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CONCTRUCTIONS AND MATERIALS FOR HEATER SYSTEMS OF THICK-FILM GAS SENSORS

Наводиться огляд товстоплівкових нагрівних систем на основі резистивних і провідних плівок. Розглянуто різноманітні геометричні розміри таких систем. Наведено приклад моделювання розподілу теплового поля в системі HYBTERM.

The paper presents the review of thick-film heaters' systems based on resistive or conductive films. The different geometrical shapes have been considered. The example of simulation of temperature field distribution (with using HYBTERM program) has also been included.

Key words: gas sensors, heater, temperature field distribution

1. INTRODUCTION

One of the most important features of thick-film technology is a big design flexibility of resistive elements. Additionally, very good heat conductivity of used substrates, low thermal capacity and possibility of resistive element geometry forming makes this technology an excellent solution for manufacturing of wide range of different heaters with given temperature distribution.

The majority of gas sensors based on semiconductive oxides (for example SnO_2, ZnO or TiO_2) operate at elevated temperature (up to 900 °C). A big gradient of temperature (gas sensors arrays) and its strictly determined distribution on the element surface is often required. Temperature is one of the main factors which determines the sensitivity, selectivity and response time of sensors. For this reason, the choice of material and construction of heater system plays a very important role in the proper operation of such devices [1,2,3].

The paper presents the synthesis of presently used heater systems in the different types of gas sensors. The special attention was laid on configuration of heating layers and proper temperature field distribution.

2. TYPICAL CONSTRUCTIONS OF HEATERS

The majority of thick-film gas sensors are resistive sensors. They take advantage of resistance changes under the influence of type and concentration of adsorbed gases on active surface of the sensor. At the present time two trends in gas sensors technique can be observed. One is the development of single, highly selective and sensitive sensors characterised by simple and cheap construction. The other trend is rapid progress in the area of multifunctional intelligent sensors' arrays that co-operate with microprocessor systems. So, the kind of sensor and its application are determined by its system of heaters.

The widely known TGS sensor manufactured by Figaro Inc. has a form of alumina tube covered by sinterd SnO_2. As a sensor heater Pt wire with gold contacts is used (Fig. 1) [4,5,6].

In thick-film technology which is characterised by layer structure of the circuit heaters for gas sensors are generally made from resistive or conductive (PdAg, PtAg, PtAu, Au, Pt) pastes.

The example of configuration of the single resistive heater is presented in Fig. 2.

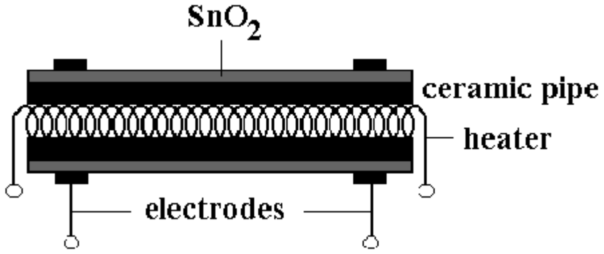


Fig. 1. Construction of Figaro gas sensor

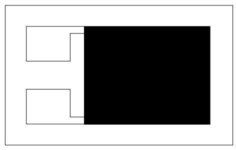
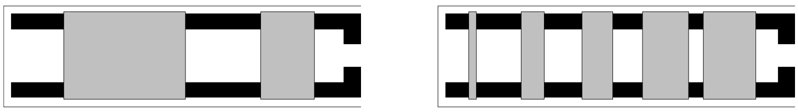


Fig. 2. Resistive heater for single sensor

Such simple solutions have the resistance about tens of ohms and good dynamic parameters. On small areas of resistive layer (with the most frequently used RuO_2 composition) high power can be dissipated in relation to the layer's dimensions. This power (in other words – temperature) depends on the geometry of heaters (except of power supply). This characteristic feature is used in construction of heater systems in sensors' arrays (Fig. 3).



а б

Fig. 3. Example of heaters' mutual placement in sensors' array:
a – with two heaters; b – with five heaters

The different operating temperature of particular sensors of array makes it possible to create system sensitive for different gases. A very important thing in such case is the proper temperature field distribution on the surface of array. This field is mainly determined by mutual placement of single heaters.

In many situations the heaters' systems are made as multilayer structures (Fig. 4).

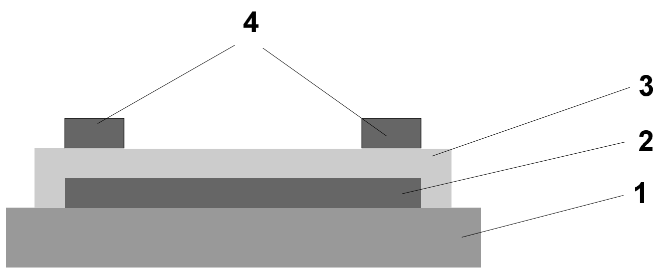


Fig. 4. Example of multilayer heaters' system (section):
1 – substrate, 2 – main heater, 3 – isolation layer, 4 – correction heaters

The multilayer heating structures have application in systems where is required the maximal linear variable temperature field. The correction heaters (laid on the top of isolation layer) can be printed on arbitrary place where the temperature correction is needed.

Generally, heaters based on conductive pastes have the better parameters. They have small sheet resistance (miliohms per square) and – what it is very important – very good time stability.

