Investigation of the electrical properties of metal chalcogenide thin films: A review

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ABSTRACT

In the present study, thin films have been successfully prepared by using various deposition methods. The electrical behaviors of obtained thin films were investigated by using Hall Effect measurement and Van Der Pauw technique as reported by many researchers. The experiment results show that the electrical resistivity reduces with increase in temperature and film thickness as well.

Keywords: Electrical properties, film thickness, resistivity, deposition

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INTRODUCTION

Thin films have been prepared using various deposition methods. It is important and need to understand the electrical properties, magnetic properties [1-4], optical properties [5-13], morphological [14-24], structural [25-34] and compositional properties [35-38] of obtained films in order to improve and produce high quality products. Over the past decade, such work has mainly focused on binary films, and ternary films. Recently, there have been few reports on the synthesis of quaternary thin films. Generally, X-ray diffraction technique and energy dispersive X-ray analysis method were used to study the structure and composition of obtained films. Meanwhile, scanning electron microscopy and atomic force microscopy were employed to analysis the morphology of films. Lastly, UV-Visible spectrophotometer was selected to investigate the optical behavior of films.

In this work, thin films were synthesized by using different deposition methods. The obtained films were characterized in terms of their electrical properties.

Literature survey

Naglaa and Masaya, 2005 [39] have reported the deposition of zinc sulfide films on glass substrate using pulsed electrochemical deposition. They proposed that the ZnS films were grown from aqueous solutions containing sodium thiosulphate and zinc sulphate with two different compositions. They conclude that the resistivity ($10^4 \Omega$cm) of the as-deposited thin films (prepared from the zinc sulphate rich solution and sodium thiosulphate rich solution) is lower than the resistivity of the annealed films ($10^5 \Omega$cm). It could be attributed to the existence of the zinc in the films, which provides the as-deposited film in gray colour. Additionally, this metal zinc can play a role as a shunt path in the electrical measurements and finally, reduce the resistivity. Low resistivity will give high power factor, higher fill factor and high efficiency. As a result, this behavior makes the films very promising for solar cell applications.

The influence of zinc doping on the electrical properties of lead sulphide films have been studied by Baligh et al., 2015 [40]. The Hall Effect measurements indicate that the value of resistivity of films was affected by the zinc doping in an increasingly proportional manner, whereas from 0.28 to 691.1 Ωcm when increasing zinc doping concentration from 0 to 2 %. It can be attributed to reduce in crystallite size which will increase the grain boundary.

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The effect of Sb doping on the properties of PbS films has been investigated by Kumar et al., 2014 [41]. They describe that the solutions were prepared in triple distilled water and the pH was maintained at 12.56. In the electrical characterization, resistance of the films was investigated by the slope of the I-V curves. They point out that the resistivity was observed to be increased with reducing the Sb doping in PbS. The obtained resistivity values have been found to be in the range $1.29 - 3.7 \times 10^6 \Omega$cm.

Al doped PbS films were synthesized on soda lime glass substrate using simple chemical bath deposition technique as proposed by Preetha and Remadevi, 2012 [42]. Resistivity measurements were performed in their research and electric contacts were given using silver electrodes. Generally, they figure out that reduce in resistivity of bulk compounds if compared to the un-doped compounds.

Khomane,2013 [43] proposed preparation of $CdS_{0.5}Se_{0.5}$ films by an inexpensive chemical bath deposition method. The films were deposited onto non-conducting glass substrate at bath temperature of 70 °C. The obtained films were yellowish orange in colour. The electrical resistivity reduces with increase in temperature from 300 to 500 K, indicating an increase in the crystallite size. Finally, they conclude that the electrical specific resistivity was estimated about $10^6 \Omega$cm.

