ALTERNATIVE MICRO-HOTPLATE DESIGNS FOR LOW POWER GAS SENSOR ARRAYS

R. Triantafyllopoulou, N. Tokpasidou, S. Chatzandroulis, A. Tserepi and C. Tsamis,

NCSR “Demokritos”, Institute of Microelectronics, 15310, Agia Paraskevi, Athens, Greece
email: ctsamis@imel.demokritos.gr http://imel.demokritos.gr/

Abstract*:* In this work we present the fabrication and characterization of cantilever-type micro-hotplates for thermal sensors based on Porous Silicon. Different device designs were modeled and fabricated and the influence of various parameters (eg. Porous silicon thickness, geometrical characteristics of supporting beams) were estimated.

Keywords: *Thermal Sensors, Chemical sensors, Porous Silicon, micro-hotplates*

1 Introduction

The use of porous silicon (PS) as a thermal isolation layer is an attractive alternative due to its very low thermal conductivity, which is comparable or less than that of silicon oxide. It has been demonstrated that the thermo-insulating properties of a closed-type 20μm thick PS micro-hotplate are similar to those of standard 0.2 μm thin nitride membranes. Closed-type [1] as well as suspended-type micro-hotplates [2] have been fabricated based on PS, the later resulting in significantly improved thermal characteristics.

However, there is one important aspect that stems from the use of Porous Silicon as material for the micro-hotplates. Since, the thermal conductivity of Porous Silicon is very low, **thicker** micro-hotplates can be fabricated compared to the thin and fragile nitride/oxide membranes, without losing the good thermal isolation provided by PS. This permits us to implement alternative micro-hotplate designs, with two or even one supporting beam, which means that we can minimize further the total area of the device as well as the power consumption. This possibility is very promising for the fabrication of low power arrays of sensors.

In this work we present the fabrication of cantilever-type micro-hotplates for thermal sensors based on PS technology. Different device designs are fabricated and the influence of various parameters (eg. PS thickness, geometrical characteristics of supporting beams, geometrical characteristics of heater, etc) are estimated.

2 Device Fabrication

As a starting material p type <100> silicon wafers with resistivity 1-10 Ω cm were used. An ohmic contact is formed on the backside of the wafer and a thermal oxide is then grown. An LPCVD polysilicon or nitride layer is deposited on top of the formed oxide, and patterned to define the area where the porous silicon is formed. Anodization is carried out in an electrolytic cell. The anodization current ranged between 10 to 80 mA/cm^2, while the anodization time ranges between 1 to 10 min. Removal of the silicon substrate can be achieved by both *dry* and *wet* techniques. After thermal treatment, a photoresist layer is deposited on the wafer by spin coating. Alternatively, SU-8 resist can be used if thicker resist thicknesses are required. Etching windows were then photolithographically opened in the photoresist and the silicon substrate is etched to provide the release of the micro-hotplate.

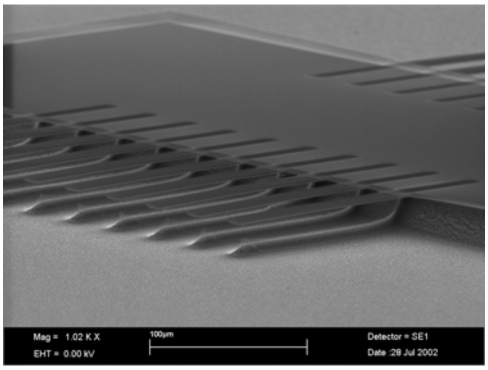

Fig. 1. *Arrays of Porous Silicon cantilevers. The thickness of the PS is 4 μm, the width 10μm and the length is 100μm.*

In case of dry etching, removal of the silicon substrate is performed with fluorine-based chemistries. A fluorine-rich gas such as SF$_6$ was used in a highly dissociating inductively-coupled plasma reactor (ICP) under operating conditions appropriately chosen to ensure nearly isotropic etching of Si.

