J. Myanmar Acad. Arts Sci. 2019 **Vol. XVII. No.2A**

SCANNING ELECTRON MICROSCOPY AND CURRENT-VOLTAGE CHARACTERISTICS OF $CaMn(CO_3)_2$ /n-Si THIN FILM

May Sandar Win*

Abstract

Mn(20mol%) doped $CaCO_3$ ceramic was first prepared by solid-state reaction method at 1000°C for 1 h. The prepared $Ca_{0.80}Mn_{0.20}(CO_3)_2$ was deposited on n-Si substrate by using thermal diffusion technique at 400°C for 1 h. Surface morphology of the $Ca_{0.80}Mn_{0.20}(CO_3)_2$/ n-Si film was investigated by Scanning Electron Microscope. Surface morphology, grain shape, grain size and diffusion layer thickness of the film were studied in this work. In addition, current-voltage characteristics of $Ca_{0.80}Mn_{0.20}(CO_3)_2$/ n-Si thin film were investigated in dark and four different illuminations of light source. Output currents were observed in the bias voltages of (-5 V - +5 V) with the step voltage of 0.2 V. Light sensitivity and output currents of the film were reported in this work.

Keywords: $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si film, Surface morphology, SEM, Thermal diffusion, Current-voltage characteristics

Introduction

Ceramics, an artifact made of hard brittle material are produced from nonmetallic minerals by firing at high temperatures. Atomic and molecular nature of ceramic materials, resulting characteristics of performances are using industrial applications. In addition to the well-known physical properties of ceramic materials in hardness, compressive strength, brittleness there is the property of electric resistivity. Categories of advanced ceramic materials are employed in a wide variety of electric, optical, and magnetic applications. Advance ceramics also have important uses in electronics, aerospace, biomedical, construction, and nuclear industries.

Carbonates are among the most widely distributed minerals in the Earth's crust. The crystal structure of many carbonate minerals reflects the trigonal symmetry of the carbonate ion, which is composed of a carbon atom centrally located in an equilateral triangle of oxygen atoms. This anion group

* Dr, Assistant Lecturer, Department of Physics, University of Yangon

usually occurs in combination with calcium, sodium, uranium, iron, aluminum, manganese, barium, zinc, copper, lead, or the rare-earth elements.

Advanced Ceramic materials are not only nonmetallic, inorganic compounds and primarily compounds of oxygen, but also compounds of carbon, nitrogen, boron, and silicon which include the manufacture of earthenware, porcelain, bricks, and some kinds of tile and stoneware. Advanced Ceramics generally display the properties of hardness, refractoriness, high melting point, low conductivity and brittleness. Advanced industrial materials, owing and modifications in their structures, serve as electrical conductors. Resistivity and conductivity of insulator (ceramic), semiconductor and conductor are shown in Fig 1.

Scanning Electron Microscope (SEM) is one of the most versatile instruments available for the examination and analysis of the microstructural characteristics of solid objects. In the present work, sample preparation, surface morphology and diffusion layer thickness of $Ca_{0.80}Mn_{0.20}(CO_3)_2$ / n-Si thin film was reported by scanning electron microscopy.

"Kutnohorite" is the chemical formula of Calcium Manganese Carbonate, $CaMn(CO_3)_2$. It is a dolomite, $CaMg(CO_3)_2$ group mineral of naturally occurring species. The Manganese analogue of dolomite, it forms a chemical substitution (solid-solution) series with that mineral, in which Magnesium replaces Manganese in the crystal structure. It is probably intermediate in the discontinuous (at normal temperatures) solid-solution series between Calcite ($CaCO_3$) and rhodochrosite ($MnCO_3$). In the present work, current-voltage characteristics of $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si thin film were investigated in dark and four different illuminations of light source.

