

Effect of Sb addition on physical and optical properties of ternary Ge-Se-Te glasses



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Abstract

- ❖ Our work investigates the changes in physical and optical properties of the GeSeTe glass matrix when Te is substituted with Sb.
- ❖ The bulk chalcogenide glass is prepared by the conventional melt quench method. X-ray diffraction is employed to determine the amorphous nature of bulk samples. The ratio of compositional elements is verified using energy-dispersive X-ray spectroscopy.
- ❖ Diffuse reflectance spectroscopy is employed to assess the optical bandgap arising from indirect electronic transitions. Its value changes with the incorporation of Sb as the fourth element.
- ❖ Differential scanning calorimetry studies shows that the addition of Sb leads to a higher transition temperature.
- ❖ IR transparency of these glasses is observable in the FT-IR spectrum except for some impurity absorption..

Introduction

- ❖ Chalcogenide glasses (ChGs) finds applications, as phase-change memories, solar cells, sensors, and photonics.
- ❖ Consist of one or more chalcogen elements (S,Se,Te) and are highly transparent in IR regime.
- ❖ They are covalently bonded to network modifiers like Ge,As,Sb.Sn etc. and properties are tuneable.
- ❖ GeSeTeSb glass family is expected to have the properties of GeSeTe, GeSbTe and GeSeSb glass families.
- ❖ Disadvantages of the ternary glass families like low sensitivity, tendency to crystallization, thermal stability are expected to improve with the addition of Sb.
- ❖ GSST chalcogenide glasses have already found application as phase change memory material. The other properties and applications are needed to be explored.

Experiment

- ❖ Pure Ge, Se, Te and Sb (5N purity) of appropriate weight percentage are loaded into quartz ampoules and sealed under vacuum (10^{-3} mbar).
- ❖ It is then heated using a rocking and rotating furnace at 1050°C for 48 hours and quenched in ice-cooled water.
- ❖ Then etched in hydrofluoric acid and the samples are taken out.
- ❖ Ground to fine powder and various characterizations are done



The average co-ordination number is given by ,

$$\langle r \rangle = \frac{aN_{Ge} + bN_{Se} + cN_{Te} + dN_{Sb}}{a + b + c + d}$$

Where a, b, c, d are the percentage composition and N_{Ge} , N_{Se} , N_{Te} , N_{Sb} are the co-ordination of corresponding element. Compositions with $2.2 < \langle r \rangle < 2.7$ makes good and rigid glasses

Composition	$\langle r \rangle$
$Ge_{20}Se_{60}Te_{20}$	2.4
$Ge_{20}Se_{60}Te_{15}Sb_5$	2.45
$Ge_{20}Se_{60}Te_{10}Sb_{10}$	2.5
$Ge_{20}Se_{60}Te_5Sb_{15}$	2.55

Conclusions

- ❖ $Ge_{20}Se_{60}Te_{20-x}Sb_x$ ($x = 0, 5, 10, 15$) glasses were synthesized by melt quench method
- ❖ X-ray diffraction pattern confirms the amorphous nature and FTIR spectrum shows these glasses are IR transparent. Presence of water impurity was observed

