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Palladium Film Via Zinc Oxide Film Hydrogen Detector

Dr. Albashir Zomrawi
Assistant Professor, College of Engineering, Karary University, Khartoum, Sudan, bashirzom@yahoo.co

***Abstract*— In this work, a comparison was carried out between two thin film hydrogen detector designs depend on the Palladium and Zinc Oxide coated on glass thin film that adept to detect hydrogen gas. Four samples have been prepared; two of them prepared from palladium metal and two other samples prepared from Zinc Oxide. Palladium and Zinc Oxide thin films were prepared on glass substrates. The films were constructed by vaporization deposition technique, which subjects to three tests. The X-Ray Diffraction (XRD) to check the crystalline structure of the samples, Atomic Force Microscope (AFM) to study the surface flatness of samples, and the scanning electron microscope (SEM) to take images of surface topography of samples. A polymer test chamber was fabricated to contain the sample. The approach of the manufacture the sensor based on passing the gas to the chamber, which adsorbs on the sample (Palladium, or Zinc Oxide), and the light is transmitted through the sample to the CCS spectrometer to measure and recorded the signal using computer. Six readings were recorded for each sample test under pressures of -0.6, -0.5, -0.4, -0.3, -0.2 and -0.1 bar. Frequencies against transmitted light intensity were then plotted for each measurement. From the data recorded.**
Results showed that, by increase of concentration of hydrogen gas in the test chamber, the sensitivity increase linearly as the gas concentration increase. This result means that, Zinc Oxide and Palladium thin film samples successfully detect hydrogen gas.
***Keywords*— Detector, Palladium, Semiconductor, Spectrometer, Thin-Film, Zinc Oxide.**

I. INTRODUCTION

Hydrogen the most basic element, has been used as a chemical for decades and is now emerging as a universal energy carrier with important environmental and energy security advantages. Hydrogen can be made from a variety of local resources and is used in many different applications, such as: producing electric power for the electric utility grid or micro-grids; FUELLING cars and buses; and providing power for materials handling equipment, people movers inside buildings, and remote communications and security EQUIPMENT [5]. The flammability limit of hydrogen is seven times wider than methane. It is therefore, critical for a hydrogen detector to have a wider measurement range for safety applications than most common fuels [2].

The use of hydrogen as a clean fuel in various applications requires practical and robust detectors to minimize risk of explosion associated with its volatile properties [7]. Common gas sensing layer is based on semiconducting metal oxides (SMO) that has several advantages such as simplicity in fabrication, low cost and high sensitivity. Current research focuses on fabricating the sensing layer using nanostructured metal oxides that offers high surface area to increase the gas molecules-sensing layer interaction [4]. Different of approaches that used to sense and detect hydrogen. Number of which are used in industry include the typical Gas Chromatography (GC), Mass Spectrometry (MS), Catalytic Bead (CB), and thermal conductivity. Semiconducting metal oxide and CB detectors are popular solid-state technologies, which employ heated catalysts to sense hydrogen. The most promising solid-state technology is based on a hydrogen-specific material, palladium, which does not require oxygen for operation. Palladium-based detectors are gaining wide popularity in industry due to their reliability and high specificity to hydrogen. Any hydrogen detector technology needs to satisfy the three basic requirements sensitivity, selectivity, and specificity [5]. Metal oxide detectors(MOS) which known also as semiconductor- based detectors, since they use a semiconducting film as the sensing element. The MOS have to be heated up to high temperatures and require the presence of oxygen. At high temperatures (300–500°C), there is a grain boundary formation in the MOS that enable detection of a number of gases. The MOS consume high power and have high false alarm issues [6]. CB detectors are a variation of this type and have an active sensing element with a coated catalyst and a passivated reference element for ambient temperature and pressure compensation. Metal oxides are semiconductor-type materials that constitute a major category of gas detectors. The most widely researched metal oxide used for sensing applications is tin oxide (SnO_2). Typical processes for manufacturing SnO_2-based detectors involve a thick semiconducting film made of micron size particles. Electron transport between particles is limited by the huge energy barriers at their grain boundaries.

