OPTICAL AND ELECTRICAL CHARACTERISTICS OF E-BEAM EVAPORATED ZnS_xSe_{1-x} THIN FILMS

By

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A thesis submitted for the degree of Doctor of Philosophy

At the Institute of Postgraduate Studies and Research

University of Malaya

Kuala Lumpur

December, 1997

ACKNOWLEDGEMENT

To the Almighty **Allah** I give thanks for giving me the help and strength to complete this research. I would also like to express my sincere gratitude to both of my supervisors: **Professor Dr. S. Radhakrishna** and **Professor Dr. Muhamad Rasat Muhamad** whose guidance, advice, patience and assistance provided me the impetus to begin and complete this work.

I am indebted to **Mrs Vijaya Lakshmi** from I. P. S. P., University of Malaya for her great effort in obtaining SEM micrographs and EDX spectra.

My thanks are also due to the staff members in Physics Department, especially in the **Solid State Laboratory**, for allowing me to use the equipment and facilities during the experimental part of this work.

To my friends and colleagues in I. P. S. P. and in **Material Science Laboratory**, especially **Mr. S. Anandan**, I express my deep appreciation for constructive discussion.

I am grateful to **Miss Habibah binti Shaari** in the office of the Department of Physics, and **Miss Zubaidah binti Yusup** in the office of I. P. S. P. for their assistance. My special thanks are registered to **Miss Teoh Mei Lin** for her encouragement and assistance in reading the draft of this thesis.

I would like to acknowledge here that this work has been supported by **Physics Department, IRPA** 09-02-03-0138. My gratitude and appreciation also go to **Public Service Department Malaysia** for awarding me a scholarship under the Malaysian Technical Cooperation Programme (**MTCP**) during the course of this work.

I would like to express my profound gratitude to the **Arab Student Aid International** for awarding me a scholarship loan during this study.

Finally, this work would not have been possible without the encouragement of my beloved parents, **Mohamed** and **Zarifa**, four **brothers** and five **sisters** and their families who prayed for my success and gave me every kind of support I need.

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ABSTRACT

Thin films of ZnS_xSe_{1-x} ($0 \leq x \leq 1$) were prepared by electron beam (e-beam) evaporation technique. The films were deposited onto glass substrates held at about 60 ° C and were fixed horizontally 15 cm above the source material. The vacuum chamber base pressure was about 2×10^{-5} torr during the deposition process. The atomic percentage of the film constituents obtained from an energy dispersive x-ray analyzer (EDX) has shown that zinc (Zn) contributes with almost 40 % of the atomic parcentage to the film composition. Sulphur (S) compositional fraction (x) has been estimated from the atomic percentages of sulphur and selenium (Se) in the individual film. The results indicated that films with x between 0.12 and 1.0 have been obtained. Scanning electron micrographs of film morphology have shown that the films exhibit smooth surfaces with relatively large grains embedded in a matrix of finer grains. The analysis of the pronounced diffraction peaks detected by x-ray diffraction (XRD) technique indicates that the films are polycrystalline with cubic structure growing preferentially along <111> axis. The grain diameter has been estimated from the broadening of the diffraction peak and is found to be in the range of 158 - 662 Å. The cubic lattice parameter a_0 has been found to vary linearly with x following Vegard's law. However, the difference between a_0 values for thin film and single crystal of ZnS_xSe_{1-x} materials has been used to estimate the stress experienced inside the films. Most of the films exhibit tensile stress with values in the range of $0.51\text{-}17 \times 10^9$ dynes/cm^2 with exception of six samples which exhibit compressive stress in the range of -4.6 to -0.05×10^9 dynes/cm^2.

A new method has been developed to estimate the thickness and the optical parameters of the films by using the experimental values of the transmission spectrum. The results of this method have been found to be in a good agreement when compared with the values obtained from the well-known envelope method. The empirical relations in the dielectric theory have been used to estimate the characteristic energies such as Penn energy gap, plasma energy, Fermi energy, the average energy of the valence electrons, the energy of the effective dispersion oscillator and the dispersion energy. The absorption edge shows three distinct regions, the high-absorption region ($\alpha > 10^{4}$ cm $^{-1}$), the exponential part and the weak-absorption tail. Depending on the film composition the direct optical energy gap E_g has been determined to be in the range of 2.58-3.73 eV. The variation of E_g with x has been found to be in a reasonable agreement with the results previously reported by other workers. The effect of the uniaxial stress and the grain size on the energy gap has been studied and the shift produced in E_g from these effects has been estimated.

