Microhotplate-Based Sensor Platform for Standard Submicron CMOS SoC Designs

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Introduction

Advances in MicroElectroMechanical Systems (MEMS) technology over more than a decade have made it possible to create microstructures that can be used as microsensors and micro-actuators for a wide range of applications. The microhotplate, [1], is one such microstructure that can be used as a basic building block for a variety of microsensors. In this paper, a technology-independent microhotplate fabrication and characterization method is described, primarily aimed at submicron low-voltage embedded gas sensor System-on-a-Chip (SoC) design applications.

Submicron CMOS Compatible Microhotplate

Microhotplates are suspended membrane structures that may incorporate a polysilicon heater and may also incorporate a separate temperature sensor. The suspended membrane structure is obtained using bulk micromachining techniques [2, 3]. Microhotplates can be designed using the standard layout tools used for integrated circuit design and can be fabricated in standard CMOS foundry processes followed by at least one post processing step. Figure 1 shows the layout of an individual microhotplate structure that is part of an array. The two thick polysilicon lines (labeled heater) define the microhotplate heating resistor and are connected in parallel to give a low impedance (around 280 ohms at room temperature), an important feature for low-voltage operation. In the center of the microhotplate, a 10 µm wide four-point serpentine polysilicon resistor is used as a temperature sensor. The open areas are obtained by a post-process gas-phase oxide etch to expose the silicon substrate next to the microhotplate. Access to the exposed silicon allows a bulk micromachining technique using XeF_2 [4] to suspend this microstructure. These devices were fabricated in a standard 0.5-µm CMOS technology. However, the design and fabrication techniques used are applicable across a wide range of standard CMOS technologies.

Temperature Sensor Calibration

The temperature sensor is calibrated by using the measured value of the temperature coefficient of resistance (TCR) of the polysilicon material. To measure the TCR value of polysilicon, the chip is first mounted in a ceramic DIP package and wire bonded. Then the entire package is heated to a known temperature with an externally controlled heat source. The four-point resistance measurement technique is used to measure the polysilicon temperature sensor resistance. A DC bias current of 100 µA is used. This value is small enough to avoid base resistance offset due to joule heating. The base resistance is the resistance of the polysilicon temperature sensor at room temperature. The temperature of the externally controlled heat source is increased from 30 ºC to 220 ºC in five-degree steps. Voltage measurements across the temperature sensor are taken for each temperature step. Figure 2 shows the change in sensor resistance with temperature, corresponding to a TCR value of 1.38E-03/ ºC.

Microhotplate Characterization

The microhotplate power efficiency is calculated by applying power-level steps to the polysilicon heater and calculating the resultant microhotplate temperature from the temperature sensor resistance and the TCR value. Figure 3 shows the microhotplate power efficiency. A temperature of over 400 ºC was achieved with less than 16 mW of heater power and less than 2.4 volts. These values are compatible with low voltage submicron CMOS SoC designs. Comparable microhotplates of the previous trampoline design required 6 volts or more to reach the same temperature. This is not compatible with low-voltage SoC technologies.

1-4244-0084-8/05/$20.00/©2005 IEEE

The microhotplate thermal time constant is measured by applying a voltage pulse of sufficient magnitude and duration to the heater. The temperature sensor is biased with a constant current (100 µA) and its transient voltage response is measured. Fig. 4 shows the measured thermal time constant waveform. The thermal time constant associated with the microhotplate is 1.7 ms.

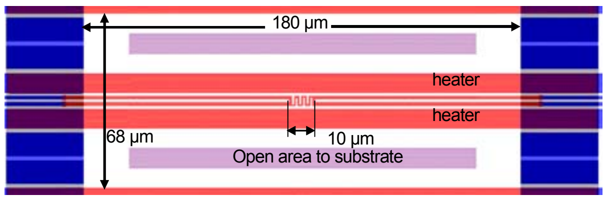

Fig.1 Layout of a microhotplate

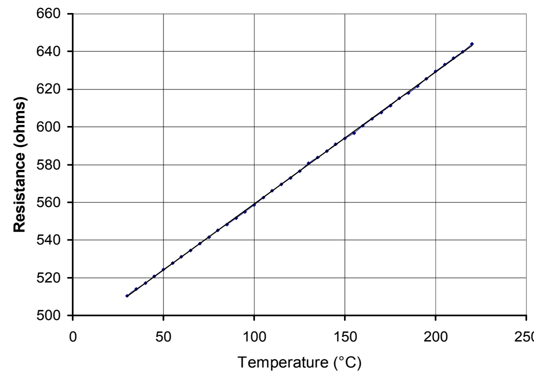

Fig. 2 Temperature sensor calibration curve

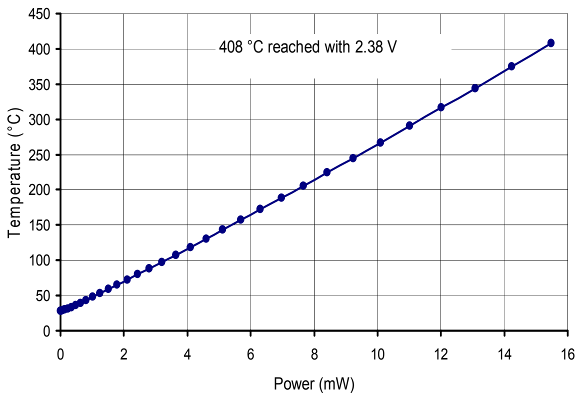

Fig. 3 Microhotplate power efficiency

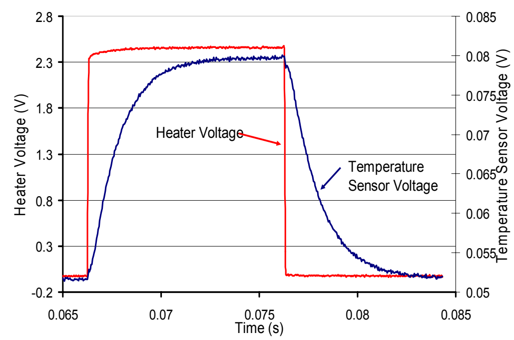

Fig. 4 Microhotplate thermal time constant

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