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II. HYDROGEN DETECTOR COMPONENTS

Hydrogen thin films detectors consists basically on seven components include; chamber, white photo diode, spectrometer, vacuum unit, gauge pressure, cylinder of hydrogen gas, and computer. Figure (1) and figure (2) below illustrate detector component and detector setup successively. A sample of palladium coated glass slide detector should be prepared first to detect hydrogen, and should be tested by X-ray to cheek its crystallization. The main detector components are;

- The coated glass substrate (Palladium thin films): should be placed inside the developed polymer square test chamber of 50 mm square base and of 75 mm height with the top removable cover. The effective volume of the chamber is 187500 mm3; it has an inlet to allow the test gas to flow in [2].
- White photo diode: is the light source used in the detector.
- CCS Spectrometer: used to measure transmitted.
- Vacuum unit: to evacuate the test chamber.
- Gauge pressure: to measure the current pressure of the chamber.
- Cylinder of hydrogen gas of a known concentration: to flow through the test chamber during measurement.
- Computer: to process the recorded signal.

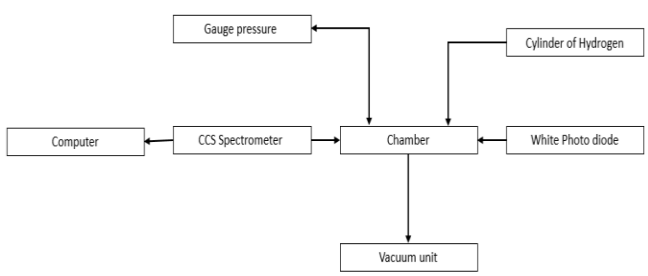

Fig:1 Detector components.

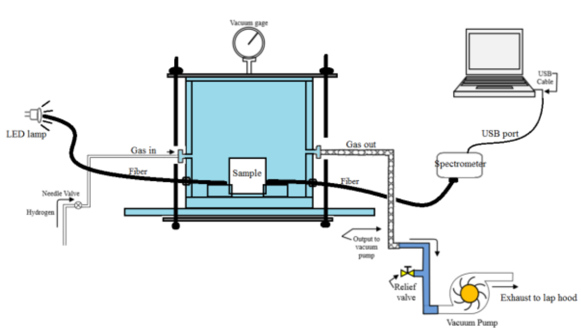

Fig:2 Detector set up.

III. MEASUREMENTS AND RESULTS

In this research work, tow testes were carried out to examine the palladium thin film detector. In both tests, results were obtained through adopting the following steps:

First, the test chamber should be opened to place the palladium thin film detector on the detector holder and close closed. Then, the necessary light source should be directed by optical fiber and allowed to pass through the sample to the spectrometer. After that, the rotary pump has to be switched on to evacuate the test chamber by about -0.7 bars. Next, the hydrogen gas of a known concentration has to be allowed to pass from the cylinder through the special inlet to the test chamber by opening the cylinder valve. Test chamber pressure should be measured by observing the gauge pressure. Spectrometer then should detect and analyzes transmitted signals and sends the data to the computer.

During the first test, number of measurements were carried out in different pressures. Six readings were observed for each sample test including pressures at -0.6, -0.5, -0.4, -0.3, -0.2 and -0.1bar. Frequency against transmitted light intensity graphs were produced for each reading. The six graphs were then combined together in one diagram with a background graph representing -0.7 pressure without Hydrogen. Figure (3) and figure (4) below represent the resultant combined graphs for both sample tests [2].

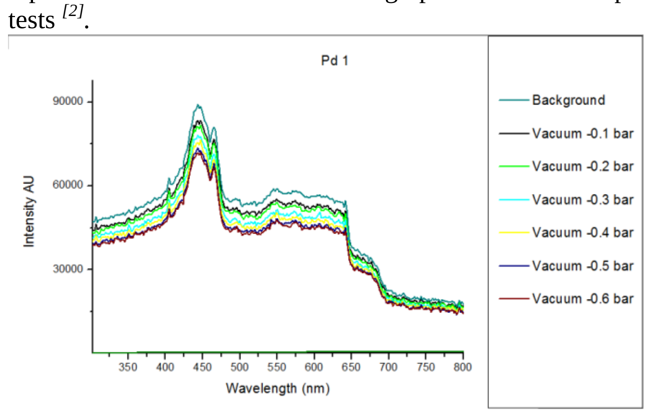

Fig:3 Combined graphs of the palladium thin film sample one (Pd 1) with a numbers of measurements were carried out in different pressures.