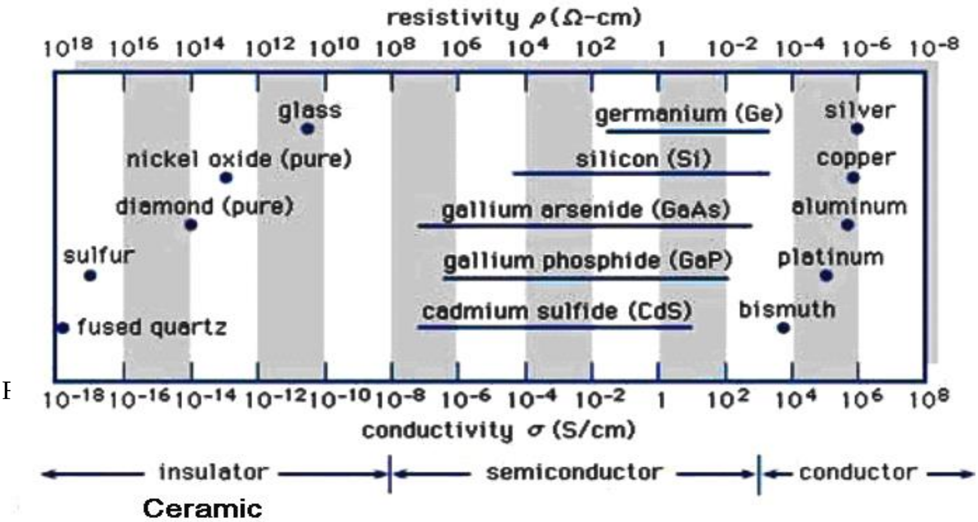

Figure 1: Resistivity of insulator, semiconductor and conductor

Experiment

Preparation of $Ca_{0.80}Mn_{0.20}(CO_3)_2$ Ceramics

For the intention sample $Ca_{0.80}Mn_{0.20}(CO_3)_2$ ceramic, raw materials of $CaCO_3$ and MnO_2 have been chosen as the starting materials. The starting materials $CaCO_3$ and MnO_2 were then mixed by the stiochiometric formula with desirable composition. These homogeneous powders were annealed at 1000 °C for 1 h. Then, sintered $Ca_{0.80}Mn_{0.20}(CO_3)_2$ powder was grounded by agate motor for 10 h to be homogeneous. 1 g of the powder and 2-methoxythanol are mixed. Obtained mixture is stirred and boiled at 100°C to get the sol state. Finally, the solution was cooled down at room temperature and was coated on cleaned n-Si substrate by spin coating method.

The sample was heat treated at 1000°C for 1 h in vacuum chamber. FOTEK MT-20 temperature controller was used to control the desire temperature and K-type thermocouple (1300°C) was used as the temperature sensor.

N-Si (100) wafer dimension of (0.5 cm x 0.5 cm) was used as the substrate. The substrate was cleaned using standard wafer cleaning process.

N-type silicon substrate was etched in $HF:H_2O$ (1:5) for 10 min, and immerse in deionized water for 10 minutes. And then, the substrate was immersed in acetone and methyl alcohol for 10 min and was rinsed in deionized water for 10 min. Next, the substrate was dried at room temperature. Finally, cleaned substrate was kept in an oven at 80°C for 10 min to dry. After cleaning process, the precursor solution was coated onto substrate by spin-coating technique. Later, coated-layer was dried at room temperature. $Ca_{0.80}Mn_{0.20}(CO_3)_2$ /n-Si material was deposited at 400°C for 1 h in thin film fabrication chamber. Experimental arrangement of thin film deposition system is shown in Fig 2.

Figure 2: Photograph of experimental arrangement of sample preparation system

Scanning Electron Microscopic (SEM) Measurement

In the present work, surface morphology and diffusion layer thickness of $Ca_{0.80}Mn_{0.20}(CO_3)_2$ /n-Si thin film were investigated by JEOL JSM-5610LV Scanning Electron Microscope (SEM) with the accelerating voltage of 15 kV and the beam current of 50 mA to study the grain shape, grain size and film quality as a function of annealing temperature. Photograph of JEOL JSM-5610LV Scanning Electron Microscope is shown in Fig 3.

Figure 3: Photograph of JEOL JSM-5610LV Scanning Electron Microscope (Japan: Kyoto)

I-V Characteristic Measurement

Light sensitive effect of $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si thin film has been investigated in dark condition (0 lux) and four different illumination conditions using (60 W) electric bulb light source. The light intensity sensor of Si-photodiode (LIGHTMETER 2330LX, SEW) was placed near the sample with parallel position to record constant intensity of light source throughout the measurement. I-V (Current – voltage) characteristics of the film in dark and in illumination conditions were also measured between the bias voltages of -5 V and +5 V with the step voltage of 0.2 V. In this measurement, DT-830B and FUKE FK9208X were used as the digital ammeter and voltmeter. Photograph of the experimental arrangement of I-V characteristic measurement is shown in Fig 4.

