NANOSTRUCTURED GAS MICROSENSOR PLATFORM

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ABSTRACT

Nanostructured materials, with their small grain size, large number of grain boundaries, and high specific surface area, hold promise to enable significant performance benefits for solid-state gas sensors. To fully realize this potential, precision nanoscale engineering of the morphology and composition of sensing materials is needed. Furthermore, multiple challenges are associated with integration of nanostructured materials into reliable and manufacturable microsensors. We will overview our efforts on addressing these challenges by developing a novel gas microsensor platform based on nanostructured alumina ceramic.

Keywords: nanoporous anodic alumina, solid state gas sensors, microsensors, ceramic MEMS

1 PLATFORM

Synkera's novel gas microsensor platform [1] is based on nanostructured anodic aluminum oxide (AAO). Due to its self-organized nanoscale morphology, formed by uniform and parallel nanopores (Figure 1), AAO is an attractive host for templated nanofabrication [2], and is well recognized and widely used in both fundamental research and application development. We use AAO as a host for the synthesis of sensing materials with composition and morphology tailored at the nanometer scale.

In addition, intrinsic anisotropy of morphology and chemistry of anodic alumina enables its micromachining via a flexible process [3] that enable fabrication of robust sensor substrates (Figure 2) that support high temperature low power operation.

Fabrication of gas microsensor from AAO includes the following steps [1]:

(1) synthesis of nanoporous anodic alumina with required thickness and pore diameter;
(2) micromachining of sensor substrates equipped with microheater and sensing electrodes;
(3) conformal deposition of high surface area (up to 100 m^2/g) nanostructured sensing materials onto the walls of the nanopores, and
(4) sensor packaging.

The resulting solid-state sensing element is formed by high density arrays of nanotubules intrinsically integrated into micromachined ceramic substrates. The effects of sensor design, specific surface area, deposition processes and other factors on sensor fabrication and performance were thoroughly evaluated and will be summarized in this presentation.

2 CASE STUDIES

Several types of gas microsensors are currently under development at Synkera Technologies using presented platform, including metal oxide conductimetric, catalytic combustion and electrochemical sensors and sensor arrays. Targeted applications include detection of humidity/moisture, air quality (formaldehyde, CO, volatile organic contaminants (VOC)), combustible gases (methane, hydrogen), hydrogen sulfide, and emission monitoring.

Some of the highlights are presented in Figure 3 - Figure 6. One example includes sensing of low level (0.1-100 ppm) of water vapor. By optimizing nanoscale morphology and surface chemistry of blank anodic alumina and using advanced operating modes, significant reduction in the detection limit were realized (Figure 3), opening opportunities for high altitude low temperature balloon-born meteorological measurements, process control and other demanding applications.

Another example is the development of air quality sensors (Figure 4, Figure 5). Using different methods for sensing materials deposition, optimizing sensing materials composition and doping, and employing precise temperature control, several routes for highly specific detection of gases of interest (formaldehyde, VOC's and CO) were discovered.

In yet another example, excellent sensitivity and reversibility for the detection of hydrogen sulfide was demonstrated with AAO/SnO_2/polymer sensors (Figure 6).

3 ADVANTAGES

Described microsensor architecture has numerous intrinsic advantages over conventional sensors. It enables low thermal mass and low power consumption, broadens the operating temperature range, and provides capability of regeneration by internal heating to high temperature. In many cases it also improves response time, sensitivity and selectivity.

