A universal basic for creating microsensory devices those are sensitive to changing environmental conditions

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Abstract. The main advantages of alumina technology and substrates of anodic alumina with a microlief in the bulk of the substrate as a universal basis for creating microsensor devices are presented. Microsensors of various types allow you to monitor the state of the environment. Specific examples of the development of microsensory devices for detecting humidity, gas composition in the environment, and the presence of ionizing and ultraviolet radiation are presented.

1. Introduction

Anodic alumina (anodic aluminium oxide) is one of prospective composition materials, applied for the creation of devices and technical systems, the functioning of which is determined by a nanostructure [1-5]. Such a material, obtained by the electrochemical oxidation of aluminium in acid electrolytes, possesses wide potential capabilities [6-9]. AA films have a regular periodical structure of nanopores, which are perpendicular to the substrate surface (figure 1) [10-13].

![Figure 1](image1.png)

Figure 1. Photos of regular periodical nanopores AA films (a) which perpendicular to the substrate surfaces (b).

At the same time the diameter of pores and the distance between them can be regulated in wide ranges (from 10 nm up to hundreds of nm) by selection of technological process. Parts made of AA have precision accuracy, planar and volumetric configurations with blind and through holes, grooves, recesses (figure 2). AA has high electromechanical parameters.
2. Anodic alumina technology

The units and various components, made of this material, have the high precision, planar and volumetric configurations with blind and through holes, slots and dimples (figure 3). The technological process is based on the integral methods and electrochemical operations of growing and etching of the oxide and aluminium with the subsequent putting on the thin metallic coatings. The diversity of forms of units made of AA stipulates the opportunity for the creation of various microsensors with the wide functionality [14-19]. Application ranges from monitoring food quality, humidity detection to metrological research (figure 4). Al₂O₃ technology is also promising for creation of molecular counters based on nanoporous Al₂O₃. Also, Al₂O₃ template is a gas micro sensor platform for conductometric (figure 5), catalytic and electro-chemical sensors featuring massively parallel arrays of sensing nanotubes integrated into a robust monolithic substrate with low power consumption (figure 6) [20-22].

Figure 2. The periodic system of precision holes (a), (b), (c), precision through slits of simple (d) and complex configurations (e), (f), a three-level microstructure in the volume of the substrate (g): the first level is microbeams 1, the second level is the recess in the body of the substrate 2, the third level - through hole 3.

Figure 3. Photos illustrate: the plasticity (a), flexibility (b), strength of thin layers (c) (thickness 0.5 µm), micron precision of periodical elements (d).
In comparison with other technologies based on self-organization, aluminum oxide is prospective for the formation of nanocapillary system matrixes in relation to the demands of high quality magnetic and magneto-optical materials and sensors based on them [23, 24]. The mentioned sensors are sensitive to the variations of optical, magnetic, electrostatic and other fields and assigned for the automatic control of operation of complex systems. An important advantage is the opportunity of their exploitation in active zones with the extreme environmental conditions (high radiation, low or high temperatures and so on), for example in the operating zone of the reactor of spatial importance is design and fabricate new types of bulk optical metamaterials, based on the usage of nanoporous alumina oxide templates filled by metal nanowires [24-27].

3. Gas sensors based anodic alumina substrates
New possibilities of increasing the selectivity of a gas sensor based on a thin film of metal oxide on a substrate of anodic alumina by using two working areas (zones) operating at different temperatures are shown. The formation of two or more working zones of the sensor on one substrate (on the same chip) also allows to reduce the energy consumption of the sensor by reducing spurious electrical resistances (figure 7).
Figure 7. Photos of a dual-zone adsorption-resistive gas sensor in the case (a) and the cover to the case with a special gas-permeable membrane (b).

Based on the results of preliminary studies, a general view of the dependence of the electric current through the sensing element of gas sensors on the concentrations of carbon monoxide and hydrogen in the environment was established (figure 8). With a certain degree of accuracy (of the order of ± 10%), these dependences are linear functions and can be used for preliminary calculations of the structural elements of two-gas sensors.

A dual-zone sensor based on Fe₂O₃ has a high sensitivity to ozone at the level of tens of ppb (figure 9). Dual-zone sensors based on various metal oxides can be used to measure the concentration of dangerous gases in industrial and office rooms [28].

Figure 8 Dependeaces of the electric current through the sensitive elements of a two-zone gas sensor on the concentrations of carbon monoxide and hydrogen in the environment.

Figure 9 Relative change in resistance (Rair/ Rg) of the sensitive layer of the NiO sensor at different ozone concentration in the ozone-air mixture.
4. Conclusion
The presented research results and specific designs confirm the promise of using nanoporous substrates of anodic alumina and micro-nanoporous metal oxides as the basis for the creation of highly efficient microsensory devices those are sensitive to changing environmental conditions.

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