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## Fast Sensitive Hydrogen Gas Detection Using Single Palladium Nanowires

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### OTHER INFORMATION

#### KEYWORDS

nanowires, hydrogen sensor, palladium

#### CATEGORIZED AS

- » **Environment**
  - » Sensing
- » **Engineering**
  - » Engineering
- » **Nanotechnology**
  - » Materials
- » **Sensors & Instrumentation**
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#### RELATED CASES

## BRIEF DESCRIPTION

University of California, Irvine researchers have developed a method which has demonstrated that by controlling the grain structure of a palladium nanowire, nanowires operating in either the RH2 (+) or the RH2 (-) modes can be obtained.

The single palladium nanowires developed by UC Irvine researchers are capable of detecting hydrogen below 1-2% (Load-of-detection of Hydrogen below 1-2%). The detection also rapidly occurs within 1 to 5 seconds.

When these hydrogen sensing single palladium nanowires detect the presence of hydrogen, their resistance increases. The change in resistance can be measured, and when there is a specific increase in resistance, this reveals that there is the presence of hydrogen.

## FULL DESCRIPTION

UC Irvine researchers have developed a method which has demonstrated that by controlling the grain structure of a palladium nanowire, nanowires operating in either the RH2 (+) or the RH2 (-) modes can be obtained. Superior H<sub>2</sub> sensing performance, including response times in the 15 second range at high H<sub>2</sub> concentrations (Hydrogen Gas) and a LODH<sub>2</sub> (Load-of-Detection) of 2 ppm have also been demonstrated for single Pd nanowire sensors operating in the RH2 (+) mode that did not break upon exposure to H<sub>2</sub>.

### Background

Since 2002, palladium nanostructures have been used in a variety of innovative ways as resistor based hydrogen sensors. These sensors can be categorized according to the mechanism by which they transduce hydrogen: Sensors that derive their signal from the volume change associated with the alpha to beta phase transition generally show decreased resistance in the presence of hydrogen (i.e., RH2 (-)) while those that measure the increased resistance of the PdH<sub>x</sub> relative to Pd show an increased resistance upon H<sub>2</sub> exposure (i.e., RH2 (+)).

Two dimensional palladium nanoparticulate films fall into the first category. An attribute of these systems is that they often have rapid response times (< 1s) that mimic the early palladium nanowire arrays, but they are much easier to fabricate.

Researchers in the field have electrodeposited single palladium nanowires and showed that these function as H sensors in this RH2 (-) mode. A RH2 (-) sensor was also produced by using a focused ion beam to cut a nanotrench with width 100-400 nm into a palladium microwire. With a few exceptions, RH (-) sensors show a LODH<sub>2</sub> in the 12% range coinciding with the threshold for the alpha to beta phase transition.

A lower LODH<sub>2</sub> can be obtained for systems capable of functioning in the RH2 (+) regime because the increased resistance of PdH<sub>x</sub> can be detected well below the 12% threshold for the alpha to beta phase transition, often at the expense of slower sensor response and recovery times. Still other researchers have recently showed that a sensitive RH2 (+) hydrogen sensor is obtained when carbon nanotubes arrayed between two electrical contacts are electrochemically decorated with palladium nanoparticles. These sensors showed a LODH<sub>2</sub> of 100 ppm with response times in the 5-10 minute range.

### Details

The disclosed single palladium nanowire sensors have many advantages over the previous utilized methods. The invention generally has the strengths of the previous methods without associated weakness.

Like the previous RH2(+) methods, the disclosed method can detect levels of hydrogens in ranges lower than 12%. In fact, the invention can detect hydrogen in the range of 1-2%. Unlike the previous RH2(+) methods, these sensors have a much faster response rate in the range of 1 to 5 seconds. In terms of the response rate, the invention is similar to the previous RH2(-) methods of sensing as they have a rapid response time. Therefore the invention combines the positive attributes of previous methods, without having their associated drawbacks.

The nanowire can also be exposed to hydrogen without fracturing for up to concentrations of approximately 10% hydrogen. By comparison, some of the other previously created palladium based sensors would fracture at 2% hydrogen concentrations.

## SUGGESTED USES

Hydrogen sensors

## ADVANTAGES

1) Rapid response rate: The invention can detect the presence of hydrogen within 1 to 5 seconds.

2) Improved measuring capability: The invention is capable of measuring hydrogen levels below 1-2% and has a rapid response time upon detection. The invention can detect hydrogen concentrations down to 2ppm.

3) Improved durability: The invented wires are exposable to hydrogen for concentrations up to approximately 10% without fracturing.

## PATENT STATUS

Country	Type	Number	Dated	Case
United States Of America	Issued Patent	8,499,612	08/06/2013	2009-611

## RELATED MATERIALS

» Xiaowei Li, Yu Liu, John C. Hemminger, and Reginald M. Penner. "Catalytically Activated Palladium Platinum Nanowires for Accelerated Hydrogen Gas Detection". ACS Nano, 2015, 9 (3), pp 3215–3225

» Fan Yang , Sheng-Chin Kung , Ming Cheng , John C. Hemminger , and Reginald M. Penner. "Smaller is Faster and More Sensitive: The Effect of Wire Size on the Detection of Hydrogen by Single Palladium Nanowire". ACS Nano, 2010, 4 (9), pp 5233–5244

## TESTING

The invention has been tested successfully, and the detailed results of the test are published in the following research paper:

Fan Yang, David K. Taggart and Reginald M. Penner. "Fast, Sensitive Hydrogen Gas Detection Using Single Palladium Nanowires That Resist Fracture " Nano Letters. Vol.9, No.5 2177-2182 (2009)

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