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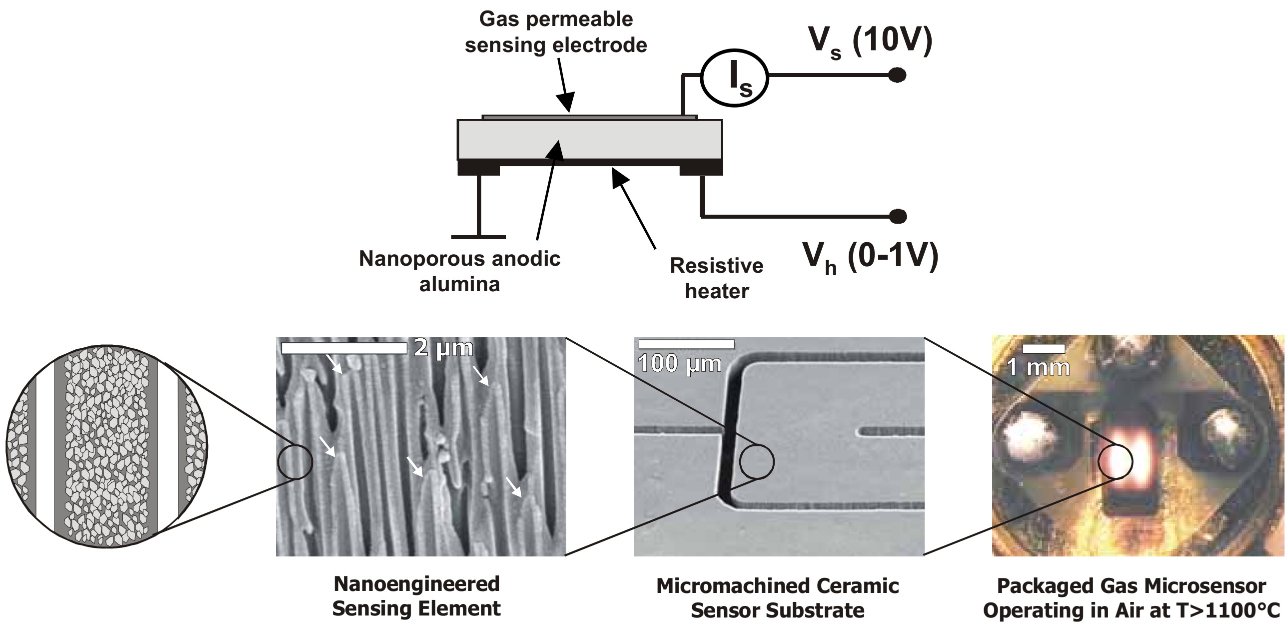

Figure 1: Outline of the Synkera's nanoengineered ceramic platform for gas microsensors.

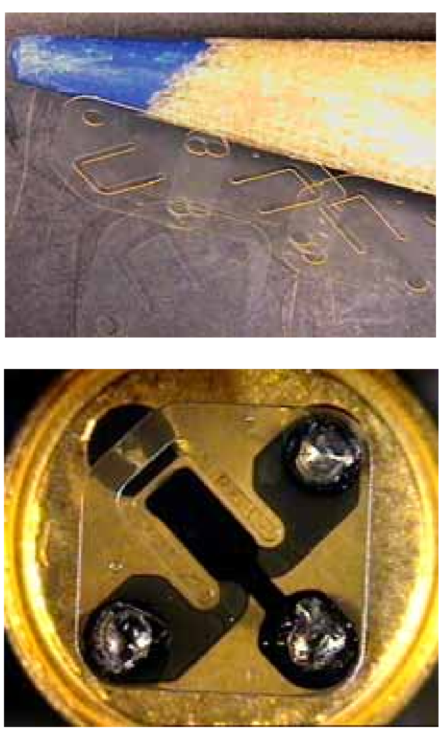

Figure 2: Synkera's micromachined AAO-based sensor substrates and packaged microsensor.

