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A demonstration of the UV light response of $ZnO+0.01Sb_2O_3$ ceramics and application for UV light sensor and UV light switch using LabVIEW-based measurement system

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ABSTRACT

In the current paper, $ZnO+0.01Sb_2O_3$ ceramics were prepared using the mixed oxide method. A LabVIEW- based measurement systems were prepared and used for all experimentation. Ultraviolet light (UV) response of $ZnO+0.01Sb_2O_3$ ceramics have been investigated. Result showed that the resistance of this sample at room temperature (30°C) decreased in the interval of 3.5 MΩ –1.65 MΩ in the presence of UV light with intensity of 2530 Lux. The measured UV light responsivity (G) was -52.857 %. The negative value of UV light responsivity showed that the resistance of this sample decreased in the presence of UV light. This sample exhibited UV light response material and indicated their potential application as UV light sensor. The resistance versus UV light intensity characteristics was determined. We present the application of $ZnO+0.01Sb_2O_3$ ceramics for UV light sensor. The operation of this sample for UV light sensor used the relationship between voltage drop across the sample and UV optical intensity. This relation was used for the measurement of UV light intensity. In addition, this $ZnO+0.01Sb_2O_3$ ceramics can be used for UV light switch device testing. The operation of this sample for UV switch device used the result from comparison between voltage drop across the sample and setpoint voltage (3.979 V). Optical alarm was used for showing the operation of UV light switch device. This sample and system will be used for teaching and learning works in future.

Keywords : optical response ceramics , ultraviolet light sensor , ultraviolet light switch, LabVIEW.

INTRODUCTION

Ultraviolet (UV) detectors play an essential role in chemical and biological analysis and flame detection (Cheng *et al*., 2008). ZnO exhibits excellent UV photosensitivity that is a key to UV photodetection. The band gap of ZnO ceramics is about 3.4 eV. Some earlier researches demonstrated the capability of ZnO UV photodetectors. ZnO is a semiconductor which has many applications, such as piezoelectric transducers, varistors, phosphors, and transparent conducting films. The main advantages of ZnO as a light emitter are its large exciton binding energy (Look, 2001). Illuminated I–V characteristics of ZnO MSM UV sensors with different contact electrodes were studied (Young, 2006). Complex impedance measurements were used to analyze the influence of ultraviolet and ozone gas on the electronic behaviour of ZnO films grown by rf magnetron sputtering (Gonçalves, 2006). Zinc oxide (ZnO) is an electroluminescent (EL) material that can emit light in different regions of electromagnetic spectrum when electrically excited (Lima, 2007). ZnO films was deposited on c-plane (0001) sapphire substrate at 250 °C. The high-temperature-dependent optical properties of ZnO film were measured by ultraviolet–visible transmission with temperatures ranging from room-temperature to 300 °C and analyzed by theoretically fitting the optical absorption edge curve (Chenghua, 2008). There are several reports on the optical properties of ZnO bulk ceramics, however, the descriptions on the application of $ZnO+0.01Sb_2O_3$ for UV switch using LabVIEW-based system has not been found in the literature.

This paper describes the demonstration of the UV light response test and the resistance versus UV light intensity characteristics of $ZnO+0.01Sb_2O_3$ ceramics and application for UV light sensor and UV light switch using LabVIEW-based measurement system.

METHODOLOGY

Sample preparation

The materials were prepared by the mixed oxide method using high purity ZnO and Sb_2O_3 powders. Preparation sample composition 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) of 1 wt.% was added and they were then pressed at 265 MPa into 12 mm diameter and about 2.5 mm high cylindrical pellets. The pellets were fired at 1100 ^{o}C with the furnace heating rate at about 5 ^{o}C/min for 4 hours. The crystalline structure of the pellet was investigated by X-ray diffraction. The opposite sites of the as-fired pellets were coated with a silver paste and the components were fired at 120 ^{o}C for 15 min.

The test for UV response

Experimental setup of the test for UV response with LabVIEW is shown in Figure 1. Front Panel and Block diagram of the test for UV response with LabVIEW is shown in Figure 2. The used sample was $ZnO+0.01Sb_2O_3$. This sample was 2.3 mm in thickness and 12.91 mm in diameter. The load resistance (R_L) was 2 MΩ. UV light source was EPROM Eraser. The equipment was prepared using LP connector, a DAQ data acquisition card, computer and LabVIEW program commercially supplied by National Instruments Corporation (http://www.ni.com). When the program started, the main menu of the LabVIEW came to screen. Users are expected to create the Front Panel and Block Diagram and set the properties of virtual devices and virtual instruments. The principle of operation was an electronic load connected in series with the sample as voltage divider. The divider which composed of load resistor and ceramic sample was used to supply a voltage as input to the LP connector and DAQ card. This card was used to detect the V_s and V_{Ls} signals generated in this voltage divider. Current from 5 V dc power supply flowed through a load resistor (R_L) of 2 MΩ and sample resistance (R_s). Voltage drop across R_s and R_L+R_s were Vs and V_{Ls}. Voltage V_s and V_{Ls} were transmitted to AI0 and AI1 of LP connector, DAQ Card, PCI slot and computer, respectively. DAQ Assistant worked by receiving voltage V_s and V_{Ls} from LP connector and transmitted through DAQ Card into computer. V_s and V_{Ls} were transmitted to Amplitude and Level Measurements for Mean (DC) measuring. Split signal splitted V_s and V_{Ls}. For resistance determination, V_s and V_{Ls} were transmitted to Substract for $V_L=V_{Ls}-V_s$. Load current (I_L) was calculated with $I_L=V_L/R_L$. Sample current (I_s) and load current ($I_s=I_L$) were equal. Sample resistance (R_s) was calculated with $R=R_s=V_s/I_s$. Resistance value (R_s) was displayed with Numeric Indicator. Resistance vs. time (R_s vs. t) of the sample was displayed using Waveform Chart. The sample was in the presence of UV light with intensity of 2530 Lux. The faces of the silver coated are parallel face, the UV light get through the sample in perpendicular direction (see Figure 1). The program was run to show the result. The Front Panel and Block Diagram were saved in computer and printed with printer. The computer will control the entire measurement process. UV light sensitivity (S) that was defined as $S=(R_{UV}-R_0)/R_0$ was calculated, where R_0 was sample resistance in the absence of UV light and R_{UV} was sample resistance in the presence of UV light with 2530 Lux.

