CHARACTERIZATION AND THERMAL DISTRIBUTION OF PLATINUM MICROHEATHERS FOR GAS SENSORS ON DIFFERENT SUBSTRATES

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Received 30 April 2011; accepted 30 May 2011.

1. Introduction

At present time, metal oxide - based gas sensors represent a viable solution for an increasing number of applications ranging from environmental and industrial monitoring to health care and detect toxic gases. Gas sensors often work in the high temperature mode that is required by the chemical reactions between the molecules of the specified gas and the surface of the sensing material, ranging typically from 400 to 700 K [1, 2]. Microheater emits heat by applying a current to a resistor, which has the advantage of low power driving as well as very short response time. Several researches have been conducted on microheaters that use SiC, Pt, poly-Si, Ni, Ag as the heating layer [1, 2]. We have compared electrical and thermal properties of meandered Pt microheaters on different substrates.

2. Experimental details

Meandered Pt microheaters were prepared on alumina and GaAs substrates. Pt for heating element was deposited at thickness about of 200 nm using dc magnetron sputtering process. TiN/Pt microheater was prepared onto the GaAs substrate. Active area of Pt heating resistor on GaAs substrate was 6.9 mm^2. The microheater on GaAs substrate had AlGaAs/GaAs membrane size of 2.9 mm x 1.8 mm formed by plasma etching. Three microheaters on alumina substrate had different active area of Pt heating resistors: the smallest (identify as num. 1) 6 mm^2, medium (2) 6.9 mm^2 and the biggest (3) 76 mm^2. For comparison, it was also described that commercial microheater on alumina (with area of heating resistor 6.9 mm^2) was used in metal oxide gas sensors developed by firm UST Sensor Technic Co. Microheater on GaAs substrate and UST sensor were mounted on TO package. Microheaters on alumina substrates and GaAs were also characterized by measuring tips.

Electrical resistivity of the microheaters was measured from room temperature to approximately 600 K. For testing purposes, the microheater was powered up with a variable voltage of 0 to -30 V source. I - V measurements were performed using voltage source Diametral P130R51D, multimeters HP 34401A and Metex MXD-4660A. Finally, thermal distribution was studied from double spiral Pt heating resistor in GaAs material.

3. Results and discussion

In the first step, electrical resistivity of Pt microheater was measured with increasing temperature. A calibration microheater was carried out to achieve temperature extraction. In the desired temperature range, the temperature dependence of resistance can be approximated by a linear relation. Measured results electrical resistivities (normalized to maximum value) of the microheaters are shown in Fig.1a. Linear dependency of electrical resistivity Pt microheathers on alumina substrates was recorded from ambient temperature to 550 K. The shift of electrical resistivity from linear region was recorded in the range of 300 - 550 K. Measured R-T characteristics were fitted in the linear range of the line from which the slope were calculated temperature coefficient of resistance (TCR) Pt for each sample.

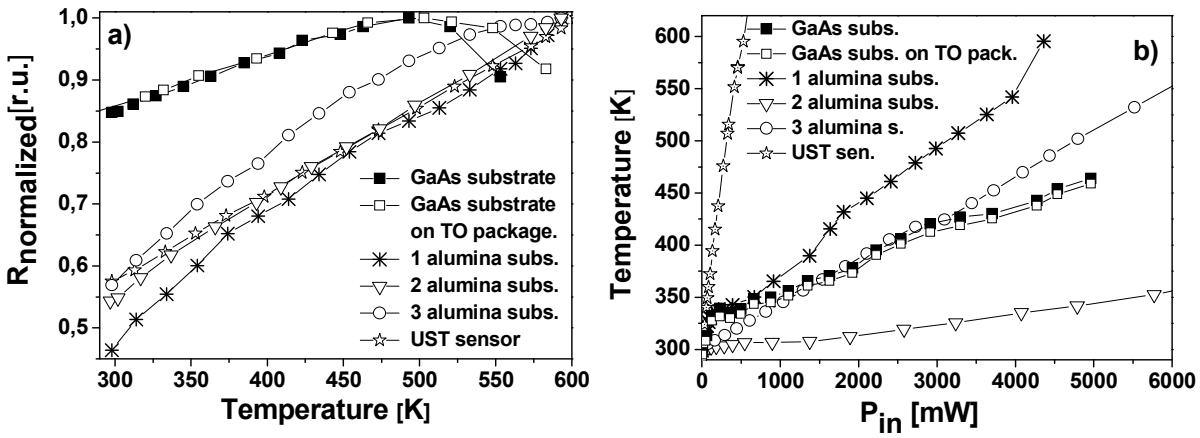

Fig.1: *a) R-T, b) P-T conversion characteristics of Pt microheater on different substrates.*

Electrical resistivity of Pt microheater was increased linear up to 510 K in case of microheater on GaAs substrate. Electrical resistivity Pt on GaAs substrate was significantly non-linear above 510 K and has decreasing tendency with increasing temperature. It was verified by multiple measurements that this phenomenon is reversible. Ballamy et al. [3] found out similar effect interface Pt-GaAs as describe about 510 K in Fig.1a. This effect is produced reaction at the GaAs-Pt interface. These can be Ga vacancies or As interstitials or

perhaps more complex defects possibly involving Pt. The defects diffuse into the GaAs under recombination stimulation. This is why the effect is not seen in devices exposed only to temperature stress or in devices in which the platinum interface reaction and hence defect production is limited by a barrier layer such as titanium in conjunction with a thin platinum layer. Defect is enhanced by recombination through the energy levels associated with the defects. At temperatures above 573K, defect is thermally activated while below 573 K, the kinetics of recombination-enhanced diffusion dominates. In our case, the diffusion barrier of TiN is only 20nm thin. Thicker layer of TiN would by better to avoid the presence of defect on the GaAs – Pt interface over temperature 573 K.