Thermal sensors have been fabricated using the process described above [3]. After the local formation of porous silicon, a TEOS oxide is deposited on top of the wafer, to provide electrical isolation. Subsequently a patterned heater made either of doped polycrystalline silicon or Ti/Pt layer is formed. A photoresist film is then deposited and patterned to define the etch windows and protect the active elements of the device during etching for the release of the membrane. Figure 2 is an SEM image of a suspended PS micro-hotplate in the form of cantilever with one supporting beam. The dimensions of the square at the end of the cantilever is 100×100 μm^2, while the lenght of the supporting beam is 150μm. The thickness of the PS layer is 4 μm.

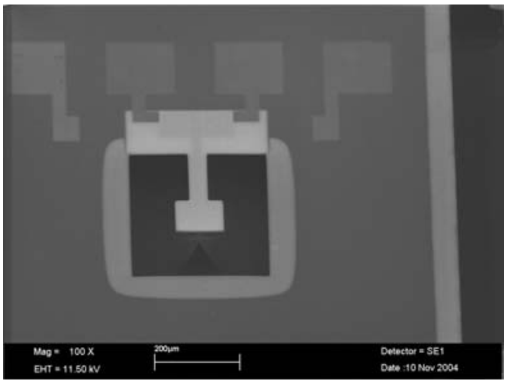

Fig. 2. SEM image of a cantilever-type PS micro-hotplate.

3 Results and discussion

For the characterization of the micro-hotplates, a constant current was passed through the heater and the voltage that developed was registered. Measurements were performed in a vacuum chamber, at reduced pressures ranging from 5×10^{-2} mbar to 1 atm, in order to minimize thermal losses due to convection in air. Fig.3 shows the change of the heater resistance as a function of the supplied power for ambient pressure 5×10^{-2} mbar for various device designs, which differ in the length of the supporting beam (A,B,C) or the layout of the device (D).

The thermal characteristics of the micro-hotplates were simulated using Coventorware software from Coventor. This is a powerful finite element analysis program, which can be used in microsystems analysis. Simulations were performed for various micro-hotplate geometries and the temperature that develops on the micro-hotplate was estimated, as shown if fig.4.

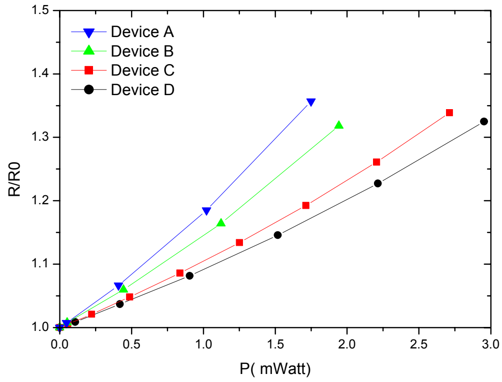

Fig. 3. Change of the polysilicon heater resistance as a function of the supplied power for various micro-hotplate designs for ambient pressure 5×10^{-2} mbar.

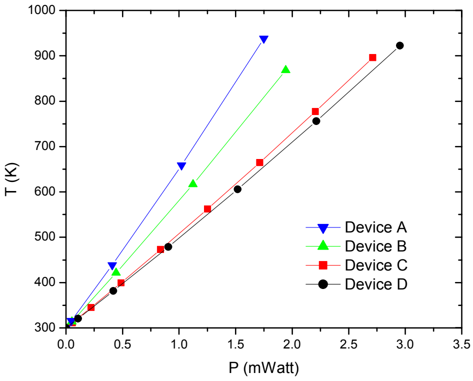

Fig. 4. Temperature estimation as a function of the supplied power for the various micro-hotplate designs for ambient pressure 5×10^{-2} mbar.

Detailed thermal characterization of the micro-hotplates as well as temperature measurements as a function of power using IR camera will be presented.

4 References

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