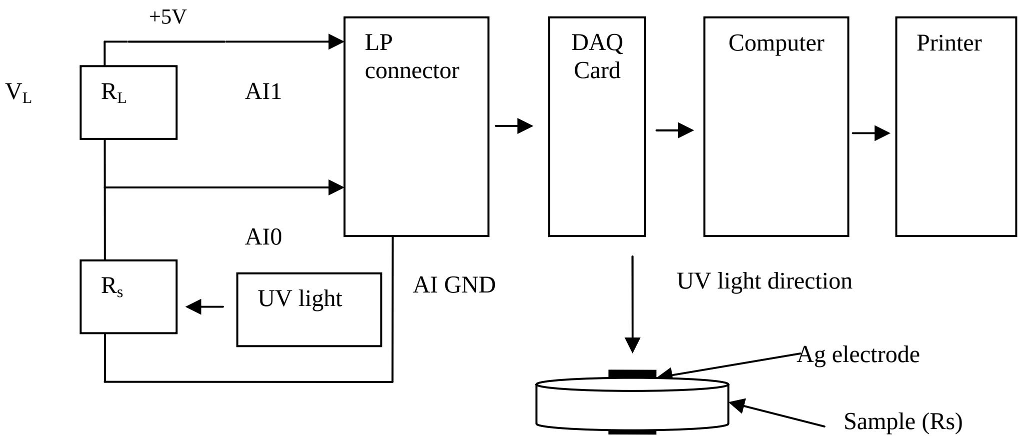

Figure 1 Experiment setup of the test for UV response with LabVIEW.

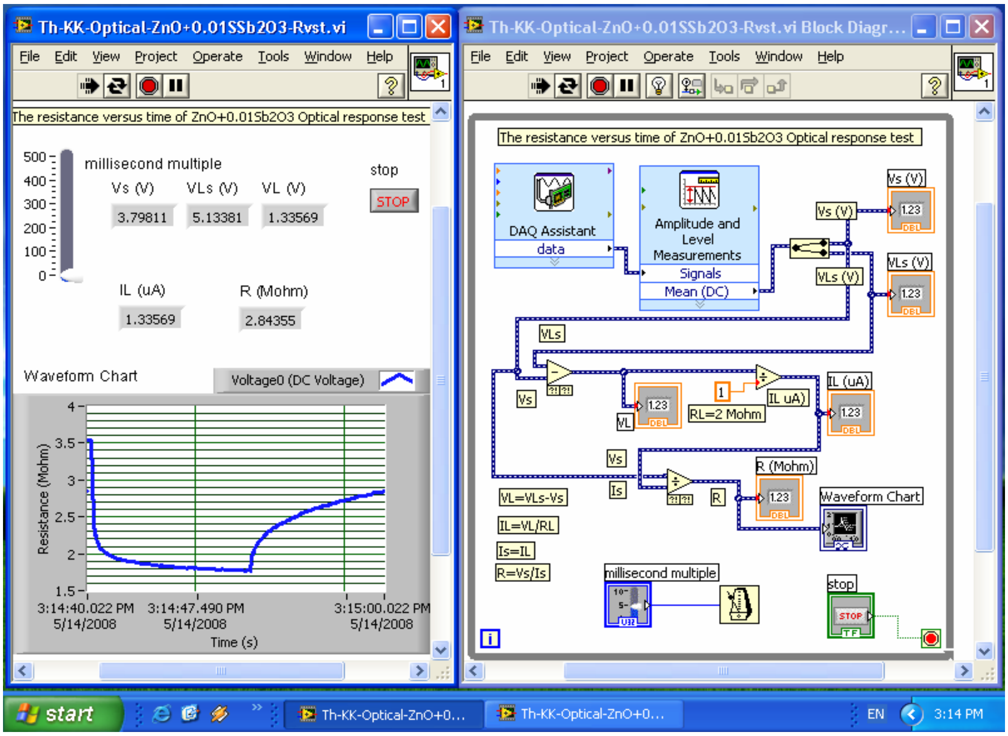

Figure 2 Front Panel and Block diagram of the test for UV response with LabVIEW.

