Effects of the deposition temperature on some of the properties of electrodeposited aluminium selenide (AL_2SE_3)

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Aluminium selenide (Al_2Se_3) is quite promising in the fabrication of electronic devices. In this paper, Al_2Se_3 thin films were deposited on glass substrate using electro chemical deposition technique in which graphite was used as a cathode while the anode was carbon. In the deposition of Al_2Se_3 the source of the aluminium was aluminium chloride while selenium dioxide was the source of selenide. In the deposition process, the reaction bath was maintained at the temperature of 30, 40, 50, 60 and 70°C for nine minutes with a deposition voltage of 1200 mV and the deposited thin films were characterized structurally, optically and electrically. The characterization of the deposited Al_2Se_3 thin films reveals that its thickness increased with increase in deposition temperature. The Al_2Se_3 thin films absorbed, transmitted and reflected electromagnetic radiation in the wavelength range of 300 to 900 nm. The films have maximum absorbance in the ultra violet region, maximum transmittance in the infra-red region with low reflectance in the ultra violet, visible and infra-red regions of the electromagnetic spectrum. Increase in the deposition temperature reduces the energy band gap of Al_2Se_3. Electrical characterization revealed that Al_2Se_3 thin film deposited at 70°C exhibited N-type conductivity while those deposited between 30 and 60°C that exhibited P-type conductivity.

Key words: Thin film, electrodeposition, characterization, temperature variation, optioelectronic devices.

INTRODUCTION

Aluminum selenide (Al_2Se_3) is a promising material for the fabrication of optoelectronic devices due to its direct energy band gap, better charge transport, good absorption coefficient and it is a high transmittance material. Despite its potential in device applications, it has received relatively low research attention when compared to other members of the III-VI family of semiconductors (Atapattu et al., 2016). Aluminum (Al) as an element has been extensively studied because of its ease of growth, well known optical and electrical properties and its abundance in the earth's crust, after oxygen and silicon (Brus, 1984). Since compound semiconductors has more functionalities than elemental semiconductors, compound semiconductors such as cadmium telluride (CdTe), zinc oxide (ZnO), zinc sulfide (ZnS), lead sulfide (PbS), etc., have received scientific attention. We chose to deposit Al_2Se_3 because of the potential of selenium in compound semiconductors such as zinc selenide (ZnSe), copper selenide (CuSe) (Dennison, 1994), lead selenide (PbSe) (Dharmadasa et al., 2014), etc.

Various deposition techniques have been

employed in the synthesis of compound semiconductor materials (McHardy and Ludwig, 1992; John and Singh, 1996; Echendu, 2016; Manas, 2019) Since the primary aim of synthesizing materials for device applications is to minimize cost, electrodeposition technique (ED) has rendered significant help to achieve the goal. Electrodeposition is cost effective, scalable, capable of re-engineering material energy band gap and has electrolytic bath longevity with self-purification. Moreover, the synthesis of nano materials can be controlled over the properties by changing the ionic concentration, pH value, temperature, deposition time and cathode voltage (Pandey, 2015; Meulenkamp and Peter, 1996; Ojo and Dharmadasa, 2016; Ojo et al., 2017). In this study, Al_2Se_3 thin films were electrodeposited on a conducting fluorine tin oxide (FTO) substrate of dimension 2.3 by 4 cm^2. Several samples of Al_2Se_3 were deposited by varying the temperature of the reaction bath. The optical, structural and electrical properties of the deposited Al_2Se_3 thin films were studied. Also, the effect of the variation of deposition temperature on the energy band gap of Al_2Se_3 thin films were examined.

MATERIALS AND METHODS

In the deposition of Al_2Se_3, aluminium chloride was the source of aluminium while selenium dioxide was the source of selenium. 50 cm^3 of 0.1 M solution of aluminium chloride was measured into a beaker and 50 cm^3 of 0.2 M solution of selenium dioxide was added to it. The resulting solution was thoroughly stirred using a magnetic stirrer. The pH of the solution was measured using a pH meter and found to be 1.88. This pH is not suitable for the deposition of Al_2Se_3. Consequently, dilute ammonia solution was added to the reaction bath while stirring using a pipette until the suitable pH of the reaction bath of 2.5 was obtained (Wang and Herron, 1991). The reaction bath was placed in a water bath maintained at 30°C. The anode and cathode were quickly arranged parallel to each other. The conducting substrate was attached to the cathode with the aid of a teflon. The anode and cathode were connected to a potentiostat to allow for the deposition of Al_2Se_3 on the conducting substrate as shown in Figure 1. A constant voltage of 1200 mV was passed into the reaction bath and the deposition time was nine minutes. The deposition process was repeated at different temperatures of 40, 50, 60 and 70°C. The deposited Al_2Se_3 thin films were characterized structurally using stylus profiler and scanning electron microscopy (SEM). The optical characterization of the deposited Al_2Se_3 thin films were carried out using a UV-VIS spectrophotometer (UV-750 series) while the electrical conductivity of the Al_2Se_3 thin films were carried out using electrical conductivity meter.