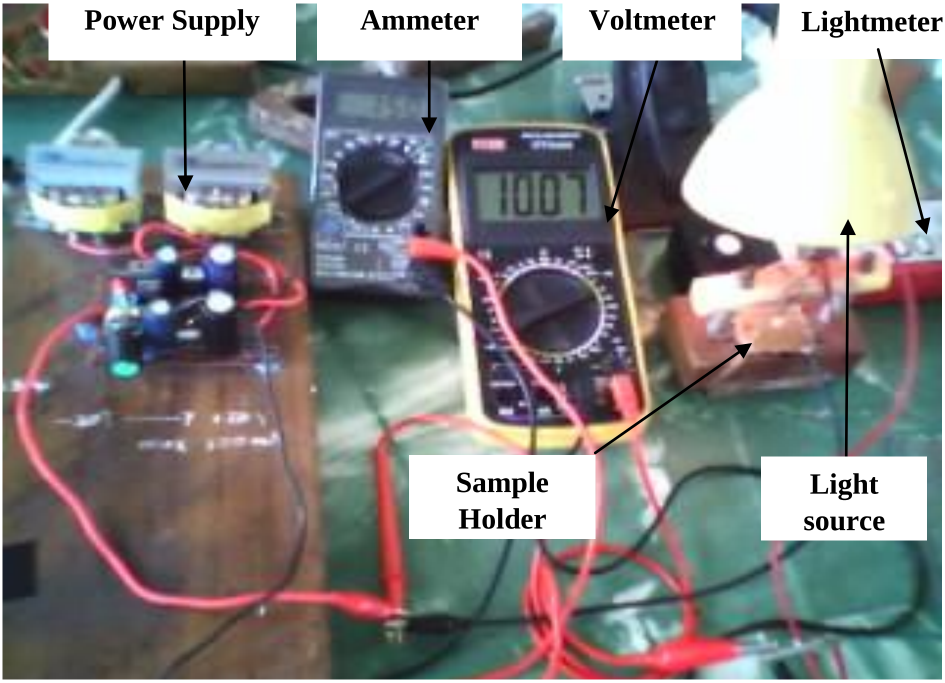

Figure 4:Photograph of the experimental arrangement of I-V characteristic measurement

Results and Discussions

SEM micrograph of $Ca_{0.80}Mn_{0.20}(CO_3)_2$ /n-Si thin film at the deposition temperature of 400°C for 1 h is shown in Fig 5 and the diffusion layer thickness of $Ca_{0.80}Mn_{0.20}(CO_3)_2$ on n-Si substrate is also shown in Fig 6.

As shown in recorded SEM micrograph, grain shapes of the samples are found to snow-like patterns. Grain sizes of the sample of micrograph are about 0.2 μm to 0.5 μm. In this micrograph, some holes are found but it is crack free layer.

As shown in observed diffusion layer thickness of the $Ca_{0.80}Mn_{0.20}$ $(CO_3)_2$ on n-Si substrate, it is found that (1) the layer boundary of the sample and substrate is mostly homogeneous and (2) the diffusion layer of the $Ca_{0.80}Mn_{0.20}(CO_3)_2$ sample on n-Si substrate is about 31.5 μm.

