

# RBS Characteristic of $\text{Cd}_{1-x}\text{Zn}_x\text{S}$ Thin Film Fabricated by Vacuum Deposition Method

N. Dahbi, D-E. Arafah

**Abstract**— $\text{Cd}_{1-x}\text{Zn}_x\text{S}$  thin films have been fabricated from ZnS/CdS/ZnS multilayer thin film systems, by using the vacuum deposition method; the Rutherford backscattering (RBS) technique have been applied in order to determine the: structure, composition, depth profile, and stoichiometric of these films. The influence of the chemical and heat treatments on the produced films also have been investigated; the RBS spectra of the films showed that homogenous  $\text{Cd}_{1-x}\text{Zn}_x\text{S}$  can be synthesized with  $x=0.45$ .

**Keywords**— $\text{Cd}_{1-x}\text{Zn}_x\text{S}$ , chemical treatment, depth profile, heat treatment, RBS, RUMP simulation, thin film, vacuum deposition, ZnS/CdS/ZnS.

## I. INTRODUCTION

IN solar cell of CdTe, the lattice mismatch between n-CdS and p-CdTe and the low band gap of CdS window layer are known to have some drawbacks on the cell performance [1], [2].

However, using higher bandgap materials like ZnS or  $\text{Cd}_{1-x}\text{Zn}_x\text{S}$  as heterojunction partner to CdTe can improve the window bandgap [2]; so the zinc-based binary and ternary group II–VI compounds (ZnS,  $\text{Cd}_{1-x}\text{Zn}_x\text{S}$ , ZnSe, and  $\text{Cd}_{1-x}\text{Zn}_x\text{Se}$ ) are of great importance in optoelectronic applications [3], [4]. Other word, because of their band gaps, any of these materials can be an excellent window layer in CdTe thin film solar cells, which is permit to use it in large applications, such as electroluminescent, photoluminescent and photoconductor devices and especially in photovoltaic cells [5].

### A. RBS Technique

The Rutherford Backscattering technique (RBS) is a well known method for studying the surface composition and depth profile of solids; this technique has been considered for the measurement of dose accumulation in a semiconductor substrate during an implant. A typical RBS system consists of a scattering chamber equipped with sample manipulators and particle detectors [6].

The number of backscattered ions from any given element is proportional to its concentration. Therefore RBS can be used as a tool to investigate the depth profile of individual element in a solid quantitatively; the number of backscattering events that occur from a given element in a sample depends upon two factors: the concentration of the element and the

effective size of its nucleus [7]. The energy measured for a particle backscattered at a given angle depends, however, on two processes; particles loose energy while traversing through the sample, both before and after a collision [8], [9]. Rutherford backscattering is now firmly established [8], as one of the most quantitative and versatile techniques of ions beam analysis. It offers the following advantage:

- 1) Nondestructive and multielemental analysis technique.
- 2) Quantitative analysis (typically  $\pm 2\%$ ) for almost elements, without requiring calibrated standards.
- 3) Elemental composition (stoichiometry) (1-5% accuracy).
- 4) Elemental depth profiles with a depth resolution of 5 - 50 nanometers and a maximum depth of 2 - 20 microns.
- 5) Surface impurities and impurity distribution in depth.
- 6) Diffusion depth profiles between interfaces up to a few microns below the surface.
- 7) RBS is relatively fast, 5 to 20 minutes, samples are typical times for measurement
- 8) The analysis is not sensitive to chemical and physical environment in the sample is situated.
- 9) Vacuum requirements are not severe.

### B. RUMP Simulation

Spectral simulation is an extremely powerful tool for understanding complex RBS spectra involving overlap of numerous elements or compounds. After defining a theoretical sample structure consisting of numerous layers of varying thicknesses, a simulation is then generally done in an iterative manner to arrive at a best set of parameters in the sample structure which fit a given sample spectrum. Used properly, SIM can provide reliable estimates for layer thickness and compositions on extremely complex samples [10].