The measurement for resistance versus UV light intensity

The determinaton for UV light intensity from Lux Meter versus voltage drop across commercial LDR (LI vs Vs)

Experiment setup for UV light intensity from commercial Lux meter versus voltage drop across commercial LDR (LI vs V_{LI}) with LabVIEW is shown in Figure 3. Front Panel and Block Diagram for displaying UV light intensity from Lux Meter versus voltage drop across commercial LDR (LI vs V_{LI}) with LabVIEW is shown in Figure 4. This program was RUN. The relation of UV light intensity from Lux Meter from computer screen (LI) and voltage drop across commercial LDR (V_{LI}) were read. The LI=f(V_{LI}) curve and the equation were written using EXCEL (Figure 5). The resultant equation was LI = 1683.3V_{LI} – 3623.3. V_{LI} is V. So, commercial LDR can be operated as UV light intensity sensor for measuring the UV light intensity from UV light source. The UV light intensity value is displayed using Numeric Indicator and The LI vs. t curve is displayed using Waveform Chart (Figure 4).

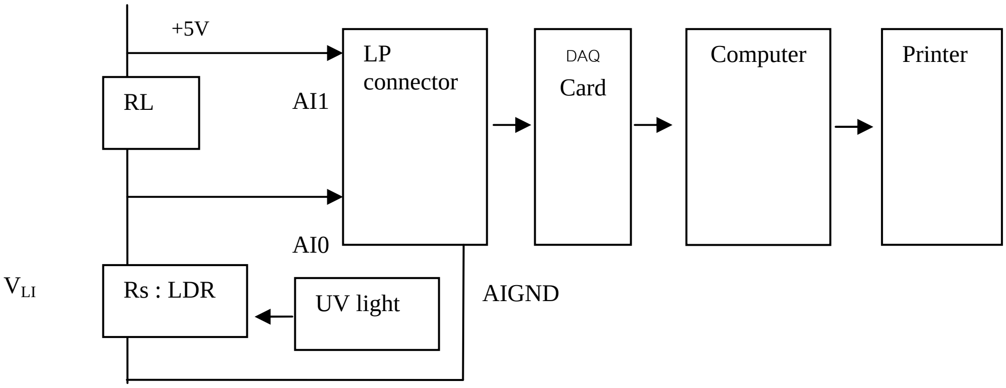

Figure 3 Experiment setup for UV light intensity from Lux meter versus voltage drop across commercial LDR (LI vs V_{LI}) with LabVIEW.

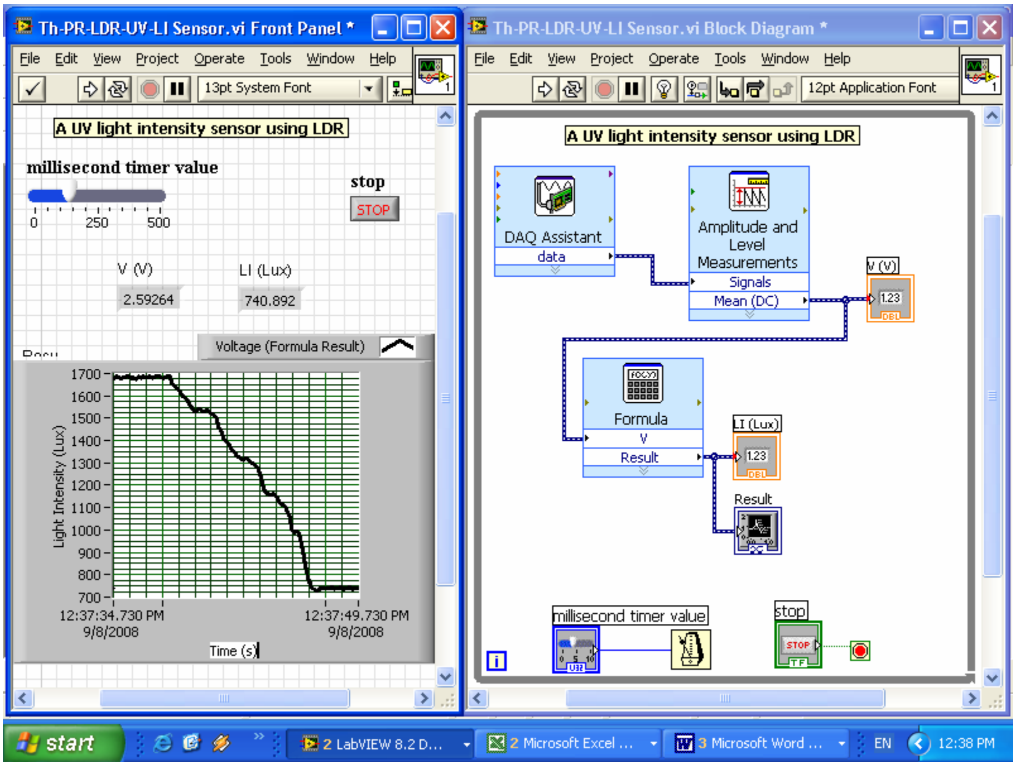

Figure 4 Front Panel and Block Diagram for displaying UV light intensity from Lux Meter versus voltage drop across commercial LDR (LI vs V_{LI}) with LabVIEW.

