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Demonstration of a Gas-Sensing Application for a Gas Switch Device Using the LabVIEW-Based Measurement System

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ABSTRACT

A standard ceramic method was used to prepare ZnO+0.01Sb_2O_3 ceramics. The measurements and processing of the data were made using: an LP connector, a data acquisition card, a computer and the LabVIEW program. The gas-response characteristics of the sample to NH_3 vapor were investigated. Result showed that the resistance of the sample at room temperature decreased in the interval of 4.4 MΩ –3.7 MW in the presence of NH_3 gas at 30°C in normal atmospheric conditions. NH_3 gas responsivity (G) was -15.909%. The result indicated a potential application in a low-cost NH_3 gas switch device. The application of ZnO+0.01Sb_2O_3 gas ceramics as an NH_3 gas switch device was investigated at room temperature. The results showed that the voltage drop across the sample decreased in the presence of NH_3 gas. The operation as an NH_3 gas switch device used the comparison of the voltage drop across the sample with a setpoint voltage (2.03 V). This result controlled the operation of a relay, solid state relay and gas alarm, respectively. It showed that the sample could be used as an NH_3 gas switch. The system has been in operation for a year and all components have functioned well.

Key words: NH_3 gas response ceramics, NH_3 gas switch device, LabVIEW

INTRODUCTION

A number of semiconducting oxides have been found to show changes in electrical resistivity in the presence of small concentrations of certain gases (Moulson and Herbert, 1990). For example, n-type SnO_2, ZnO, Fe_2O_3, TiO_2 and Ag_2O are exploited in gas-sensor technology. Most of these materials are also sensitive to water vapour and must therefore be used at temperatures in excess of about 350°C when the adsorption of water vapor is negligible. The sensing behaviour of n-type semiconductors appears to be governed by the adsorption of oxygen in the neck regions between grains. As adsorption proceeds, a positive space charge develops in the oxide, as electrons transfer from the conduction band or from donor dopants to the adsorbed oxygen, and a corresponding negative charge accumulates on the surface. The simple synthesis of $CuFe_2O_4$ nanoparticles as NH_3 gas-sensing materials has been studied (Zhipeng, 2007).

A common characteristic of the data acquisition systems mentioned was the use of data loggers or microcontrollers to measure and acquire the signals and to transmit them to a PC through an RS-232 serial port (Barney, 1988; Forero, 2006).

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There are several reports on the properties of ZnO bulk ceramics, however, no description in the literature was found of the application of $ZnO+0.01Sb_2O_3$ for gas-sensing in a gas switch device using the LabVIEW-based measurement system.

This paper describes a data acquisition system using LabVIEW designed and implemented with facilities for monitoring the gas-sensing of a $ZnO+0.01Sb_2O_3$ gas ceramic. The $ZnO+0.01Sb_2O_3$ sample was applied as an NH_3 gas switch device.

MATERIALS AND METHODS

Gas ceramic application for gas response demonstrative device

This experimental work was carried out at the Physics department, Faculty of Science, Prince of Songkla University, Thailand.

The materials were prepared by the standard ceramic technique using reagent-grade raw oxides. High purity ZnO and Sb_2O_3 powders were used. The chemical composition of the preparation sample was $ZnO+0.01Sb_2O_3$. The powders were weighed and mixed in a mortar and a mixer for 10 min. An organic binder, PVA (polyvinyl alcohol) of 1 wt% was added and the sample was then pressed at 265 MPa into cylindrical pellets with a 12 mm diameter and about 2.5 mm high. The pellets were heated at 1200°C with a furnace heating rate of about 5°C/min for 4 h. The opposite sides of the pellets were then coated with a silver paste and the components fired at 120°C for 15 min.

The experimental setup for the gas sensing application using LabVIEW is shown in Figure 1. The front panel and block diagram are shown in Figure 2. The sample used was $ZnO+0.01Sb_2O_3$, with a load resistance (RL) of 1 MΩ and a gas source of ammonia. The equipment was developed using an LP connector, a data acquisition card (DAQ), a computer and the LabVIEW program commercially supplied by the National Instruments Corporation (http://www.ni.com). The program starts by showing the main menu of the LabVIEW on the screen. Users are expected to create the front panel and block diagram and to set the properties of the virtual devices and virtual instruments. The principle of the operation was an electronic load connected in series with the sample as the voltage divider. This ceramic sample voltage divider was used to supply a voltage to the input of the LP connector and DAQ card. The card was then used to capture the V_s and V_{Ls} signals generated in the voltage divider. Current from a 5 V DC power supply flowed through a load resistor (R_L) of 1 MΩ with a sample

