Design, Simulation and Fabrication of Platinum Based Micro-heater for Gas Sensing Application

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Abstract

The paper presents the design, simulation and fabrication of Platinum (Pt) based Microhotplate for gas sensing application. In order to reduce the power consumption, various geometries of microhotplate were simulated using ANSYS. Based on power consumption and average temperature distribution, double spiral pattern of microheater was selected. A Pt resistor of 30 Ω is fabricated on a thin SiO_2 membrane. Electrical testing of microhotplate was performed. A temperature of 520 °C was achieved at 19 mW power consumption.

Keywords: Micro-heater, Gas sensor, ANSYS-Simulation.

Introduction

Micro-heaters are electro-thermo-mechanical systems. They find applications in various fields ranging from chemical and pressure sensors to micro-propulsion systems .The layers of the MHP consist of a silicon substrate, dielectric membrane and heating element [1-2]. Micro-heaters are basically resistive structures that can attain a temperature of 300–400ºC due to joule heating when a voltage is applied across them. The main part of power consumption in a microhotplate consists of various thermal losses like conduction through bulk silicon substrate, convection in air from all exposed surfaces and radiation [3]. In present paper, the design of micro-heaters is optimized for low power consumption, low thermal mass, uniform temperature and enhanced thermal isolation from the surroundings. In general, MEMS-based micro-heaters have been realized using bulk micromachining and their thermal time constants are in the range of a few milliseconds [4]. Micro-heaters could be operated in either static (constant temperature) or dynamic mode (time-varying temperature). In the static mode, a constant voltage is applied across them which results in a constant steady-state temperature.

Design & Simulation

The transient and steady-state electro thermal simulation of the microhotplate has been carried out by ANSYS, a widely used finite element based software for simulation of MEMS devices. In this simulation, the SOLID69 element has been used, which supports the basic thermoelectric analysis taking the joule heating effect into consideration. SOLID69 has 3-D thermal and electrical conduction capability.

Table 1: Material properties used for the simulation

Material Properties	**Si**	**SiO_2**	**Pt**
Thermal Conductivity (W/m/K)	149	1.4	72
Resistivity (ohm-m)	1.0×10^{-1}	5.05×10^{13}	0.5×10^{-6}
Specific Heat(J/kg/K)	0.7×10^{3}	710	133
Density (kg/m^3)	2.33×10^{3}	2200	21400

The temperature of Si substrate surrounding the hotplate was fixed at 25º C as the boundary condition. Six different sizes of membrane have been simulated.

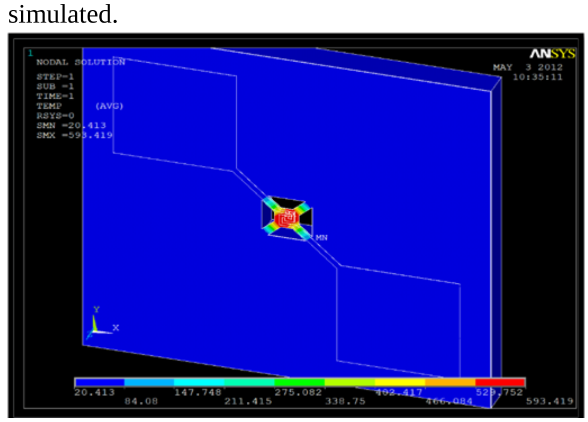

Fig. 1 Temperature distribution of Pt resistor at 0.9V.

The maximum temperature of 593 °C was obtained at 0.9V in case of small size of dielectric membrane as shown in Fig. 1.

Fabrication

Fabrication flow of the device is shown in Fig. 2. The structure after fabrication of the microhotplate is shown in Fig.3.

Results and Dicussion

The simulation results of double spiral microheater successfully showed the uniform temperature distribution on the active area of the microhotplate which is essential for better sensing mechanism. The microhotplate structure is successfully fabricated using bulk micromachining technique and shown in Fig. 3. The fabricated structure was electrically tested and it gives the temperature of 320 °C at 48.0 mW power consumption.

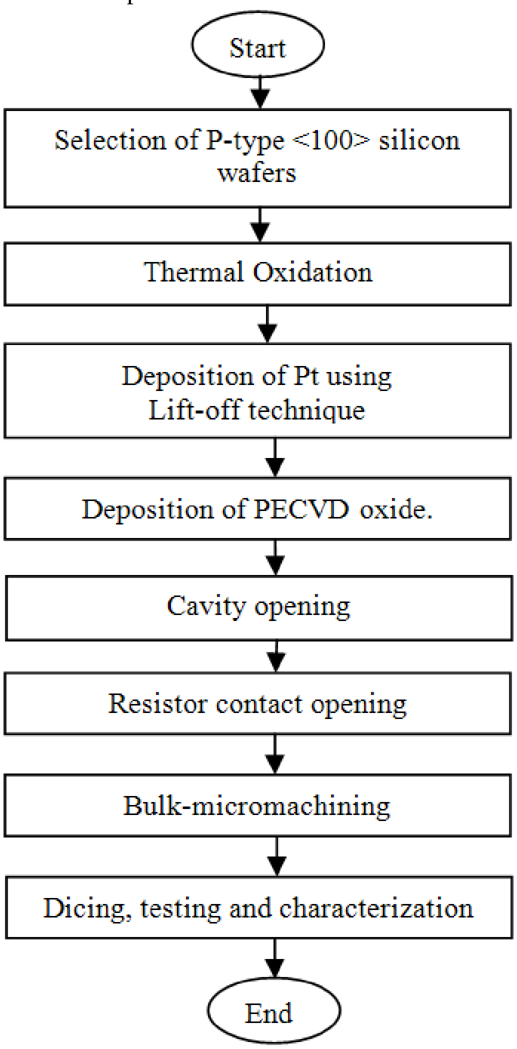

Fig. 2. Flow chart for MHP fabrication.

Conclusions

Design, simulation and fabrication of double spiral platinum based microhotplate with SiO_2 dielectric membrane have been done by electro-thermal analysis using ANSYS. Smaller membrane size thickness leads to the reduction of losses and thermal mass which in-turn improve the temperature value. The structure is fabricated using bulk micromachining technique and electrically tested.

Fig. 3. Structure of Microhotplate after fabrication.

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