FABRICATION OF A THIN-FILM THERMAL CONVERTER WITH RESISTIVE SENSING

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Abstract

A new thin-film thermal converter was designed and constructed. It senses the temperature rise of the heater using resistors made of vanadium oxide ($V0_2$). This paper presents details of the fabrication process and materials selection.

Introduction

Thin film thermal converters with thermocouples as temperature sensing devices have been extensively studied [1, 2]. They are currently used as AC-DC transfer national standards in most of the NMIs and also in secondary calibration labs. Resistive sensing was also used in the past in classical wire thermal converters [3]. A thin film converter was also introduced with aluminium as material for the sensing resistor and a feedback circuit to allow isothermal operation and fast response [4].

Our basic design was presented in a previous paper [5]. We used vanadium oxide (VO_2) as material for the sensing resistor. It has a high temperature coefficient of resistivity (TCR) (in the order of $0.02 \cdot K^{-1}$) allowing a high sensitivity of the device.

Basic design

Figure 1 shows the basic design of the device. A bifilar NiCr heater is used to reduce Thomson and Peltier effects [1]. With the aim of simplicity, in the first design no additional Si mass is left underneath the heater during the etching process. Low frequency optimization will be considered in a second step. Four VO_2 resistors are sputtered on the membrane, two of them near the heater (R_1 and R_4) and two of them on the silicon frame (R_2 and R_3). When a voltage (or current) is applied to the heater R_1 and R_4 are heated and R_2 and R_3 remain at ambient temperature. The four resistors are connected in a Wheatstone bridge configuration. The pads V_A and V_B are connected to the terminals of the detector. The source of the bridge is connected to V_T and to the pads 1 and 2.

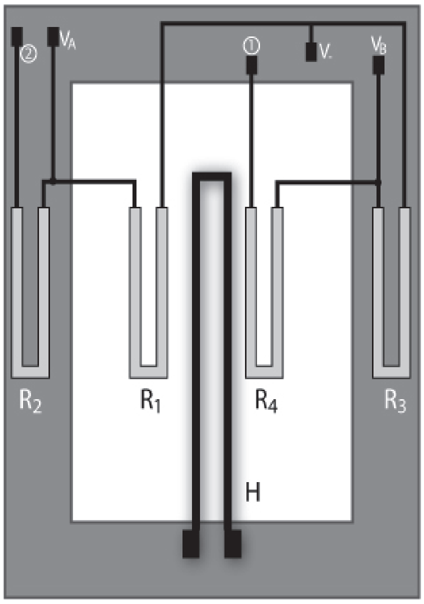

Fig. 1: Basic design. H is the bifilar NiCr heater, R_1, R_2, R_3, R_4, are the VO_2 resistors. In grey is the silicon frame and in white the free Si_3N_4 standing membrane.

Figure 2 shows the Wheatstone bridge used to measure the changes of the resistances. The voltage source of the bridge is 2 V. The four resistors have a resistance of 10 kΩ and are made of VO_2. Thus, any change in the ambient temperature does not change the balance of the bridge.

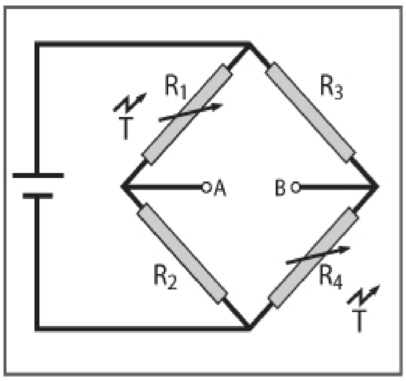

Fig. 2: Wheatstone bridge used to measure resistors change

Materials

Four inches Si wafers are used, with a low stress Si_3N_4 layer on both sides. We choose Si with volumetric resistivity lower than $10^{-2}\Omega$ cm to reduce ac-dc difference at high frequency [6]. Nitride thickness is in the order of 8000 Å, obtained by PECVD. For the heater we selected a NiCr alloy with bulk resistivity of 108 μΩ.cm and a TCR of 50 ppm/°C. The resistors of the bridge were made of VO_2 with a TCR of $0.02 \cdot K^{-1}$. The connection pads were made of Aluminium.

Microfabrication Process

Surface and bulk micromachining was done over (100) Si wafer, with 8000 Å thick Si_3N_4 layer on both sides. This nitride layer works as mask for Si wet etching, and as a membrane for structural support. Isopropanol standard cleaning was applied.
Four photolithographic processes were needed to complete the device, mask designs are shown in figure 3. A double side EVG620 mask aligner was used. Cavity at the back side was performed completely by wet chemical etching. HF was used to open nitride area, and KOH solution to etch silicon.

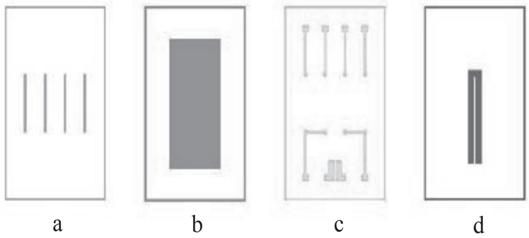

Fig. 3: Mask designs for each photolithographic process: a) Resistive sensors of VO_2 b) Back side cavity c) Al pads d) Heater of NiCr

Surface micromachining at sop side of the wafer was performed by DC / RF sputtering and lift off technique. A Boc Edwards Auto 500 physical vapour deposition system was used to deposit the three active layers. They were performed from NiCr (80/20 wt%) alloy, VO_2 and aluminium targets.

Figure 4 shows a photograph of the device at an intermediate step during the fabrication process.

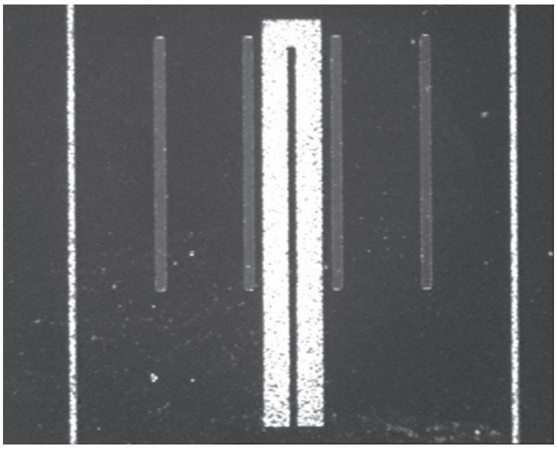

Fig. 4: Photograph of the device during process: 4 resistors and heater..

Conclusions

The feasibility of the device was demonstrated theoretically and with finite element simulations.
The fabrication process is already optimized. Process details and results of ac-dc differences will be presented at the conference.

References

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