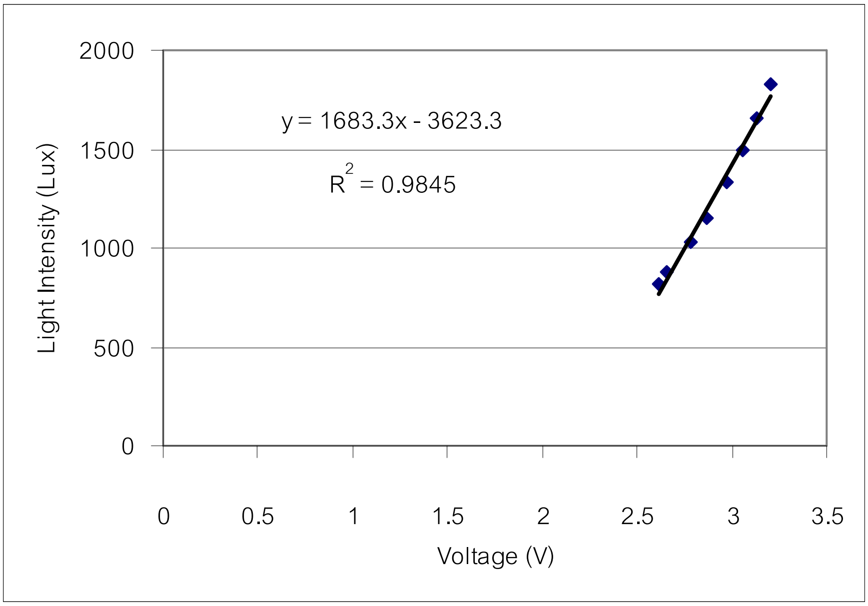

Figure 5 The LI=f(V_{LI}) curve and the equation were written using EXCEL.

Sample resistance versus UV light intensity measurement

Experiment setup for sample resistance vs. UV light intensity with LabVIEW is shown in Figure 6. Front Panel and Block diagram for sample resistance vs. UV light intensity with LabVIEW is shown in Figure 7. The used ceramic sample was a $ZnO+0.01Sb_2O_3$. The UV sensor was a commercial LDR. The load resistance (R_{L1}) was 2 MΩ. UV light source was EPROM Eraser. The divider which composed of load resistor and ceramic sample was used to supply voltage as input to the LP connector and DAQ card. Current from 5 V dc power supply flowed through a load resistor (R_{L1}) of 2 MΩ and sample resistance (R or R_s). Voltage drop across R_s and R_L+R_s were V_s and V_{Ls}. Voltage (V_{LI}) was generated using commercial LDR for UV light intensity measuring. Voltage V_s, V_{Ls} and V_{LI} were transmitted to AI0, AI1 and AI2 of LP connector, DAQ Card, PCI slot and computer, respectively. DAQ Assistant worked by receiving voltage V_s, V_{Ls} and V_{LI} from LP connector and transmitted through DAQ Card into computer. V_s and V_{Ls} were transmitted to Amplitude and Level Measurements for Mean (DC) measuring. Split signal splited V_s, V_{Ls} and V_{LI}. For resistance determination, V_s and V_{Ls} were transmitted to Substract for $V_L=V_{Ls}-V_s$. Load current (I_L) was calculated with $I_L=V_L/R_L$. Sample current (I_s) and load current ($I_s=I_L$) were equal. Sample resistance (R) was calculated with $R=V_s/I_s$. Resistance value (R) was displayed with Numeric Indicator. Voltage (V_{LI}) was transformed to be UV light intensity (LI) with Formula and LI = $1683.3V_{LI}$ – 3623.3. UV light intensity value (LI) was shown with Numeric Indicator. UV light intensity (LI) and Resistance (R) of the sample were transmitted to X Input and Y Input of Build XY Graph for displaying R vs. LI graph. The sample was in the presence of UV light. The program was run to show the result. The Front Panel and Block Diagram were saved in computer and printed with printer.

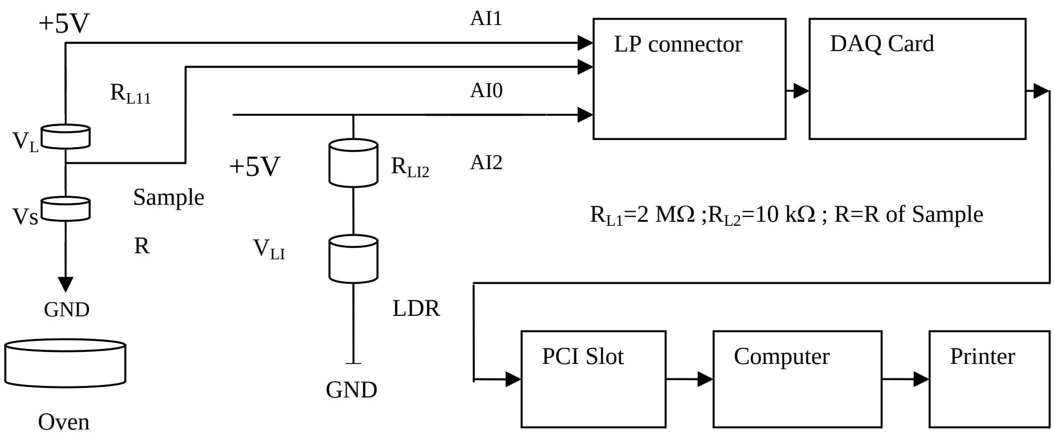

Figure 6 Experiment setup for sample resistance vs UV light intensity with LabVIEW, where the used sample was a ZnO+0.01Sb2O3 and the UV sensor was a commercial LDR.