RESULTS AND DISSCUSSION

The Al_2Se_3 deposited at several temperatures adhered very well to the substrate. The colour of the deposited Al_2Se_3 thin films varied from pale yellow to deep yellow as the deposition temperature increase. This may be due to increase in the deposition of selenium ions on the substrate as the temperature increases. Measurement of the thickness of the deposited Al_2Se_3 using a stylus profiler revealed that the thickness of the deposited Al_2Se_3 varied from 1.8 to 3.7 microns with the thickness of the deposited Al_2Se_3 increasing with increase in deposition temperature. This shows that increased in the deposition temperature causes more of the anions and cations to be deposited on the substrate. Figure 2 shows scanning electron micrograph of the deposited Al_2Se_3 thin film. The scanning electron micrograph revealed that Al_2Se_3 was uniformly deposited on the glass substrate and it has average size and spherical shape with facet edge. The micrograph also reveals the level of agglomeration while little agglomeration was predominant in the sample. The low level of agglomeration as depicted in Figure 3 shows the suitability of the deposited material in fabrication of electronic device as uniformly deposited materials with smooth surfaces are mostly used in the fabrication of electronic devices (Nelson, 2003).

Figure 3 shows the absorbance spectrum of Al_2Se_3 thin films electrodeposited at different temperatures. The figure revealed that the Al_2Se_3

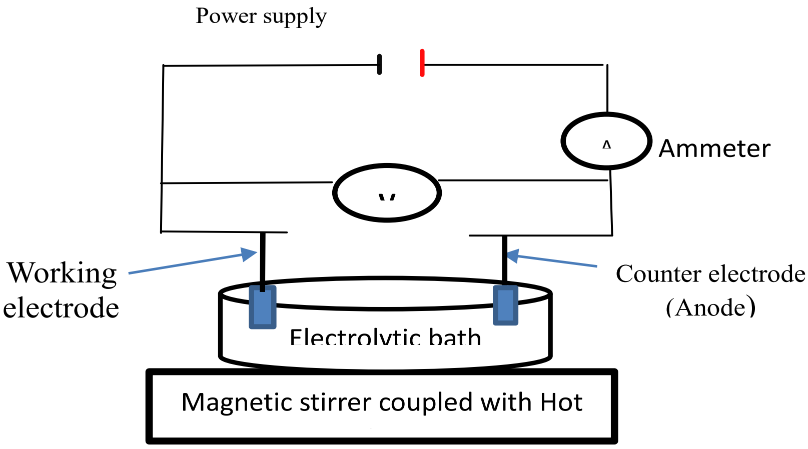

Figure 1. Schematic diagram of the electrodeposition method.

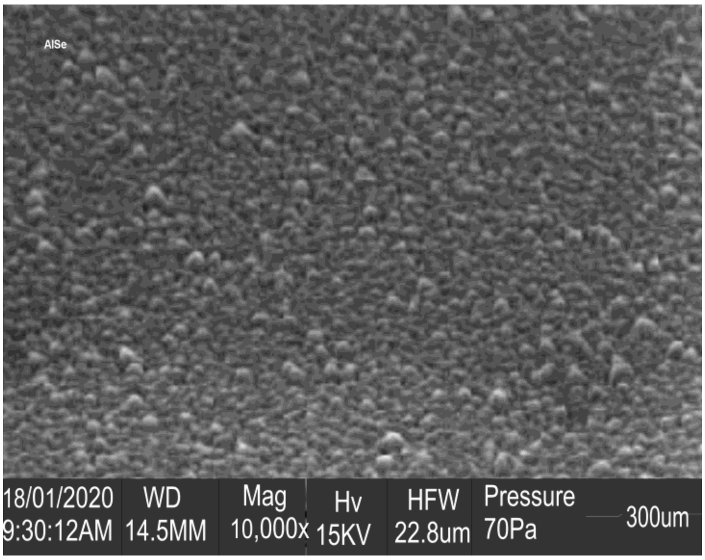

Figure 2. Scanning electron micrograph of the electrodeposited aluminum selenide.