Spray pyrolysis was used to prepare CuS films as developed by Nho et al.,2012 [44]. They claim that this deposition technique could prepare large-area films without post deposition annealing and additives. The CuS films were synthesized from solutions of $(NH_2)_2CS$ and $CuCl_2$ mixed at ratios of 3:2, 4:1 and 5:1 on glass substrates in the temperature range of 160 to 240 °C. The electrical investigation show that for all ratios of starting materials, the low resistivity was stable obtained at temperatures from 170 -220 °C. However, high resistivity could be seen for the sample prepared at 240 °C.

Cu-doped PbS films were prepared on glass substrates using chemical bath deposition method as reported by Zheng et al., 2016 [45]. The substrate was dipped vertically into bath containing $Pb(CH_3COOH)_2$, NaOH and $SC(NH_2)_2$. It is observed that resistivity of the films reduce from 16 Ωcm to 0.15 Ωcm as the copper concentration increases from 0 to 6.3 %. This phenomenon could be explained by the fact that an increase in the carrier concentration and larger crystallite sizes. However, resistivity increases from 0.15 Ωcm to 1.09 Ωcm for further increase in copper concentration from 6.3% to 7.9%. In this case, they explain that an increase in resistivity is because of increase in the grain boundaries, lattice defects and discontinuities.

Chemical spray deposition technique was employed to prepare $Cd_{1-x}Fe_xSe$ films onto glass substrate as proposed by Ashok and Syed, 2015 [46]. During the experiment, ferric chloride, cadmium chloride and selenium powder were used as the precursors. They observe that the electrical resistivity of these films is of the order of $10^6 \Omega$cm and indicates variation depending on "x" value. On the other hand, they point out that the electrical resistivity for CdSe and FeSe films are $10.7 \times 10^6 \Omega$cm and $1.23 \times 10^6 \Omega$cm, respectively.

Chemical bath deposition method was used to produce Cu_2S thin films in the presence of precursors such as copper chloride, thiourea and ammonia as described by Shinde et al., 2012 [47]. Deposition was carried in alkaline conditions (pH between 8 to 9) at room temperature. They conclude that the electrical resistivity reduces from 6.4×10^{-2} to $8.9 \times 10^{-3} \Omega$cm when the thickness increases from 130 to 400 nm. They explain that when film thickness increases, the islands of aggregated particles transform into continuous bands. On the other hand, Soliman et al., 2015 [48] also produce similar results. They claim that electrical resistivity decreases with increasing thermal evaporated Cu_2S film thickness from 113 to 453 nm.

On the other hand, quaternary thin films have been prepared by many researchers. Kumar et al., 2009 [49] have reported that Cu_2ZnSnS_4 films were synthesized using spray pyrolysis method on soda lime glass substrate. The electrical resistivity was investigated using Van Der Pauw technique for the films deposited under various substrate temperatures in the range of 563 to 723 K. They conclude that the resistivity was found to vary from 0.2 to 2 Ωcm. Mkawi et al., 2013[50] suggest that the electrical property depend on the copper concentration in the precursor. They can observe that the resistivity of electrodeposited Cu_2ZnSnS_4 films decreased from 12.5 to 6.98 Ωcm with increasing the copper content from 0.01 M to 0.04 M.

CONCLUSION

The electrical resistivity of the films was successfully measured by using different tools. The SI unit of resistivity is the ohm.meter. Generally, low resistivity means a particular film that readily allows the flow of electric current. The

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obtained results indicate that there are many conditions such as film thickness, crystallinity of sample, and morphology of films can affect electrical resistivity properties.

REFERENCES

[1] K.W. Liu, J.Y. Zhang, D.Z. Shen, B.H. Li, X.J. Wu, B.S. Li, Y.M. Lu, X.W. Fan, *Thin Solid Films*, **2007**, 515, 8017.

[2] G. Abdullah, H.M. Ibrahim, *J. Sol Gel Sci. Technol.*, **2013**, DOI10.1007/s10971-013-3194-3.

