

**OPTICAL AND ELECTRICAL STUDIES ON MELT GROWN
LEAD TIN SELENIDE AND LEAD TIN TELLURIDE
CRYSTALS**

By

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**SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF
THE DEGREE OF DOCTOR OF PHILOSOPHY OF
INDIAN INSTITUTE OF TECHNOLOGY, NEW DELHI.**

1979

ACKNOWLEDGEMENT

In moments of accomplishment it is my privilege to express my deep sense of gratitude to my supervisor Professor O.P.Agnihotri for suggesting the area of investigation and the guidance he gave me. Without this help the present work would not have been possible.

I am extremely grateful to Professor M.S.Sodha and Professor S.S.Mathur for making my admission possible and provision of special facilities which helped me to complete this investigation.

I am also thankful to the following Professors: P.K.C.Pillai, D.S.Verma, I.K.Verma, A.B.Bhattacharyya and B.B.Tripathi for their support during the course of this work. My colleagues A.K.Garg, B.K.Gupta, R.Thangraj, A.Raza, V.Dhar, A.K.Sharma and F.K.Tiwari deserve kudos for providing valuable suggestions and their co-operation during the course of this work. Thanks are due also to H.B.Singh, H.S.Sharma, V.Dhar and V.D.Arora for expert and competent workshop assistance, spectroscopy, x-ray and electronmicroscopy work. I must not forget to thank the Library staff for their prompt service and ready help they gave me from time to time during my work.

I am also grateful to Dr. N.Seshagiri, Dr. S.G.Patil and Dr. S.L.Sarnot for their moral support and encouragement. I am deeply indebted to my family for living through my moments of emotional crisis and helping me overcome that through their love and guidance.

The support to this work by the School of Material Science and Technology, and the Electronics Commission is gratefully acknowledged.

Finally, I must thank Mr. S.D.Malik for efficient typing of the manuscript and Mr. N.S.Gupta for preparing excellent drawings of the diagrams.

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ABSTRACT

In the alloy systems $Pb_{1-x}Sn_xSe$ and $Pb_{1-x}Sn_xTe$, by varying the Pb/Sn ratio the energy gap can be adjusted to match wavelengths within the range 5-15 μm . The work on these compounds has been stimulated by their application in infrared detection both as sensors of thermal radiation and as wide band detectors. For detector purposes improvements are needed in the crystal growth methods to permit still better crystal uniformity and purity. Very little is known about electrically effective impurities and more work is required. In the present studies, $Pb_{1-x}Sn_xSe$ ($x = .1, 0.03$ and 0.17) and $Pb_{1-x}Sn_xTe$ ($x = 0.37$) crystals have been grown from the melt by a simplified bridgeman method. The essential equipment like double zone furnace and driving system with a slow speed for crystal growth were designed and fabricated. The growth parameters like the design of the ampoule, temperature gradient and pulling rate were optimised. Techniques of x-ray and electron diffraction have been used to investigate the structure of the as grown crystals. It has been found that SnSe crystal is orthorhombic with lattice parameters $a_0 = 4.30A^\circ, b_0 = 4.05A^\circ, c_0 = 11.62A^\circ$, and $Pb_{1-x}Sn_xSe$ ($x = 0.03$ and 0.17) and $Pb_{1-x}Sn_xTe$ ($x = 0.37$) crystals are cubic with lattice

parameter value $a_0 = 6.124 \text{ \AA}$, 6.106 \AA and 6.412 \AA respectively. The composition was determined for each crystal from the determined values of lattice parameters.

It is found that the as grown crystals are p-type with carrier densities in the range of 10^{18} per cm^3 . For the fabrication of efficient infrared devices low carrier densities are required. In order to reduce the carrier concentration, isothermal annealing experiments have been done. Carrier reduction and change of carrier type in the as grown $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$ ($x = 0.03$ and 0.17) was also achieved by cadmium diffusion experiments. It is found that diffusion experiments provide a quick method of reducing carrier concentration. Carrier concentration of the order of $\sim 10^{17}$ per cm^3 can be achieved in two to three day's time with cadmium diffusion while isothermal annealing takes much longer time (weeks) to reduce carrier concentration to the same level.

While the optical properties of PbSnTe have received some attention, not much work appears to have been done in PbSnSe . In order to understand the optical properties of PbSnSe , the properties of PbSe and SnSe should be known. While PbSe has been investigated in detail, not much is known about SnSe . The as grown SnSe crystals in the present investigation were of layer type and could easily be cleaved. Absorption coefficient and refractive index were determined

as a function of photon energy. It was found that the fundamental absorption in SnSe arises from an indirect allowed transition and the gap energy is 0.91 eV at 300K for lowest carrier concentration sample. The gap was found to vary between 0.91 eV to 0.92 eV for different carrier concentration samples. The values of E_g at 300 K for $Pb_{0.97}Sn_{0.03}Se$, $Pb_{0.83}Sn_{0.17}Se$ and $Pb_{0.63}Sn_{0.37}Te$ are 0.244, 0.112 and 0.108 eV respectively. The absorption coefficients for $Pb_{1-x}Sn_xSe$ ($x = 0.03$ and 0.17) and $Pb_{1-x}Sn_xTe$ ($x = 0.37$) in the long wavelength region is proportional to λ^2 and is due to free carriers. This free carrier absorption also depends on carrier concentration. From these measurements conductivity effective mass of holes has been determined for these samples. The optical dielectric constant in $Pb_{1-x}Sn_xSe$ and $Pb_{1-x}Sn_xTe$ have been determined and plotted as a function of composition alongwith the data of other investigators. At 300 K, the optical dielectric constant in $Pb_{1-x}Sn_xTe$ is between 40 to 60 and in $Pb_{1-x}Sn_xSe$ is between 20 to 35. In view of the smaller dielectric constant PbSnSe holds promise for fabricating devices with faster response time as compared to PbSnTe. Infrared plasma reflection measurements were carried on the as grown samples and effective mass of holes determined.

LIST OF PUBLICATIONS

1. X-ray Investigations on Bridgeman Grown $Pb_{1-x}Sn_xSe$ and $Pb_{1-x}Sn_xTe$ Single Crystals.
Int. Journal of Material Science and Engineering.,
accepted for publication (in press).
2. Single Crystal Growth of SnSe.
Int. Journal of Crystal Growth., accepted for
publication (in press).
3. Infrared Absorption in p-type PbSnSe
Nuclear Physics and Solid State Physics Symposium.
I.I.T. Bombay., Dec. 1978.
4. Crystal Growth and Optical Properties of ~~Pb~~SnSe
Journal of Physics and Chem. of Solids. (Communicated).
5. Optical Absorption Spectrum of Tin Diselenide Single
Crystals. Journal of Applied Physics. 47, 997 (1976).

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