THE TOPOLOGY DESIGN OF THICK-FILM ELECTROCHEMICAL SENSOR ARRAY

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The current trends in sensor technology are a sensor miniaturization, integration of sensing element with measuring circuits and integration of sensors elements to sensor array. The hybrid technology seems to be optimal for design and production of electrochemical sensor array. This work is focused on topology design of thick-film electrochemical sensor array and presents new electrochemical sensor array for voltammetric measurement. This sensor array is placed on 50,8 mm x 50,8 mm alumina substrate. The supposed advantages of this sensor array are the increasing of speed of measurement, accuracy of measurement and enlarging of measuring possibilities against the common optical sensors system.

Keywords: Thick-film, Electrochemical sensor, Sensor array.

1. INTRODUCTION

The current trends in sensor technology are a sensor miniaturization, integration of sensing element with measuring circuits and auxiliary systems (channels, filters, capillaries, micro pumps [1]) and integration of sensors elements to sensor array. The hybrid technology seems to be optimal for design and production of electrochemical sensor array. The main advantage of thick-film (TFT) technology lies in very good mechanical, electrical and thermal properties, small scale batch production and mainly in low price and simply production [2], [3].This work is focused on a topology design of thick-film electrochemical sensor array for voltammetric measurements only.

The topology design of thick-film electrochemical sensor array is very complicated. It is more complicated than design of electrochemical sensor with one electrode part. Many problems mentioned below must be resolved.

First problems group is a group of problems, which are solved in design of electrochemical sensor with one electrode part only [4], [5]. These problems are focused to design of electrode part (high size of working electrode area, high size of reference electrode area in a two-electrode system, high size of auxiliary electrode area in a three-electrode system, uniform current density between working and reference electrodes in two-electrode systems or between working and auxiliary electrodes in three-electrode systems, ...), materials of electrodes, connection part protection against solution, design of sensor connection to measure device, etc.

Second problems group is a group of problems, which are specific for sensor arrays. Sensor array design is more complicated, because of a little substrate where must be placed more electrode parts, contact and conductors than in a case of simple electrochemical sensor with one electrode part. For example, problems are the interconnection of sensor elements, connection of sensor elements with contact (20 leads or more are on the substrate), more crossing of leads (high price and more complicated technological process), the transfer of various analytical samples to various electrode's elements, etc. Next, one of new trends is an integration of sensors with capillaries, channels, filters or micro pumps. The sensor array design is more complicated again.

2. Sensor Array Topology Design

The topology design of thick-film electrochemical sensor array was started as the design of the three-electrode sensor for two or three-electrode system of measurement. The transfer of analytical sample to the electrode part was supposed to be done by drop-coating method. The fig. 1 shows the analytical sample drop-coated over the electrode part of the sensor element.

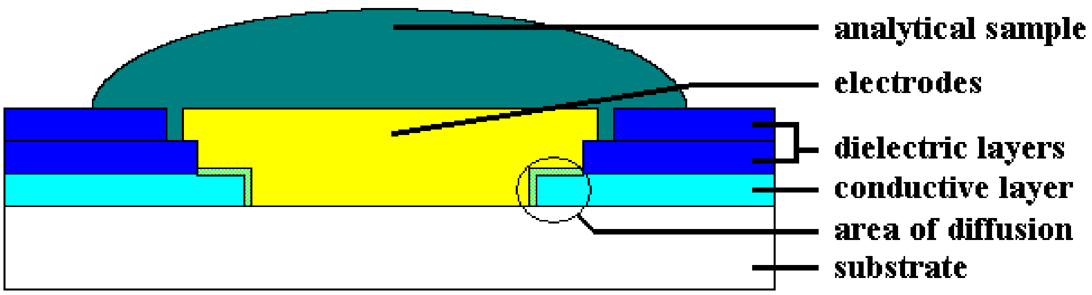

Fig. 1: The analytical sample drop-coated over the electrode part of the sensor element.

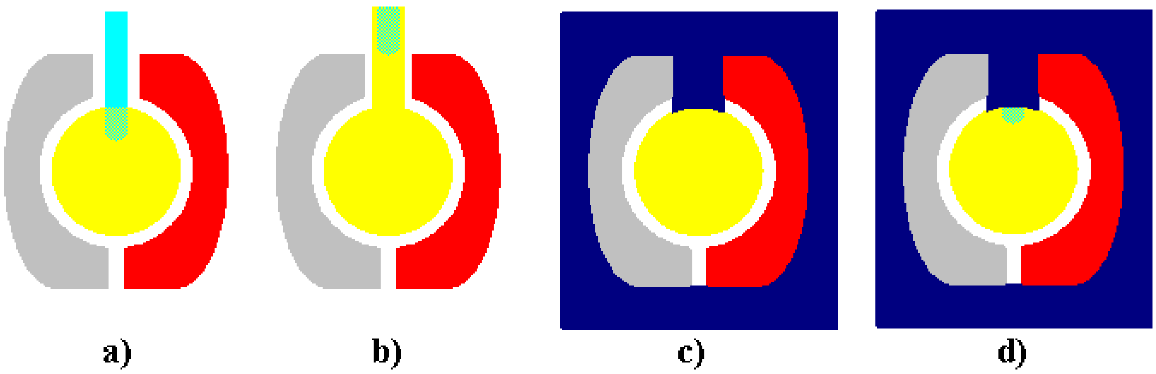

Fig. 2: Diffusion surface optimisation of contact area between conductive layer and working electrode in electrode part of the electrochemical sensor. a) conventional contact; b) contact displaced outside from electrode part; c) contact overlaid by dielectric layer; d) minimal contact – working electrode layer is screen-printed as the last layer).