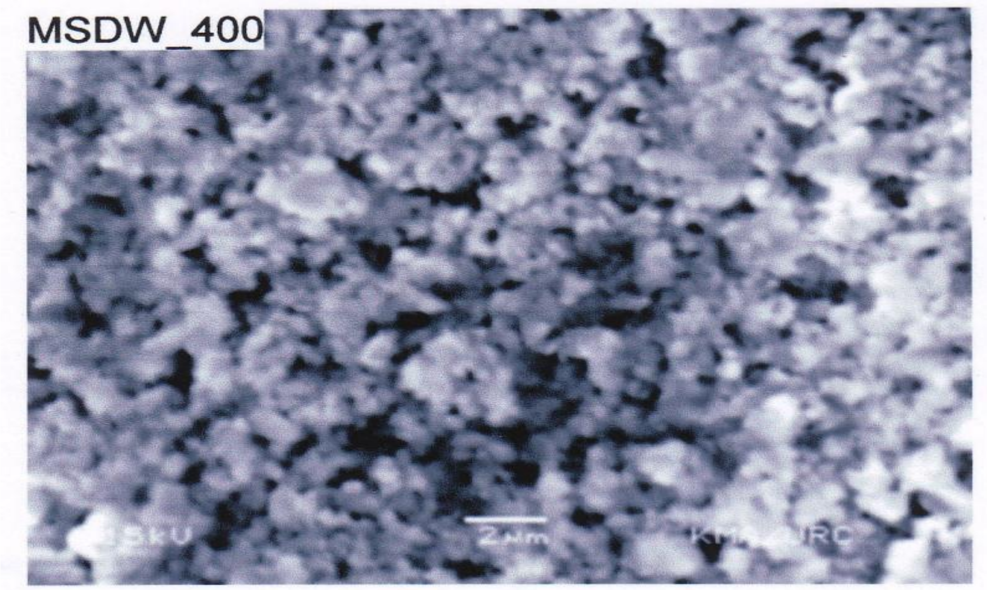

Figure 5: SEM micrograph of the $Ca_{0.80}Mn_{0.20}(CO_3)_2$ /n-Si thin film

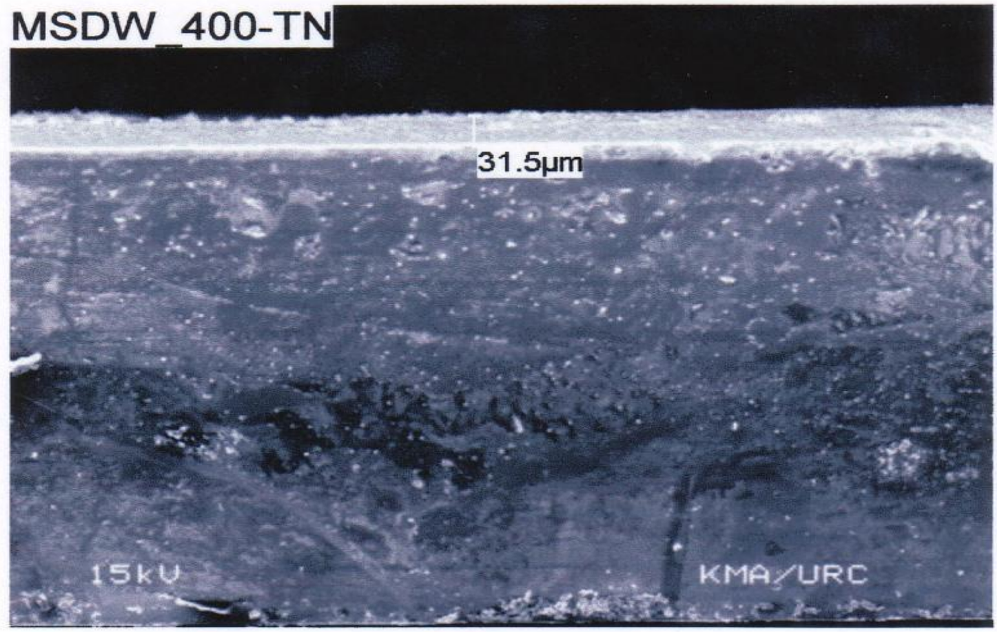

Figure 6: Diffusion layer thickness of the $Ca_{0.80}Mn_{0.20}(CO_3)_2$ on n-Si thin film

Current-Voltage Characteristics of $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si Thin Film

Current-voltage measurements of $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si thin film in the bias voltages of (-5 V - +5 V) under the different illumination conditions were investigated to study the photosensitive effect of the sample. Copper are used as electrodes for the top and bottom regions. I-V characteristic curves of the $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si thin film under dark (0 lux), ambient (390 lux), 1000 lux, 1500 lux and 2000 lux using (60W) electric bulb are shown in Fig 7(a) – (e).

