NEW GAS SENSOR FABRICATED BY THICK FILM TECHNIQUE WITH SNO_2 AND WO_3 SENSITIVE LAYERS

Zdeněk KRÁL, Master Degree Programme (5)
Dept. of Microelectronics, FEEC, BUT
E-mail: zdenek_kral@hotmail.com

Supervised by: Dr. Jaromír Hubálek, Dr. Eduard Llobet, Dr. Xavier Vilanova

ABSTRACT

Gas sensors for the detection and monitoring of gases have wide utilization in various fields of application such as process control, automotive applications and environmental monitoring. Different techniques were used for sensor fabrication. I report on semiconductor metal–oxide gas sensors which were made by a screen–printing deposition process. This method is particularly suitable for small scale and low–cost sensors with good reproducibility.

1 INTRODUCTION

One of the key factors that distinguishes a thick film technique is the method of deposition, such as screen-printing or drop-coating. In fact, screen-printing is a simple and automated manufacturing technique that allows the deposition of a controlled amount of paste with a thickness ranging between few micrometers and some tens of micrometers [1]. In this work, I present a thick film gas sensor with six layers deposited onto the same side of a substrate. The first layer is a heater. The heater is present here to set the working temperature, because this type of sensor works mainly at high temperature (150–600 °C). The second to fourth layers are insulating. The fifth layer comprises the electrodes. Finally, a sensitive layer is deposited. The quality and thickness of the deposited layers depends on the following parameters: viscosity of the paste, size of the apertures in the net, net tension, flood blade hardness and velocity, and finally distance between the net and substrate [2]. More details about these parameters will be described below. The final steps in this work are mounting and bonding sensor chips onto standard TO-8 packages and making a characterization of the heater.

2 FABRICATION OF THICK FILM GAS SENSOR

Fabrication the sensor involves a design sensor topology (heater, electrodes), a paste selection, screen-printing, drying at low temperatures (125–150 °C), firing at high temperature (500–1000 °C), and packaging.

2.1 SCREEN PRINTING OF MULTILAYERS

All pastes contain an organic vehicle for improving viscosity and also small amounts of binder for improving the adhesion of the film to the substrate. Pt conductor paste was used for the heater. ESL 5545 was chosen because this paste is determined for use on 96% alumina substrates as resistance-thermometer and heater applications. The stainless screen (MESH 400/25 µm) was designed for this paste. For the electrodes, a newly developed gold ESL 8881-BA paste designed for 96 % alumina substrates was employed. The paste exhibits high coverage and excellent wire bondability by Al and Au. The stainless screen (MESH 325/25 µm) was used for the gold paste. The insulating layers were applied between heater and electrodes. Two types of dielectric pastes were chosen. The first one, ESL 4913-G is cadmium-free, lead-free, and nickel-free non-porous multilayer dielectric for use on alumina substrates. Particularly, this dielectric is not compatible with the selected gold paste for electrodes. Only two layers with ESL 4913-G paste was designed. The paste ESL 4905-CH, which is compatible with gold paste, has an excellent TCE match to 96 % alumina, and was designed for the third insulating layer [3]. The stainless screen (MESH 325/30 µm) was used for all dielectric pastes. The angle of the fibers was 45 ° for all screens. All layers was dried at 125 °C for 10÷15 min after printing and fired at 850 °C peak for 10 min before printing next layer. During firing process the organic vehicle completely burn away front of temperature peak where the powder is annealed to adhere particles to particles and particles to substrate.

The active layer consists of four different sensitive layers from different materials. Therefore, each of them was printed individually by using the same stainless screen (MESH 325/15 µm). Two of them are fabricated from commercial powder (WO_3 and SnO_2) milled in planetary mil and two are prepared from commercial nano-powder. The active layers were dried at 125 °C for 10÷15 min before printing next layer. When all active layers were printed, the sensors were fired at 600 °C for 20 min.

2.2 PACKAGING

The substrate 2”x 2” and 250 µm thick with printed sensors was backside cut by laser beam and broken. Sensors must be placed to a package and contacted with wire to assure connection with inputs of sensors. TO-8 package was used. The sensor is heated to relatively high temperatures and cannot lie directly on package because of power lost and package heating. The substrate is distanced from package with metal columns and glued with epoxy commonly used for SMD. Interconnection was made by bonding with 25 µm thick Al wire. The bonded spots are fixed with Ag paste.

