Microelectronics and Solid State Electronics 2014, 3(1): 11-14
DOI: 10.5923/j.msse.20140301.02

Effect of Metal-Semiconductor Contact Geometry on Electrical Properties of Al/ZnSe Thin Films

I. A. Amatalo[1,*], N. E. Makori[1], J. Maera[2], D. Wamwangi[3], P. M. Karimi[1]

[1]Department of Physics, Kenyatta University, Nairobi, Kenya
[2]Department of Physics, Maasai Mara University, Narok, Kenya
[3]School of Physics, University of Witwatersrand, Johannesburg, South Africa

Abstract The desire for smaller, more efficient and faster semiconductor devices has made design of metal-semiconductor contacts and characterization very vital. There is little research if any on the effect of metal-semiconductor contact geometry on I-V characteristics of ZnSe thin films. Various circular and rectangular thin filmed Al/ZnSe devices were designed by varying the shape and area of the Aluminium metal contact. Fabrication was done by thermal vacuum evaporation technique of zinc (99.99%) and selenium (99.99%) alloy powder onto masked glass slides using an Edward Auto 306 RF/DC magnetron evaporation chamber. Aluminium metal was subsequently deposited on the ZnSe thin films using circular and rectangular masks. Silver paste was used as the ohmic contacts. I-V characteristics were obtained using the Keithley 2400 source meter and data analyzed using Origin Software. From the J-V characteristic curves, the dark diode ideality factors ranged between 6.0 and 7.3 and were lower for circular Schottky devices than for rectangular ones. Device with circular Schottky contact area of $2.0423\times10^{-4}m^2$; a smaller inter-electrode spacing of 4mm had the lowest diode ideality factor of 6.361.

Keywords Metal- semiconductor devices, Schottky contact area, Vacuum deposition, Ideality factor

1. Introduction

Zinc Selenide is a naturally n-type semiconductor with a cubic zinc blende structure and a direct band gap of 2.7eV at room temperature. Thin film Schottky devices provide a solution for cheaper, fast switching devices which can be incorporated with other thin film semiconductors to form thin film high speed optical devices, diodes or transistors among others [1]. There is limited research and literature if any on circular thin film Al/ZnSe Schottky diodes with top annular Aluminium Schottky contact and Silver as top Ohmic contact. Most literature is on rectangular Schottky contacts and preferably interdigitated contacts [2]. There is need to fabricate more efficient devices by taking into account the electric field and thus adjusting the geometry and area of Schottky contacts.

The evaluation of a Schottky contact using diode ideality factor provides a useful method for characterizing metal-semiconductor devices. In this paper we report the effect of metal-semiconductor contact geometry on I-V characteristics.

* Corresponding author:
abiamata@yahoo.com (I. A. Amatalo)
Published online at http://journal.sapub.org/msse

2. Experimental

Thin film depositions were carried out using an Edward Auto 306 RF/DC magnetron evaporation chamber and the deposition parameters are presented in table 1. Prior to deposition of ZnSe the glass slides were cleaned using a standard process. A mixture of 0.547g, 99.99% Selenium and 0.453g, 99.99% Zinc metal were put in a silica tube and Argon gas passed through. The tube was heated until Zinc melted. The heating for 5 minutes and cooling for 30 minute cycles were repeated three times while shaking the tube to ensure homogeneity in the mixture. It was then sealed using an oxy-acetelyn flame to form an ampoule, then allowed cooling slowly to a room temperature of 300K to 305K.

The ampoule was broken and the brown mixture of Zinc and Selenium was ground in a clean porcelain mortar to form a powder and thermally evaporated from a molybdenum boat under a pressure of 5.0×10^{3} millibars on to well cleaned glass slides using circular and rectangular ink masks. The slides were removed from the chamber and soaked in 90% ethanol at room temperature. The ethanol was agitated to remove the masks. They were then washed in distilled water. This process was repeated four times to remove the ink masks.

The ZnSe thin films were then annealed at 473K in

Argon ambient for one hour using a Lindberg tube furnace. They were then allowed to cool to room temperature in an Argon atmosphere. Aluminium metal of thickness 1000nm was then deposited as the contact using circular masks to produce annular contacts of area 1.75952×10^{-4} m^2 and $2.0423 \times 10^{-4} m^2$ for circular device 1 and circular device 2 respectively. Rectangular masks were used to produce rectangular Schottky contacts of area $2.0 \times 10^{-5} m^2$ and $2.5 \times 10^{-5} m^2$ for rectangular device 1 and 2 respectively (Figure 1). These devices were then annealed at 473K for thirty minutes in Argon atmosphere and allowed to cool slowly to room temperature in an Argon atmosphere. Silver paste was then applied as a top ohmic contact.