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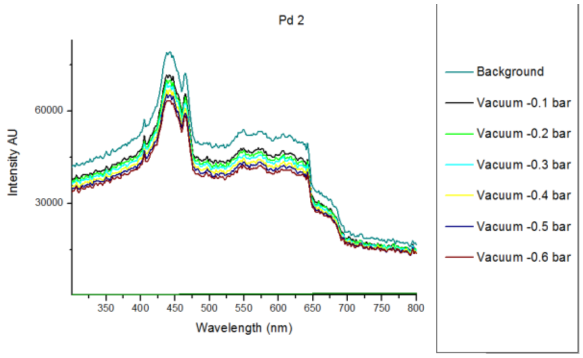

Fig:4 Combined graphs of the palladium thin film sample two (Pd 2) with a numbers of measurements were carried out in different pressures.

By analyzing the above figures, it can be noted that by increase of concentration of hydrogen gas in the test chamber, the transmitted light is also increase. Or in other word, the palladium and zinc oxide thin film sample successfully detect hydrogen gas. Also, it can obviously note that, visible band located in the region of 500-650 nm is the suitable wavelength that can be used to detect hydrogen gas[2].

In the Manganese dioxide detector, the gas absorbance response was carried out at operating temperature of 240°C. No response was recorded below this operating temperature, possibly because of a slow chemical activation between adsorbed gas molecules and the sensing layer [1].

In the second test, number of measurements were carried out in different pressures. Six readings were observed for each sample test including pressures at -0.6, -0.5, -0.4, -0.3, -0.2 and -0.1bar. Frequency against transmitted light intensity graphs were produced for each reading. The six graphs were then combined together in one diagram with a background graph representing -0.7 pressure without Hydrogen [3]. Figure (5) and figure (6) below represent the resultant combined graphs for both sample tests.

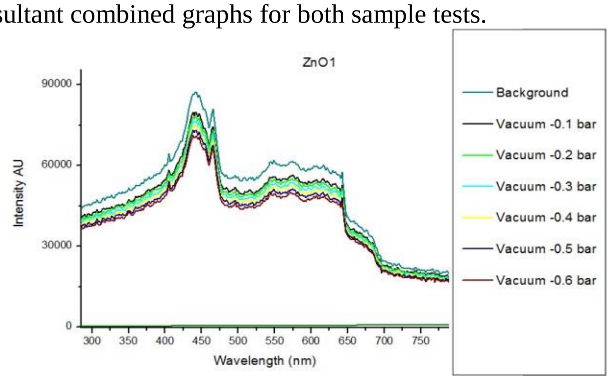

Fig:5 Combined graphs of the first sample.

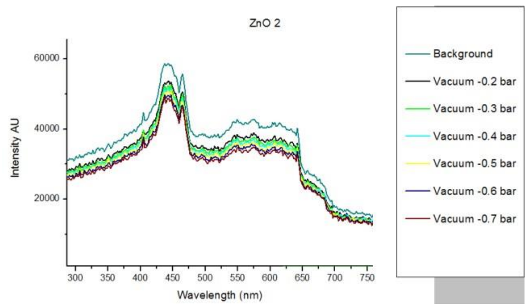

Figure 6: Combined graphs of the second sample

In these results, and by referring to the resultant figures above, it can again be noted that, increase of concentration of hydrogen gas in the test chamber increase the transmitted light. The thing that means, Zinc Oxide thin film sample successfully detect hydrogen gas.

Analogue to the previous result, it was found to be that, 500-650 nm visible wavelength is suitable for hydrogen gas detection.

IV. CONCLUSION

In this study, two tests were carried out in order to compare between two developed hydrogen detectors. The first test depended on the Palladium coated glass thin film where the second one depended on optical fiber coated with manganese dioxide. From the measurements carried out and results obtained, it can be concluded with the following points:

- Both, Palladium coated glass thin film detector and optical fiber coated detector efficiently detect Hydrogen gas.
- Palladium coated glass thin film detector has rapid response to low hydrogen concentration, moreover, it has a wide dynamic range specifically in the range of 500-650nm.
- Palladium coated glass detector can be used in the room temperature.
- On the other hand, Pd/MnO_2 coated optical fiber detector is sensitive at elevated temperature of 240°C, therefore, it is suitable to be used in hot environment.
- Design wise, It can also be noted that Pd/MnO_2 coated optical fiber detector is more expensive compared with Palladium coated glass thin film detector.

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