Challenges and Opportunities for Sustainable Hydrogen Detection

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ABSTRACT

Hydrogen is a form of clean energy with the potential to replace the dependability on fossil fuels by powering vehicles. In comparison to other combustible gases such as methane and propane, hydrogen has a lot of remarkable properties (for example, lower density, low boiling point, minimum ignition energy) which make it a potential candidate in today's emerging economy called the 'hydrogen economy. Since hydrogen is gas without color, odor and taste, it is almost impossible to sense the hydrogen by human organs and therefore, different technology, devices and systems are prerequisite to identify its presence in the particular environment, Additionally it is also difficult to quantify its concentration during production, storage, and transportation applications. Highly flammable nature of hydrogen reinforce the need of detection of any minor leaks. Hydrogen sensors have been successfully employed for management and monitoring in manufacturing plants, small scale production units , pipelines, refilling stations, turbine generators where hydrogen is used as a coolant and for shuttle, rocket launching station as well as many other operation of space and defence industries. The presented paper will provide a summary in the areas of hydrogen detection technology for various industries and processes.

I. Introduction

Depending on the applications, hydrogen are often used as (i) strong chemical agent for several elements (ii) desulphurization for variety of petroleum products (iii) rocket fuels for space and other applications (iv) for metallurgical processes (v) for nuclear energy plants (v) welding and galvanic plating etc. except for these, hydrogen may be used as an energy carrier to resolve the matter of limited availability of fossil fuels. within the atomic energy stations, uncontrolled production of hydrogen can form potentially explosive mixtures with air which may result into explosions. Figure 1, is explaining hydrogen based economy where hydrogen may be utilised as green energy source of power.

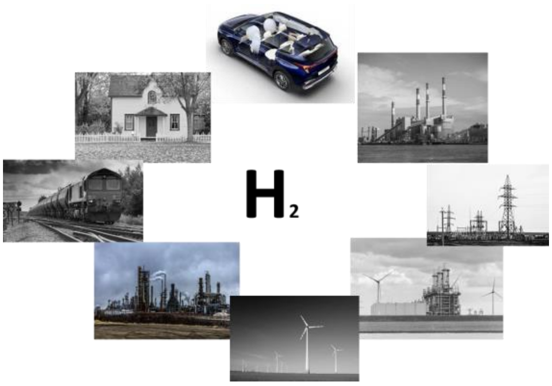

Figure 1. Hydrogen based economy, where it can be used as green source of power.

A hydrogen explosion resulting into a nuclear accident has recently been reported in 2011 at the nuclear power plant in Fukushima, Japan. It is possible to detect Hydrogen at very initial stages through sensor

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based technology than can further avoid explosion and failure of transformers in power units.

Although the quantity and detection of hydrogen has a long history, dating back to hydrogen measurements at airship filling stations [1], still a faster, precise, and selective hydrogen detection in various units of industry is essentially required. In general, Hydrogen sensors are a type of transducer devices that detect hydrogen gas molecules and generate an electrical signal proportional to the concentration of hydrogen gas [2]. It generally have two major elements viz. tensing element and transduction element, where transducer may consists of many vital parts such as such as signal processing equipment, amplifiers and power supplies. Hydrogen sensors are more suitable than traditional hydrogen detection technologies such as gas chromatographs and mass spectrometers because of their lower cost, smaller size, and faster reaction. Because of these characteristics, they are more suitable for portable and in-place hydrogen detection in a wide range of applications.

Despite the very fact that such sensors area unit well-established to be used in manufacturing plants a daily basis and operated by trained personnel, the emergence of a hydrogen gas economy continues to demand low-priced, low-maintenance, easy-to-install, easy-to-use, correct gas sensors appropriate to be applied by non-specialized people in variety of applications.

II. Literature review

There are several different types of hydrogen sensors on the market or in development. The majority of hydrogen sensing concepts have been known for a long time [3, 4], and hydrogen sensors have been commercially accessible for a long time. However, in order to meet the demands of a future hydrogen economy, extensive research is underway to enhance sensitivity, selectivity, reaction time, and reliability while also reducing sensor size, cost, and power consumption. Sensing technique of a hydrogen sensor depends over the interaction of hydrogen with the detector of the device [3,4]. As a results of this interaction with hydrogen the sensing material suffers a change in temperature, ratio, electrical properties, mass change and other mechanical transformations. These transformations are converted into an electrical signal by a transducer to detect and quantify the Hydrogen concentration. There are various well known Hydrogen detection technologies like (i) Catalytic type [5, 6], (ii) Thermal conductivity based [7, 8], (iii) Electrochemical type [9, 10], (iv) Resistance type [11, 12], (v) Work function based [13, 14], (vi) Mechanical [15, 16] and (vii) Optical [17, 18].

The most widely utilised materials for Hydrogen detection are palladium and platinum; nevertheless, these metals are prone to mechanical damage when exposed to hydrogen. Palladium has a high solubility of Hydrogen and a selective interaction with it, making it a good contender for metallic multilayer sensors. Due to the enlarged resistance of Pd composite compound relative to Pd, the sensing property relies on a rise in electrical ohmic resistance following the absorption of Hydrogen from the defined environment.

There are reports that suggest hydrogenated Pd-Co multilayer structure can play an important role in Hydrogen gas sensing applications. In a very recent work reported by Gautam et al.[20], hydrogen absorption properties of sputtered Pd capped Mg thin films samples have been investigated and it was found that the saturation of hydrogen absorption to have occurred at 250 °C.

