DEVELOPMENT OF CHEMICAL SENSORS AND ALARM SYSTEMS FOR ENHANCING EXPLOSION AND FIRE PROTECTION IN RESIDENTIAL AND INDUSTRIAL FACILITIES

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Annotation. This study focuses on the development of chemical sensors and alarm systems aimed at ensuring explosion and fire safety in both residential and industrial facilities. The integration of advanced sensor technologies with intelligent alarm mechanisms provides early detection of hazardous gases, vapors, and fire precursors. Such systems contribute to timely risk prevention, minimizing damage, and improving overall safety standards. The research emphasizes the importance of reliable, cost-effective, and energy-efficient solutions for practical application in modern safety infrastructures.

Keywords: Chemical sensors, alarm systems, explosion safety, fire protection, residential facilities, industrial safety, early detection, risk prevention.

Аннотация. Данное исследование направлено на разработку химических сенсоров и систем оповещения, обеспечивающих взрывную и пожарную безопасность в жилых и промышленных объектах. Интеграция современных сенсорных технологий с интеллектуальными механизмами оповещения позволяет осуществлять раннее выявление опасных газов, паров и факторов, предшествующих возгоранию. Такие системы способствуют своевременному предотвращению рисков, минимизации ущерба и повышению общих стандартов безопасности. В исследовании подчеркивается важность надежных, экономичных и энергоэффективных решений для практического применения в современных инфраструктурах безопасности.

Ключевые слова: Химические сенсоры, системы оповещения, взрывобезопасность, пожарная безопасность, жилые объекты, промышленная безопасность, раннее выявление, предотвращение рисков.

Аннотация. Ушбу тадқиқот турар-жой ва саноат объектларида портлаш ва ёнғин хавфсизлигини таъминлашга қаратилган кимёвий сенсорлар ва огоҳлантириш тизимларини яратишга йўналтирилган. Илғор сенсор технологияларини ақлли сигнал бериш механизмлари билан интеграция қилиш хавфли газлар, буғлар ва ёнғин хавфини келтириб чиқарувчи омилларни эрта аниқлаш имконини беради. Бундай тизимлар хавфни ўз вақтида бартараф этиш, зарарни минималлаштириш ва умумий хавфсизлик стандартларини оширишга хизмат қилади. Тадқиқот ишончли, арзон ва

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энергия тежамкор ечимларни замонавий хавфсизлик инфратузилмаларда амалий қўллаш аҳамиятини таъкидлайди.

Калит сўзлар: Кимёвий сенсорлар, огоҳлантириш тизимлари, портлаш хавфсизлиги, ёнғиндан ҳимоя, турар-жой объектлари, саноат хавфсизлиги, эрта аниқлаш, хавфнинг олдини олиш.

Introduction

The main purpose of this research is to design and develop innovative chemical sensors and alarm systems that can effectively enhance explosion and fire protection. The project seeks to ensure early detection of hazardous conditions, reduce the risk of accidents, and strengthen safety measures in residential and industrial environments.

One of the most critical threats in both industrial and domestic fire and explosion incidents is methane detonation. Methane's lower explosive limit (LEL) is generally defined as 5%, while its upper explosive limit (UEL) reaches 16%. For this reason, the development of chemical sensors and detectors that guarantee fire and explosion protection in residential and industrial facilities is of great importance [1,2]. Across many developed countries, extensive research is underway to design systems and sensors capable of detecting explosive and fire-hazardous gases [3,4]. The present study is focused on creating highly responsive and sensitive sensors for effective monitoring of explosive gas mixtures.

A review of current gas sensor technologies in industry shows that thermocatalytic and semiconductor sensors remain among the most reliable solutions for reducing explosion risks. With the rapid global expansion of the transport, energy, and oil and gas sectors, safety requirements for preventing explosions in industrial and household facilities continue to grow. This highlights the urgent need for both theoretical and practical research aimed at advancing fast, selective, and sensitive sensors for real-time monitoring of explosive mixtures in indoor environments.The aim of this work is to develop sensitive, selective chemical sensors for methane gas and to create highly efficient detectors and gas analyzers for natural gas monitoring based on them. During the experiments, the laws of oxidation of combustible substances were studied and the catalyst composition of a selective thermocatalytic sensor for methane was developed. Methods for determining explosive concentrations of natural gas in closed ecological systems under optimal conditions that ensure stability, sensitivity and selectivity were selected. Sensitive and rapid methods and reliable detectors were created for detecting methane leaks and accumulations.