Next, the fig. 1 also shows the area of diffusion between conductive layer and working electrode. If the working electrode is gold layer and if silver conductive layer is used, the diffusion area is often enlarged on surface of working electrode. This case is very dangerous, because potential dependence of materials, which are analyzed, may be changed. Therefore the contact between the working electrode and the conductive layer is protected by dielectric layer or is minimized, as is shown in the fig. 2.

The first topology design of the electrochemical sensor array with the three-electrode sensor elements for two or three-electrode system of measurement is shown in the fig. 3. The reference and auxiliary electrodes are interconnected in columns and every working electrode is connected separately to sensor connector. The working electrodes were suggested to be switched by multichannel potentiostat. Because the potential stability is very bad in the two-electrode system [6], the work was focused on the three-electrode sensor for the three-electrode measuring system only. Because the potential of reference electrode can be influenced by the potential of other reference electrodes in this design, the potential will by potentially unstable. Therefore was decided that the reference and auxiliary electrodes must be connected to the connector separately and the working electrodes can be interconnected. This optimized design is shown in the fig. 4.

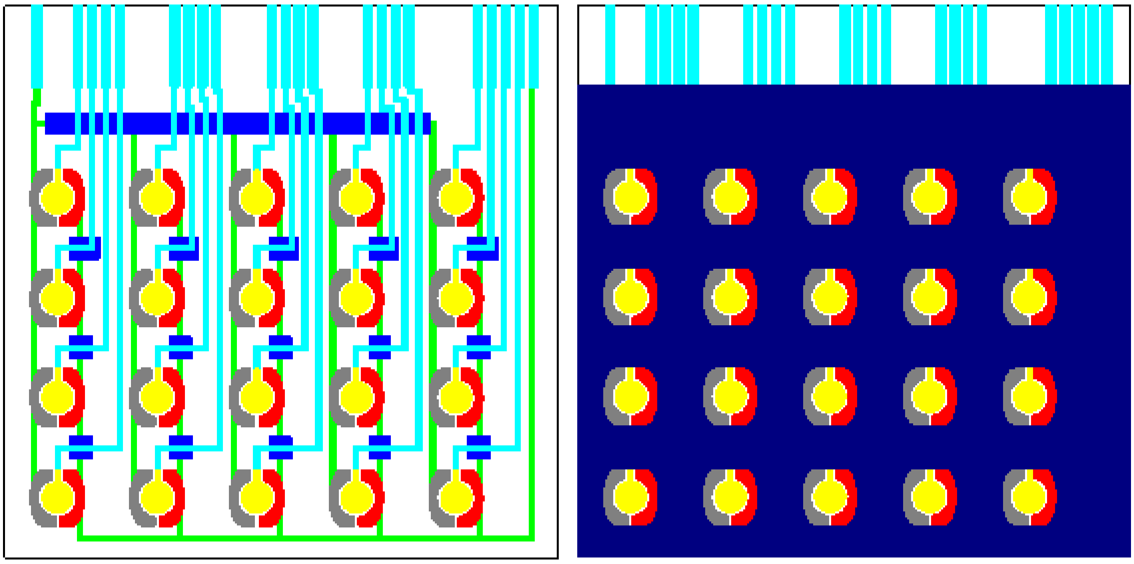

Fig. 3: Topology design of the electrochemical sensor array with the three-electrode sensor elements for two or three-electrode system.

