Hydrogen Leakage Detection System based on Wireless Sensor Network

Seok Cheol Lee', Hoon Sik Jiang% Seung Hoon Nahm'', Chang Soo Kim[2]

' Center for Material Measurement, Korea Research Insititute of Standards and Science, Gajeongro. 267, Yuseong Daejeon, Korea
[2] Dept. of IT Convergence and Application, Pukyong National University, Yongsoro. 45, Namgu Busan, Korea

{sclee05, shnahm}@kriss.re.kr, physdrjhs@gmail.com, cskim@pknu.ac.kr

Abstract. This paper describes the hydrogen gas leakage detection system based on wireless sensor networks. The hydrogen energy is gaining much attention as a possible future substitute for fossil fuel in the transport sector but it should be used with caution and always involves the safety management devices. The goals of current study are the development of high performance sensor systems using carbon nanotube and supporting the wireless communication based on Zigbee. The result of sensor core using carbon nanotubes shows the quick response time about the desorption than existing commercial sensors and gains the accurate data in wireless communications.

Keywords: Hydrogen energy, Leakage management, Real-time monitoring

1 Introduction

Hydrogen energy offers the highest potential benefits in terms of diversified supply and reduced emissions of pollutants and greenhouse gases. Moreover hydrogen energy can realize the ideal fuel inexhaustibility, cleanliness, convenience. Similar to electricity, hydrogen is a high-quality energy carrier, which can be used with a high efficiency and zero or near-zero emissions at the point of use. It has been technically demonstrated that hydrogen can be used for transportations, heating, and power generation, and could replace current fuels[1]. Although hydrogen has many advantages, it should be used with caution. Hydrogen gas is combustible which has wide explosive and very fast propagation speed. For the reason, hydrogen gas has some risk which includes leakage, diffusion, ignition, and explosion in the whole process - production, transportation, and storage, thereby needs the safety device and systems. Hydrogen sensor for leakage detection limit of the gas explosion in the concentration range of skills required to accurately detecting and works in

[1] Seung Hoon Nahm is a corresponding author (E-mail : shnahm@kriss.re.kr)

conjunction with safety devices must be able to take immediate action. Thus, we suggest the hydrogen leakage detection system which consists of carbon nanotube sensor able to detect the gas quickly than existing sensor, driving circuit by bridge and real-time data monitoring system based on the wireless sensor networks (WSNs).

2 System Design

A goal of the proposed systems is that the implementation of the real-time monitoring systems support the data acquisition from the distributed sensors that is installed to reserved points and processing the sensor data. The proposed model for a real-time monitoring system consists of devices for processing the acquisition data from each sensor network node, attaching to the points of contact and its mechanisms in real-time. The real-time monitoring system requires real-time data acquisition by each sensor network node requires states to be checked automatically and requires a middleware system that performs event processing. Moreover, a sensor handler processor is also required, which prevents data loss from the real-time sensor framework, supports the response time, and constructs multiple communications in cases of networks that are destroyed [4,5].

The proposed model for real-time hydrogen monitoring applications consist of the construction of sensor nodes with installation, mechanisms of data management on sensor networks and sensor middleware applications based on sensor agents. This system consists of three main parts. First, sensor fields are the sensor nodes that consist of wireless sensor nodes combined with MWCNT hydrogen sensors, temperature sensors, humidity sensors, and the wireless communication module. Second, the distributed sensor gateway (DGS) is able to manage the sensor nodes in the sensor fields, and to perform data acquisition and data management. The last is agent middleware for sensor monitoring by web services and other platforms. Fig.1 shows the proposed model for real-time hydrogen sensor monitoring system.

