small thickness of the second insulating film **5** reduces a covering ability of the second insulating film over the conductive film **4**. This makes the separation of the second insulating film from the conductive film easier when a pulse of current is applied across the conductive film **4**. Also, the small thickness of the second insulating film **4** increases the amount of oxygen which can permeate through the second insulating film, thus increasing oxidation of the conductive film **4**. Therefore the lifetime of the micro-bridge heater may be short due to thermal stress caused by repeated application electric pulses. Further, applying electric pulses repeatedly in normal use causes thermal oxidation of the conductive film **4** due to thermal stress.

SUMMARY OF THE INVENTION

Accordingly, one object of this invention is to provide a sensor including a micro-bridge heater that has a lower internal stress, and a high tolerance to thermal stress.

Another object of this invention is to provide a micro-bridge heater in which the second insulating film protects from oxidation.