Zigbee Based Wireless System for *f*-MWCNT Based Ammonia Gas Sensor for Clinical Breath Analyzer Applications

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Abstract: Herein, we report a ZigBee based healthcare monitoring system emphasizing in the aspects of MWCNT based ammonia (NH_3) gas detection, sensor electronics, wireless communication system and non-invasive health care monitoring is reported. Sensitivity and response of functionalized multiwalled carbon nanotube (*f*-MWCNT) were studied. The basic design of portable e-nose system including ZigBee protocol and embedded system along with graphical user interface (GUI) has been carried out. The sensitivity of the signal conditioning circuit was 60mV/ppm of ammonia gas and is large enough for the microcontroller to process the incoming signal from signal conditioning circuit.

Introduction

Recent scientific advances in sensors and low-power wireless communications have simplified the design of portable sensing system. These systems are having detection and processing locally and also it can be used for patient health monitoring. Sensing technology has extensive applications such as automotive industry, medical applications, indoor and environmental air quality monitoring [1]. Gas sensing technology with wireless system becomes fabulous application in healthcare. In last decade, various portable health monitoring systems are developed for monitoring the blood pressure, heart-rate [2], infant [3], activity [4] and etc. Nowadays, people are interested on carbon nanomaterial based sensing technology for making efficient system for patient monitoring. The electrical conductivity of the CNTs can change dramatically due to acceptance of the electrons from the NH_3 gas molecule. The CNTs based NH_3 gas sensors have been extensively investigated in recent years [5, 6]. Generally, portable breath analyser systems are placed at patient end (transmitting station) and sensor data are collected and delivered through wireless module to the base station (receiver end). ZigBee protocol is a self-configuring, short-range (10-300 feet), low-cost and very low-power system that enable unique flexibility, mobility and ease of use [7]. In this paper, we present our research work on gas sensing properties of *f*-MWCNT and equivalent wireless system for room temperature healthcare monitoring.

Results and Discussion

Commercially available Multi Walled Carbon nanotubes were purified using acid treatment. Further, the carboxylic group (-COOH) functionalized MWCNTs were prepared as per previous reports [8]. The resultant product was probe sonicated for 1 hr, filtered and thoroughly washed with ultrapure water till it reached neutral pH. The collected solid was dried in vacuum oven at 70 ◦C for 6 hrs. Transmission electron microscopy image (as shown in Fig.1a) of the *f*-MWCNTs showed that the outer walls of the *f*-MWCNTs have been affected by the acid treatment introducing carboxylic groups disrupting the uniform graphitic structure. The characteristic peaks were found at 1695cm-1 which is assigned to the C=O stretching vibrations in the carboxylic groups in the Fourier transform infrared (FT-IR) spectrum (as depicted in Fig. 1b) [9].

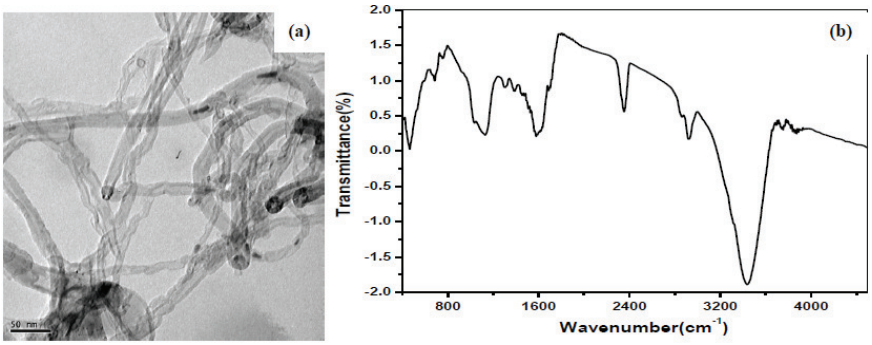

Figure 1. (a) TEM image and (b) FT-IR spectrum of the *f*-MWCNTs

In order to study the gas sensing properties of the material, *f*-MWCNTs were spin-coated onto alumina substrates patterned with inter-digitated array (IDA) gold electrodes (finger gap of 700 µm). The concentrations tested were in the range of 2-10 ppm for ammonia gas. In our present investigation, we have attempted to demonstrate that *f*-MWCNTs based sensor for the detection ammonia at concentrations relevant to the elevated levels found in the exhaled human breath *i.e.* (2- 10 ppm). The sensitivity of the material was found to be linear in the concentration range of 2-10 ppm as shown in Fig.2a. The *f*-MWCNT gas sensor was interfaced with signal conditioning unit through Wheatstone bridge circuit. Based on the gas concentration, voltage at the amplifier end was varied and resistance changes were monitored by I-V measurement unit. Sensor signal conditioning circuit sensitivity is approximately 60mV/ppm of ammonia gas. Fig. 2b shows the signal conditioning output voltages with different gas concentration ranges from 2 to 10 ppm.