[3] P.P. Shiv, J.C. Pivin, R. Chandra,D. Kanjilal, L. Kumar, *Vacuum*, **2015**, 111, 150.

[4] S.A. Muhammad, G.A. Yousef, A.M. Mohammad, M.A.K. Rana, R. Saira, N. Shahzad, *J. Mater. Chem. C*, **2015**, 3, 6755.

[5] A.A. Moayad, *Moldavian J. Phys. Sci.*, **2005**, 4, 313.

[6] P. Gupta, B. Maiti, A.B. Maity, S. Chaudhari, A. K. Pal, *Thin Solid Films*, **1995**, 260, 75.

[7] G. Sasikala, R. Dhanasekaran, C. Subramanian, *Thin Solid Films*, **1997**, 302, 71.

[8] K. Anuar, W.T. Tan, N. Saravanan, L.K. Khor, S.M. Ho, *J. Nepal Chem. Soc.*, **2010**, 25, 2.

[9] M.M. El-Nahass,*Appl. Phys. A SolidsSurf.*,**1991**, 52, 353.

[10] K. Anuar, K. Zulkefly, S. Atan, W.T. Tan, S.M. Ho, N. Saravanan, *Indian J. Eng. Mater. Sci.*,**2010**, 17, 295.

[11] R.D. Soumya, K.S. Ajaya, D. Lata, L.J. Paliwal, R.S. Singh, A. Rameshwar, *J. Saudi Chem. Soc.*, **2014**, 327.

[12] S.M. Ho, *Oriental J. Chem.*, **2014**, 30, 1009.

[13] Z. Ali, A.K.S. Aqili, A.Maqsood, S.M.J. Akhtar, *Vacuum*,**2005**, 80, 302.

[14] K. Anuar, R. Nani, S.M. Ho, *Int. J. Adv. Eng. Sci. Technol.*,**2011**, 7, 169.

[15] Q. Liang, G. Zeng, B. Li, W. Wang, H. Jiang, J. Zhang, W. Li, L. Wu, L. Feng, *J. Wuhan Univ. Technol. Mater. Sci. Ed.*, **2015**, 30, 307.

[16] K. Anuar, S.M. Ho, N. Saravanan, K. Noraini, *Arabian J.Chem*, **2010**, 3, 243.

[17] Y.W. Choi, M.S. Seol, W.S. Kim, K.J. Yong, *J. Phys. Chem. C*,**2014**, 118, 5664.

[18] K. Anuar, W.T. Tan,A. Dzulkefly, J.H. Md, S.M. Ho, M. Shanthi, N. Saravanan, *Jurnal Kimia*, **2010**, 4, 1.

[19] T.M. Khan, M.F. Mehmood, A. Mahmood, A. Shah, Q. Raza, A. Iqbal, U. Aziz, *Thin Solid Films*, **2011**, 519, 5971.

[20] K. Anuar, S.M. Ho, Kelvin, W.T. Tan, N. Saravanan, *Eur. J. Sci. Res.*,**2011**, 66, 592.

[21] G. Bakiyaraj, R. Dhanasekaran, *Cryst. Res. Technol.*,**2012**, 47, 960.

[22] K. Anuar, S.M. Ho, W.T. Tee, K.S. Lim, N. Saravanan, *Res. J. Appl. Sci. Eng. Technol.*,**2011**, 3, 513.

[23] R.B. Kale, C.D. Lokhande, R.S. Mane, S.H. Han, *Appl. Surf. Sci.*,**2006**, 252, 5768.

[24] K. Anuar, S.M. Ho, *Int. J. Chem. Res.*,**2010**, 1, 1.

[25] M. Tomakin, M. Altunbas, E. Bacaksiz, S. Celik,*Thin Solid Films*, **2012**, 520, 2532.

[26] K. Anuar, S.M. Ho, S. Atan, N. Saravanan, *Stud. Univ. Babes Bol. Chem.*,**2010**, 55, 5.