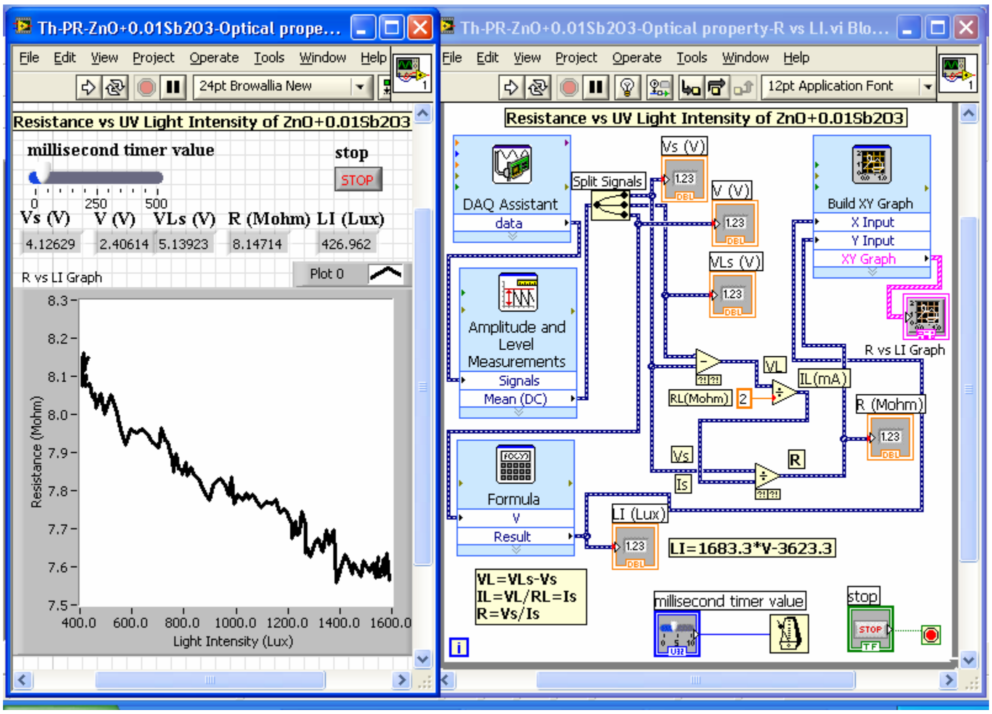

Figure 7 Front Panel and Block diagram for sample resistance vs. UV light intensity with LabVIEW, where the used sample was a ZnO+0.01Sb2O3 and the UV sensor was a commercial LDR.

Optical ceramic application for UV light sensor

Experimental setup for optical ceramic application for UV light sensor with LabVIEW is shown in Figure 8. Front Panel and Block Diagram for optical ceramic application for UV light sensor with LabVIEW is shown in Figure 9. UV light intensity (LI) was measured using commercial optical sensor and voltage drop across the $ZnO+0.01Sb_2O_3$ sample (V_s) was measured with LabVIEW. The LI and Vs were read and plotted using EXCEL (Figure 10). The resultant equation was $LI = 52883V_s^2 - 139723V_s + 92454$. Experiment setup for the measurement of UV light intensity using the $ZnO+0.01Sb_2O_3$ UV optical sensor with LabVIEW was the same as Figure 8. Front panel and Block Diagram for UV light intensity measurement using the $ZnO+0.01Sb_2O_3$ UV optical sensor with LabVIEW was the same as Figure 9. The relation of $LI = 52883V_s^2 - 139723V_s + 92454$ was written into Formula for transforming the voltage across the sample (Vs) to be the UV light intensity (LI). So, the $ZnO+0.01Sb_2O_3$ sample operated as UV light intensity sensor for measuring the UV light intensity. The UV light intensity value was displayed using Numeric Indicator and The LI vs. t curve was displayed using Waveform Chart.

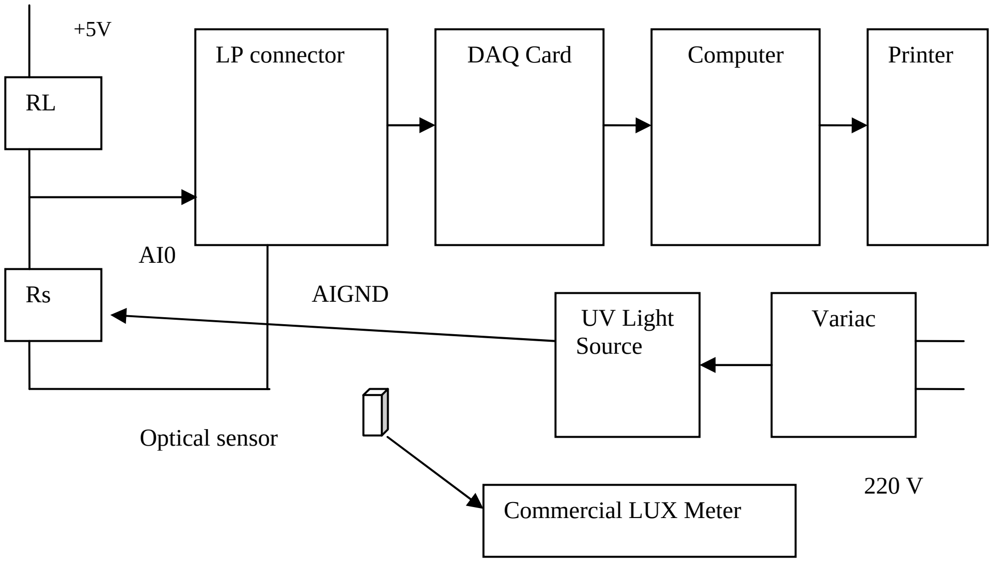

Figure 8 Experimental setup for optical ceramic application for UV light sensor with LabVIEW.