The calculated values of TCR for Pt on alumina substrates were in the range from 2400 to 4000 10^{-6} K^{-1}. The value of TCR for Pt on GaAs substrate was only 1060 10^{-6} K^{-1}. Fig.1b shows the so-called power to temperature (P–T) conversion characteristic of the Pt microheaters. There is also good linearity in the P - T conversion characteristic.

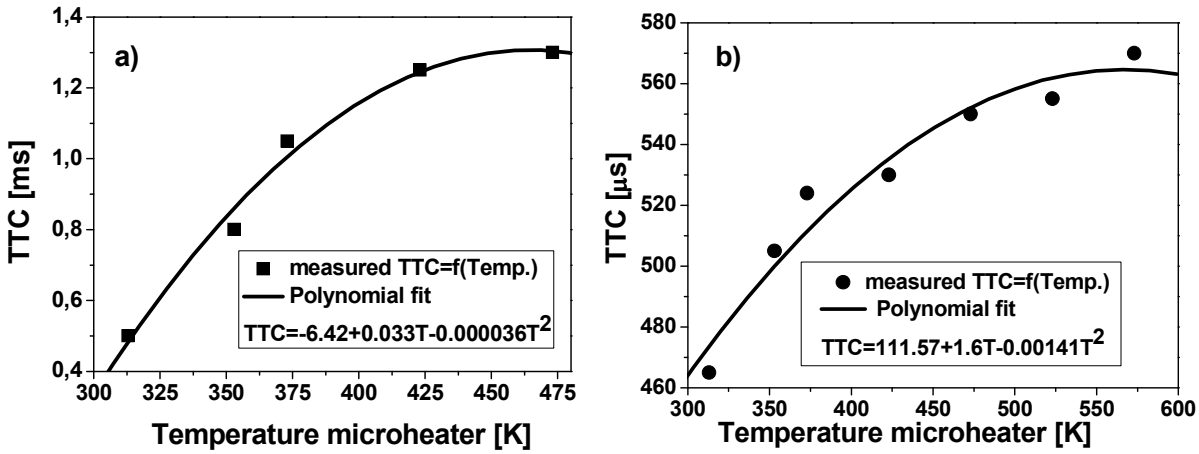

Fig.2: *TTC versus temperature of Pt microheaters on a) GaAs and b) alumina substrate.*

It is important to know thermal time constant (TTC) of stabilization temperature on the microheater in terms of subsequent use in gas sensor. Fig.2 shows TTC versus temperature of microheater. Fig.3a shows schematic image Pt double spiral of microheater on GaAs substrate. Fig.3b shows P-T characteristic microheater and lateral thermal distribution measured by T1, T2 and T3 Pt temperature sensors. GaAs appears to be a good thermal insulator for the microheaters of gas sensors. The Pt double spiral of microheater has active region defined only at close quarters of microheater. This structure will be next study after the creation suspended microheater.

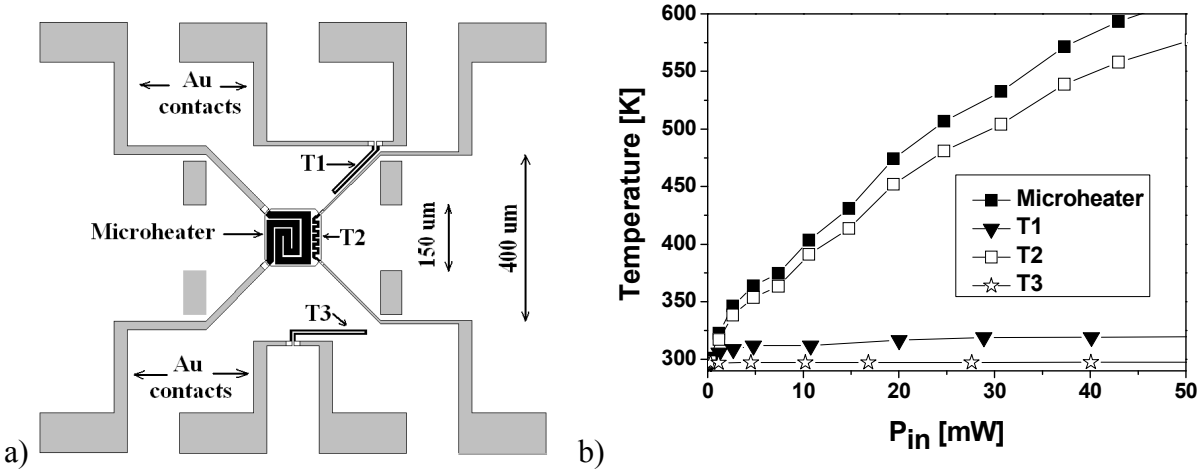

Fig.3: *a) Schematic image Pt double spiral of microheater on GaAs substrate. b) Measured lateral thermal distribution by T1, T2 and T3 Pt temperature sensors from powered microheater.*

4. Conclusion

Finally, we have fabricated and compared electrical and thermal properties of meandered Pt microheaters on different substrates (GaAs and alumina). Value of TCR for Pt microheater was changed in range of 1064 – 4000 10^{-6} K^{-1}. Power consumption in the Pt meander microheater on alumina substrate was 340 mW at the temperature 523 K. Microheaters had very short response time in the range of 0.5 – 1.4 ms. Lateral thermal distribution was measured by temperature sensors. This study confirm that GaAs is perspective material for develop metal oxide - based gas sensor.

Acknowledgement

This work was supported by Scientific Grant Agency of Ministry of Education of Slovak Republic and Slovak Academy of Sciences No. 1/0553/09.

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