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Expanding analytical potential of hybrid sensor arrays

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Abstract

Three types of array from resistive sensors based on polymer composites with carbon filler, tin oxide and thermo-catalytic sensors were compared. Special attention was given to ways of expanding gas analysis systems by using hybrid sensor arrays and kinetic parameter of sensory response.

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Keywords: analyte, gas sensor, electronic nose, polymer composite.

1. Introduction

The employment of multi-sensor analyzers of electronic nose type is a new perspective focus for chemical analysis. Nowadays there are significant achievements in applying such systems for monitoring environment and technology processes, criminology, perfumery, fire safety, medical diagnostics, etc. [1]. Taking into account the requirements for portability, mobility and not high costs it is preferable to use sensors like polymer, metal oxide and other chemiresistors on designing multi-sensor devices.

The practice of applying systems with single-type sensor arrays, however, shows, that they can define only rather limited analyzers. This results in expanding array with other type sensors or applying special operating conditions [2]. In particular, pulse operation of analyzer supply enables to use kinetic parameters of sensor response as additional informative factor about subject content under analyses [3].

The most important indicators of any analytical system efficiency are accuracy, sensitivity and selectivity. For multi-sensor gas analyzer these indicators are interconnected and defined by separate sensor responses to stated set of analyzers. Therefore, sensor array with minimum standard errors should show the highest sensitivity and selectivity [4].

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The aim of the work is to optimize hybrid array of resistive sensors under pulse operation according to parameters of analytical efficiency to analyze the quality of air and technological environment content.

2. Experimental part

Experimental multi-sensor system is a set of three functional nodes: sensor array, subsystem of sampling and sensor array signal processing unit.

2.1. Sensor array

System sensor array consisted of five polymer composite (PC) sensors. As isolating composite polymer matrix three differently modified polyorganosiloxanes were used: polymethylsiloxane, polyphenylmethylsiloxane and polycyanopropylphenylsiloxane. Carbon black N472 at 8…10 % was used as composite electrically-conductive filler. Additionally, one thermo-catalytic (TC) sensor and two metal-oxide (MO) sensors with different operating temperature were injected into sensor array. The specific thing of TC sensors is the sensitivity to a wide group of flammables, that are able to be acidified by ambient oxygen on active catalyst sites [5]. Among resistive sensors composite chemiresistors can be considered as high-selective [6] and MO sensors in this group have average selectivity [7].

2.2. Subsystem of sampling

Sensor array in amount of 21 ml was put into measure cell that was blown by air pulser with 50 ml/min speed. Pulse sample dosing was produced with 3…5 % accuracy by injecting vapor mixtures of saturated analyte vapors into air line with the help of syringe**.** The list of used analytes, symbols of their samples, as well as the results of sample chromatographic calibration on gas chromatograph "Chromos GC 1000" are given in Table 1.

Table1. The results of sample chromatographic calibration.

№	Analyte	Sample symbol	Sample volume (*ml*)	Vapour concentration (*ppm*)	Sample symbol	Sample volume (*ml*)	Vapour concentration (*ppm*)
1	Ethanol	Et 5	5.0	43.9	Et 2	2.0	14.8
2	Petroleum ether	PE 5	5.0	120.0			
3	Acetone	Ac 5	5.0	185.0			
4	Diethyl ether	Ep 5	5.0	437.0			
5	Toluene	Tl 5	5.0	25.5			
6	Propanol-2	Pr 5	5.0	32.4	Pr 2	2.0	11.6
7	Butanol	Bt 5	5.0	4.4	Bt 2	2.0	1.4
8	Chloroform	Cl 5	5.0	106.0			

All analytes were separate pure substances except petroleum ether that is a mixture of alkanes (mainly C_5-C_6 isomeric structure, up to 85%) with distillation range 30-80^{0}C.

2.3. Sensor array signal-processing unit

Sensor array analog data collection and process were made by measurement module E14-140 produced by "*L-Card*" under program *LGraph2*. The task of sample identification was performed by processing obtained signal panel of the entire sensor array with the help of multilayer perceptron artificial neural network. The needed number of network inputs n_i was equal to equation $n_i=n_s\times n_t$, where n_s is a quantity of sensors in the array and n_t is a