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Creation of Selective Sensors and Alarms for Monitoring Carbon Dioxide and Methane

Eshkobilova Mavzhuda Ergashboevna
Samarkand University of Architecture and Civil Engineering
mavjudaesh1983@gmail.com

Abduraxmonova Z. E.
Assistant of the department of pharmacology of Samarkand State Medical University

Abstract: *Carbon monoxide (II) (carbon monoxide) and methane (natural gas) are among the toxic and explosive components of atmospheric air. According to statistics, the death rate from carbon monoxide poisoning (II) over the last decade amounted to 23.4% of all deaths from acute poisoning. Therefore, the creation of a new generation of gas-sensitive semiconductor materials and the creation of selective semiconductor gas sensors and signaling devices based on them, providing quantitative determination of carbon monoxide (II) and methane in atmospheric air, process and exhaust gases, are important issues.*

Keywords: *selective, semiconductor sensor, automatic alarm, film, atmospheric air, modernization, diversification, pH solution, methane, gas-sensitive, thermocatalytic.*

In our republic, special attention is paid to the control of the composition of environmental objects, certain results are being achieved on the creation of methods and means of monitoring the composition of atmospheric air. The strategy of actions for further development of the Republic of Uzbekistan for 2017-2021 defines the tasks of "further modernization and diversification of industry by transferring high-tech processing industries, first of all, to a qualitatively new level aimed at accelerated development of production of finished products with high added value based on deep processing of local raw materials" [2]. Of great importance in this regard is the development of selective gas-sensitive materials and the creation of import-substituting sensors and signaling devices based on them.

The aim of this study is to create carbon monoxide and methane-sensitive nanocomposite films based on tetrotoxysilane and metal oxides and to develop highly sensitive semiconductor sensors and signaling devices based on them.

During the study, for the first time on the basis of titanium and cadmium oxides, a sol-gel synthesis of a gas-sensitive material for a semiconductor carbon monoxide sensor was carried out, the composition and ratio of components of the gas-sensitive material were determined, providing high sensitivity of a semiconductor carbon monoxide detection sensor.

The alarm is designed for automation, controlling a wide range of carbon (II) concentration and oxidation, as well as determining the influence of various factors on its metrological and operational parameters.

In studies in the field of synthesis and research of porous gas-sensitive materials for semiconductor sensors, the greatest sensitivity and selectivity for a carbon monoxide detection sensor was observed

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in a film obtained on the basis of TEOS/(TiO_2+CaO). The conducted studies have shown that the properties of the gas-sensitive film depend on the medium of the solution used to produce the film. In Figure 1 below, we see that at different pH values, gas-sensitive film samples synthesized on the basis of TEOS and CDO will have a different surface structure after heat treatment.

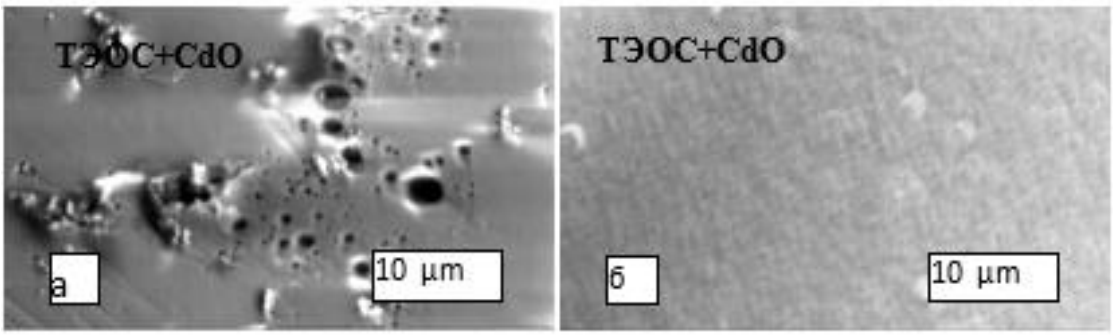

Figure-1.Surface structure of the synthesized gas-sensitive material at pH = 0.1 (a) and pH = 0.5 (b) based on TEOS and CdO

Thus, a change in the pH of the solution affects the morphology of fuel by changing the relative rates of Sol hydrolysis and polycondensation reactions, allowing to obtain different structures of its surface.

The results of determining the effect of the H_2O/TEOS ratio on the sol-gel synthesis of GSM are shown in Table 1. From the table we see that the stability of the solution reaches a maximum when the amount of water corresponding to 1 mole of TEOS is 20-25 moles.