3 RESULTS

The heater meander is designed (Fig.1) to assure homogenous distribution of temperature. The detail of finished sensor without active layers is in Fig.2. Fig.3 show sensor with four different active layers. Packaged sensor is presented in Fig.4. The heater resistance and power was measured for 10 samples of sensors. The dependence of resistance versus temperature with deviation of values is plotted in Fig.5. The linear regression was determined from average values. It is

$$T = 239.7 + 48.9 \cdot V_{sup\,ply}\text{, [K]} \qquad (1)$$

where T is temperature calculated due to immersed voltage. The relative error of temperature is 1.7% if the voltage is set according to linear regression. Fig.6 shows a power needed for sensor heating. The consumption of the sensor working at 600 °C is approximately 1.5 W.

Fig. 1: *Designed meander for heater*

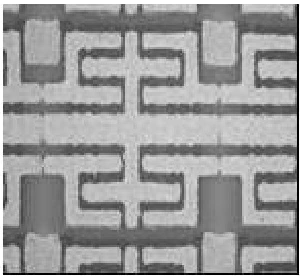

Fig. 2: *Auxiliary view on a comb structure of electrodes and pads for heater*

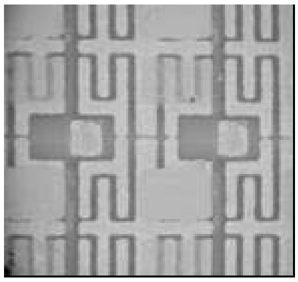

Fig. 3: *The substrate with sensitive SnO_2 and WO_3 thick-film layers*

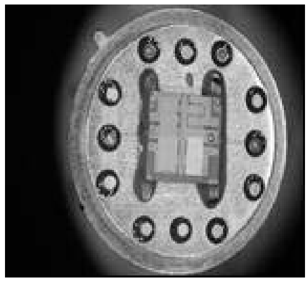

Fig. 4: *The chip with four sensitive thick films of SnO_2 and WO_3 mounted and bonded on standard TO-8 support*

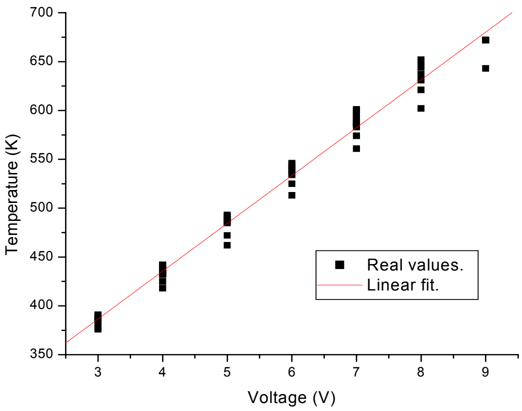

Fig. 5: *Heater characteristic*

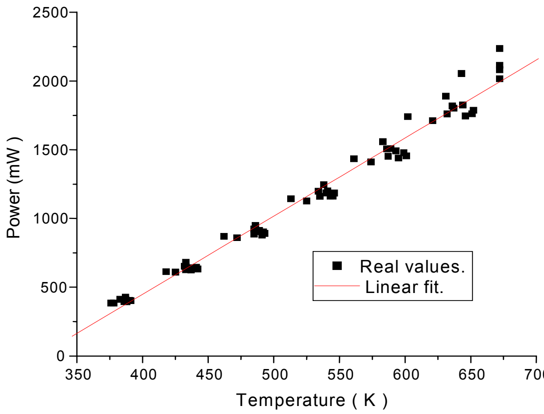

Fig. 6: *Power characteristic of heater*

4 CONCLUSION

A screen–printed thick-film gas sensor with experimental SnO_2 and WO_3 sensitive layers have been designed and realized. The characterization of the heater was also investigated and deviation of the resistance is very small. The sensor is ready for characterization in gases. The sensing performance in gases will be explored and presented in my diploma work.

REFERENCES

[1] Guidi, V., Butturi, M. A., Carotta, M. C., Cavicchi, B., Ferroni, M., Malagú, C., Martinelli, G., Vincenzi, D., Sacerdoti, M., Zen, M.: Gas sensing through thick film technology, Sensors and Actuators B 84(2002) 72-77.

[2] White, N. M.: Thick film technology, Elsevier Science B. V.(1994)

[3] Characteristics of ESL pastes available on URL: http://www.electroscience.com/products.html