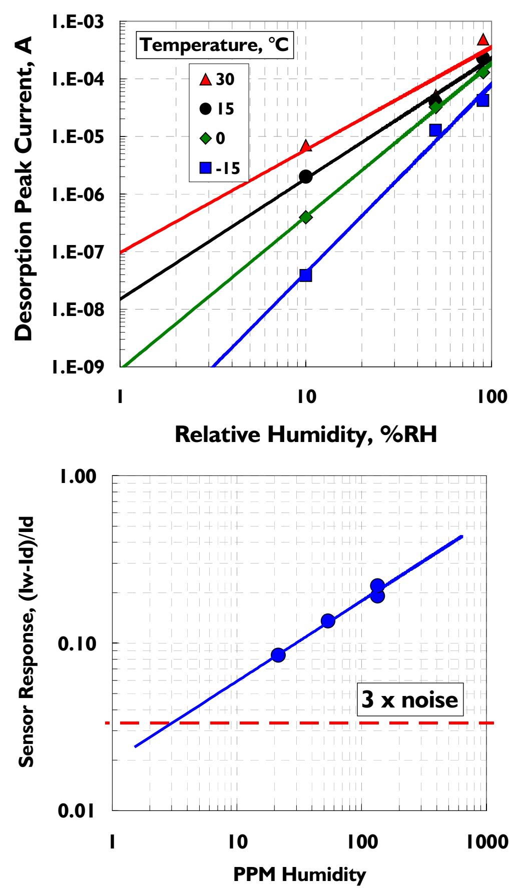

Figure 3: Response of moisture sensor at different temperatures and humidity levels.

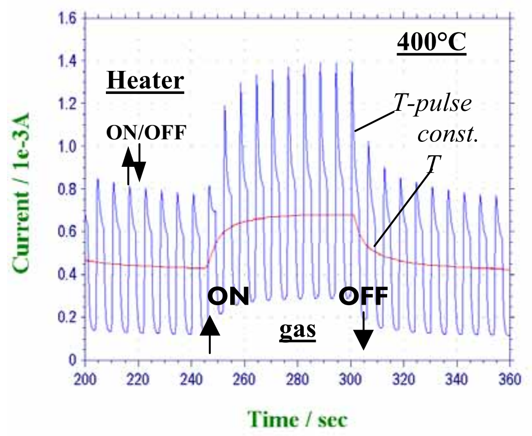

Figure 4: Response of AAO/SnO_2 – based sensor to 2.5 ppm HCHO at constant temperature and in pulsed temperature mode.

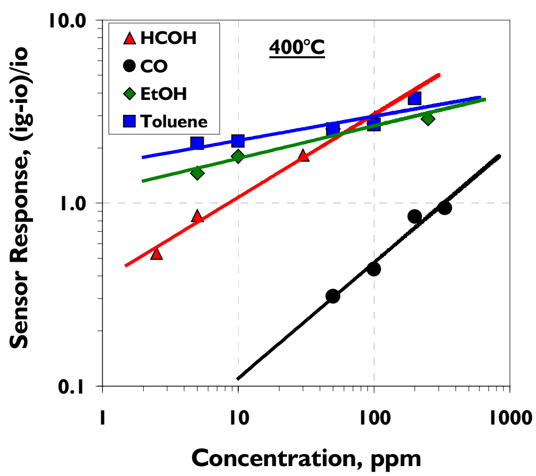

Figure 5: Sensitivity plots for detection of different gases by AAO/SnO_2 – based sensor.

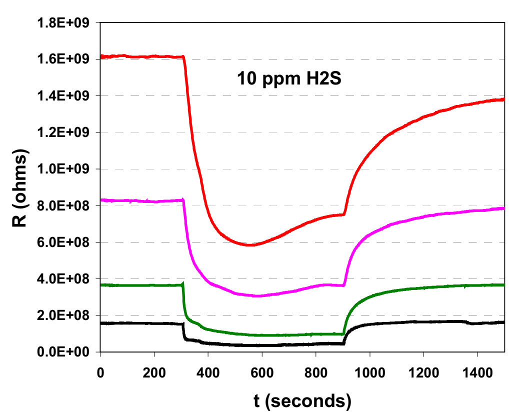

Figure 6: Response of doped AAO/SnO2/polymer – based sensor to 10 ppm of hydrogen sulfide at different temperature.

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