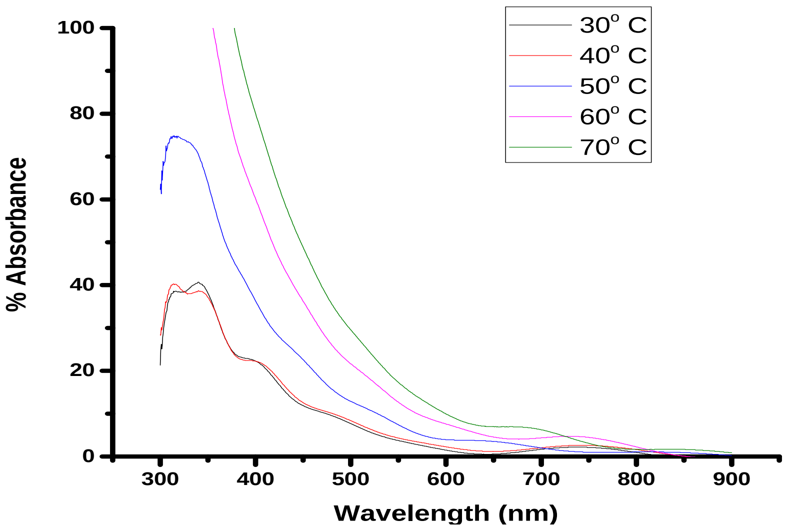

Figure 3. Absorbance spectrum of the electrodeposited Al_2Se_3 at different deposition temperature.

thin films absorbed light from 300 to 900 nm with maximum absorbance at 350 nm which is in the ultraviolet region of the electromagnetic spectrum. As revealed in Figure 3 Al_2Se_3 thin films deposited at 60 and 70°C exhibited a negative exponential decay nature with no maximum absorbance peak.

Figure 4 shows that the transmittance spectrum of Al_2Se_3 increases as the wavelength increases with minimum transmittance in the ultra-violet region and maximum transmittance in the infra-red region of the electromagnetic spectrum. Al_2Se_3 thin films electrodeposited at lower temperatures have high percentage of absorbance compared to those deposited at higher temperatures. The high transmittance property of Al_2Se_3 shows that the material has a high potential to act as a window layer material in different devices. Window layer materials are materials with higher transmittance and lower absorbance (Okujagu and Okeke, 1997). Figure 5 reveals that Al_2Se_3 thin films electrodeposited at different temperatures have low reflectance in the ultra-violet, visible and infra-red regions of the electromagnetic spectrum. This shows that Al_2Se_3 thin film is a poor reflector of electromagnetic radiation. The plot of α^2 against photon energy (Tuac's plot) for the determination of the energy band gap of the electrodeposited Al_2Se_3 thin films deposited at different temperatures is shown in Figure 6. The determined energy band gap of Al_2Se_3 varied from 2.11 to 2.65 eV. The figure reveals that as deposition temperature increases, the energy band gap of the deposited Al_2Se_3 thin film decreases. This shows that for the electrodeposited Al_2Se_3 thin films, increase in the deposition temperature reduces the energy band gap of the deposited thin film.

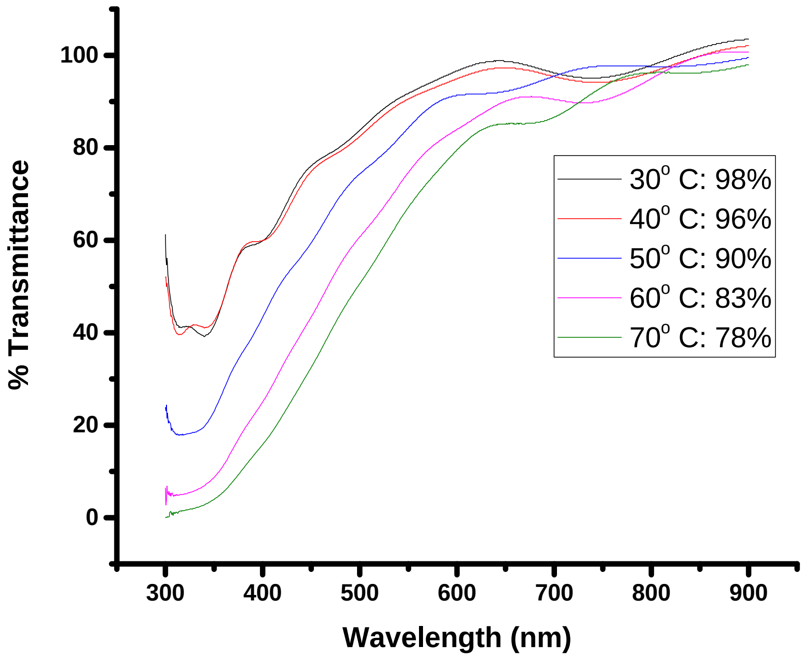

Figure 4. Transmittance spectrum the electrodeposited Al_2Se_3 at different deposition temperatures.