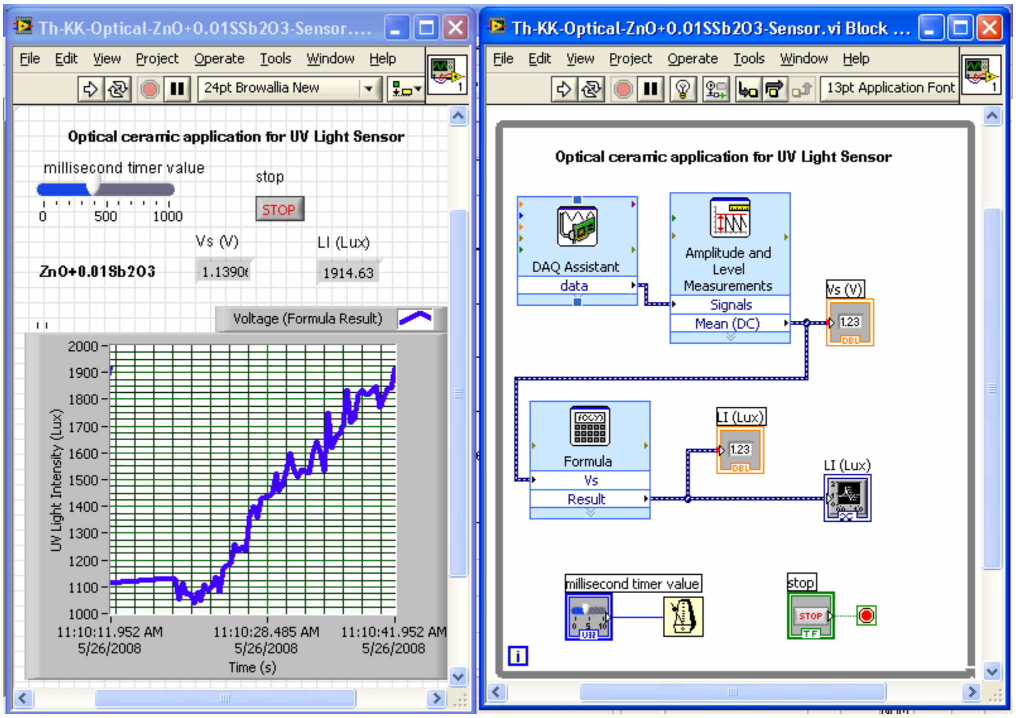

Figure 9 Front Panel and Block Diagram for optical ceramic application for UV light sensor with LabVIEW.

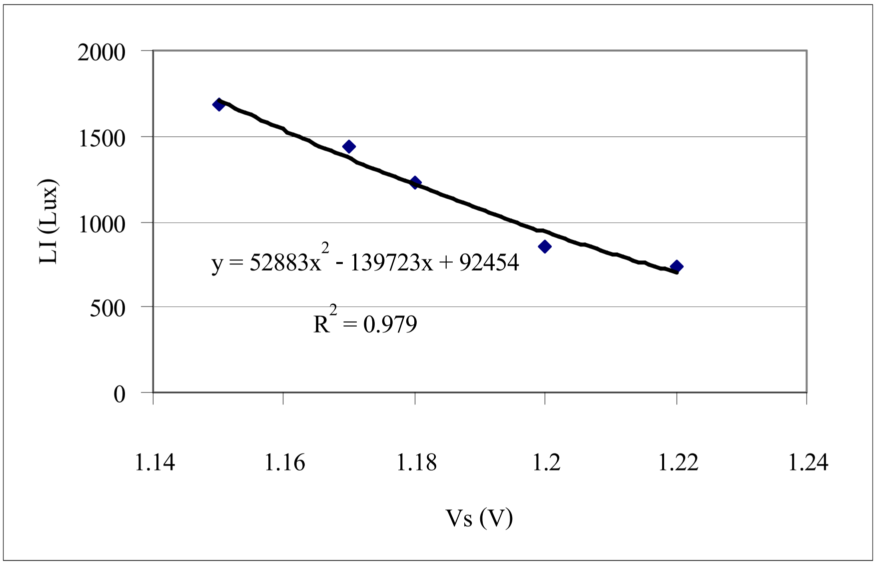

Figure 10 The relationship for UV light intensity from commercial optical sensor versus voltage drop across the $ZnO+0.01Sb_2O_3$ sample (LI vs. Vs) for calibration.

Optical ceramic application for UV light switch

Experimental setup for optical ceramic application of ZnO+0.01Sb_2O_3 for UV light switch with LabVIEW is shown in Figure 11. Front Panel and Block diagram for optical ceramic application of ZnO+0.01Sb_2O_3 for UV light switch with LabVIEW is shown in Figure 12. The used sample was ZnO+0.01Sb_2O_3. The load resistance (R_L) was 2 MΩ. Light source was UV light. Current from 5 V dc power supply flowed through load resistor (R_L) 2 MΩ and sample resistance (Rs). Voltage drop across R_s was V. Voltage (V) was transmitted to AI0 of LP connector, DAQ Card, PCI slot and computer, respectively. DAQ Assistant2 worked by receiving voltage (V) from LP connector and transmitted through DAQ Card into computer. Voltage (V) was transmitted to Amplitude and Level Measurements for Mean (DC) measuring. For UV optical switch test, initially, UV light was not applied, the voltage across sample (V) was transmitted to Operand 1 of Greater and setting voltage (Vset) was transmitted to Operand 2 of Greater. The setting voltage was 3.979 V. The voltage (V) was greater than setting voltage (Vset). The result (0 V) from Greater was transmitted to Not gate. Set Volt LED was light. Load LED was dark. The voltage from Not gate was transmitted to DAQ Assistant1. DAQ Assistant1 controlled for transmitting the 5 V to relay drive circuit, switch 3-5 was closed. Solid state relay did not electrically conducted, the electric current from 220 V line can not flow through UV light alarm. Finally, UV light was applied, the voltage drop across sample (V) was transmitted to Operand 1 of Greater and setting voltage (Vset) was transmitted to Operand 2 of Greater. The voltage (V) was less than setting voltage (Vset). The result (5 V) from Greater was transmitted to Not gate. Set Volt LED was dark. Load LED was light. The voltage from Not gate was transmitted to DAQ Assistant1. DAQ Assistant1 controlled for transmitting the 0 V to relay drive circuit, switch 3-5 was opened. Solid state relay electrically conducted, the electric current from 220 V line can flow through UV light alarm. This operation worked repeatedly, the UV light alarm was controlled, successfully. This sample operated as UV light switch. The voltage value (V) was displayed with Numeric Indicator. The voltage versus time (V vs t) curve was displayed using Waveform Chart. Program was run to show the result. It was done in order to use this sample for UV light switch test.