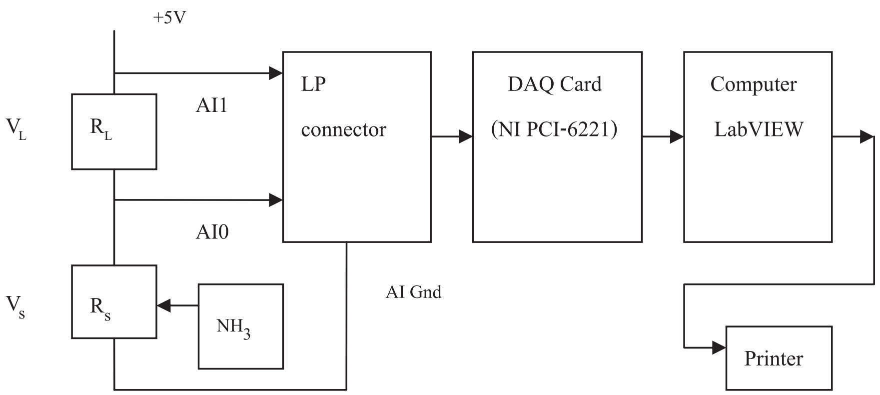

Figure 1 Experimental setup of the demonstration device for a gas-sensing application using NH_3 gas response and LabVIEW.

resistance (R_s). The voltage drop across R_s and R_L+R_s were defined as V_s and V_{Ls}, respectively, which were transmitted via AI0 and AI1 to the LP connector, DAQ card, PCI slot and computer, respectively. The DAQ assistant worked by receiving voltages V_s and V_{Ls} from the LP connector, which were then transmitted through the DAQ card into the computer. V_s and V_{Ls} were measured for amplitude and level to display the mean DC. The split signal separated V_s and V_{Ls}. Resistance determination was defined as $V_L=V_{Ls}-V_s$. The load current (I_L) was calculated using $I_L=V_L/R_L$, while the sample current (I_s) was equal to the load current ($I_s=I_L$). The sample resistance (R) was calculated using $R=V_s/I_s$ and was displayed by a numerical indicator. The resistance versus time (R vs. t) of the sample was displayed using a waveform chart. The experiment was carried out in an ammonia gas environment. Program runs, the front panel and block diagram were saved on a computer and printed, with the computer controlling the entire measurement process. NH_3 gas sensitivity (S) was defined as:

$$S = [R_g-R_0)/R_0)]*100$$

where R_0 = sample resistance in the absence of ammonia gas

R_g = sample resistance in the presence of ammonia gas.

Gas-sensing application for gas switch device

The experimental setup for implementing the gas-sensing application in a gas switch device with LabVIEW is shown in Figure 3. The associated front panel and block diagram are shown in Figure 4. The sample used was ZnO+0.01Sb_2O_3, with a gas source of NH_3. Current from the 5 V DC power supply flowed through the load resistor (R_L) of 1 MΩ generating a sample resistance (R_s). The voltage drop across R_s was defined as V_s and was transmitted via AI0