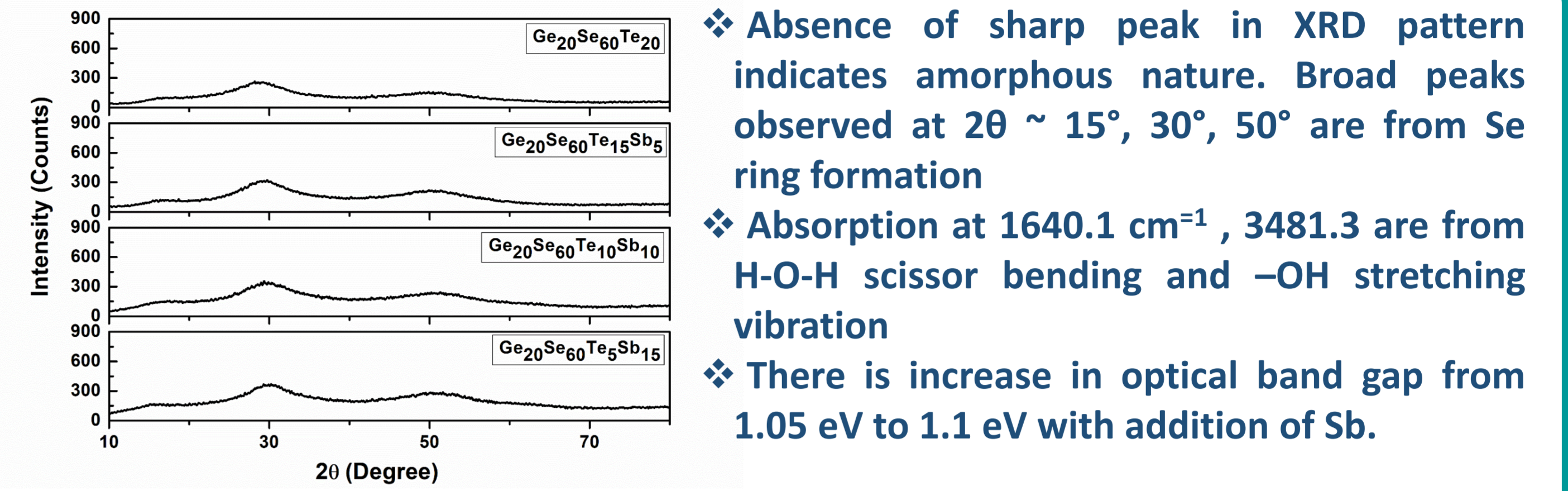
- ❖ EDAX analysis ensures the glasses are similar to nominal composition
- ❖ Increase in optical band gap is observed from diffuse reflectance spectrum. T_g also increases considerably with the addition of Sb. This is because higher co-ordination of Sb increases number of bonds.