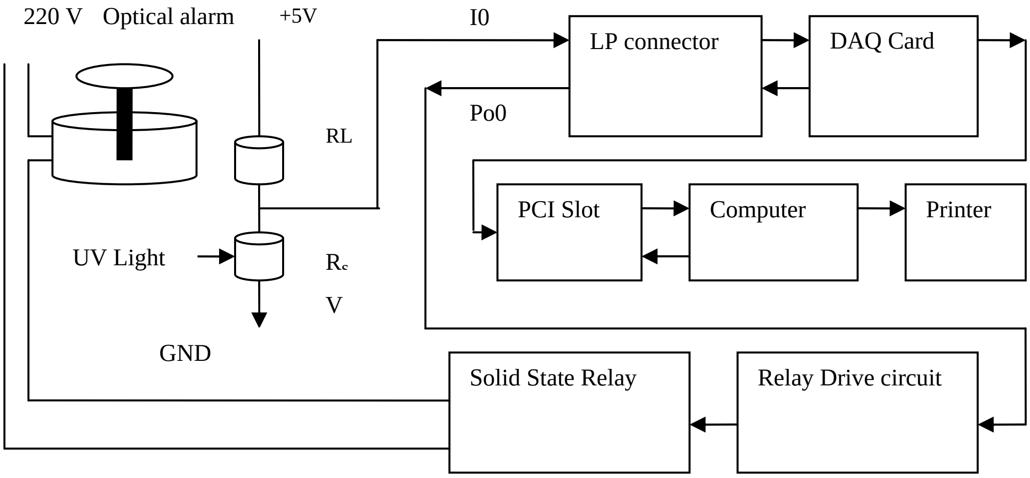

Figure 11 Experiment setup for optical ceramic application for UV light switch with LabVIEW.

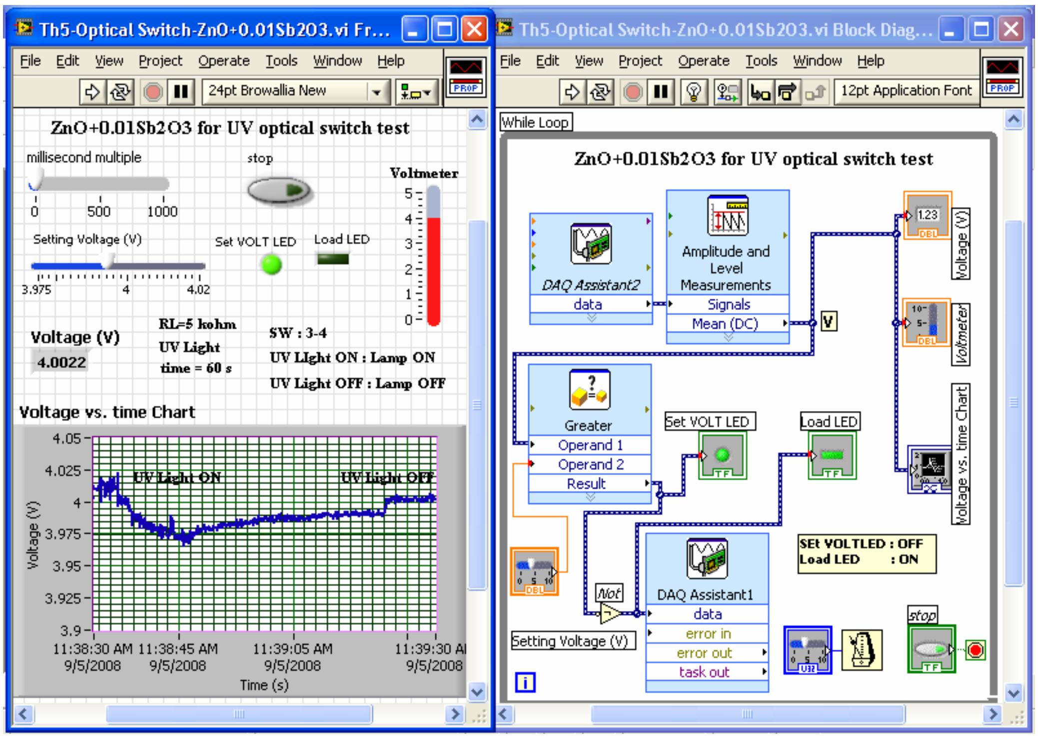

Figure 12 Front Panel and Block diagram for optical ceramic application for UV light switch with LabVIEW.

