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Sensors and Actuators A 120 (2005) 589–595
SENSORS AND ACTUATORS A PHYSICAL
www.elsevier.com/locate/sna

A multisensor in thick-film technology for water quality control

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Received 8 November 2004; received in revised form 3 March 2005; accepted 4 March 2005
Available online 11 April 2005

Abstract

A set of sensors for water quality measurement has been developed. It consists of a multisensor designed to measure the following parameters: pH, temperature, dissolved oxygen, conductivity, redox potential and turbidity. The system has been built-up in thick-film technology, using when possible commercially available serigraphic pastes. The multisensor can be implemented in in situ portable or stationary instrumentation for water quality monitoring. The technology used in the multisensor implementation provides fundamental properties of miniaturization, reasonable precision and low cost. The complete system also includes electronic acquisition, signal conditioning and computing capabilities.
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Keywords: Water quality; Thick-film electrodes

1. Introduction

Traditionally the control of water quality has been carried out by means of sampling, transport and further analysis at the laboratory. Although this is a current methodology comprising some advantages, it also shows a number of drawbacks. For instance, there usually is a long gap between sampling and detection of a certain kind of contamination; data are not obtained continuously; data are collected only at a small number of fixed sampling locations and these methods might miss small-scale variations. Additionally, some water quality parameters can only be determined in situ, and the sampling-transport-analysis protocol is, in general, accurate but expensive. Many of these disadvantages can be solved by using water quality remote sensing technologies via the development of in situ and/or stand-alone water quality instrumentation. In this respect there is an increasing interest in the development of single, compact multiparametric integrated flexible instrumentation capable of meeting changing water quality control needs. Following this timely area of research we show here the development of multiparametric instrumentation for water quality measurement. The system is prepared to measure in situ the following parameters of interest: pH, temperature, dissolved oxygen, conductivity, ORP (redox potential) and turbidity. The developed system is simple and compact and has been manufactured using thick-film technology.

2. Experimental

Although the development of sensors in thick-film technology is not new [1–9], the development of novel innovative multiparametric instrumentation might be of interest as thick-film technology is an appropriate tool for solid-state manufacturing which allows flexible designs of different configurations and the fabrication of large number of sensors.

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doi:10.1016/j.sna.2005.03.006

Following the above-mentioned ideas, one central goal in our research was the development of easy-to-use, low-cost and accurate enough instrumentation for water quality control in thick-film technology, using when possible commercially available serigraphic pastes. The instrumentation we have developed consists of a certain number of sensors in hybrid technology that can be implemented in portable or stationary instrumentation for water quality monitoring. A description of the set of thick film water sensors is given below.

2.1. Manufacturing process

The system containing a set of water quality sensors has been prepared using thick-film technology procedures on a RUBALIT 708S (supplied by Ceramic Tec) alumina substrate with an area of 2 in. × 1 in. and a thickness of 0.64 mm. In one side of the alumina substrate the electrodes for conductivity, pH, ORP, dissolved oxygen and reference were located, whereas on the back the semiconductor sensors for temperature and turbidity were sited. Also for research purposes the system also includes two individual electrodes (graphite) for the possible incorporation of certain ion-selective membranes. In order to prepare the above-mentioned set of electrodes, three screens were used corresponding to the conductive layer, working as a conductor of the signal, the active layer, which is different for different electrodes, and a protective layer (see Fig. 1). The conductive paste was Ag/Pd/Pt C4081T (supplied by Heraeus). The layout of the tracks was made to join the board to a flat cable connector with a separation of 3 mm between terminals. The active pastes for the different electrodes were; (i) redox electrode: Au 8081 (supplied by ESL), (ii) reference electrode: Ag C11075S (supplied by Heraeus) and Ag/AgCl (supplied by GEM), (iii) conductivity and pH: resistive pastes of RuO_2 R8921 (supplied by Heraeus), (iv) dissolved oxygen: resistive pastes of RuO_2 R8921 (supplied by Heraeus) and TiO_2 (supplied by Ferro), (v) conductive materials for ion-selective electrodes: graphite 711 (supplied by ACP). The protective paste was the IP9025SP model (supplied by Heraeus). The electrodes were fabricated following serigraphic methods, using polyester screens. The screen for the conductive and the active areas was of 230 mesh (Saatilane Hitech 90/48) and a film of 30 μm (Ulano CDF3) for final layers thickness of 10 μm after firing. For the protective layer a screen of 180 mesh (Saatilane Hitech 71/55) and a film of 50 μm (Ulano CDF5) were used for a thickness after firing of 15 μm. The pastes were serigraphied using a semiautomatic serigraphic machine (AUREL model 1010).

The firing process for the Ag/Pd/Pt, Ag and Au pastes was carried out at 850 °C in a cycle of 60 min with a peak of 10 min. For the resistive RuO_2 paste, the firing was at 700 °C in a cycle of 30 min with a 10 min peak. The protective paste was fired at 550 °C in a 45 min cycle and a peak of 2 min. The graphite paste heated at 200 °C for 1 h and the Ag/AgCl paste was heated 10 min at 80 °C.

2.2. pH measurement

Traditionally, the measurement of pH has been made by means of the use of the well-known glass electrode. Nevertheless, although this electrode is very accurate it is relatively large and high in cost. As an alternative, we have used here, pH electrodes based on solid-state thick-film technology. Studies with different metal oxide pastes were carried out and finally a thick-film electrode by screen printing of ruthenium(IV) oxide resistive paste for potentiometric pH measurements has been characterized. In the multiparametric instrumentation the resistive pastes HERAEUS R8921 of resistivity 99.5 $\Omega\,sq^{-1}$ fired at 700 °C has been used. Typically the pH-active surface has approximately an area of 6 mm^2 and a thickness of 30 μm. It presents a sensitivity, dynamic response and influence to interferences similar to the results obtained by other authors using different types of sensor materials [6,7]. Typically, the electrode showed a sensitivity of -57 ± 3 mV/pH in a linear range of response up to 12 unities of pH and a standard potential of 650 ± 20 mV versus Ag/AgCl reference electrode (see Fig. 2). The pH testing was carried out using acid and alkali solutions. The pH response time is lower than 5 s and the life time is greater than 6 months.

Interferences of common anions, cations (halides, sulfate, phosphate, sodium, potassium, calcium, etc.) and redox agents (sulfite, hydrogen peroxide) were studied in concentrations up to 0.01 M for the thick-film RuO_2 electrode (elec-

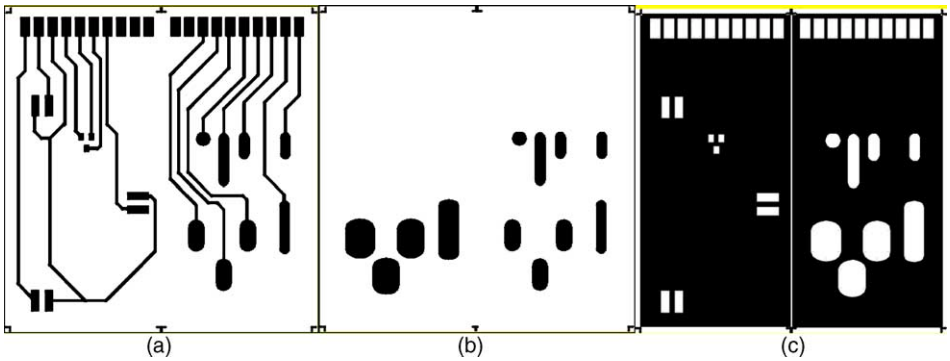

Fig. 1. Layout of the three layers; (a) conductive, (b) active and (c) protective.

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