[27] R.I. Chowdhury, M.S. Islam, F. Sabeth, G. Mustafa, S.F.U. Farhad, D.K. Saha, F.A. Chowdhury, S. Hussain, A.B.M.O. Islam, *Dhaka Univ. J. Sci.*,**2012**, 60, 137.

[28] X.X. Liu, Z.G. Jin, S.J. Bu, J. Zhao, Z.J. Cheng, *J. Inorg.Mater.*,**2004**, 19, 691.

[29] K. Anuar, S.M. Ho, N. Saravanan, *Turk. J. Sci. Technol.*,**2011**, 6, 17.

[30] C.M. Shen, X.G. Zhang, H.L. Li,*Appl. Surf. Sci.*, **2005**, 240, 34.

[31] K. Anuar, S.M. Ho, W.T. Tan, C.F. Ngai, *Am. J. Appl. Sci.*,**2011**, 8, 359.

[32] A. Bansal, P. Rajaram, *Mater. Lett.*,**2005**, 59, 3666.

[33] K. Anuar, S.M. Ho, W.T. Tan, J. Md, S.Y. Gwee, *Thammasat Int. J. Sci.Technol.*, **2010**, 15, 62.

[34] J.H. Lee, W.C. Song, J.S. Yi, K.J. Yang, W.D. Han, J. Hwang, *Thin Solid Films*, **2003**, 431, 349.

[35] T, Mahalingam, S. Thanikaikarasan, R. Chandramohan, K. Chung, J.P. Chu, S. Velumani, J.K. Rhee, *Mater. Sci. Eng. B*, **2010**, 174, 236.

[36] K. Anuar, S.M. Ho, W.T. Tan, Kelvin, N. Saravanan, *Eur. J. Appl. Sci.*,**2011**, 3 75.

[37] R.B. Kale, C.D. Lokhande, R.S. Mane, S.H. Han, *Appl. Surf. Sci.*,**2006**, 252, 5768.

[38] K. Anuar, S.M. Ho, K.S. Lim, N. Saravanan, *Chalcogenide Lett.*, **2011**, 8, 405.

[39] F. Naglaa, I. Masaya, *Sol. Energy Mater. Sol. Cells*,**2005**, 87, 747.

[40] T. Baligh, G. Abdelaziz, A. Salem, K. Najoua,*Mater. Sci. Semicond. Process*, **2015**, 34, 82.

[41] R. Kumar, R. Das, M. Gupta, V. Ganesan, *SuperlatticesMicrostruct.*,**2014**, 75, 601.

[42] K.C. Preetha, T.L. Remadevi, *Phys. B*, **2012**, 407, 4173.

[43] A.S. Khomane, *Optik*,**2013**, 124, 2432.

[44] P.V. Nho, P.H. Ngan, N.Q. Tien, H.D. Viet, *Chalcogenide Lett.*, **2012**, 9, 397.

[45] X. Zheng, F. Gao, F. Ji, H. Wu, J. Zhang, X. Hu, Y. Xiang,*Mater. Lett.*,**2016**, 167, 128.

[46] U.U. Ashok, G.I. Syed, *J. Saudi Chem. Soc.*, **2015**, 19, 667.

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[47] M.S. Shinde, P.B. Ahirrao, I.J. Patil, R.S. Patil, _Indian J. Pure Appl. Phys._, **2012**, 50, 657.

[48] H.S. Soliman, M.M. Saadeldin, K. Sawaby, A. Eldenglawey, _Canadian J. Pure Appl. Sci._, **2015**, 9, 3247.

[49] Y.B.K. Kumar, G.S. Babu, P.U. Bhaskar, V.S. Raja, _Sol. Energy Mater. Sol. Cells_, **2009**, 93, 1230.

[50] E.M. Mkawi, K. Ibrahim, M.K.M. Ali, A.S. Mohamed, _Int. J. Electrochem. Sci._, **2013**, 8, 359.