

07.8-6 AEM STUDY OF CVD LOW-CARBON BORON CARBIDE PHASES. By K.L. Smith and I.D.R. Mackinnon, Department of Geology, University of New Mexico, Albuquerque, New Mexico, U.S.A.

Boron carbides are hexagonal p-type semiconductors, with electrical conductivity nearly independent of temperature. Boron carbides have large Peltier heats and are resistant to radiation damage. Thus, they are promising materials for thermoelectric power generation in nuclear reactors or in space [1]. Distortions of the boron carbide lattice from ideal periodicity (stacking faults, twins etc.) dramatically increase the Peltier coefficient.

Kevill et al. (1986) manufactured boron carbides with nominal compositions of 16.5 and 6 at.% C [2]. The latter composition is well outside the accepted single-phase composition range of 10-20 at.% C. SEM studies showed that the samples with 16 at.% C are hexagonal plates and that the boron carbides with 6 at.% C are needles with truncated pyramidal terminations.

A high resolution TEM and EDS study of these CVD products [2] shows that three phases are present: 1) Needles with truncated pyramidal terminations and unit-cell parameters similar to known boron carbides. 2) Crystal plates with unit cell parameters similar to known boron carbides, which show superlattice ordering and contain trace amounts of Mg and Si. 3) Hexagonal crystal plates with  $a = 4.4\text{\AA}$  and containing small but significant amounts of Si and Al. The first two phases are consistent with Kevill et al.'s results, whereas the latter crystals may represent a new boron carbide phase. In addition, superlattice ordering has not been reported previously and may represent another mechanism by which the Peltier coefficient could be increased.

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1. Emin D. (1987) Icosahedral boron-rich solids. *Physics Today*, Jan 87, 55-62.
2. Kevill D.N., Rissmann T.J., Brewe D. and Wood C. (1986) Growth of crystals of several boron-carbide compositions by chemical vapor deposition. *J. Crystal Growth*, 74, 210-216.

07.8-7 COMPOSITION DEPENDENCE OF STRUCTURAL PROPERTIES OF FLASH EVAPORATED  $\text{Cu}_{2-x}\text{In}_x\text{Se}_2$  THIN FILMS. By Preeti Kashyap, Mukesh Jain, O.P. Agnihotri, H.K. Sehgal, Department of Physics, Indian Institute of Technology, Delhi, India.

There is considerable interest in the study of ternary alloy semiconductor films because of their possible use in electronic and opto-electronic applications.

$\text{Cu In Se}_2$ , a I-III-VI<sub>2</sub> semiconductor, is a suitable material for applications in solar cells, optical detectors and light-emitting diodes because of its high absorption coefficient, direct band gap, stability, etc (L.L. Kazmerski, *Nuovo Cimento*, 1983, 2D, 2013-2027).

The crystalline properties of  $\text{Cu In Se}_2$  thin films using a variety of processes have been reported, but the results are inconclusive (M. Varela et al., *Thin Solid Films*, 1985, 130, 155-164).  $\text{Cu}_{2-x}\text{In}_x\text{Se}_2$  were deposited at different substrate temperatures by flash evaporation method, one of the best techniques for growing stoichiometric films of the alloys in which the constituents have different vapour pressures (Mukesh Jain et al., *Infrared Physics*, 1984, 24, 417).

Transmission Electron Microscopy investigations carried out on these 200-300 Å thick films indicate that the films are polycrystalline with f.c.c. structure. Lattice parameter and average grain size vary with a change in substrate temperature and the composition of the films. The lattice constant shows a maximum for  $x=1$  and then decreases with any variation in  $x$ . Lattice parameters of the films deposited at higher temperatures show lower values as compared to the films deposited at lower substrate temperatures with the same value of  $x$ .

Optical band gap varies linearly with composition and indicates the feasibility of this material for Photovoltaic application since the band gap is suitably wide. Preparation of Photovoltaic devices using flash evaporated  $\text{Cu}_{2-x}\text{In}_x\text{Se}_2$  is in progress in our laboratory.

07.8-8 PROPERTIES OF FLASH EVAPORATED EPITAXIAL LEAD MERCURY CHALCOGENIDE FILM. By Mukesh Jain and H.K. Sehgal, Department of Physics, Indian Institute of Technology, Hauz Khas, New Delhi - 110016, India.

Thin films of lead mercury chalcogenides ( $\text{Pb}_{1-x}\text{Hg}_x\text{CH}$ ;  $\text{CH}=\text{S, Se and Te}$ ;  $0.07 \leq x \leq 0.93$ ), useful materials for I.R. detectors (N.C. Sharma et al., *Appl. Opt.*, 1977, 16, 2945; D. Trbojevice et al., *Infrared Physics*, 1980, 20, 193), were grown on freshly cleaved KBr(100) single crystal substrates by flash evaporation technique. Analysis of electron micrographs and diffraction patterns indicates that films deposited at low substrate temperature (25°C) show polycrystalline f.c.c. structure for lead rich ( $0.07 \leq x \leq 0.50$ ) films and amorphous in mercury rich ( $0.60 \leq x \leq 0.93$ ) films of lead mercury sulphide and lead mercury telluride materials, whereas, lead mercury selenide films show a f.c.c. polycrystalline structure. Lead rich films of these materials can be deposited as epitaxial with {100} zone axis orientation of the f.c.c. grains if the KBr substrates are maintained at 100°C during the growth. Optical band gap in the epitaxial films varies between 1.03 eV and 1.44 eV in lead mercury sulphide films, between 0.15 eV and 0.11 eV in lead mercury films, and between 0.23 eV and 0.13 eV in lead mercury telluride films. The magnitude of the direct optical band gap and lattice parameters decrease with increase in substrate temperature. The observed variation in structural and optical properties of the films with change in mercury concentration and growth conditions has been explained on the basis of an atom by atom condensation process. According to this process it is considered that the evaporated material leaves the heated boat and reaches the substrates in its atomic form. The random movement of the atoms trapped on the substrate is influenced by the substrate temperature and this is in turn influences the nucleation and growth of the deposited material leading to the observed structural variation in the new ternary  $\text{Pb}_{1-x}\text{Hg}_x\text{CH}$  lattices. Thermal and laser beam annealing also improve the structural symmetries of the films deposited at low temperature. The crystallographic structure of the films are observed to relax gradually to the higher symmetry structure i.e. epitaxial of the films grown at higher substrate temperatures. The lattice parameters of the annealed films are observed to be smaller than their counterparts grown at 25°C.