Gas-sensitive nanocomposite materials were created using the sol-gel synthesis method, and sensitive semiconductor sensors for methane were

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developed on their basis. Two-channel gas analyzers were created for the continuous detection of natural gas in air and process gases using semiconductor and thermocatalytic sensors. Metrological and analytical properties of methane composition were studied. Using the catalysts we developed (0.75In2O3-0.25Ag2O and 0.25Fe3O4-0.75Ni2O3), a TKS was prepared that provides selective detection of explosive concentrations.

The output signal of the sensor measurement sensing element (catalyst: 0.75In2O3-0.25Ag2O) is proportional to the total concentration of combustible gases (H2, CO, CH4), and the output signal of the comparison sensing element (a mixture of CO and H2) is proportional to the concentration of the component (CH4) that is not selectively detected. The difference between the signals of the first and second elements is proportional to the concentration of CH4.

During the testing of the created sensors, special experiments were conducted to select the optimal value for the supply voltage, determine the dynamic, gradational and other characteristics of the sensor, as well as determine the level of its selectivity and stability.

The highest sensor signal for methane (CH4) was observed at a bias voltage of 2.6 V. A comparison of the signal values for methane and natural gas showed that the bias voltage providing the highest signal for natural gas (2.8-3.0 V) was higher than for methane (2.6 V).

The reaction time of the developed sensor (t0.1) is 3-4 seconds, the time constant (t0.63) does not exceed 9 seconds, the settling time (t0.9) is 13 seconds, and the time of full output of the analytical signal (tп) for the sensor is within 17-18 seconds, which once again confirms the possibility of fast control of the amount of natural gas by the developed sensors. The dependence of the sensor signal on the methane concentration (in the range from 0.1 to 5.0 % vol.) is directly proportional

The experimental results show a similarity in the relationship between the developed TKS signal and the natural gas concentration. This confirms the ability of the developed TKS to control explosive natural gas concentrations (0-5.0% vol.) in the air and inside vehicles.

Two types of sensors were used in the experiments: TKS-1 – a sensor containing a catalyst in the measuring and compensation element, and TKS-2 – a sensor containing a catalyst only in the measuring element.

From the above results (Table 2), we can see that TKS-1 is insensitive to H2 and CO. The signal of the CH4 sensor, under the same conditions (1% H2, CO and CH4 mixtures), is 36.8 times larger than the H2 signal and 159.3 times larger than the CO signal.

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Unlike TKS-1, the sensor without a catalyst in the compensatory sensing element (TKS-2) is sensitive to H2 and CO. The signal values of this sensor for 1% H2, CO and CH4 are 103.9 mV, 29.1 mV and 97.0 mV, respectively. Thus, TKS-1 has a higher selectivity than TKS-2.

The errors of the sensors are not more than 2.0% due to non-measurable components. The stability of the CH4 sensor was tested for 1000 hours in air with a natural gas concentration of 1.00% vol. The experiments showed that the sensor signal remained stable over the specified time period.

In the studied range, the relationship between the signal and the concentration is strictly proportional, with the basic relative error varying from 0.2 to 1.4% (Table 3). The additional error of the sensor with temperature changes does not exceed 2%.

The total additional error of TKS-CH4 is ±3.5% due to changes in temperature (–10 to +40 °C), pressure (600-800 mm Hg), and humidity (40-95%).

According to the above data, the proposed TKS significantly outperforms mass-produced sensors in selectivity. During the experiments, the comparative characteristics of selective thermocatalytic sensors developed in the gas analysis laboratory of SamSU during 1990-2019 were studied. The experimental results are presented in Table 6. Based on the above data, it was shown that TKS-1, manufactured using sol-gel technology based on 75%In2O3 + 25%AgO and 25%Fe3O4 + 75%Ni2O3 catalysts, is more sensitive than previously developed analogues (TKS-2 and TKS-3). Thus, in order to create a selective and highly sensitive sensor for methane, the catalyst (0.75In2O3-0.25Ag2O and 0.25Fe3O4-0.75Ni2O3) was chosen.

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