The electrical dc-conductivity of the films has been investigated. The ohmic behaviour of the current - voltage (I - V) characteristics indicates a good electrical contact between the metal electrodes and the sample. The model proposed by Mott and Davis has been employed in order to explain the variation of conductivity with temperature in the range of 20 - 475 K. The effects of various parameters such as sulphur concentration, film thickness and grain size on the activation energy and the conductivity of ZnS_xSe_{1-x} films have been investigated. It was found that, as in the other II - VI compounds the impurities and native defects, which might be unintentionally introduced into the films during their preparation, have a significant contribution to the dc - conductivity.

ABSTRAK

Filem-filem nipis ZnS_xSe_{1-x} ($0 \leq x \leq 1$) telah di sediakan dengan menggunakan penyejatan alur elektron. Filem-filem ini telah dimendapkan ke atas substrat kaca pada suhu 60 ^{0} C dan diletakkan melintang 15 cm di atas sumber bahan tersebut yang berada pada tekanan 2×10^{-5} torr ketika proses pemendapan. Peratus atom kandungan filem yang diperolehi dari suatu pengalisis sebaran sinar - X (EDX) menunjukkan bahawa zink (Zn) menyumbangkan hampir 40 % daripada atom kepada komposisi filem. Pecahan komposisi (x) sulfur (S) telah dianggarkan dari peratusan atom sulfur dan seleneum (Se) dalam filem individu dan keputusannya menunjukkan bahawa filem-filem yang diperolehi mempunyai nilai *x* antara 0.12 dan 1.0. Mikrografs mikroskop imbasan elektron (SEM) yang diambil pada permukaan filem menunjukkan bahawa filem-filem ini mempamirkan permukaan yang rata dengan hablur bersaiz besar ditabur dalam matrik yang lebih halus. Analisis corak interferens dari kesan belauan sinar - X (XRD) menunjukkan bahawa filem-filem itu adalah polihablur dengan struktur kubus yang tumbuh berorientasikan arah < 111 >. Garis pusat hablur yang diukur dari pelebaran corak interferens dianggarkan diantara 15.8 - 66.2 nm. Pemalar kekisi a_0 didapati berubah secara linear dengan *x* mengikut Hukum Vegard. Seterusnya, perbezaan antara nilai untuk filem nipis dan hablur tunggal bahan ZnS_xSe_{1-x} digunakan untuk mengukur tegasan yang telah dihasilkan di dalam filem-filem itu. Kebanyakan filem itu menunjukkan bahawa ia mengalami tegasan tensil dengan nilai dalam lingkungan $0.51\text{-}17 \times 10^{19}$

dynes/cm sementara enam sampel menunjukkan bahawa ia mengalami tegasan mampatan dalam lingkungan – 4.6 ke – 0.05 × 10^{19} dynes/cm.

Satu kaedah baru telah dicadangkan untuk mengukur ketebalan dan pemalar optik filem-filem dengan mengunakan nilai spektrum transmisi yang diukur. Keputusan yang diperolehi dengan cara ini didapati sama tepat dengan yang diperolehi dari kaedah bungkusan. Hubungan empirik dalam teori dielekrik telah digunakan untuk mengukur sifat sifat tenaga valen, cirian jurang tenaga Penn, tenaga plasma, tenaga Fermi, tenaga purata elektron, tenaga sebaran penggetar berkesan dan tenaga sebaran. Spektrum pekali serapan α menunjukkan tiga kawasan yang berlainan; kawasan penyerapan tinggi ($\alpha > 10^4$ cm^{-1}), bahagian eksponen dan ekor penyerapan lemah. Bergantung kepada komposisi filem jurang tenaga optik terus E_g didapati berada dalam lingkungan 2.58 - 3.73 eV. Perbezaan E_g dengan x didapati bersetuju dengan keputusan yang diperolehi terdahulu. Kesan tekanan unipaksi dan saiz hablur kepada jurang tenaga dikaji dan perubahan yang dihasilkan pada E_g dari kesan-kesan ini telah diukur.

Sifat elektrik filem-filem diselidik melalui pengkonduksian arus terus (dc). Perlakuan ohm pada ciri arus – voltan (I-V) menunjukkan pengkonduksian baik antara elektod logam dan permukaan sampel tersebut. Model yang dikemukakan oleh Mott dan Davis telah digunakan untuk menerangkan perbezaan pengkonduksian dengan suhu pada julat 20 - 475 K. Kesan-kesan struktur filem, seperti kepekatan sulfur, ketebalan filem dan saiz hablur kepada tenaga pengaktifan dan pengkonduksian ZnS_xSe_{1-x} filem dikajikan. Adalah didapati bahawa seperti dalam semua sebatian II-VI, kecacatan dan pengdopan yang mungkin diperkenalkan secara tak sengaja ke dalam filem-filem itu semasa proses pemendapan, boleh mempengaruhi pengkonduksian arus terus.