MEMS Based H_2 Gas Sensors

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INTRODUCTION

Hydrogen is currently expected to join electricity and fossil fuels as a primary energy carrier in the 21st century. Significant R&D efforts are currently directed toward creating the basic building blocks of such an H_2 economy: production, storage, transport and utilization. A common need of these building blocks is the ability to detect and quantify the amount of H_2 gas present. This is required for health and safety reasons, as well as for monitoring H_2 based processes, e.g. H_2 fueled automobiles would require sensors to detect gas leaks, as well as to monitor and regulate the air/H_2 mixture.

An effective H_2 detection and monitoring system requires a sensor element that functions in a variety of challenging environments. It needs to be selective to H_2 in a range of atmospheres, including the O_2-rich high-humidity environments found in fuel cells, as well as in O_2 depleted atmospheres. Speed of detection is a critical requirement for rapid response to potentially hazardous leaks. Low power consumption is requisite for use in portable instrumentation and personnel monitoring devices. Ultimately, these must be achieved by an element that is safe and economical.

This paper reports on progress in developing MEMS (Micro-Electro-Mechanical Systems) based H_2 gas sensors. These sensors couple novel thin films as the active layer with a MEMS structure known as a Micro-Hotplate. This coupling has resulted in a H_2 gas sensor that has several unique advantages in terms of speed, sensitivity, and amenability to manufacturing.

EXPERIMENTAL

SENSOR FABRICATION

H_2 gas sensors have been produced at ATMI using a MEMS based CMOS foundry process.[1] In this process, microhotplate device structures were designed using CAD layout software. These designs were fabricated through the MOSIS foundry service.[2] The as-received chips were etched in house using XeF_2 to create suspended micro-hotplate device structures. The structures, (~200µm x 200µm in size) were functionalized by depositing a H_2 sensitive coating that consisted of a rare earth thin film overcoated with a palladium based top-layer.[3] The final fabrication step was the dicing and packaging of the chips, which was done by a commercial foundry.

SENSOR TESTING

Accurately measuring the speed of response to H_2 was an important consideration for the sensor test apparatus. The data collection system consisted of automated measurement system capable of a scanning speed of 250 channels/s. To achieve fast gas switching speeds, the gas manifold used low volume 4-way valves in combination with 1/8" tubing and a small test chamber size (~10 cm^3).

The ambient gas used for the experiment was triple filtered compressed dry air or dry N_2. H_2 was blended with the ambient gas using mass flow controllers with ranges of 200 and 5000 sccm respectively.

RESULTS AND DISCUSSION

The top panel of Figure 2 shows the resistive response of a micro-hotplate based H_2 gas sensor, where the micro-hotplate was held at an elevated temperature by passing current (< 5 mA) through the embedded polysilicon heater. In this experiment, the sensor was cyclically exposed 10 times to 0.25% H_2 in dry air. The lower panel of Figure 2 focuses on the transition of one particular cycle with an expanded time scale indicating a rise time of < 0.5 s. Detection of concentrations as low as 200 ppm H_2 have also been demonstrated.

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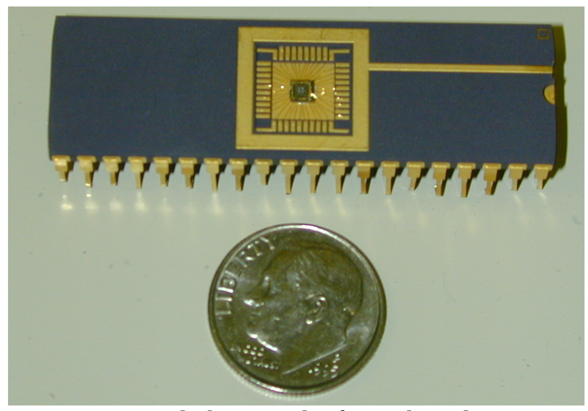

Figure 1. Optical photograph of a packaged H_2 sensor.

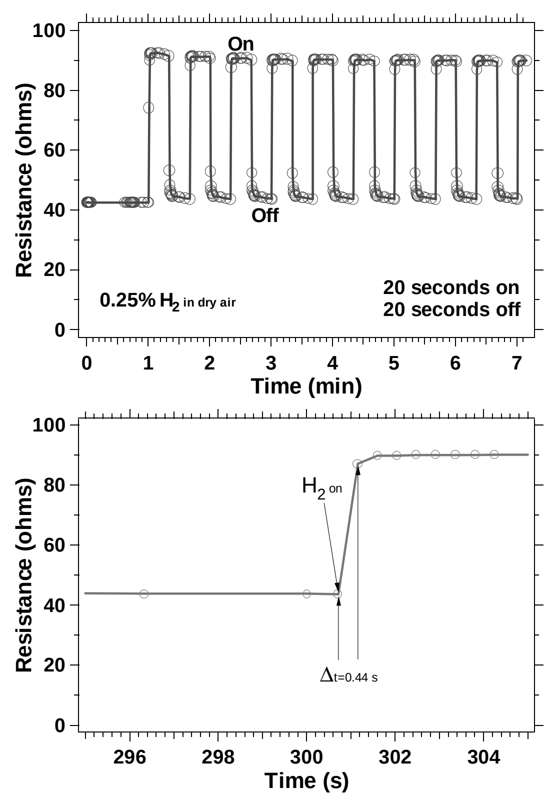

Figure 2. Resistive response of a microhotplate based H_2 gas sensor to repeated exposure to 0.25% H_2 in air. The lower panel demonstrates a speed of response < 0.5 sec.

REFERENCES

[1] Suehle, J. S., R. E. Cavicchi, et al. IEEE Electron Device Lett. **14**: 118(1993).
[2] www.mosis.org
[3] US Patents 6,006,582; 6,265,222