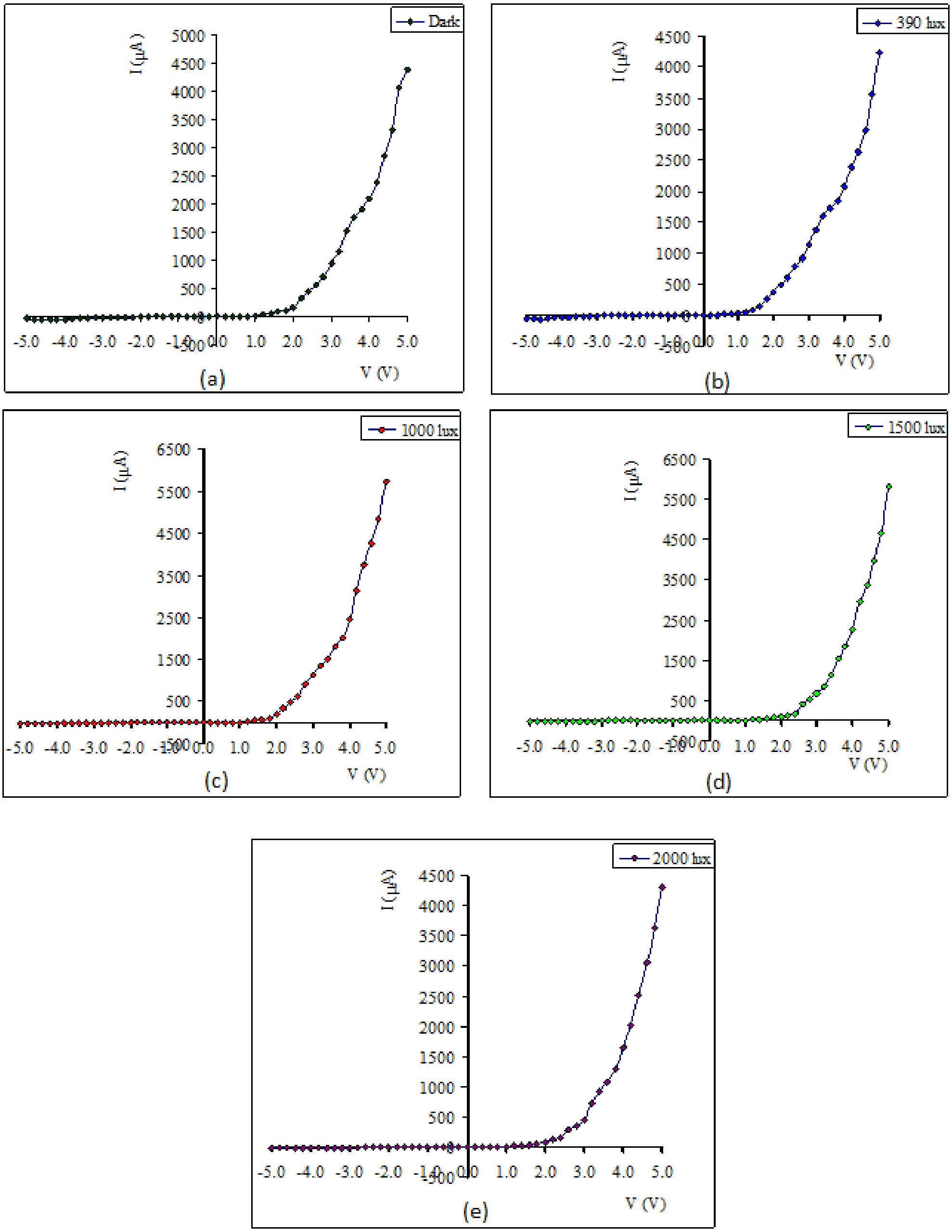

Figure 7: Current-voltage characteristic curves of $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si thin film under (a) dark (0 lux), (b) 390 lux (ambient), (c) 1000 lux, (d) 1500 lux and (e) 2000 lux illuminations

Current-voltage characteristic curves of the $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si thin film like as the junction diode characteristics. The output current of the film in the reverse saturation region (third quadrant) is found to linear. In the forward region (first quadrant), the output current is found to exponentially increase with increasing bias voltage. At (0 V) bias, the output current is (0 A) that shows the junction diode characteristic. Furthermore, comparison of the output currents as a function of (0 – 5 V) bias voltages in different illumination conditions is shown in Fig 8. Maximum output currents of the $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si thin film at +5 V in different illumination conditions are listed in Table 1. As presented in Table 1, the maximum output current of the film is 5810 μ A in 1500 lux illumination. The sample is a light sensitive device.