RESULTS AND DISCUSSION

Sample phase

The diffractogram of the $ZnO+0.01Sb_2O_3$ pellet is shown (Figure 13) and found that this sample phases were ZnO and $Zn_{2.33}Sb_{0.67}O_4$.

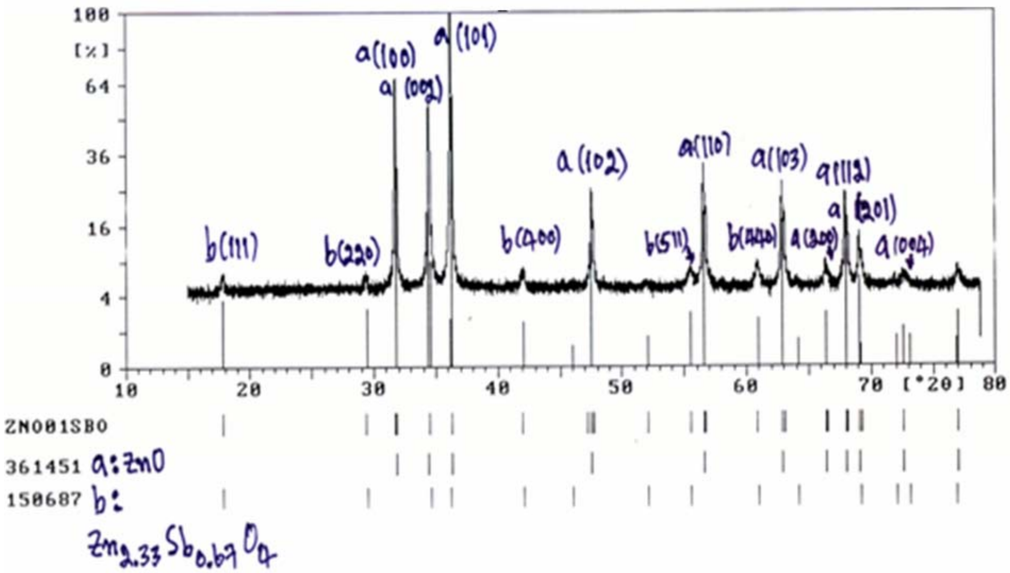

Figure 13 The diffractogram of the $ZnO+0.02Sb_2O_3$ prepared sample.

UV response test

The result for resistance versus time measurement of $ZnO+0.01Sb_2O_3$ is shown (Figure 2). Result showed that the resistance of this sample at room temperature decreased from 3.5 MΩ to 1.65 MΩ in the presence of UV light with intensity of 2530 Lux. A R-t characteristic indicates that a UV optical response was achieved. UV optical responsivity (G) of this sample was calculated with $G = [(R_f-R_i) / R_i]*100$, where R_i and R_f were the sample resistance before and after in the presence of UV light. UV optical responsivity (G) of this sample was -52.857 %. The negative value of UV optical responsivity showed that the resistance of this sample decreased the presence of UV light. Optical ceramic application for UV light sensor.

Resistance versus UV light intensity

The result for sample resistance vs UV light intensity with LabVIEW, where the used sample was a $ZnO+0.01Sb_2O_3$ and the UV sensor was a commercial LDR is shown in Figure 7. When the UV light intensity increased, the sample resistance was decreased because of energy gap effect.

UV light sensor

The result can be see from the Front Panel of LabVIEW for UV light sensor test of $ZnO+0.01Sb_2O_3$ (Figure 9). From the curve of UV light intensity versus time, this sample can be used as UV light sensor at room temperature. So, computer can demonstrate the application of this sample for the UV light sensor.

UV light UV light switch device

The result can be see from the Front Panel of LabVIEW for opical ceramic application of $ZnO+0.01Sb_2O_3$ for UV light switch device (Figure 12). From this figure, voltage drop across load resistor was a high value when UV light did not illuminate. But voltage drop across load resistor was a low value when UV light illuminated. This sample can be used as optical switch at room temperature. When UV light was incident on the sample surface, the optical alarm will work. The description on the application of $ZnO+0.01Sb_2O_3$ for UV switch using LabVIEW-based system has not been found in the literature [1,2,3,4,5,6].

CONCLUSION

1) The $ZnO+0.01Sb_2O_3$ ceramic pellets fabricated by the mixed oxide method have disc-shaped form.
2) This pellet exhibited UV light response. Result showed that the resistance of this sample at room temperature increased in the interval of 3.5 MΩ to 1.65 MΩ in the presence of UV light with intensity of 2530 Lux at room temperature. The measured UV light responsivity value is about -52.857 % in ambient air. This results signify the application potential of this pellets for UV light detection.
3) The $ZnO+0.01Sb_2O_3$ ceramic pellet showed resistance versus UV light intensity at room temperature.
4) The $ZnO+0.01Sb_2O_3$ ceramic pellet was developed for the use as UV light sensor at room temperature.
5) The $ZnO+0.01Sb_2O_3$ ceramic pellet was developed for the use as UV light switch at room temperature. The solid-state circuitry ensure accurate about the operation of UV light switch.
6) An automatic, low cost data acquisition system for monitoring the optical response ,UV light sensor test and UV light switch has been developed using a procedure based on virtual instrumentation. It measures and displays the graphics of the results. The proposed equipment is based on LP connector, a DAQ data acquisition card, computer and LabVIEW program, for processing, displaying and storing the collected data.
7) This test was conducted from April, 2008 and indicated that the equipment developed was suitable for studying the optical ceramics at room temperature. This experimental work was carried out at the Physics Department, Faculty of Science, Prince of Songkla University, Thailand.

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