Table 1. Dependence of the gaseous sensitivity of the material to CO on its TiO_2 and CdO ratios (n=5, P=0.95)

Composition of fuel and lubricants	Sensor signal, mV.		
	$\bar{x} \pm \Delta x$	S	$Sr*10^2$
TEOS /(100%CdO)	23,9±0,2	0,16	0,67
TEOS /(100%TiO2)	28,2±0,4	0,32	1,14
TEOS /(5%TiO_2+95%CdO)	26,7±0,3	0,24	0,9
TEOS /(25%TiO_2+75%CdO)	33,2±0,2	0,16	0,48
TEOS /(50%TiO_2+50%CdO)	38,5±0,1	0,08	0,21
TEOS /(75%TiO_2+25%CdO)	42,5±0,4	0,32	0,76
TEOS /(95%TiO_2+5%CdO)	37,1±0,3	0,24	0,65

According to the results of studies of the sensitivity of gas-sensitive material GSM based on TiO_2 and CdO, it was found that the highest sensitivity in the process of monitoring CO corresponds to a mixture of TiO_2 and CdO obtained in a ratio of 3:1. Therefore, in subsequent experiments, TEOS/ (75% TiO_2 + 25% CdO) was used as GSM in the process of creating a SCS that determines CO. Semiconductor sensors designed to determine the macro- and micro-quantities of carbon monoxide PS-CO 1 M the results of the study of the dependence of the useful analytical signal SCS-CO_2M on the amount of CO are presented in Table 2.

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Table 2. Dependence of the sensor signal on the amount of so (n=5, P=0.95)

SCS-CO1M				SCS-CO2M			
quantity CO, mg/m^3	Sensor signals, mV			quantity CO mg/m^3	Sensor signals, mV		
	$\bar{x}\pm\Delta x$	S	Sr*10^2		$\bar{x}\pm\Delta x$	S	Sr*10^2
75	3,4±0,1	0,08	0,45	0,10	13,7±0,2	0,16	1,2
175	7,3±0,1	0,16	0,34	0,50	58,4±0,1	0,08	0,8
225	10,1±0,2	0,12	0,26	0,60	68,9±0,2	0,16	0,2
600	29,8±0,3	0,14	0,11	1,20	141,5±0,3	0,24	0,2
900	37,6±0,4	0,08	0,09	1,40	164,4±0,4	0,32	0,2
1200	52,4±0,4	0,12	0,15	1,60	211,0±0,4	0,32	0,2
1750	70,3±0,5	0,20	1,23	2,00	247,4±0,3	0,16	0,3
2250	89,5±0,4	0,18	0,21	2,40	275,9±0,4	0,16	0,1
2750	10,2±0,6	0,18	0,20	2,80	311,2±0,4	0,16	0,2
3000	22,0±0,3	0,16	0,16	3,00	335,1±0,2	0,12	0,1

The table shows that in the studied range, the signal of semiconductor sensors such as PS-CO 1 M and PS-CO 2 has a rectilinear dependence of the concentration of carbon monoxide in the gas mixture. The stability of the sensor signal was checked during 2000 hours of continuous experiments. The results of the experiment showed that the calculated value of Δtg for the studied period of time is 2.5%.

The interest in methane detection sensors is due to their wide application in environmental control, process control in the chemical, gas and petrochemical industries, and ensuring the safety of machinery. During the experiments, the metrological characteristics of sensitive element sensors for detecting methane made on the basis of zinc and cobalt oxides were checked.

The optimal temperature of the gas-sensitive floor is determined by the maximum value of its signal to the gas under study. The temperature dependence of the sensitivity of SCS-CH_4 to gases was studied dynamically in the temperature range of 200-500 ^{0}C. A study of the state of the sensor signal based on SiO_2/ZnO and CuO from temperature in the presence of CH_4 showed that the optimal temperature value tracking the maximum SCS-CH_4 signal on methane is 375 ^{0}C. Analyses and subsequent activity of films based on ZnO and CuO in the process of methane enrichment are shown in Table 3.

Table 3.The results of the study indicate that most obese people do not have access to knowledge about ZnO and CuO, which leads to methane obesity (n = 5, P = 0.95).

№	Composition GSM	Amount of methane in solution, mg/m3	Sensor signal, 1/R кОм$^{-1}$		
			x+Δx	S	Sr
1	SiO_2/ZnO	1000	397±2	1,61	0,41
2	SiO_2/ZnO+1%CoO	1000	605±3	2,41	0,40
3	SiO_2/ZnO+5%CoO	1000	1441±5	4,02	0,28
4	SiO_2/ZnO+10%CoO	1000	2273±7	5,63	0,25

According to the results of the experiment, we see that the sensor with the highest sensitivity in the process of detecting methane corresponds to a gas-sensitive material with a content of SCS -CH_4 SiO_2/ZnO+10% CoO.

Thus, the basic metrological description of the SCS -CH_4, defining the developed CH_4, was studied. These sensors detect CH_4 in a wide range of concentrations and have good metrological and operational characteristics. In terms of expression, reproducibility, and detection limit, SCS -CH_4 is not inferior to existing analogues, surpassing in some (mass, size, speed, selectivity, and others) widely used in practice sensors for detecting hydrocarbons. The proposed areas of application of the developed sensors are thermal power engineering, oil and gas industry, as well as utilities. As a result of the use of SCS -CH4, timely detection of methane is achieved; fire hazard prevention; reduction of hazards in production; construction of an automated gas safety system; creation of a microclimate system.

The composition of the catalyst of the measuring and compensating sensing element of the methane sensor is established in the work. Using a technique to ensure selectivity with the use of the above catalysts, a thermocatalytic sensor was manufactured for the selective determination of methane in the presence of carbon monoxide and hydrogen[1].

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