Abstract of PhD Thesis

Title: Study of sensor nanostructures using hybrid semiconductor receptors based on block copolymers for the detection of sub-ppm NO2 at room temperature

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One of the most serious problems facing civilization today is environmental pollution. Many pollutants in the atmosphere are direct causes of respiratory, nervous, or cardiovascular diseases. These include suspended particulates ($PM_{2.5}$, PM_{10}), nitrogen oxides (NO_x), volatile organic compounds (VOCs), sulfur oxides (SO_x), polycyclic aromatic hydrocarbons (PAHs), carbon monoxide and dioxide (CO, CO_2), and ozone (O_3). Therefore, continuous and accurate monitoring of atmospheric composition is crucial for the early detection of threats, particularly through continuous analysis of concentrations of toxic gases that pose a risk to both human health and the surrounding environment.

There are numerous methods for the qualitative and quantitative analysis of gas mixtures. Metal oxide semiconductors have been used for decades to detect air pollutants and toxic gases as thin and thick receptor layers in electrochemical sensors. Another group of materials with high potential for gas detection at room temperature is organic semiconductors, particularly conductive polymers. A leading trend is also the creation of hybrid materials and heterostructures that combine the functionalities of individual structural components, such as mixtures of organic polymers with nanostructured inorganic materials. Given the numerous threats posed by gases, the diversity of methods used for their detection, and the wide range of receptor materials, it is necessary to narrow the focus to a selected group of gases and types of gas sensors. Consequently, this dissertation focuses on detecting very low concentrations (sub-ppm) of NO_2 using microelectronic gas sensors based on nanostructured materials, both organic and inorganic, as well as their hybrids.

The research problem addressed in the dissertation involves the development of active, hybrid semiconductor receptors based on block copolymers. The hybrid nature of the developed and analyzed structures involves the controlled formation of materials in the form of mixtures: in the solid phase of nanostructured zinc oxide (ZnO, n-type conductivity), and an organic semiconductor based on poly(3-hexylthiophene) (P3HT, p-type conductivity) in the form of a bulk-heterojunction material blend. These semiconductor structures were tested as active receptors in microelectronic electrochemical sensors—chemoresistors. The developed sensor elements were examined and tested by exposing them to low concentrations of nitrogen dioxide (NO_2) (below 1 ppm – sub-ppm) under various environmental conditions at room temperature. The dissertation describes a series of research and technological processes leading to the production of chemiresistive sensors using the materials studied. The influence of UV radiation on the responses obtained in variable gas atmospheres, both dry and humid, and the aging effects of the studied structures were presented. The culmination of the research was conducting experiments aimed at developing an appropriate sensor configuration and determining whether and how the sensor parameters of the chemiresistor using hybrid heterostructures of grafted block copolymer and nanostructured zinc oxide as a gas-sensitive receptor would change compared to a receptor consisting solely of one component of this hybrid, with one of the key features being the ability to detect sub-ppm NO_2 at room temperature.