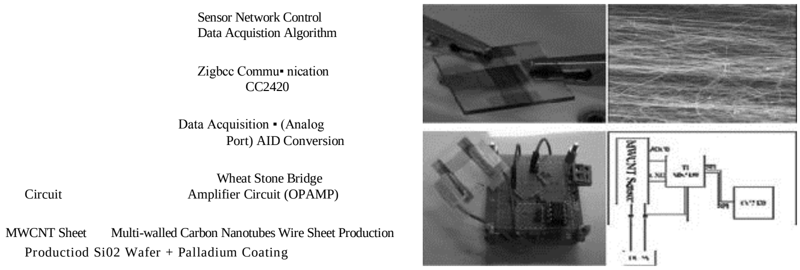

Fig. 1. Hydrogen Leakage Detection System

3 Carbon Nanotubes based Hydrogen Sensor

The prototype sensor consists of multi-walled carbon nanotube wires with coated palladium on a SiO_2 wafer with four electrodes as shown Fig 2(L). We observed the sensor core with a scanning electron microscope (SEM) device as shown Fig 2(R). The method of the detection method is carbon nanotube with Pd. Coated films detect by changes in resistance when the gas is leaked. If hydrogen is detected, the resistance value drops or rises. It is connected the interface board which is based on the bridge and amplification circuit. Schematic diagram of this sensor is shown in Fig 2.

Fig. 2. Carbon Nanotube Sensor

Given that the nano-wire's initial response to any exposure of hydrogen was distinct and immediate, this intrinsic characteristic served as an ally for the successful detection of hydrogen. Since the nano-wire's resistance changed with respect to how much and how long the device has been exposed to hydrogen, the most popular and accurate way of detecting resistance changes was through the use of Wheatstone Resistive Bridges, as illustrated in Figure 3. The main objective of the Wheatstone Resistive Bridge stage is to detect the differences in resistance between a nano-wire and a passivated nano-wire The passivated nano-wire was encased with silicon nitride. Using a passivated nano-wire encased in glass to be the resistor, only the resistance changes caused by exposure to hydrogen was detected, and not from other variables such as temperature. With no hydrogen present, the passivated and exposed nano-wires were similar in resistance, and the output voltage of our sensor was approximately 0 V, which is very close to the ideal condition. Fig 3.shows the schematic diagram of sensor control interfaces. The Wheatstone Resistive Bridge and the Difference Amplifier were combined through an additional non-inverting gain amplifier stage to buffer, amplify, and provide a high impedance input to the Wheatstone bridge before the signal from the resistive bridge was processed by the difference amplifier.

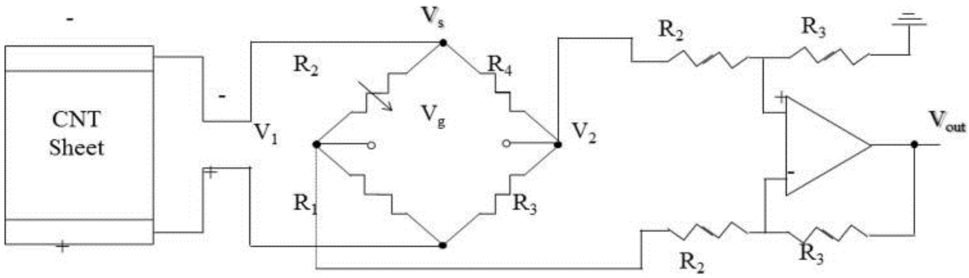

Fig. 3. Sensor Control Interface

We have tested the prototype sensor for verifying its performance with gas leakage measurement system. The test conditions are that the room condition is 25 Celsius, 75 % humidity at 1 atm. and use the Agilent 34401A multimeter at current or resistance mode with GPIB interface. We provide the voltage with DC 3, 5, 9, 12, 24 V and 1 Amp. current for finding the optimized operation. Fig 4. shows the gas leakage measurement system.

