Name: ***Adam Abdullah Bahishti***
Supervisor: ***Prof. M. Zulfequar***
Co-supervisor: ***Prof. Mushahid Husain***
Department: Department of Physics
Title: ***Design and Fabrication of Photon Drag – Detectors and TEA CO_2 Laser as their Evaluation, and Study the Effect of the Laser Irradiation on Amorphous Semiconductor***

Abstract

The whole research work can be divided in two parts as follows-

Part A: Designing and fabrication of photon drag detectors and TEA CO_2 Laser

Part B: Study of laser irradiation effect and photo-induced effect in amorphous semiconductor; particularly on optical and thermal properties of chalcogenide glasses.

A-1 Designing and Fabrication of Photon Drag-detectors

Designing and fabrication of germanium photon drag-detector has been done successfully. The exit end of the detector is cut at a critical angle of 14.5^0, so that 64 % of incident laser radiation can travel in the Ge bar. Choice of length and resistivity of the germanium is an important design parameter to increase responsivity. Hence, two types of photon drag-detectors have been designed and fabricated with following specifications.

(a) Resistivity and dimension of the Ge bar choosen as-

(i) **Type A detector:** 1.0 Ω-cm, p-type, 2mm×2mm×20mm

(ii) **Type B detector:** 2.5Ω-cm, p-type, 2.5mm×2.5mm×30mm

(b) Responsivity and response time of the detectors for CO_2 laser is as follows:

(i) **Type A detector:** 674 mV/MW, nanosecond/ sub nano-second

(ii) **Type B detector:** 872mV/MW, nanosecond/ sub nano-second

(c) Damage Threshold Intensity: 20MW/cm^2

A-2. Designing and Fabrication of TEA CO_2 Laser

Designing and fabrication of TEA CO_2 laser has been done. To obtain low divergence, a plano-concave configuration has been chosen. A quartz mirror with thick coating of aluminium has been used for fully reflecting mirror which provides a specular reflectance adequate for a high gain laser. A partially aluminium coated flat germanium mirror has been used to get laser output. Instead of brewsterized ends, adjustable laser mirrors in vacuum tight holders has been used. Linear pin-rod configuration has been used for electrical excitation in which cathode consist of a string of about 116 pins, 7.5 mm apart each being loaded with a 1.0 K Ω carbon composition resistor (1 Watt). The anode is a sand blasted copper tube of 7 mm diameter. The pin to anode separation is about 3 cm. The current excitation pulses are obtained by discharging a 0.02 μF capacitor of 10 nH with the help of a spark gap through the laser electrodes using variable high voltage DC (0 -30 kV) supply. The capacitor can be charged to voltages upto 30 kV, and on its discharge, the exciting pulses have a peak current of upto 5 Ampere per pin. The exciting pulses have duration of about 1 μs. The optimum pressure of CO_2 gas for maximum gain is found to be 35 Torr whether He is present or not. For highest gain partial pressure of CO_2 = 35 Torr, N_2 = 20 Torr and He = 30 Torr are about to be optimum. Maximum peak gain is found with partial pressure of CO_2 at 25 Torr and N_2 at 25 Torr. This is quite encouraging if one wishes to avoid He in this binary mixture of equal ratio.

B-1 Laser Irradiation Effect on Optical Properties of Chalcogenide Glasses

Laser irradiation effect on optical properties of Se-Te based chalcogenide thin films with Ga, Al, and Hg metallic additives has been studied using TEA N_2 laser as an irradiation source. Melt-quenching technique has been adopted to prepare all compositions of the investigated glassy systems. The as-quenched glassy alloys have been grounded and the resulting fine powder has been used to prepare the thin films by PVD method on pre-cleaned glass substrate. The amorphous structure of the prepared thin films has been characterized using XRD. The optical absorbance (*A)* and transmittance (*T)* measurement have been done using Camspec (model M550) UV/VIS/NIR double beam. Laser irradiation has been carried out using pulsed transverse electrical excitation at atmospheric pressure (TEA) nitrogen laser (wavelength