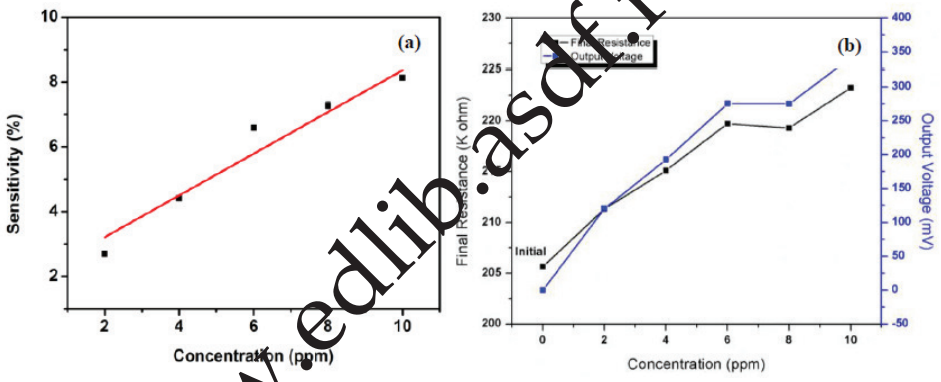

Figure 2. (a) Sensitivity and (b) Signal conditioning output voltage of *f*-MWCNTs sensor with various NH_3 gas concentrations (2-10ppm)

In electronics part of the work, three types of sensors were used for monitoring the vital parameters; namely, Humidity (HSM-20G), temperature (LM 35) and NH_3 concentration (*f*- MWCNT sensor). The signal conditioning circuit that process the voltage or current signal produced by the sensor which is directly related to the real quantity being detected. Signal conditioning part consists of three stages as depicted in Fig.3a. In Wheatstone bridge, resistance change was converted into voltage change. However, we need constant current or constant voltage source for biasing the bridge circuit to provide the stable operation. The instrumentation amplifier consists of operational amplifiers with high CMRR (common mode rejection ratio). Differential input signal was amplified by amplifier. The gain value has been chosen based on the input voltage from the sensor and bias limitation. By using 5th order LPF we can suppress the high frequency noise present in the amplified signal. The roll off rate of this LPF was very high compare to the other lower order LPFs. After LPF, signal was fed into ADuC 7026 Microconverter and ZigBee Module for further signal processing.

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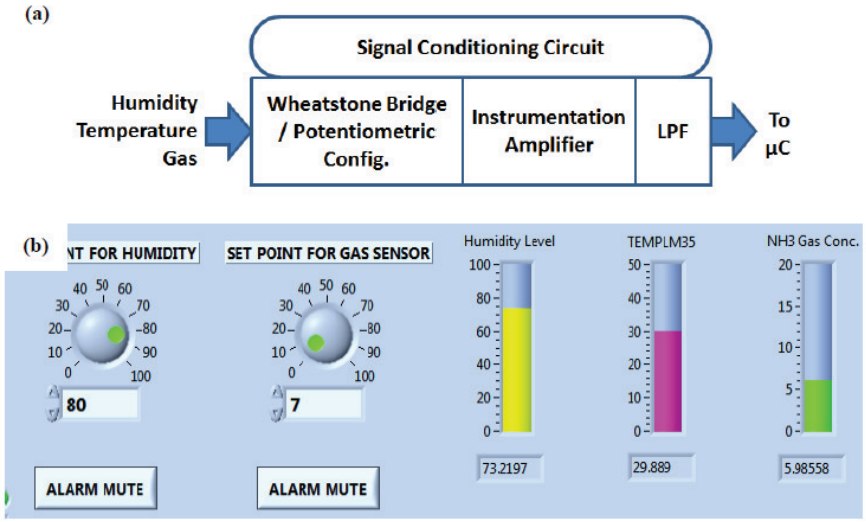

Figure 3. (a) Block diagram of sensor signal conditioning unit and (b) GUI system for patient monitoring

RF module in the base station receives the data which is transmitted from the sensor nodes (Patient end). At receiver end, received data were sent to the computer through RS-232 communication cable and then processed and displayed using Graphical User Interface (GUI) in the base monitoring station. The GUI platform was successfully developed using LabVIEW software that able to interact with ZigBee RF Module. We have developed a GUI system for monitoring the gas concentration in human breath, relative humidity (%RH) and ambient temperature which is shown in Fig.3b.

Conclusion

In summary, *f*-MWCNT based sensor was fabricated to analyze the sensor properties towards NH_3 gas at concentrations relevant to the elevated levels found in the exhaled human breath (2-10 ppm). The fabricated NH_3 gas sensor was interfaced with ZigBee based wireless system for monitoring the ammonia concentration in the exhaled breath. Moreover, the usage of low power wireless sensor system would be suitable for monitoring the patient health at low cost. Other important features of this wireless and GUI system are easy installation, handling and easy monitoring.

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