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Effect of pigment concentration and particle size of TiO_2 support on performance of chemochromic hydrogen tape sensor

Kyudae Hwang [a,*], Ali T-Raissi [b], Nan Qin [b]

[a] Department of Mechanical Engineering, Yuhan University, Gyeonggi-do, 14780, Republic of Korea

[b] Florida Solar Energy Center, University of Central Florida, 1679 Clearlake Rd., Cocoa, FL 32922, United States

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ABSTRACT

A chemochromic hydrogen tape sensor has been developed to detect hydrogen leaks using titania (TiO_2) supported palladium oxide (PdO) pigments encapsulated within a silicone matrix. This study has been carried out to investigate the effects of pigment (PdO-TiO_2) concentration and particle size of TiO_2 support on detection performance in terms of color contrast of a chemochromic hydrogen tape sensor. The irreversible hydrogen tape sensors were tested with different concentration from 0.2 wt% to 10.0 wt%. Several pigments were synthesized using three different TiO_2 support with particle sizes ranging from 100 nm to 5 μm. The experimental results exhibit that the color of the pigment with 0.2 wt% shows distinctive color change in minimum and the optimal pigment concentration for silicone matrix type irreversible tape sensor is 3.0 wt%. In addition, TEM analysis revealed that the PdO particles become larger and agglomerated as increasing the particle size of TiO_2 support. The pigment with Aldrich TiO_2 particle size ≤5 μm has a good performance than smaller one.

Introduction

From the point of view of environmental protection, many studies have been conducted on the renewable and sustainable energy resources such as solar, wind, tidal, geothermal to replace fossil-based energy. Among these energy resources, hydrogen (H_2) considered as an ideal energy carrier in the near future due to its high energy density and non-polluting byproduct [1]. Hydrogen has a potential to substitute fossil fuel in applications such as automobiles, airplanes and rockets without carbon emissions and it can also be converted directly into electricity at efficiencies of 85–90% by the fuel cell technologies [2]. Due to its flammable nature, the detection of hydrogen leak during transportation and storage is critical. A number of hydrogen detection sensor technologies have been developed including catalytic sensors, thermal conductivity measurement, electro-chemical sensors, semiconducting metal-oxide type sensor, MOS (metal-oxide-semiconductor) field-effect transistor, optical sensors, and acoustic sensor etc. Many researches of hydrogen detection have been focused on the electronic sensors. However, the electronic sensors have several drawbacks including loss of sensitivity in the field due to environmental effect [3]. A chemochromic hydrogen tape sensor can utilize chemical reaction induced color change of palladium oxide (PdO) pigment to

* Corresponding author.
E-mail address: hwang@yuhan.ac.kr (K. Hwang).
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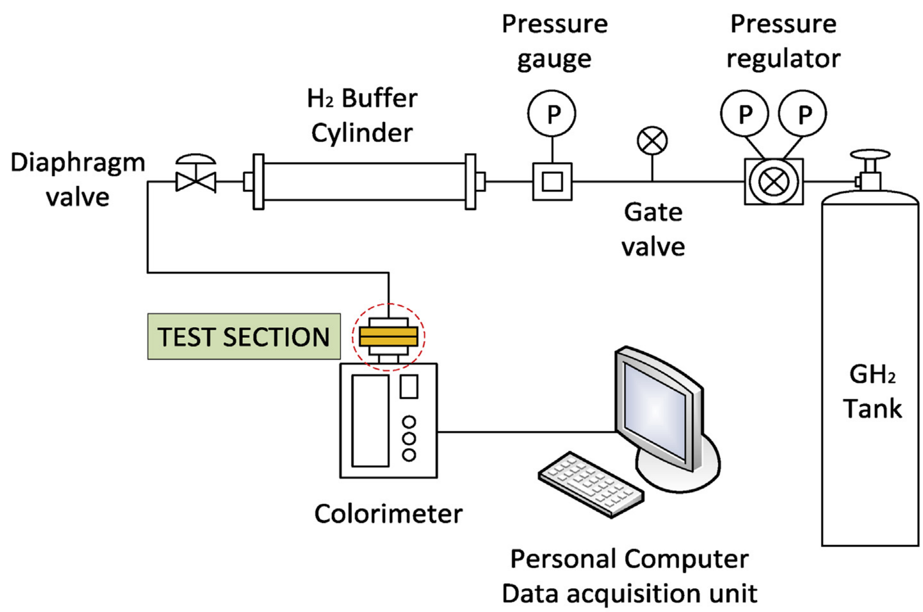

(a)

(b)

Fig. 1 – Apparatus for continuous measurement of color contrast due to hydrogen exposure. (a) schematic drawing of the test section; (b) picture depicting the unit used in the experiments. (For interpretation of the references to color/colour in this figure legend, the reader is referred to the Web version of this article.)

upon contact with hydrogen. The color change from beige to dark gray occurs as a result of PdO reduction by hydrogen to form elemental Pd. A chemochromic hydrogen tape sensor has many advantages such as broad temperature stability, simple usage, rugged, passive operation, rapid response, no toxic ingredients and cost effectiveness. It also does not introduce impurities into the gas stream [4].

Several studies of the chemochromic hydrogen tape sensor have been conducted on the hydrogen reduction kinetics of TiO_2 supported PdO pigments by means of TG/DTA(thermos gravimetric/differential thermal analysis) and the effect of PdO particle size and level of PdO agglomeration on the TiO_2 support surface on the performance using the TEM-XRD analysis since it has been developed [5–7]. However, the studies of optimal concentration of the TiO_2 supported PdO pigments to reduce fabrication cost of sensor and the effect of TiO_2 particle size on the performance have not been reported. Therefore, we conducted experimental studies in order to