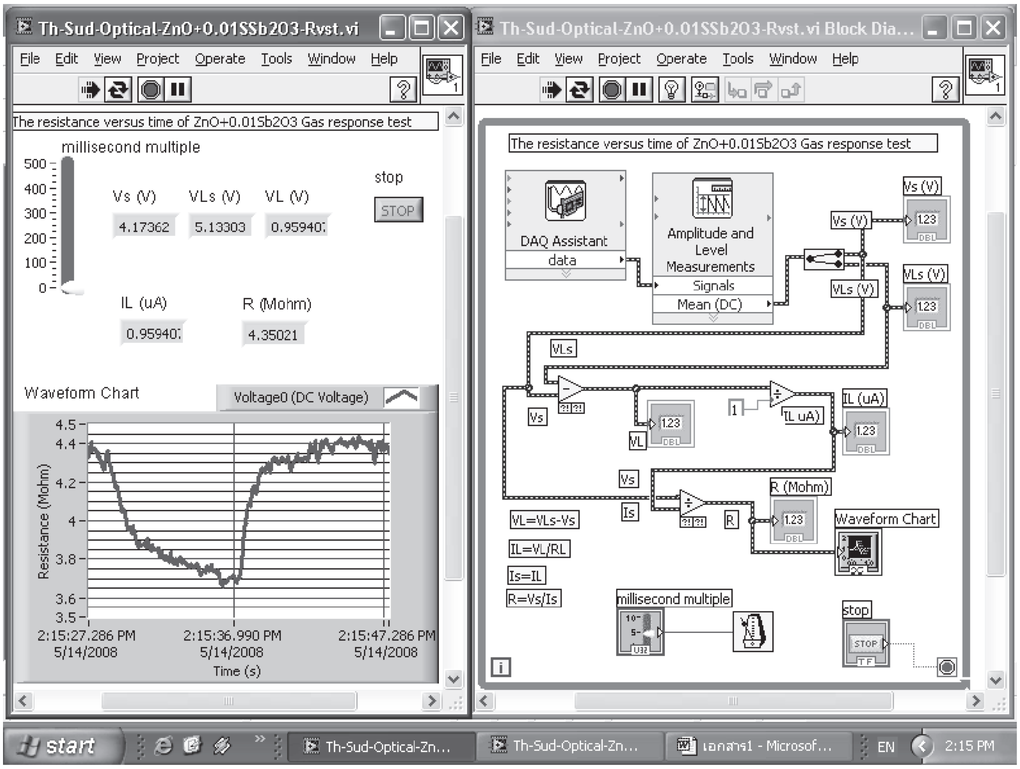

Figure 2 Front panel and block diagram for the experimental setup for the gas sensing application.

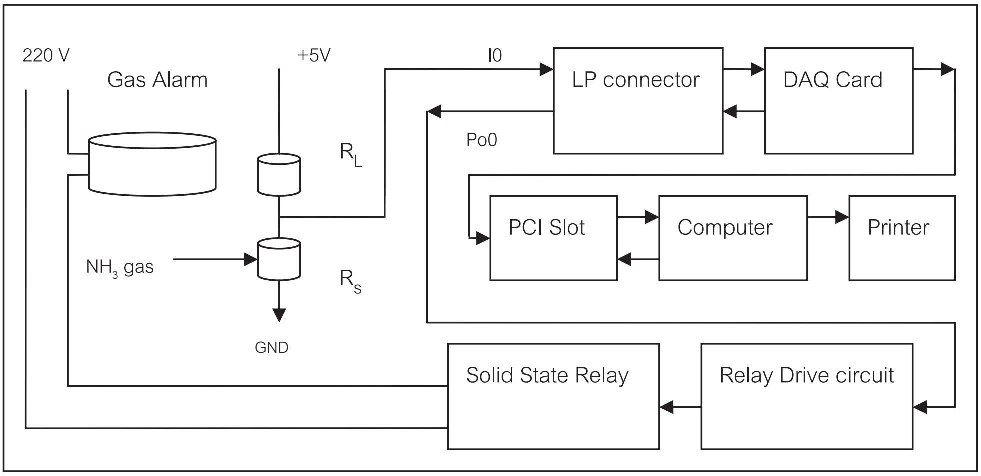

Figure 3 Experimental setup for implementing the gas-sensing application in a gas switch device with LabVIEW.