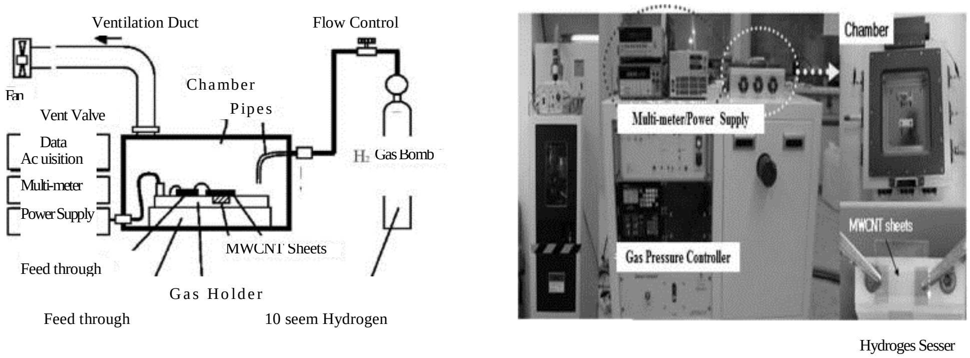

Fig. 4. Gas Leakage Measurement System

We have tested the various experiment and acquired the following results. The prototype sensor responses actively when the DC Power providing 9 and 12 V. Current and resistance variation is responded to a stimulus of the hydrogen in full detail. The absorption of hydrogen is rapidly by MWCNT but desorption is relatively slowly According to upper result, the sensor prototype needs the amplifier by the Wheatstone bridge and a circuit for desorption of hydrogen. Fig. 5 presents MWCNT based hydrogen sensors as the proposed model in comparison with FCM6812 commercial hydrogen sensors. The proposed model has a faster response time than the commercial hydrogen sensor. Moreover, we can use it continuously because of its property of desorption. The existing commercial hydrogen sensors have an internal heater for desorption of the hydrogen gas and have greater power consumption and a high loss of heating. However, the proposed model can perform desorption without an internal heater simply by the turning off the power. Therefore, the proposed model has lower power consumption than the existing commercial hydrogen sensors.

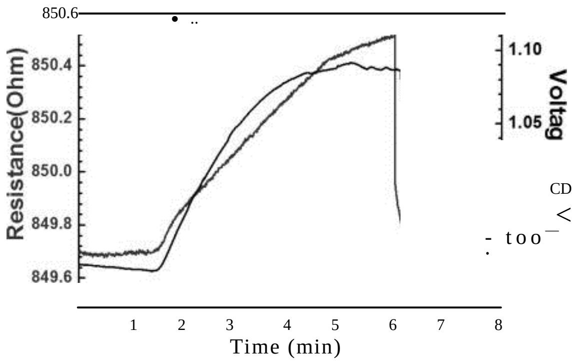

Fig. 5. Data Result — Prototype and FCM6812

To make a full functioning device that runs independently, a sensor control interface that gathers data and controls itself or another actuator device by electric signals such as voltage and current is needed. Existing measuring devices for hydrogen detection are relatively large in size and are installed in a fixed area. These devices are not easy to install with respect to small mechanical components such as valves or gas regulators. Therefore, the development of a hydrogen measuring machine is required. For solving these problems, we are approaching some suggestion with micro-controller based control mechanism. The proper selection of our micro-controller was essential to the success of the design. It was a requirement that the micro-controller included an onboard A/D converter with enough resolution to track the changes of the sensors, and be capable of conditioning and processing the data received from the sensor interface. The micro-controller was programmed to run as a state machine, and had two different re-programmable modes of operation. In each mode of operation, the micro-controller operated within the following states: initialize, collect data, transmit data, and sleep. The first mode of operation was for the level monitoring of hydrogen. This mode ran through each state until a discernable threshold of hydrogen was detected. This threshold was set at a level that hydrogen concentration would be high enough to pose serious danger. Once this level of hydrogen concentration was detected, the micro-controller forced the RF front end to transmit an emergency pulse to the central monitoring station. The second mode of operation was for data transmission. In this mode, the micro-controller collected data from the sensor interface, and queued this data to the RF front end to be transmitted to the central monitoring station. This mode was for a constant tracking of hydrogen levels, while the level monitoring mode was to alert the end user that hydrogen has indeed been detected. The state flow diagrams for the level monitoring mode, and data transmission mode are shown in Fig. 6

