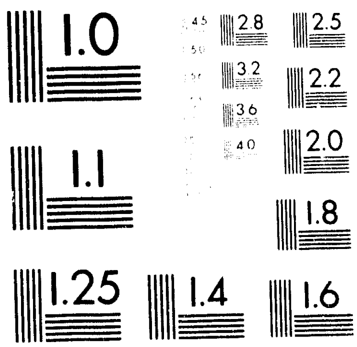
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Robust, Wide-Range Hydrogen Sensor For Use in Commercial, Space, and Government Applications

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A large need exists throughout industry, DOE, NASA and many other private and government agencies for a practical and reliable technique for detecting hydrogen. Hydrogen is used, produced, stored or transported as part of a number of manufacturing applications, and is found throughout the NASA complex. Hydrogen leaks pose a constant fire and explosion threat, and existing techniques for detecting hydrogen suffer from a number of limitations. Existing hydrogen sensors have limited dynamic range, poor reproducibility and reversibility, are subject to false alarms, and tend to be slow, unreliable and difficult to use. In order to address this need, Sandia has designed, fabricated, tested, and demonstrated a new generation of hydrogen sensor which overcomes the limitations of existing technologies. This new technology, known as the Robust, Wide-Range Hydrogen Sensor Technology, was created by integrating special catalytic alloy films into Sandia's existing CMOS microelectronic technology, creating a microelectronic based hydrogen sensor technology, as shown in Figure 1. The Robust Wide-Range Hydrogen Sensor, shown in Figure 2, contains PdNi transistor sensors for detecting low concentrations of hydrogen (part per million), PdNi resistor sensors for detecting higher concentrations of hydrogen (up to 100%), and on-chip micro-thermometers and micro-heaters for maintaining constant chip temperature. Custom control and communication electronics can be fabricated on the same small piece of silicon containing the sensor elements, allowing the fabrication of the entire sensor system on a single chip, including analog, digital, and communication electronics. Extensive characterization of this technology reveals that it provides a practical and cost effective solution to the problem of detecting hydrogen. This device has demonstrated a six order of magnitude dynamic range, outstanding reproducibility and reversibility, and good long term stability. The technology is manufacturable, and the sensors are simple to use. The devices have been shown to operate in non-oxygen ambients and in vacuum.

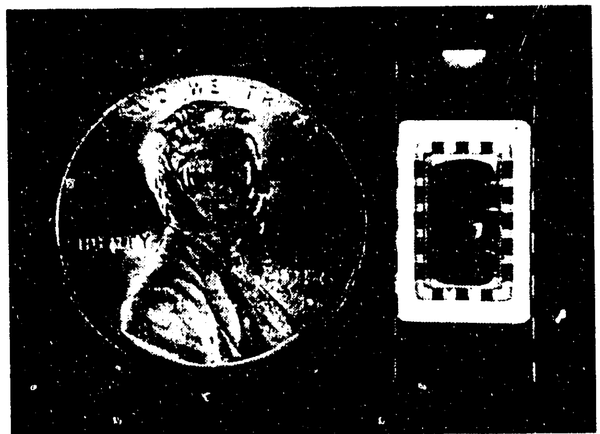

Figure 2. Sandia's Robust-Wide-Range Hydrogen Sensor overcomes the limitations of existing technologies.

These sensors are presently being used in a multi-point hydrogen leak detection system at NASA's Stennis Space Center. Work is underway to use the devices in a number of additional NASA ground based and flight systems. In addition, these sensors have been used in field applications in support of environmental monitoring at the Hanford waste sight, and

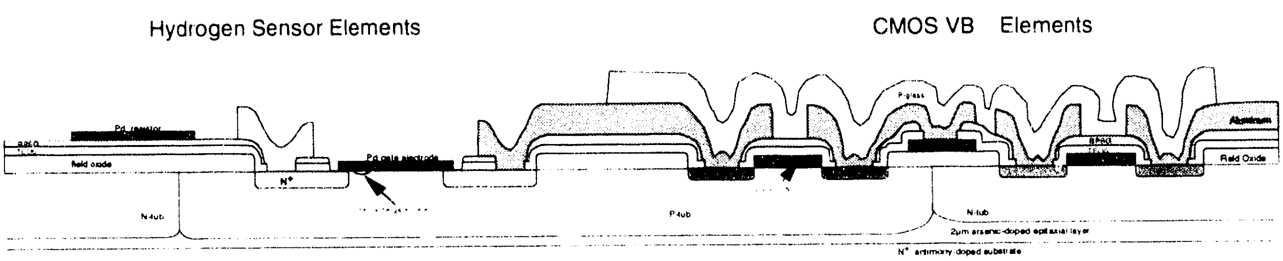

Figure 1 Cross section of Sandia's Robust, Wide Range Hydrogen Sensor. Integration of sensing alloys with the CMOS technology allows fabrication of control electronics on-chip with the sensor elements.

have been used in field applications involving nuclear reactor safety. Table 1 presents a comparison of the Sandia Robust, Wide-Range Hydrogen Sensor with a popular commercial hydrogen detector.

Table 1: Comparison of Sandia Robust, Wide-Range Hydrogen Sensor to a Popular Commercial Sensor

Characteristic	Commercial Electrochemical Hydrogen Sensor	Sandia Robust, Wide-Range Microsensor	Sandia Performance Advantage
Size	.8 liter	.0004 liter	**2,000 times smaller**
Weight	.2 Kg	1 gm	**200 times lighter**
Cost per sensor	$700	$100 (Estimated cost in production)	**7 times cheaper**
Dynamic Range	.1%-4% hydrogen (1.6 order of magnitude dynamic range)	.0001%-100% hydrogen (6 order of magnitude dynamic range)	**4.4 orders of mag. more dyn range**
Temperature Range	-10°C to 50°C, no temp control capability.	on chip temperature control, ambient gas can be -100°C to 140°C	**Works over greater temperature range**
Work in Vacuum?	no	yes	**Greater Range**
Acid leaks possible?	yes	no	
Poisoned by NO_2?	yes	no	
Speed of Response near Lower Explosive Limit	60 seconds	2 seconds	**30 times faster (speed is critical)**
Practical for pinpointing leaks?	no	yes	
Will work in hostile vibration/radiation environments?	no	yes	
Integrated Control Electronics?	no	yes	

In this presentation we will describe the fabrication technology which is used to make 10,000 of these devices in a single production run. We will present extensive electrical results showing the sensitivity, selectivity, stability and performance in a variety of operating environments, including oxygen free environments. In addition, we will provide results from some of the more interesting field tests which are presently underway, including rocket test stands at the Stennis Space Center.

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