337.1 nm, peak power 100 kW, and pulse width 1 ns) with peak average energy density of ~3.5 x 10^5 W/cm^2 for different time. Observed irradiation effect on optical properties is summarised below-

- Analysis of the optical absorption spectra indicate indirect allowed transition in Se-Te system.Tail energy width (E_U) increases with increasing irradiation time as well as Te content reveals that the laser irradiation produces disorder in material, causing an increase in the number of localized states in the band gap. As a result optical band gap (E_g) decreases with increasing irradiation time as well as Te content. It is also observed that absorption coefficient (α) and extinction coefficient (k) increases with laser irradiation time. However the optical band gap (E_g) increases by increasing Ga content in $Se_{96-x}Te_4Ga_x$ system. Increase in Optical band gap with Ga content make it behave different than other effect of other metallic impurities as increase in Te, Al and Hg concentration leads to a decrease in optical band. In Se-Te system with Al additive laser irradiation does not show significant effect at higher Al concentration. It concludes that alloy with rich Al content is more stable and less sensitive to the laser irradiation. In Se-Te system with Hg additive optical energy gap decreases rapidly with increasing in Hg%. It suggests that addition of Hg make more localized density of the states available than Al. In addition laser irradiation shows strong effect at higher Hg concentration (12%) however at higher Al concentration only slight change in optical band gap is observed. *It concludes that alloy with rich Hg content is more sensitive to laser irradiation and alloys with rich Aluminum content is less sensitive*.

B-2 Laser Irradiation Effect on Thermal Properties of Se-Te Glassy Alloy

Pellet of $Se_{96}Te_4$ glassy alloys with thickness 1 mm and diameter 12 mm has been pressed in separate aluminium pans. The pellet of $Se_{96}Te_4$ has been irradiated by placing it in a specially designed pellet holder attached with laser irradiation setup at a distance of 8 cm from the TEA nitrogen laser output head (wavelength 337.1 nm, peak power 100 kW, and pulse width 1 ns) with peak average energy density of ~3.5 x 10^5 W/cm^2. The sample has been irradiated for 5, 10, 15 and 20 minutes. Thermal characterization of pristine and irradiated pellet has been done by using DSC plus (Rheometric scientific company, UK). Observed result from the analysis of thermogram given below-

- Onset crystallization temperature (T_c) increases with increasing laser irradiation time however there is no significant change in the glass transition temperature (Tg). The extent of super cooled liquid region (ΔT) decreases with increasing of laser irradiation time. Degree of crystallization is increases with increasing irradiation time. The enthalpy of crystallization which is closely associated with the metastability of glasses, first decreases after laser irradiation and then slightly increases with increasing of irradiation time. The decrease of ΔT with irradiation time leads to the conclusion that glassy $Se_{96}Te_4$ alloy is unstable against laser irradiation.

B-3 Effect of Metallic Impurities on Photoconductivity of Se-Te Based Chalcogenide Thin Films

Effect of Al and Hg metallic additives on photoconductivity of Se-Te based glassy alloy has been studied. Thin films of Se-Te-Al and Se-Te-Hg alloy have been used. Observed effect is summarised below-

- Dark conductivity and photo conductivity increased with Al%. Dark and photo activation energies decrease with increasing Al as well as Hg content. The value of γ wit Al additive found from 0.62 to 0.66 which confirms presence of localized or traps states in the gap of the material in Se-Te-Al system, However with Hg additive the value of γ is found to be approx 0.5 for all samples which confirms that recombination process takes place in Se-Te-Hg glassy system is bimolecular. $I_{ph} > I_{dc}$ in all samples at room temperature. Decrease in photosensitivity with increasing in Al and Hg content also shows structural defect production due to addition of Al and Hg content. Analysis of transient photoconductivity shows that τ_d increases with increasing Al content. Carrier lifetime (τ_c) also found to be increasing with Al content. However effective decay time constant (τ_{eff}) increases with Hg content. Photosensitivity of alloy with minimum Hg concentration is higher however in the system with Al additive photosensitivity was almost half of alloy with Hg additive. Same pattern was found in the study of laser irradiation effect on optical properties however in case of laser irradiation effect, alloy with higher concentration of Hg is more sensitive to irradiation.