STRUCTURAL, THERMAL, ELECTRICAL, AND OPTICAL PROPERTIES OF AMORPHOUS Ge-ALLOY FILMS

BY

PREM NATH M. Sc. (Hons. School), M. Tech.

Thesis submitted to the
Indian Institute of Technology, Delhi
for the Award of the Degree of
DOCTOR OF PHILOSOPHY

Department of Physics
Indian Institute of Technology, Delhi
May, 1975

THESIS SUPERVISOR:

Professor K.L. Chopra,
Thin Films and Materials
Science Laboratory,
Department of Physics,
Indian Institute of
Technology, Delhi,
New Delhi-110029(India).

ACKNOWLEDGEMENTS

It is a pleasure to express my profound gratitude to Professor K.L. Chopra. His inspiring guidance, constant encouragement, and critical evaluation, in all phases of this work, has been chiefly instrumental in inculcating in me a spirit of enquiry and a sense of devotion.

I wish to thank Dr. A. Bhaskara Rao, Technical Manager, Electronics Corporation of India, Ltd., for his continued interest in my work.

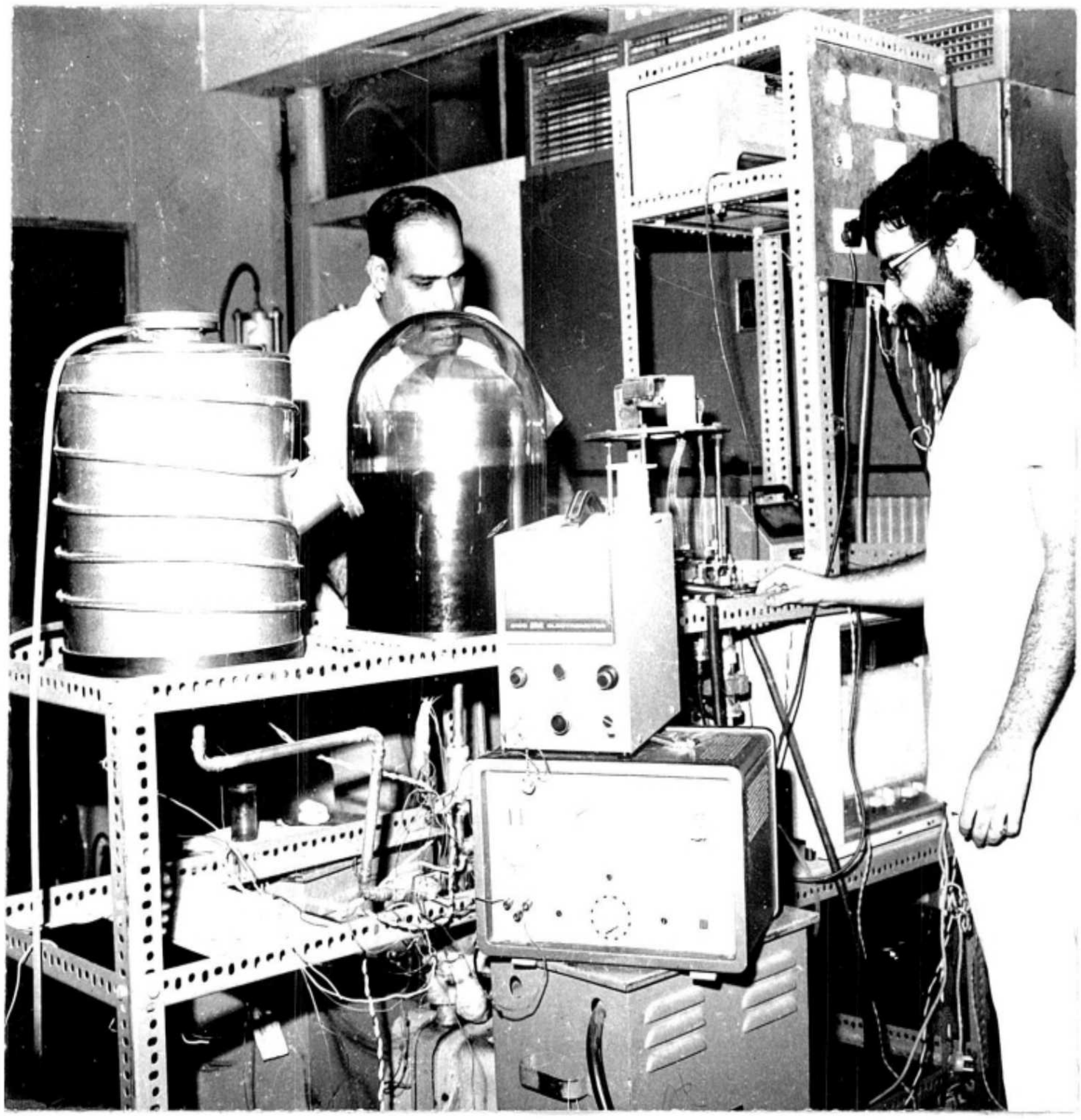
The unstinted cooperation extended by all my colleagues, especially Dr. A. C. Rastogi, of the Thin Film Group is gratefully acknowledged.