A reversible change in electrical resistance due to hydrogen loading was observed by Kumar et al. [21] in pulsed laser deposited nanostructured Pd thin films having typical response time of 10-20s whereas a fast hydrogen desorption time (2s) is reported by Kumar et al.[22] in Pd capped Samarium thin films.

The United States and Japan, in particular, contribute significantly to research on hydrogen sensor applications. Joshi et al. [23] employed electrochemically produced Pd nanoparticles and sputtered Pd thin films for hydrogen gas measurement at ambient temperature, and a comparison analysis concluded that electrochemically synthesised Pd nanoparticles have stronger H_2 sensing properties than sputtered palladium thin films.

At temperatures ranging from 0 to 200 degrees Fahrenheit, a thick film Pd resistive sensor has been reported to monitor hydrogen concentrations in the range of 0.5 to 30% [24]. Despite the fact that the detection is limited to hydrogen, gases such as CO, SO_2, and H2S can poison the sensor response, reaction time, and resistance. CO poisoning has an influence on sensor responsiveness.. The impact CO poisoning over the sensor response is discovered to depend upon the palladium movie morphology that's successively keen about the tactic and conditions of film fabrication [25].

a very thin, micro level, hydrogen sensor made of palladium and nickel [26] alloy has also been reported and claims are made for an amazing measuring variety of 0.1–100%. The Ni was brought to suppress the phase exchange discovered in natural palladium way to hydrogen absorption. a skinny Mg–Ni alloy movie lined with Pd layer has also been suggested for hydrogen detection inside the variety 10 ppm – 10% at temperature [27].

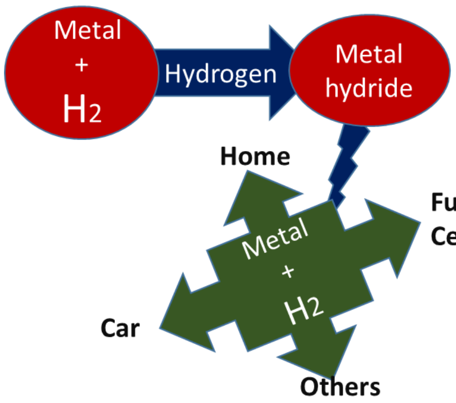

Figure 2. Capturing and relasing of hydrogen through metal hydride.

Hydrides generation and their nature of the reversible solid state solution of hydrogen in the alloy were found to be accountable for the altering and overall shifting in the film's resistance. Palladium-capped rare earth metal films have also been found to be sensitive to hydrogen. The electrical resistivity of rare earth metals, such as yttrium [28], increases significantly after reversible hydrogenation.

It has also been proposed to employ a discontinuous ultrathin palladium film sensor on a siloxane treated glass substrate as a hydrogen sensing material [29]. Isolated nano-sized palladium particles have been supporting the detection of hydrogen through hydrogentaion in nanocluster palladium film. These forms of detecting technology and mechanisms have been used with palladium mesowire architectures as well as discontinuous nanoclustered palladium morphologies [30]. This sensor has a 75-millisecond response time, functions at ambient temperature, consumes little power, and is resistant to CO, O_2, and CH_4 poisoning.

III. Challenges in hydrogen detection

Production of hydrogen through various means such as solar light harvesting, photon energy conversion, and electro catalytic conversion of water into oxygen, protons, and electrons, storage of hydrogen as molecular hydrogen and through anchoring with metal hydrides, carbon-carbon chain-linking as well as reduction to hydrocarbons, and combustion of hydrogen for real-time application are major challenges in the hydrogen-based economy. Figure 1 depicts the capture of hydrogen with metal in a solid state for safe storage and release of hydrogen as needed. Because of its extremely combustible nature, hydrogen use poses a greater explosion risk than many other liquid and gas fuels, therefore detection of hydrogen is critical at all stages..

Despite the fact that various reports and products based on modern technology are available on the market, the hydrogen leak in the refinery has the potential to become a big disaster. Exposure to hydrogen, even in little levels, provides a number of concerns to people who work with it, including the possibility for burns and respiratory difficulties in those who are exposed. If the concentration is high enough to deprive humans in the nearby region of oxygen, asphyxiation is a possibility. Because it has no odour or taste, one would be completely unaware of the risk. When anything is lit, it can quickly spread, making it a potential source of a large fire or explosion. Hydrogen embrittlement, which erodes the strength of metals, can also be caused by hydrogen.

I. Lifetime: to work out current and future application and operating costs, likewise as identify replacement and maintenance needs, an appropriate lifespan should be identified.

II. Reliability: Sensors must have long -term reliability that produces consistent results. it's also good to achieve a full understanding of any test conditions that would cause false alarms or damage the sensor during a way that may affect its reliability

III. Cost: While some class detectors may include minimal cost, performance, reliability and lifelong value mustn't be sacrificed. The risks that include unreliable sensors are too great to chop.

IV. Conclusions

Hydrogen use in industry has risen dramatically in recent decades, and future projections show that it will continue to rise in tandem with energy demand. Petroleum refining, metal processing, fertiliser production, and food processing are all examples of hydrogen usage. The expansion of refinery facilities in developing countries, as well as the increased use of metals and semiconductors, fueled growth. Increasing hydrogen use, however, necessitates a greater ability to detect hydrogen leaks promptly in order to avoid dangerous scenarios.

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