Table 1. Deposition parameters for ZnSe thin films

Evaporator boat	Molybdenum
Substrate	Glass slides
Substrate temperature	300K
Substrate to source distance	8cm
Vacuum	5.0×10^{3} millibars

2.1. Electrical Analysis

By varying the voltage in steps of 0.1volts, the corresponding current was read from a Keithley 2400 Source meter connected to record current at room temperature. Graphs of current against voltage were plotted using Origin software.

Circular and rectangular Schottky devices labeled according to the Schottky contact area were characterized. Circular device 1 (area $1.75952 \times 10^{-4} m^2$) and circular device 2 (area $2.0423 \times 10^{-4} m^2$) I-V characteristics were compared. The same was done for Rectangular device 1 (area $2.0 \times 10^{-5} m^2$) and rectangular device 2 (area $2.5 \times 10^{-5} m^2$).

3. Results and Discussions

A graph showing forward I-V characteristics of the circular and rectangular devices is shown in figure 2. It can be seen that the I-V characteristics are rectifying in nature. This indicates the existence of a potential barrier between the thin films of Aluminium and n-type ZnSe. At low voltages □ 1volts, conduction mechanism is ohmic [3]. At voltages between 1V and 4V, a square law is observed (I α V^2) It can be seen that circular device 2 with large Schottky contact area has better rectifying properties than for the same type, but with smaller area. The same can be seen for rectangular devices. This can be attributed to reduced contact resistance as area increases. This also enhanced the forward conduction of the Schottky region in the rectifier and resulted in the majority of current being transported via the Schottky region [4].

