MONITORING SYSTEM FOR UNDER-WATER PIPE LINE

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Abstract

The growing interest in new under-water pipe lines for the delivery of natural gas (in Baltic Sea, Mediterranean region, Caspian Sea, Black Sea, etc.) needs a new instruments for the monitoring of leakage and/or possible destruction of the pipes, which could not only disturb fragile ecological systems of Baltic and other seas, but also can lead to the technological catastrophes. We plan to develop a prototype of the system consisting of pervaporation membrane and gas sensors. Overall system will be immersed into water and will be fabricated in two versions: as a stationary instrument dipped into sea water and as an instrument towed along the pipe line. Micromachined metal oxide semiconductor gas sensors used for the detection of methane concentrations is designed and fabricated using "nano-on-micro" approach. Overall system is optimized from the point of view of minimum power consumption, which is necessary to assure its long term operation under autonomous conditions.

1. Introduction

Natural gas resources are unevenly distributed around the world, which means that pipelines and liquefied natural gas shipping routes have to connect production regions with consumption markets. The growing imbalance between local demand markets and local production regions requires major increases in global transport capacity [1]. It is a necessary to develop systems which can be used for monitoring of under-water pipelines.

Micromachined metal oxide semiconductor gas sensors, used in detection of methane concentrations, can be designed and produced using "nano-on-micro" approach [2]. The micro-machined gas sensors based on semiconducting metal oxides (MOX) have been added to on-chip sensors and electronics. This was one of many benefits resulting from evolution of micromachining technologies for MEMS, aiming in improvement of thermal response and power consumption of the sensors. Pervaporation (PV) is recognized as a separation process in which a binary or multicomponent liquid mixture is separated by a partial vaporization through a dense membrane. In this technique feed contacts one side of a membrane, whereas permeate is transported to the opposite side [3].

One of the goals of this work was a synthesis of appropriate sensor precursors, followed by preparation and deposition of nano-composite materials onto MEMS gas sensors. The sensor should be isolated from the environment by a selective membrane.

2. Design and fabrication

2.1. MEMS Gas sensor

New gas sensors are based on micro hot plates over silicon oxide/silicon nitride layers and realized by microfabrication technology satisfying requirements like minimum power consumption, small dimensions, low cost and long-term stability (Fig.1). Silicon oxide and silicon nitride layers were deposited by CVD technique.

Figure 1. Packaged gas sensors. It is gas sensing nano-material (Pd-doped Tin dioxide with particle size of about 10nm) deposited on MEMS substrate.

Platinum microheater, used to reach the working temperature, maintains as high a film temperature as 450°C with less than 50 mW of input power. Sensing layer consists of 3wt.% Pd doped SnO_2 nanopowder with specific area of about 100 m^2/g. The sensing material was prepared by direct precipitation of Tin dioxide powder from a solution of Tin (II) sulphate using oxidation with hydrogen peroxide solution. Then it was deposited by screen printing over dielectric membrane with heater.

2.2 Membrane preparation

Two kinds of membranes were investigated: planar ceramic membranes made of TiO_2 modified by perfluorosilanes and polymeric membranes made from polydimethylsiloxane (PDMS). Ceramic membranes are prepared from metal oxides, e.g. alumina, zirconia or titania.

Polydimethylsiloxane membranes of different thickness were prepared using PDMS solution, crosslinking agent and hexane as a solvent.

3. Experimental results

3.1 Gas sensor response to methane

Methane sensor sensitivity as a function of methane concentration is presented in Fig. 2. Response of the sensor is linear in the range of 0.125-2.5%. Sensor response time is 0.3 s, with duty cycle of 1% (measurement every 20 s), average power consumption is <1 mW. At the end of heating cycle (250 ms), temperature of sensing layer was 450˚C.

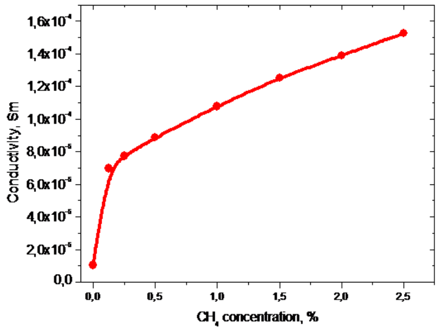

Fig. 2. Methane sensitivity of the sensor operating in a constant temperature mode (T = 450 ± 10˚C).

3.2 Pervaporation results

Permeation fluxes of water as a function of inverse membrane thickness are presented in Fig.3.

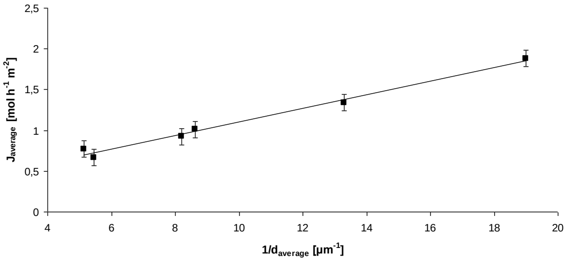

Fig. 3. Permeation fluxes vs. inverse PDMS membranes thickness.

As it is shown in Fig. 4 the higher ethanol concentration in feed caused higher ethanol flux. Moreover, ethanol fluxes rose faster than water fluxes.

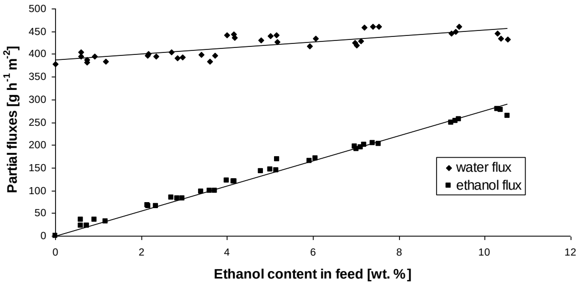

Fig. 4. Partial fluxes vs. ethanol content in feed mixture.

Results obtained for water-ethanol system proved that organic compound is selectively transported through PDMS membrane. Moreover, components of natural gas should show much higher selectivity through PDMS membrane than ethanol.

4. Conclusions

Sensing layer made of nanostructured metal oxide semiconductor was deposited onto the surface of a thin dielectric membrane. Gas sensor showed sensitivity properties and linear answer for presence of methane.

Modified ceramic and PDMS membranes were investigated to obtain the hydrophobic barrier for selective transport of organic compounds to the sensor surface. Polydimethoxysilane membranes of different thickness were investigated using pervaporation. The permeate flux was inversely proportional to the membrane thickness. Results obtained for pervaporation measurements with water-ethanol system, showed that organic compound was selectively transported through hydrophobic membrane. Both types of membranes will be further investigated in contact with artificial sea water containing methane.

References

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