## II. PREVIOUS STUDIES

A study by Isaiah et al. [11] focused on synthesizing ZnS/CdS multilayer films and finding how chemically and thermally activated interdiffusion between these layers can be used to convert this multilayer to  $\text{Cd}_{1-x}\text{Zn}_x\text{S}$  films for optoelectronic applications. In our previous work [12] we demonstrated that homogeneous  $\text{Cd}_{1-x}\text{Zn}_x\text{S}$  thin films can be synthesized from vacuum deposited CdS/ZnS multilayer structures, with  $x=0.6$  through chemical and thermal-activated diffusion. In this work we prepared also a  $\text{Cd}_{1-x}\text{Zn}_x\text{S}$  films but from ZnS/CdS/ZnS structure. Most of the high efficiency solar cell preparation techniques involve the optimization of the properties of CdS/ZnS interface after the film deposition using  $\text{CdCl}_2$  and/or temperature processing [13].

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Although, the conventional vacuum evaporation has proved its potential as a low cost technique, there is very limited publication on the post deposition process induced trapping states in CdS/ZnS thin film solar cells deposited with this technique.

### III. PREPARATION OF TINS FILMS

$\text{Cd}_{1-x}\text{Zn}_x\text{S}$  window have been deposited onto quartz substrate from ZnS/CdS/ZnS multilayer structure by the following steps:

- 1) 0.03- $\mu\text{m}$  thick CdS film, sandwiched between two 0.04- $\mu\text{m}$ -thick ZnS films, was first deposited onto Quartz substrates by vacuum deposition method with a typical working pressure of  $10^{-4}$  Pa were used during evaporation.
- 2) A chemical treatment was used by dipping our films in 1%  $\text{CdCl}_2$  methanol solution for about 30 s.
- 3) Then, films were dried with an infrared lamp and then rinsed in the deionized water.
- 4) Finally the samples were annealed in air at 400 °C for 15min.
- 5) Rutherford backscattering (RBS) was used to characterize the films, the details of RBS - technique were showed in our previous work [12].

### IV. RESULT AND DISCUSSION

For further studies on the interdiffusion between layers, we consider Fig. 1, which shows a typical RBS spectrum of several layers of CdS and ZnS stacked on top of each other in the form ZnS/CdS/ZnS/Quartz structure. Data are shown before and after chemical treatment and proceeding thermal treatment for a backscattering yield of 2 MeV  $\text{He}^+$  ions plotted as a function of the energy of scattered ions. The data represented by the solid line is overlaid with a corresponding theoretical fit as generated by RUMP code. Clearly, the spectra indicate that the signals resulting from the matrix elements that are due to a uniform and homogeneous thick substrate (quartz) represented by two step edge signals for both O and Si. The other overlapping peaks are due to scattering from Cd, Zn, and S components. Separation was performed by deconvolution technique which was applied to each RBS experimental data, Fig. 2. In the untreated sample, Fig. 1 (a), if one examines the three layers where CdS is sandwiched between two ZnS layers, then intermixing of the three layers took place where such that chemically activated diffusion of Cd into ZnS film takes place more readily.