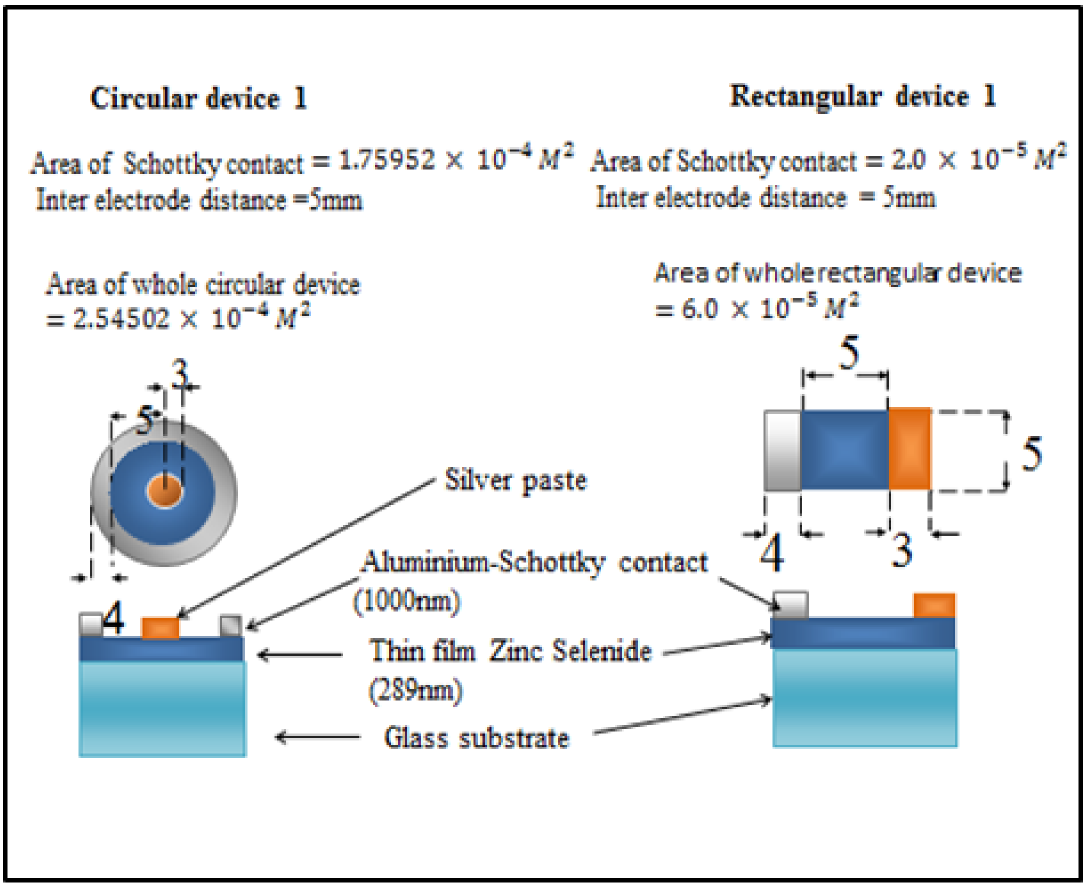

Figure 1. Device dimensions for rectangular and circular devices

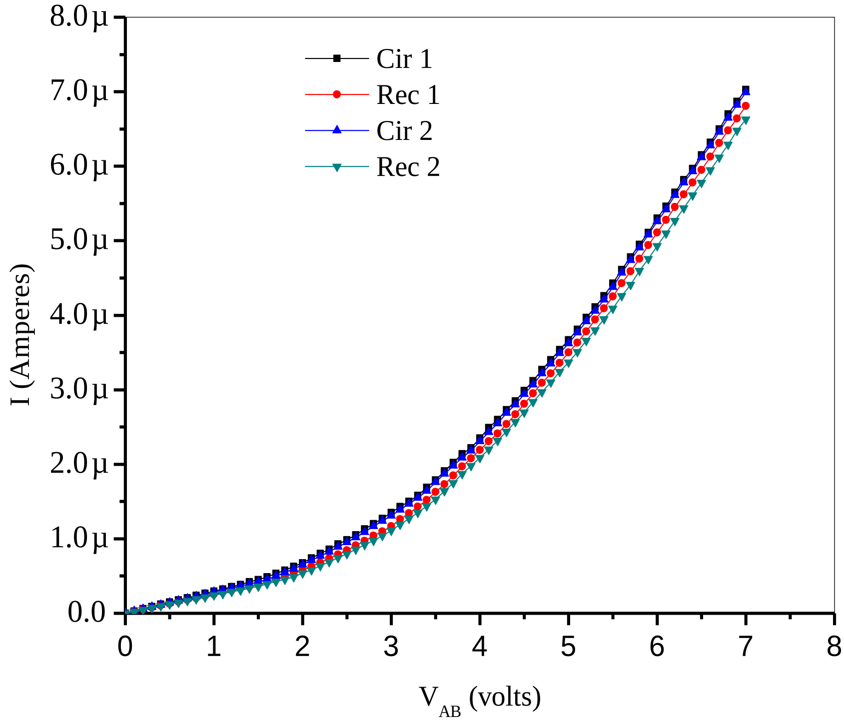

Figure 2. Effect of contact area and geometry on dark forward I-V characteristics

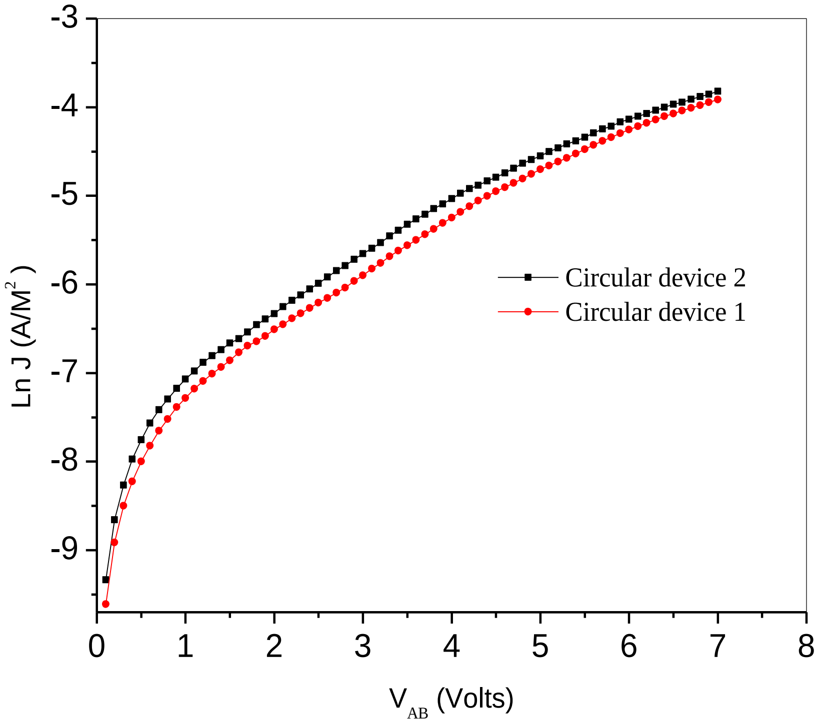

Figure 3. Effect of area on circular metal contacts on Ln J characteristics

The current density J of a Schottky diode of saturation current J_0 and diode ideality factor n are related by [5]:

$$J = J_0\left[\exp\left(\frac{qV_{AB}}{nK_BT}\right)-1\right] \quad (1)$$

Where -1 sets J to zero when $V_{AB} = 0$; and V_{AB} is the applied voltage.

And $$J_0 = R^* T^2 \exp(\frac{-q\phi_B}{K_B T}) \quad (2)$$

Thus $$\ln J = \ln J_0 + \frac{qV_{AB}}{nK_B T} \quad (3)$$

The effect of diode resistance can be modeled with a series combination of a diode and a resistor R through which current flows. The voltage V_{AB} across the diode can then be expressed in terms of the total voltage drop V across the series combination of the diode and resistor therefore $V_{AB} = V - IR$ [6]. A plot of $\ln J$ versus applied voltage V_{AB}; for circular devices is shown in fig 3

Table 2. Dark ideality factor for rectangular and circular devices of ZnSe film thickness of 289nm

	Device 1	Device 2
Ideality factor (n) Circular	6.512	6.361
Ideality factor Rectangular	7.318	7.269

Diode ideality factor is higher for rectangular devices due to high electric field enhancement at the edges, compared to a uniform distribution of electric field in circular one [4]. In diodes, the highest electric field under reverse bias always occurs inside the depletion region near the electrode corners due to electric field enhancement. This electric field causes an avalanche of charge carriers and thus increases the diode ideality.

High series resistance causes a voltage drop across the barrier to be less than the voltage applied across the terminals of the diode [6]. Large values of ideality factor can be attributed to series resistance in the ZnSe semiconductor caused by defects which crept into the film during preparation [7]. The Schottky devices, which had smaller, inter electrode distance and larger Schottky contact area had the lowest and thus better diode ideality factor due to reduced series and contact resistance respectively.

4. Conclusions

Deposition of ZnSe thin films was done by thermal vacuum evaporation method. Fabrication of metal-semiconductor devices was successfully done, and from their $\ln J$ versus V characteristics, the diode ideality factor was seen to range between 6.361 $\pm$ 0.01 to 6.512 $\pm$ 0.01 for circular devices and 7.269 $\pm$ 0.01 to 7.318 $\pm$ 0.01 for rectangular of film thickness 289nm. It can be concluded that devices with larger metal contacts and thus shorter inter electrode spacing (device 2) have the lowest diode ideality factors and thus better electrical characteristics.

REFERENCES

[1] K. G. Rao, K. V. Bangera and G. K. Shivakumar, "Photoconductivity and photo-detecting properties of vacuum deposited ZnSe thin films.," *Solid State Science B.*, pp. 1921-1925, 2011.

[2] S. V. Averine, Y. C. Chan and Y. L. Lam, "Geometry optimization of interdigitated Schottky-barrier-metal-semiconductor-metal photodiode structures," *Solid State Electronics 45*, pp. 441-446, 2001.

[3] S. Venkatachalam, D. Mangalaraj and S. K. Narayandass, "Characterization of vacuum evaporated ZnSe thin films," *Physica B 39*, pp. 47-55, 2007.

[4] B. W. Liou, "Fabrication of high breakdown voltage silicon Scottky barrier diodes using various edge termination structure.," *Thin solid films 517*, pp. 6558-6564, 2009.

[5] D. A. Neamen, Semiconductor Physics and Devices, New york: Mc Graw Hill, 2003.

[6] H. Lu, D. Cao, X. Xiu, Z. Xie, R. Zhang, Y. Zheng and Z. Li, "Schottky rectifiers fabricated on bulk GaN substrates analyzed by electron-beam induced current technique.," *Solid state electronics 52*, pp. 817-823, 2008.

[7] S. Chaliha, M. N. Borah, P. C. Sarmah and A. Rahman, "Study of Au, Ni-(n)ZnSe Thin Film Schottky Barrier Junctions," *International Journal of Thermophysics 27*, pp. 332-337, 2009.