Electrical conductivity measurement of the electrodeposited Al_2Se_3 thin films deposited at different temperatures reveals that Al_2Se_3 thin films deposited between 30 and 60°C is a P-type semiconductor while Al_2Se_3 thin film deposited at 70°C is an N-type semiconductor. This shows that deposition temperature can cause the conductivity of electrodeposited Al_2Se_3 thin films to change from P –type to N –type (Figure 2).

Conclusion

Al_2Se_3 thin films were successfully deposited on glass substrate at different temperatures using electrodeposition technique. The results showed

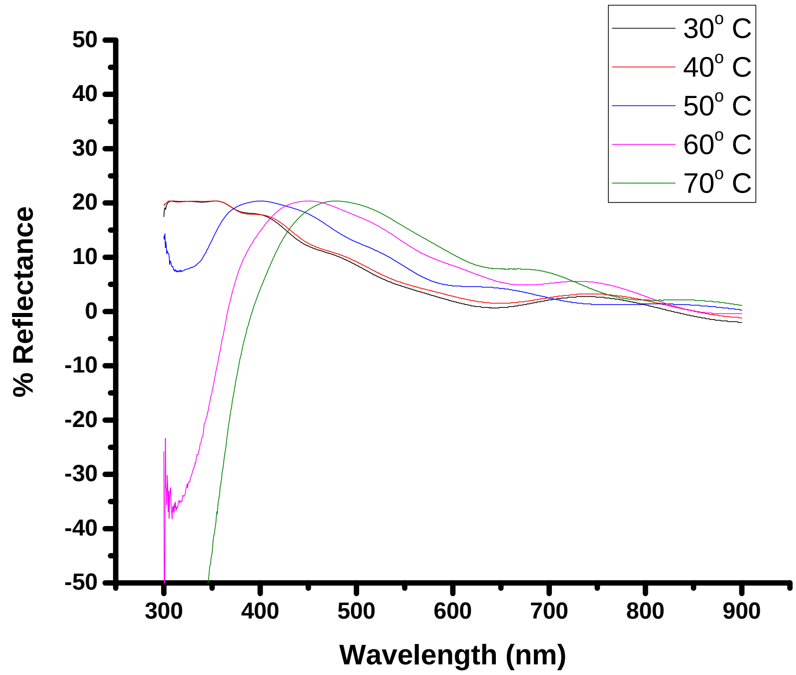

Figure 5. Reflectance spectrum of the electrodeposited Al_2Se_3 at different deposition temperatures.

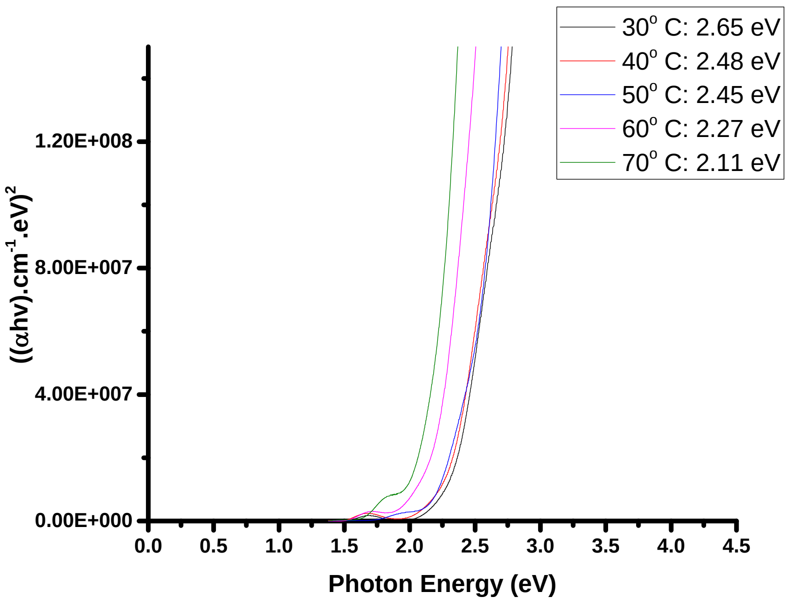

Figure 6. Energy band gap of electrodeposited Al_2Se_3 at different deposition temperatures.

that the structural, optical and electrical properties of the deposited Al_2Se_3 thin films are affected by the deposition temperature. It was also observed that the Al_2Se_3 can have varying energy band gap and conductivity when the deposition temperature is varied. The optical properties of the deposited Al_2Se_3 revealed that the material can be used for the fabrication of optoelectronic devices such as emitters and collectors and for the formation of heterojunctions. Al_2Se_3 thin films should be further characterized electrically to know its fill factor, the dark and open voltage characteristics for a better understanding of its electrical characteristics.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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