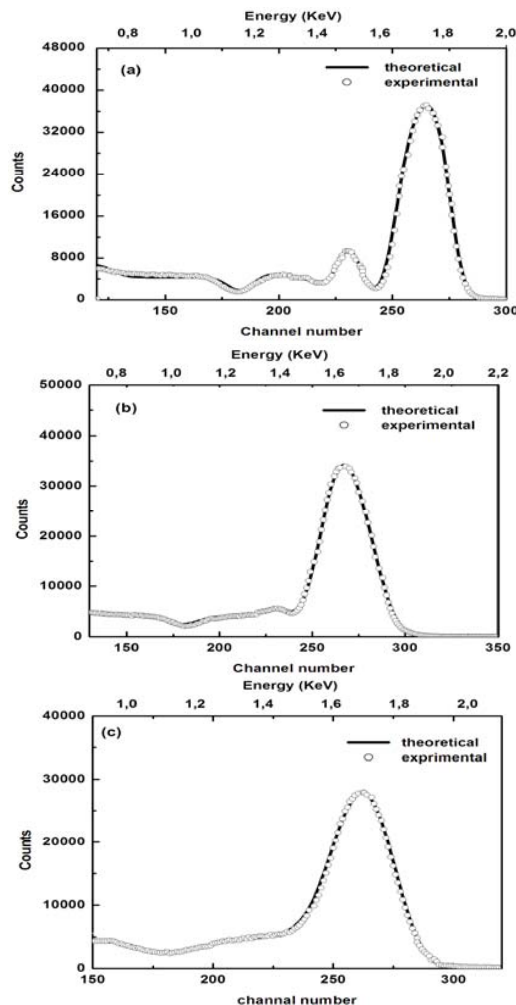


Fig. 1 Typical 2 MeV RBS spectrum of ZnS/CdS/ZnS structure deposited on quartz: (a) before chemical treatment, (b) after chemical treatment, and (c) after annealing at 400°C for 30s

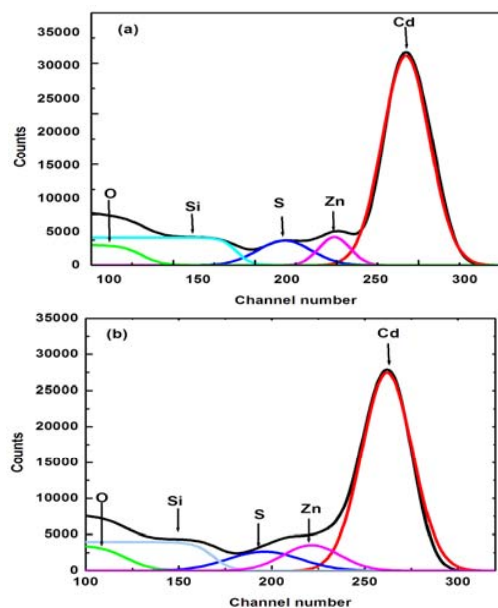


Fig. 2 Illustration of 2 MeV RBS spectrum deconvolution using peakfit program code, version 4, for ZnS/CdS/ZnS multilayer: (a) after chemical treatment, (b) after annealing at 400°C for 30s

After chemical treatment in  $\text{CdCl}_2$  for 30s, it is observed that the Cd signal shows an increase by 75% in width followed by a decrease in height by some 37%; this means that an increase in area due to the chemical treatment by about 10% is noted. The signal due to Zn shows a 64% decrease in height and an increase of 54% in width (22% decreases in area). The S signal exhibits a decrease by 46% in height and an increase of 49% in width (20% decreases in area). Comparison between depth profiles before and after chemical treatments, cf. Fig. 3 indicates that Cd, Zn, and S signals centers show movement towards the substrate, by 61%, 30%, and 52% respectively.

The depth profile of the same sample is shown in Fig. 3 as a compared with that after 400°C thermal annealing. Here, the Cd signal has increased by about 10% in the total area prior to annealing. Thermally activated diffusion seems to have increased the overall mixing of the layers. This latter has resulted in about 55% fluctuation of the Cd throughout the structure while the changes resulting in Zn are about 45% to finally obtain the structure  $\text{Cd}_{1-x}\text{Zn}_x\text{S}$  with  $x=0.45$ . From these observations, one may infer that Cd is readily more mobile in this structure than Zn; not only by thermally activated diffusion processes but also chemically activated diffusion. Shaw and Ruda [14], found that the diffusion coefficient of Cd, which is also a measure of the mobility, have previously reported an increase in  $\text{Zn}_{1-x}\text{Cd}_x\text{S}$  with the increase in  $x$  or Cd content, which is in agreement with our finding in relation to the high mobility of Cd. It is also obvious from Fig. 3 that the stacked thin layers of CdS and ZnS respond faster to intermixing processes than the stacked thick layers, as expected. Isaiah and his team [11], from the depth profile of ZnS/CdS/ZnS structure (the  $\alpha^2$  versus  $h\nu$  plot of the annealed

structure) shows a single sharp absorption edge in the energy region lying between the absorption edges of ZnS.