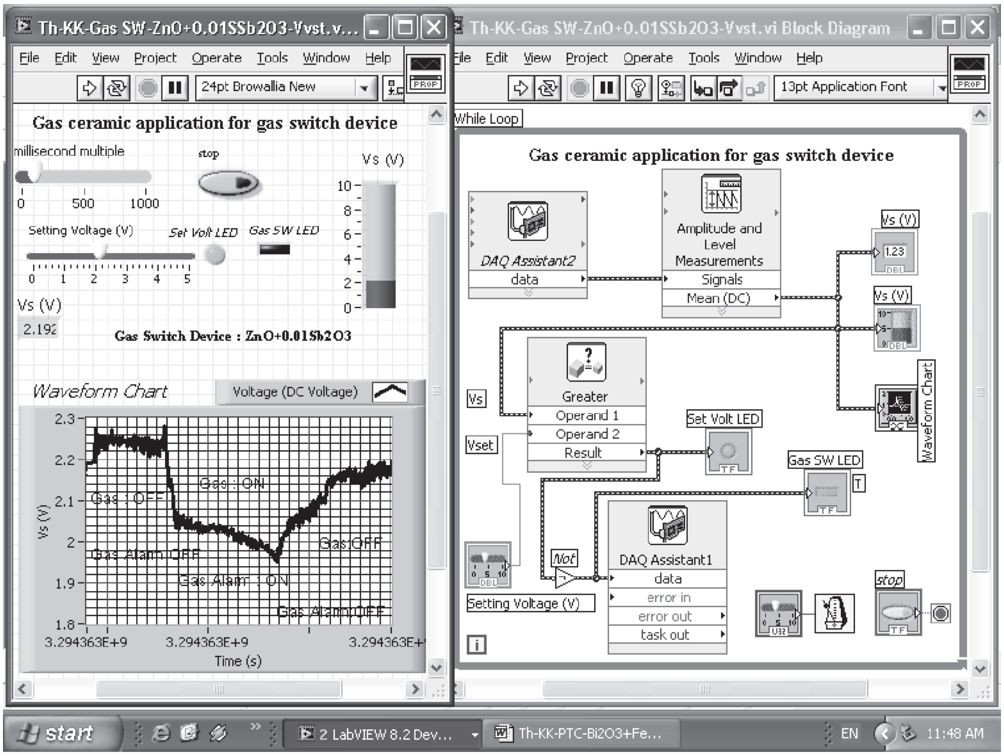

Figure 4 Front panel and block diagram for implementing the gas-sensing application in a gas switch device with LabVIEW.

to the LP connector, DAQ card, PCI slot and computer, respectively. The DAQ Assistant2 received voltage Vs from the LP connector and transmitted it through the DAQ card to the computer. V_s was measured for amplitude and level to display the mean DC. For the gas switch device test, initially, NH_3 gas was not applied and the drop across the sample voltage (V_s) was transmitted to Operand 1 of Greater and the setting voltage (Vset) was transmitted to Operand 2 of Greater. The voltage (V_s) was greater than the setting voltage (Vset). The result (0 V) from Greater was transmitted to Not gate. The Set Volt LED was illuminated and the Gas alarm LED was not. The voltage from Not gate was transmitted to DAQ Assistant1. DAQ Assistant1 controlled transmitting the 5 V to the relay drive circuit, with switch 3-5 closed. The solid state relay did not conduct electricity, so the electric current from the 220 V line could not flow through the gas alarm. When the NH_3 gas was applied, the drop across sample voltage (V_s) was transmitted to Operand 1 of Greater and the voltage (Vset) was transmitted to Operand 2 of Greater. The voltage (V_s) was less than the setting voltage (Vset). The result (5 V) from Greater was transmitted to Not gate. The Set Volt LED was not illuminated and the Gas alarm LED was illuminated. The voltage from Not gate was transmitted to DAQ Assistant1. DAQ Assistant1 transmitted the 0 V to the relay drive circuit and switch 3-5 was opened. The solid state relay conducted electricity, so the electric current from the 220 V line could flow through the gas alarm. This operation was carried out repeatedly, so that the NH_3 gas alarm was controlled successfully, with the sample operating as an NH_3 gas switch device. The voltage value (V_s) was displayed with a numerical indicator. The voltage versus time (V_s vs t) curve was displayed using a waveform chart, in order to control the gas switching of the gas alarm.

RESULTS AND DISCUSSION

Gas response demonstrative device

The result of the gas-sensing application using a demonstration device based on an NH_3 gas response with ZnO+0.01Sb_2O_3 is shown in Figure 2. This shows that the resistance of this sample at room temperature decreased from 4.4 MW to 3.7 M in the presence of NH_3 gas. An R-t characteristic indicates that a gas response was achieved. The ammonia gas responsivity (G) of this sample was -15.909%. The negative value of G showed that the resistance of this sample decreased in the presence of NH_3 gas. Gas ceramics were applied in the demonstration using the NH_3 gas response.

Gas switch device

The results can be seen in Figure 4 from the front panel and the block diagram of the system in LabVIEW using ZnO+0.01Sb_2O_3 in an NH_3 gas switch device. The results showed that the voltage drop across the sample was high in the absence of NH_3 gas, but the voltage drop across the sample was low in the presence of NH_3 gas. This indicated that the sample could be used as a gas switch device at room temperature. Therefore, the computer demonstrated the application of this sample as a gas switch device - when the sample was in the presence of NH_3 gas, the gas alarm worked.

CONCLUSIONS

The ZnO+0.01Sb_2O_3 ceramic pellets fabricated by standard ceramic techniques were in a disc-shaped form. This pellet form exhibited an NH_3 gas response. The results showed that the resistance of this sample at room temperature decreased in the interval of 4.4 MW to 3.7 MW in the presence of NH_3 gas. The measured gas responsivity value was about -15.909% in ambient air. This result signified the application potential of these pellets for NH_3 gas detection. The $ZnO+0.01Sb_2O_3$ ceramic pellet was developed for use as an NH_3 gas switch device that operated at room temperature. The solid-state circuitry ensured accurate operation of the gas switch device. An automatic, data-acquisition system for monitoring the gas response and a gas switch device test were prepared using a procedure based on an LP connector, a data acquisition card, a computer and the LabVIEW program.

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