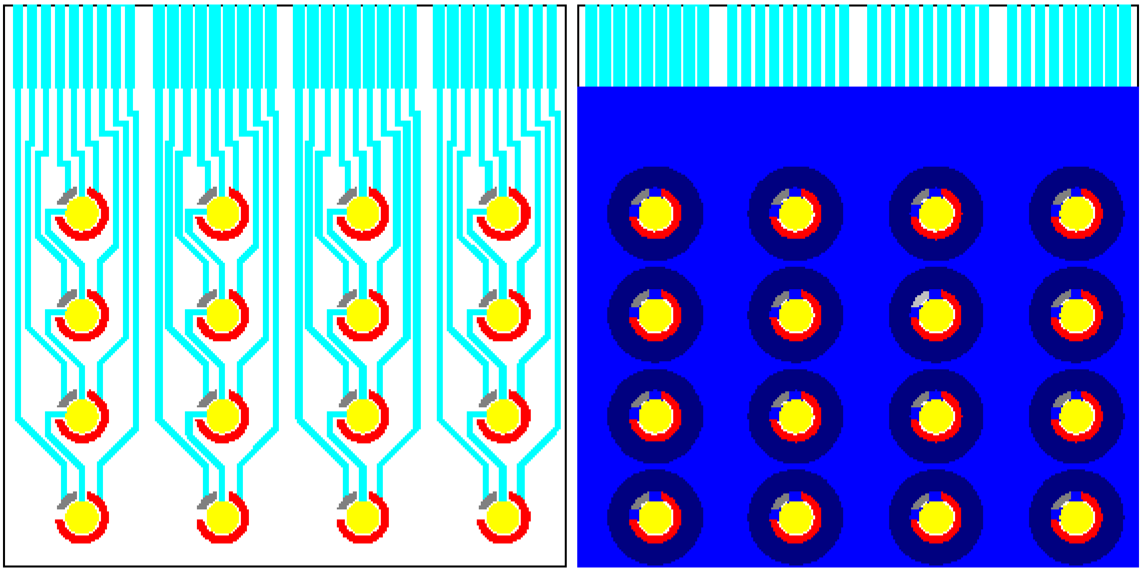

Fig. 4: Optimized topology design of the electrochemical sensor array with the three-electrode sensor elements for the three-electrode system only.

Real sample of electrochemical sensor array (see fig. 5), was made on 96% alumina substrate. The gold paste ESL 8881-B was used as the material for Au working electrode and the silver paste ESL 9912-K was used as the material for auxiliary and reference electrode. The dielectric layer was made from the dielectric paste ESL 4913-G and the conductive layer was made from the PtPdAg paste ESL 9562. This sensor array is placed on 2” × 2” alumina substrate.

Fig. 5: The real sample of electrochemical sensor array.

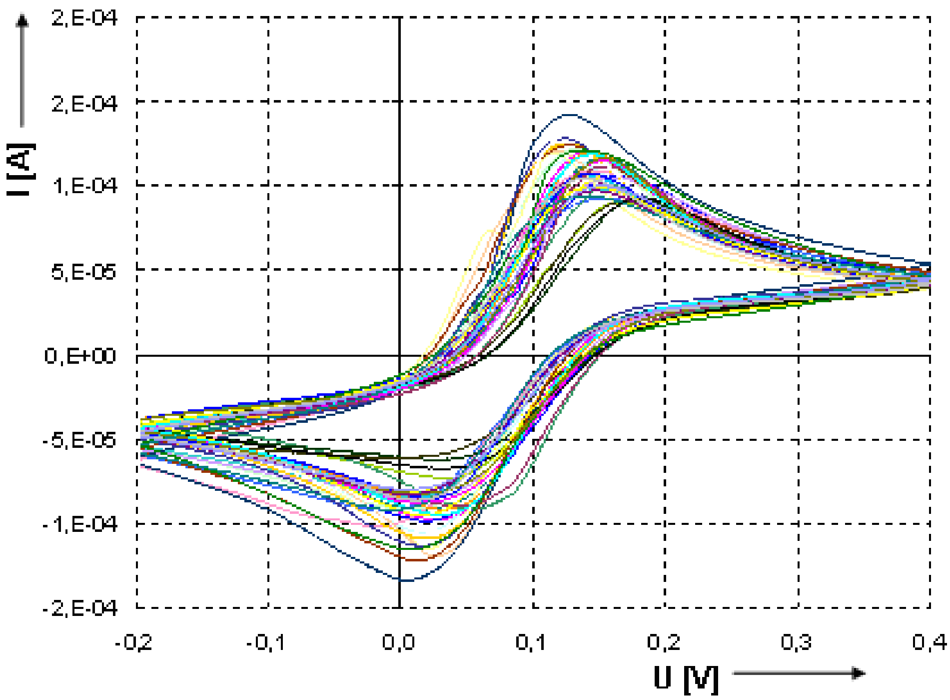

Fig. 6: The output current response of all electrodes from the three measured sensor arrays to the standard electrochemical couple of potassium ferrocyanide-ferricyanide solution.

Presently, the electrochemical sensor array is in the phase of testing. The measurement of standard electrochemical couple of potassium ferrocyanide-ferricyanide was done as one of the first tests. Measurements were done with the three samples of the sensor arrays using cyclic voltammetry [7], [8], in the potential range U = <-200; +400> mV. The scan rate was set to 20 mV.s^{-1}. The achieved results are shown in the fig. 6.

From the obtained results showed in the fig. 6 is clear that all electrodes on the sensor array work properly. Little problem could be the difference between results obtained with each measured sample of sensor array. This phenomenon will be one of the objectives for next experiments.

3. CONCLUSIONS

The topology of new electrochemical sensor array was designed and presented. The possible problems with potential stability and diffusion area between the working electrode and conductive layer were presented and solved. The array was designed with the three-electrode sensor elements for the three-electrode system of measurement only. Therefore the potential stability would be better. The sensor array was made and tested in the standard electrochemical couple of potassium ferrocyanide-ferricyanide. The first results showed that the all electrodes on the sensor array work properly.

4. ACKNOWLEDGEMENTS

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