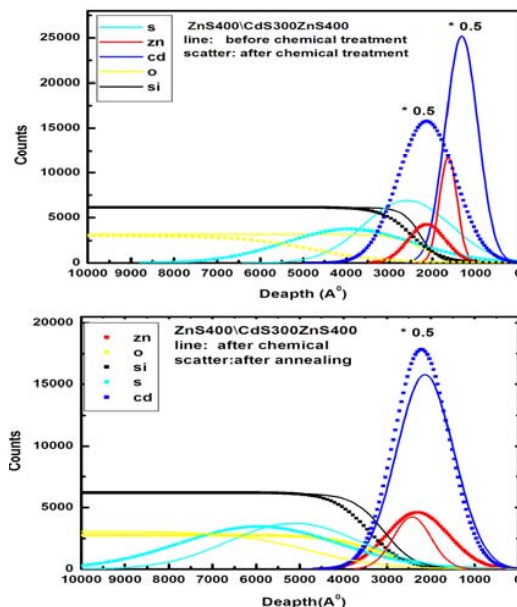


Fig. 3 Comparison between depths profiles of ZnS/CdS/ZnS multilayer before and after chemical and thermal treatments.

## V. CONCLUSION

In this study, we found that a homogenous  $\text{Cd}_{1-x}\text{Zn}_x\text{S}$ , with  $x=0.45$  thin films can be synthesized from vacuum deposited ZnS/CdS/ZnS multilayer onto quartz via vaporization method. As a future work we can study the photovoltaic parameters  $\text{CdTe}/\text{Cd}_{1-x}\text{Zn}_x\text{S}$ .

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## REFERENCES

- [1] T. Chu, S. Shirley, and S. Ang, "Electrical properties of CdS/CdTe heterojunction," J. Appl. Phys. vol. 64(3), pp. 1233-1237, 1988.
- [2] T. Chu, S. Chu, J. Britt, C. Ferekides, and C. Q. Wu, "Cadmium zinc sulfide films for heterojunction devices", *IEEE Photovoltaic Specialist Conference*. Vol. 2, 7-11, 1991, pp. 1136-1140.
- [3] L. Arriaga, and A. Fernández, "Determination of flat band potential and photocurrent response in (Cd,Zn)S used in photoelectrolysis process", *International Journal of Hydrogen Energy*, vol.27 (1), pp. 27-31, 2002.
- [4] H. Mar, and H. Ruda, *Wide gap II-VI Compounds for Opto-electronic Application*. New York: Chapman & Hall, 1992, ch.7.
- [5] J. Dona, and J. Herrero, *Thin Solid Films*. Vol. 268, pp. 5-12, 1995.
- [6] R. Tesmer, and M. Nastasi, *Handbook of Modern Ion Beam: Materials Analysis*. Pittsburgh, MRS, 1995.
- [7] J. Ziegler, and J. E. J. of Appl. Phys. vol. 45, pp.1888, 1974.
- [8] W. Chu, J. Mayer, and M. Nicolet, *Backscattering Spectrometry*. Florida: Academic Press, 1978.
- [9] J. Williams, and J. Poate, *Ion Implantation and Beam Processing*. Australia: Academic Press, 1984.

- [10] L.Doolittle, "Algorithms for Rapid Simulation of Rutherford Backscattering Spectra", *Nucl. Instru.and Meth*, vol. B9, 3, pp. 344-351, 1985.
- [11] O.Isaiah, I.Oladeji, and L.A.Chow, "Synthesis and processing of CdS/ZnS multilayer films for solar cell application", *Thin Solid Films*, vol. 474,pp. 77-83, 2005.
- [12] N. Dahbi, and D. A rafah, "Characterization and Processing of CdS/ZnS Thin Layer Films Deposited onto Quartz for Solar Cell Applications", *Energy Procedia, Science Direct*, vol. 18, Pgs1-1624, pp. 85-90, 2012.
- [13] V.Komin, B.Tetali, V.Viswanathan, D.Morel and C.Ferekindes, "The effect of the CdCl<sub>2</sub> treatment on CdTe/CdS thin film solar cells studied using deep level transient spectroscopy", *Thin Solid Films*, vol. 431-432, pp. 143-147, 2003.
- [14] D. Shaw In, and H. Ruda, *Wide Gap II-VI Compounds for Opto-Electronic Applications*. New York: Chapman & Hall, 1992, ch. 10.