References

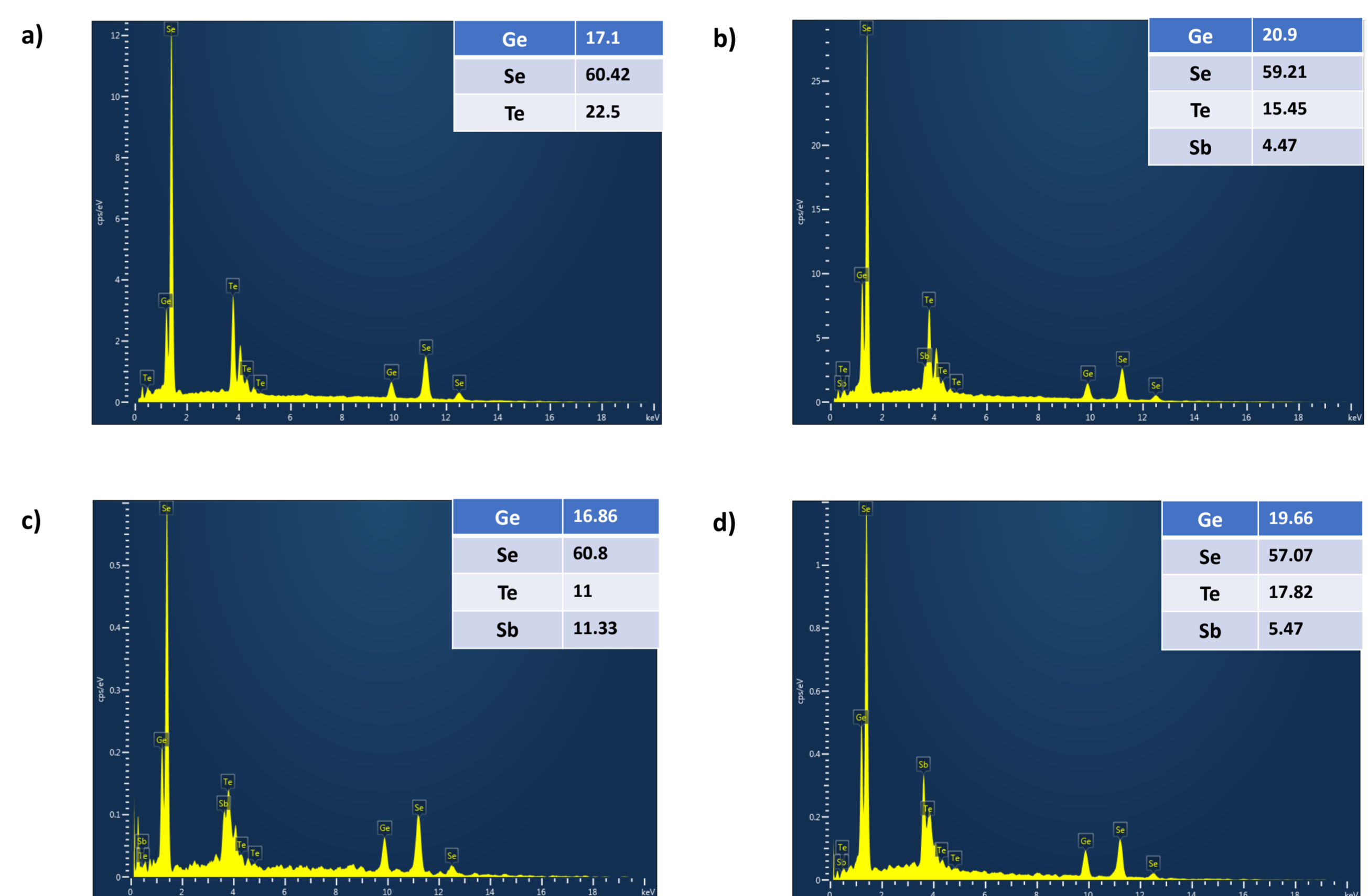
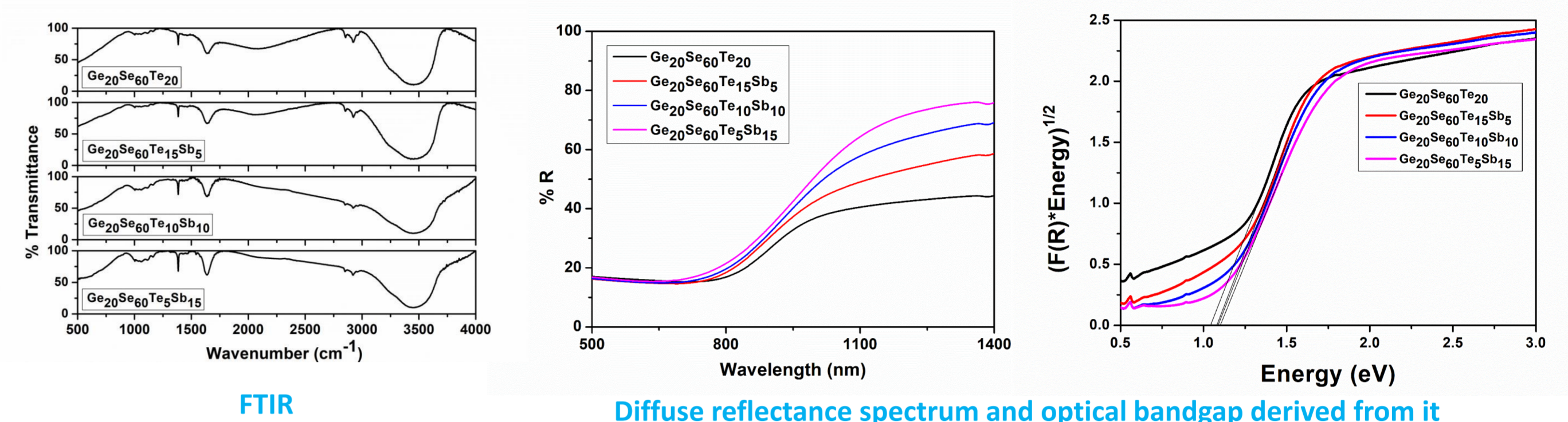
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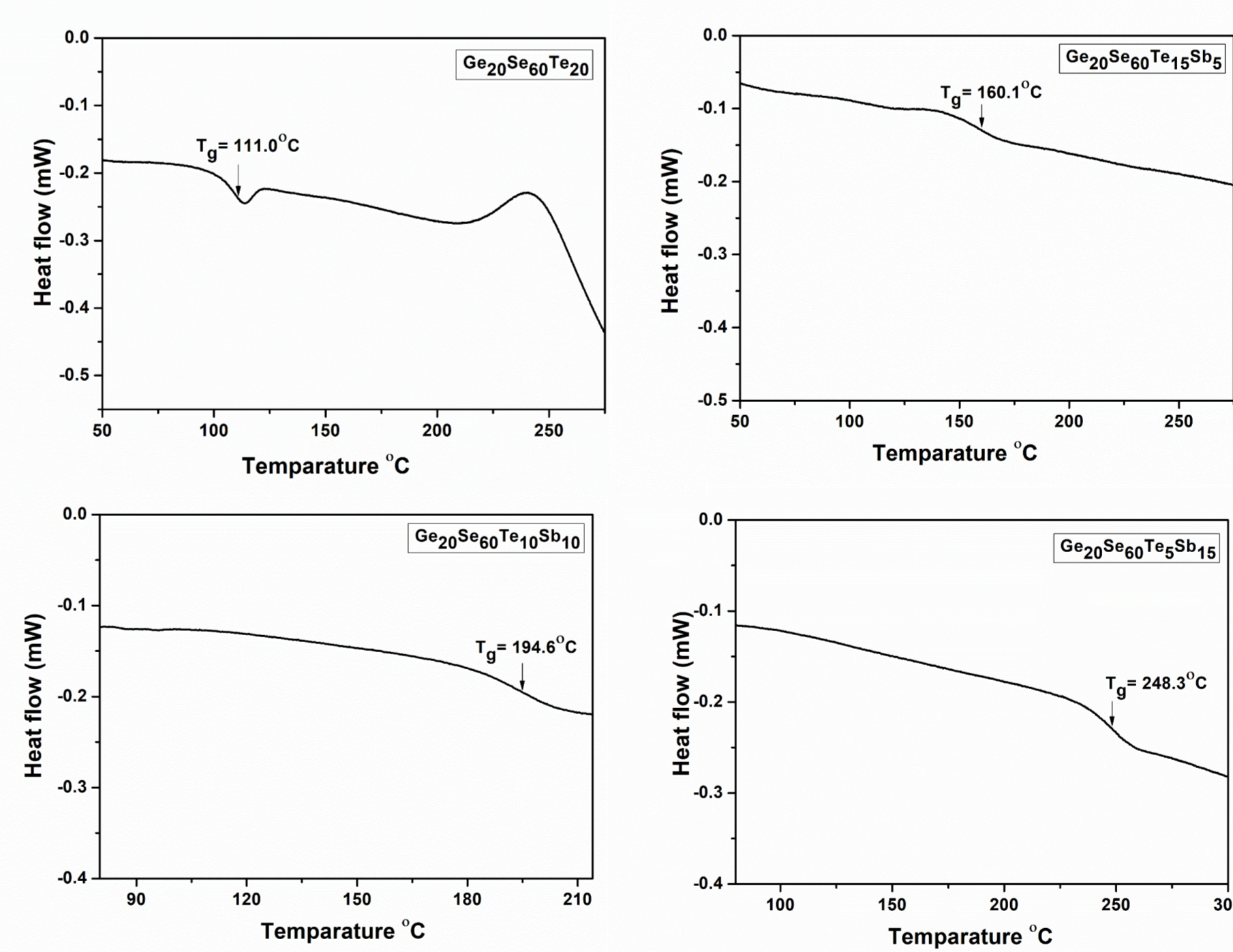
Results



- ❖ Absence of sharp peak in XRD pattern indicates amorphous nature. Broad peaks observed at $2\theta \sim 15^\circ, 30^\circ, 50^\circ$ are from Se ring formation
- ❖ Absorption at 1640.1 cm^{-1} , 3481.3 are from H-O-H scissor bending and -OH stretching vibration
- ❖ There is increase in optical band gap from 1.05 eV to 1.1 eV with addition of Sb.



EDAX spectrum of each composition and their corresponding weight percentage in table



- ❖ Actual compositions were similar to nominal compositions
- ❖ T_g value increases from 111.1°C to 248.3°C
- ❖ Addition of Sb at expense of Te increases Se-Sb, Sb-Sb bonds than Se-Se and Te-Te bonds.

Bond	Bond energy (kcal/mol)
Ge-Se	49.44
Se-Sb	43.98
Se-Se	44.04
Te-Te	33

Differential scanning calorimetry thermogram of the different compositions

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