Moreover, the possible operating temperature is much higher for heaters made from conductive films (up to 1000 °C). An example of such heater is illustrated in Fig. 5.

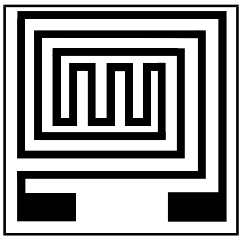


Fig. 5. Example of heaters made from conductive ink

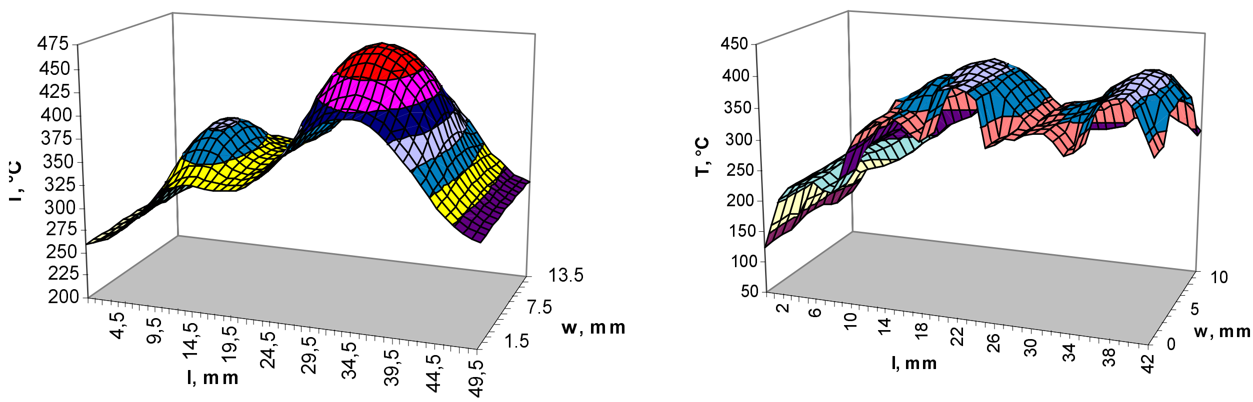
This topology is often called meander construction. The shape and material used for the manufacturing of such heater systems depend on application, active layer and housing construction.

3. EXAMPLE INVESTIGATIONS

The computer simulations and laboratory tests were made for the gas sensors' arrays. Each of those matrixes consists of five sensors which operate in different temperature (for detection of different types of gases). The investigations were carried out for two types of heaters' configuration (two and five heaters).

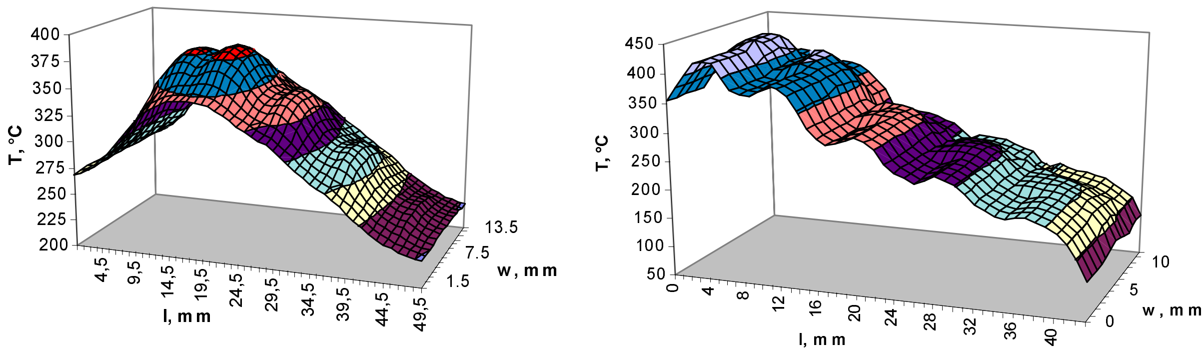
The HYBTERM program (elaborated in Dept. of Electronic Systems on Rzeszów University of Technology) is the integrated, interactive packet for simulation of stationary temperature fields, especially in hybrid microcircuits. This program allows to solve 3-D non-linear boundary problem of complicated heat transfer in the hybrid microcircuit. The basis of using of HYBTERM program is the complete thermal characteristic of the microcircuit. This characteristic includes the coefficients of heat transfer inside the microcircuit and between the circuit and the environment by convection, radiation and conduction. The specific property of the hybrid microcircuits has been distinguished in thermal characteristic, i.e. a non-planar, multilayer structure [7].

The laboratory measurements of temperature field distribution have been performed with using infrared RAYTEK meter (point non-contact method).



a *b*

Fig. 6. Temperature field distribution in sensors' array with two heaters:
a – simulation, b – measurement



a *b*

Fig. 7. Temperature field distribution in sensors' array with five heaters:
a – simulation; b – measurement

The obtained results show that the temperature field distribution is much more uniform for sensors' arrays with five heaters.

4. CONCLUSIONS

The basic problem in the design of resistive heaters' systems is selection of proper resistor geometry. In many cases very complicated computational algorithms are needed. The modern computer programs are very useful tools in designing process of those thermal elements. The selection of construction and fabrication material of heaters' systems is an individual problem in each case of a sensor and it depends on many internal and external factors.

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