Thanks are also due to my colleague Mr. S. R. Das for reading the manuscript and making the necessary corrections.

The financial support extended by IIT Delhi, Council of Scientific and Industrial Research (India), and the Defence Grants-in-Aid Scheme of Defence Research and Development on "Electrical Properties of Amorphous Semiconductors," is gratefully acknowledged.

Special thanks are due to Mr. V.N. Sharma for his efficient typing of the manuscript.

(PREM NATH)



Vacuum unit fabricated by the author.

ABSTRACT

Stable, homogeneous, single phase, amorphous alloy films of Ge with different concentrations of Al, Cu, Fe, and Te have been prepared by simultaneous vapor deposition technique. Electron microscopy and electron diffraction studies show that these films are amorphous upto a maximum concentration of $\sim$20 at % for Cu, $\sim$20 at % for Fe, $\sim$30 at % for Al, and $\sim$80 at % for Te. The cyclic annealin and crystallization temperature studies of these films indicate that, whereas Al and Te increase the stability of the amorphous phase, the addition of Cu and Fe decreases it. The thermal conductivity measurements show that the phonon mean free path is independent of temperature. The value of the phonon mean free path yields the size of coherently scattering units as $\sim$3 Å for GeTe and $\sim$5 Å for Ge. The electrical resistivity decreases gradually with increasing Al content. In contrast, a rapid decrease in the electrical resistivity is observed in the case of Fe and Cu. The thermoelectric power of Ge-Cu and Ge-Fe systems assumes small values ($\sim$ several μV/deg) for Cu and Fe concentrations greater than a few at. %. In contrast, Ge-Al and Ge-Te systems exhibit large positive thermopower at all compositions. The temperature dependence of the electrical resistivity of the alloy films show that the

addition of Cu and Fe results in a drastic decrease in the activation energy of conduction. On the other hand, the addition of Al and Te increases the activation energy and, in fact, Ge-Al and Ge-Te films exhibit intrinsic-like conduction in the temperature range 100-400 K. The Ge-Cu and Ge-Fe films exhibit hopping conduction below 400 K and the related density-of-states is upto 100 times larger than in pure a-Ge films. In the low concentration region ($<$ 2 at. %), the metallic impurities cause the optical absorption edge of a-Ge to shift to higher energies. The changes are similar to those observed on annealing of pure a-Ge films. With increase in metal concentration, an increase in optical absorption at higher energies and a shift of the low absorption region of α Vs $h\nu$ curve to lower energies is observed. At sufficiently high metallic concentrations, a nearly flat spectral dependence of the absorption coefficient is observed and the absorption edge is poorly defined. In contrast to the behaviour of metallic impurities, amorphous Ge-Te films exhibit a well-defined absorption edge and the optical gap increases continuously with Te concentration up to $\sim$ 80 at. % Te.

CONTENTS