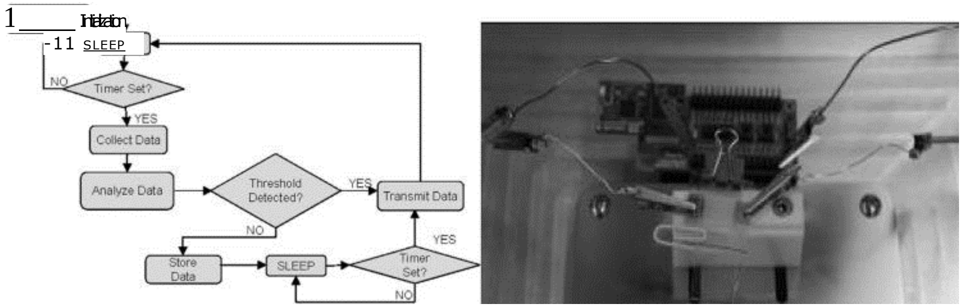

Fig. 6. Wireless sensor based hydrogen sensor

The aim of using sensor network is to implement a real-time monitoring and control system for hydrogen leakage. Sensor network supports the real-time leakage monitoring is based on some sensor devices and gateways by running peer to peer network. In this experiment, our measuring point is the real-time processing such as detection the gas, determine the dangerous situation, running to actuator like valves, alarms when hydrogen is leaked. For implementation, we made a Telos-B wireless sensor device include TI-MSP430 and CC2420 (2.4Ghz Zigbee support). Then, we installed the real-time operating system called TinyOS to Telos-B. Fig. 7 presents the data acquisition results by transmitting RS-232C interfaces.

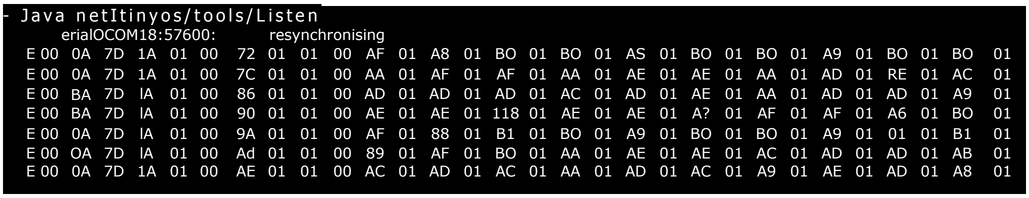

Fig. 7. Data acquisition

4 Conclusion

Hydrogen gas itself has flammability when there is a 4 to 75 % concentration of hydrogen in the air mixture. This type of hazard can start with a leakage problem in a facilities system. For solving the problem, we proposed a highly sensitive sensor based on multi-walled carbon nanotubes for detection at a low level hydrogen concentration. The prototype hydrogen sensor shows higher performance results compared with current commercial sensors and acquire the digital data applicable to other information devices or systems.

Acknowledgement

This research was supported by the Converging Research Center Program funded by the Ministry of Education, Science and Technology (2011K000774).

References

1. Dicks A: Hydrogen Energy Research and Collaboration in Australia. Proceedings WHEC2010, vol. 78, No.4, pp. 473-477. (2010)
2. Amaseder F, Krainz G: Liquid Hydrogen Storage Systems developed and manufactured for the first time for Customer Cars. SAE World Congress. (2006)
3. Agboussou K, Chahine R, Hamelin J, Laurencleel F, Anouar A.: Renewable energy systems based on hydrogen for remote applications. Journal of Power Sources, No. 96, pp.168-172. (2001).
4. Sekhar P K, Broshaa E L, Nelsona M A, Williamsona T L and Garzona F H, Development and testing of a miniaturized hydrogen safety sensor prototype. Sensors and Actuators B: Chemical vol. 148, Issue 2, pp. 469-477. (2010)
5. Lee S C, Real-time Detection Mechanism of Hydrogen Leakage and its Safety Management Systems. A Dissertation for the Degree of Doctor of Philosophy Pukyong National University, Korea. (2011)