Abs. 2588, 206th Meeting, © 2004 The Electrochemical Society, Inc.

LOW-POWER MICRO-SCALE CMOS-COMPATIBLE SILICON SENSOR ON A SUSPENDED MEMBRANE

A.Y. Kovalgin, G. Iordache, J. Holleman
MESA[+] Research Institute, University of Twente,
P.O. Box 217, 7500 AE Enschede, The Netherlands

In this paper we describe a new, simple and cheap silicon device operating at high temperature at a *very low power of a few mW*. The device can be utilized in chemical sensors or chemical micro-reactors requiring high temperature and very low power consumption e.g. in portable, battery operated systems. As a direct application, we mention a gas sensor (i.e. Pellistor) for hydrocarbons (butane, methane, propane, etc.) based on temperature changes due to the catalytic combustion of hydrocarbons. The power consumed by our device is at about *2% of power* consumed by conventional Pellistors.

The essential part of our device is a nano-size conductive link 10-100 nm in size (the so-called *antifuse*) formed in between two polysilicon electrodes separated by a thin SiO_2 layer (Fig 1). To create a silicon-SiO_2-silicon antifuse, the insulating SiO_2 layer between two silicon electrodes is destroyed (*antifused:* insulator becomes conductive) by a two-step electrical stress, during which the insulator melts locally [1-3]. The link acts as both a heat source and heat detector, and can be heated up when a constant current flows between the electrodes.

To minimize the heat losses by thermal conductivity, the antifuse-based heater has been realized on a suspended membrane (Fig 1, Fig 2). We developed a *fully clean room CMOS compatible*, simple and low cost method for processing of thermally isolated suspended membranes. The method allows for the "release" etch of the membranes with devices already fabricated and aluminum bonding pads patterned. For the "release" etch, a selective etchant was used, not attacking the masking oxide, nitride membrane, and the aluminum patterns [4]. Such an anisotropic wet etchant enables "self-stopping" at the (111) crystallographic planes of the Si substrate.

Measuring resistance versus power applied across the link, one can clearly observe a resistance increase for the power increasing from 1 mW up to 2.5 mW (Fig 3). This can be attributed to the metallic behavior of the poly silicon and therefore indicates a temperature rise of the antifuse. A maximum resistance at 2.5 mW corresponds to the intrinsic point of silicon and can be estimated at about 1000 ^{o}C for the doping concentration used. Starting from this point, the heat-generated carrier concentration exceeds the doping concentration, which leads to the resistance drop. Further increase of power causes re-melting the link (1415 ^{o}C for Si) and results in its bigger diameter and, therefore, lower resistance. This step is called re-programming. As the temperature required for sensing combustible gases when using a catalyst is much lower, the lower operating power disables re-programming.

To confirm the feasibility of the devices to maintain a hot surface and perform as Pellistor-type sensors, we carried out a number of gas sensing experiments. In Fig 4 one can notice a clear response after butane is introduced into the measuring chamber. When a combustible gas is burnt inside the pores with the help of a catalyst, this generates extra heat that increases a surface temperature and therefore gives rise to an increase of the device resistance.

REFERENCES

[1] V. E. Houtsma, Ph.D. Dissertation, University of Twente, Enschede, The Netherlands, (1999).
[2] A. Y. Kovalgin, J. Holleman, A. van den Berg. In "*Sensor Technology 2001*", ed. M. Elwenspoek, Kluwer Academic Publishers, p. 107-112, (2001).
[3] A.Y. Kovalgin, J. Holleman, A. van den Berg. Eurosensors 2002 – Book of Abstracts, edited by J. Saneistr and P. Ripka, pp. 31-32.
[4] G.Yan, P.C.H.Chan, I-Ming Hsing, et.al., *Sensors and Actuators* A **89** (2001), p. 135-141.

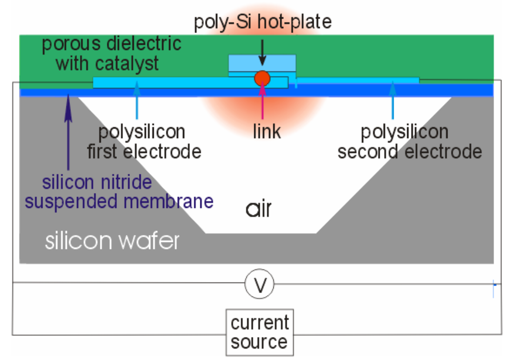

Fig 1. Schematic of a suspended-membrane device.

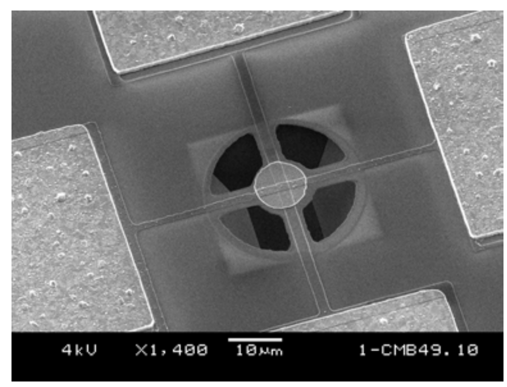

Fig 2. SEM image of a fabricated device

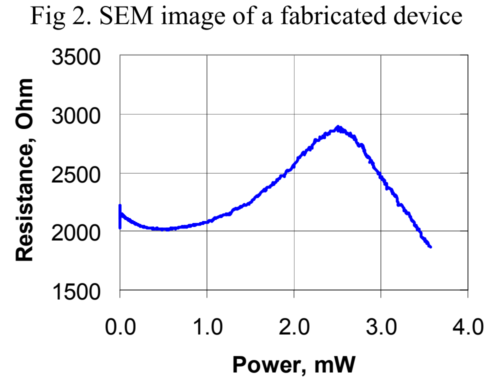

Fig 3. Electrical resistance of the link versus applied power

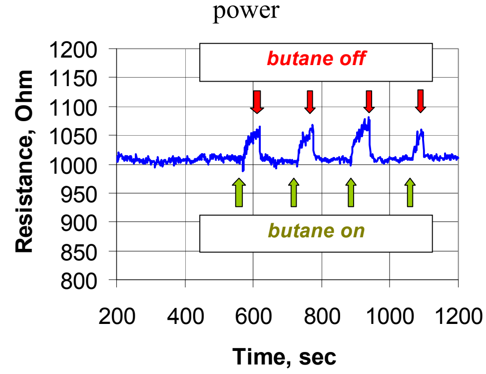

Fig 4. Sensing of Butane: the peak direction upwards can be attributed to the Pellistor-like behavior.