Hydrogen Composite Tank Project

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Objectives

Develop a palladium nanowire-based hydrogen sensor that has fast response, is resistant to reactive gases, operates at room temperature, and it intrinsically safe.

Technical Barriers

This project addresses the following technical barrier from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

- B. Sensors

Approach

We propose to develop a hydrogen gas (H_2) sensor based on palladium nanowire arrays (PNAs) as shown in Figure 1. We discovered these sensors in 2001 (Favier et al., 293 *Science* 2227) and demonstrated that PNAs exhibit a variety of desirable attributes for the detection of hydrogen gas, including:

- Fast response (<25 ms baseline to 90% signal for 5% H_2 in N_2),
- Room temperature operation,
- Efficient power utilization (10^{-7} - 10^{-8} watts), and
- Resistance to poisoning by reactive gases including O_2 and CO.

Beginning in 2004, we will embark on a three-year project to improve PNA H_2 sensors for use in real-world hydrogen sensing applications. The goals of this project can be summarized as follows:

First, the performance of PNA H_2 sensors will be optimized over a range of environmental parameters including humidity and temperature (from –40°C to 200°C) while in the presence of contaminating gases such as CO, O_2, and H_2S. Sensor parameters to be optimized will include the nanowire diameter and length and the identity and thickness of the polymer support. Second, we shall seek to improve the performance of PNA H_2 sensors at high temperatures (where preliminary experiments show the limit-of-detection for H_2 is much higher than at ambient temperature – e.g. >5% at 80°C). Of particular interest is the use of palladium alloys with both nickel and silver since such alloys exhibit higher hydrogen solubility at elevated temperatures. Third, we will investigate the feasibility of several new types of H_2 sensors based on the PNA design. One idea to be explored involves the use of coaxially layered bimetallic nanowires in which an ultra-thin copper cladding is electrochemically applied to core nanowires composed of pure palladium. Because the chemisorption of many interfering species (e.g., CO, hydrocarbons) is weaker on copper than on

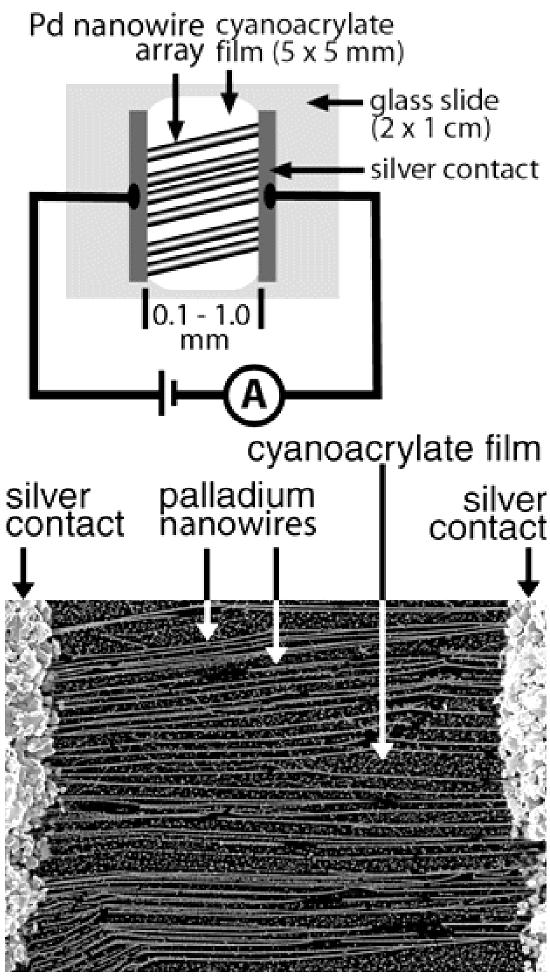

Figure 1. (top) Schematic Diagram of PNA H_2 Sensor, (bottom) Scanning Electron Microscopy (SEM) Image of a PNA H_2 Sensor (The total width of this SEM image is approximately 300 μm.)

palladium, this copper outer layer will filter out these contaminants while permitting dihydrogen to dissociate and penetrate to the palladium core. A second direction will be the development of a sensor architecture that can be prepared directly on silicon surfaces using conventional silicon microfabrication technology. Our first efforts in this direction have culminated in a recent publication (*Analytical Chemistry* **75** (2003) 4756). These early results already suggest that an exciting new generation of microfabricated hydrogen sensors, exploiting a sensing mechanism closely related to that responsible for the operation of the PNA H_2 sensors, are possible.