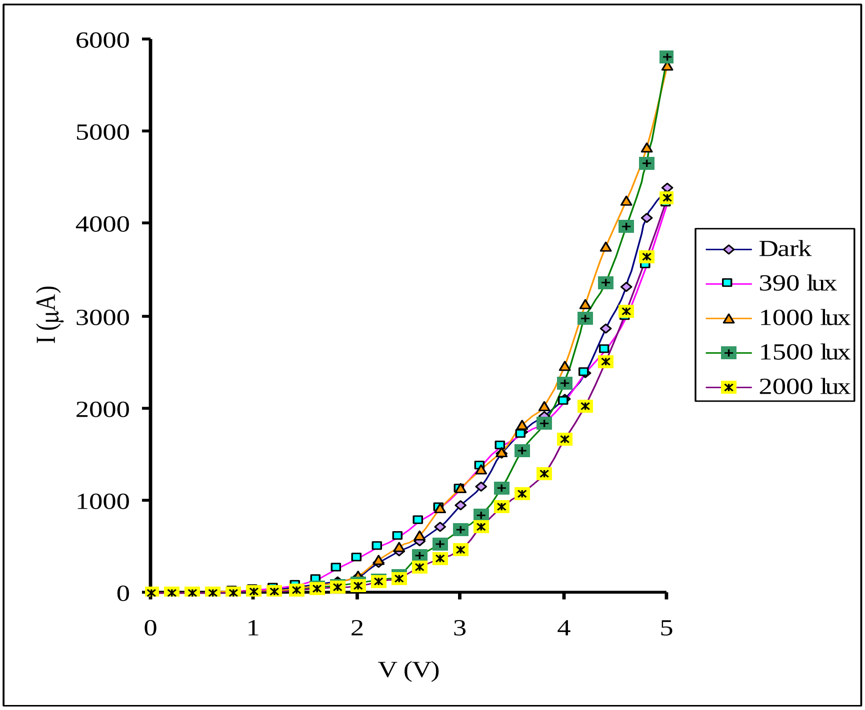

Figure 8: Comparison of the I-V characteristic curves of $Ca_{0.80}Mn_{0.20}(CO_3)_2$/ n-Si thin film in dark and in different illumination conditions

Table 1: Maximum output currents of $Ca_{0.80}Mn_{0.20}(CO_3)_2$/n-Si thin film in different illuminations

Sr No	Illumination (lux)	I_{max} (□A)
1	0 (dark)	4390
2	390	4230
3	1000	5720
4	1500	5810
5	2000	4290

Conclusion

Mn (20 mol%) doped Calcium Carbonate, $CaCO_3$ thin film was deposited on n-Si substrate by using thermal diffusion method at 400°C for 1 h in vacuum chamber. Surface analysis of the sample was investigated by SEM at room temperature. According to SEM micrographs, grain shapes of the samples are found to snow-like pattern. Grain sizes of the sample are about 0.2 μ m to 0.5 μ m. Some holes are found in SEM micrographs but it is crack free layer. Homogeneously layer was found to be deposited on n-Si substrate with 31.5 μ m in thickness.

I-V characteristics of the film were reported under dark and different illuminations. From the I-V characteristic curve, it is shown that the film has the junction diode characteristic. The output currents in reverse saturation region and forward region were investigated. The maximum output currents were compared for the different illuminations. The maximum output current is found to be 5810μ A for 1500 lux illumination condition. According to experimental results, the sample is found to be light sensitive.

Acknowledgement

The authors are grateful to Dr Khin Khin Win, Professor and Head of the Department of Physics, University of Yangon for her kind permission to carry out this work.

References

Bhattacharva P (1995) "Semiconductor Optoelectronic Devices" (New Delhi: Prentic-Hall)

Engler P et al 1988 The Rigaku Journal 5 (2) 3

Moulson A J & Herbert J M (1997) "Electroceramics Materials, Properties & Applications" (London: Chapman & Hall)

Pillai S O (2006) "Solid State Physics" (New Delhi: New Age)

Tsuchiya T & et al (2006) Sci Lett 231 11

Xiu X et al (2007) Journal of Materials Science and Technology 23 (4) 509

Yoo J et al (2005) Journal of the Korean Physical Society 47 576

Xu Y (1991) “Ferroelectric Materials and Their Applications” (Amsterdam: North-Holland)

2001 “Vacuum Technique and Thin Film Deposition” (California: California Institute of Technology)

2011 Encyclopedia Britannica Library CD-ROM Catalogue