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Investigations of Structural, Thermal and Compressive Strength of Selenium the Tellurium-Cadmium System

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ABSTRACT: Cadmium (Cd) doping has enhanced the mineral properties, glass mesh, and movement traits of the $\text{Se}_{90}\text{Te}_{10}$ glassy alloy. The $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ alloy has a strength 0.032 kN, accompanied by limited ductility, and displays brittle fracture behavior typical of amorphous chalcogenide glasses. (DSC) at varying heating rates was employed to examine the crystallization kinetics in bulk $\text{Se}_{90}\text{Te}_{10}$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ compositions; X-ray diffraction analysis was utilized to identify the crystalline structure of $\text{Se}_{90}\text{Te}_{10}$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$, confirming the non-crystalline nature of both materials. Various kinetic frameworks were developed utilizing activation energies for glass transition and crystallization processes. “The Kissinger equation” was employed to determine the effective crystallization activation energy (E_c). “The Sestak-Berggren” approach was applied to analyze DSC crystallization data due to its compatibility with the observed experimental results. Therefore, elevated heating rates were determined to be suitable when combined with the Johnson-Mehl-Avrami framework, while the crystallization characteristics of bulk $\text{Se}_{90}\text{Te}_{10}$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ compositions under different heating conditions were investigated using DSC analysis.

KEYWORDS: Chalcogenides; $\text{Se}_{90}\text{Te}_{10}$; thermal analysis; cadmium; activation energy; DSC

1 Introduction

Non-crystalline chalcogenide semiconductor compounds have recently demonstrated considerable importance and necessity from a physics research standpoint [1–3]. The phase diagram and amorphous components of the binary Se-Te system have garnered significant interest [4]. Due to their superior hardness and reduced aging effects compared to Se, Se-Te alloys have attracted attention [5]: additives are used to improve the properties of SeTe and the properties of SeTe can be altered by varying the type and percentage of the additive. Selenium and tellurium-based compounds are utilized across various technologies, including detectors, transistors, and other semiconductor applications. Se-Te compositions have attracted interest due to their provision of enhanced mechanical strength and mitigation of deterioration processes relative to elemental selenium.

The a.c. conductivity of SeTe and SeTe M (M = Cd, In, Sb) alloys was studied by Chandel et al. [6]. Sharma and Kumar [6,7] studied the electrical properties of the Zn and In doped $\text{Se}_{85}\text{Te}_{15}$ alloy and the AC conductivity of Cd and Ge doped $\text{Se}_{70}\text{Te}_{30}$ alloy. They investigated the influence of cationic substitution

(replacing Cu^{2+} in the solid solutions of these crystals with Zn^{2+} and Cd^{2+} ions) on the temperature of the structural phase transition, the number of polymorphic forms, and the processes involved in the phase formation [6]. Te is semi-metallic, so the alloys rich in Te are metallic and hence limit the formation of glasses. However, the Se rich alloys are semi-conducting. Glasses that are rich in Te do not make good glass formers either [8].

Thus, Cd incorporation potentially modifies the activation energy governing (Se-Te) alloy transport mechanisms. The thermal characteristics of chalcogenide glasses determine glass mobility, thermal stability, and practical applications. Differential scanning calorimetry (DSC) represents a primary crystallization kinetics method for investigating. Glass kinetics are crucial for examining glass transition phase behavior, which is investigated through DSC methodology, commonly employed for studying glass material transformations under glass transition conditions [9]. The measurements taken using the differential scanning calorimetry can help to obtain the accurate value of the glass transition temperature, T_g . Nonetheless, the kinetic element of the glass transition makes it clear that the temperature of glass transition strongly depends on the heating rate. This behavior was used to identify the various methods employed in the process of transition. DSC measurements can be used to determine one of the most significant kinetic parameters for glass transition, the activation energy (E). E was calculated from the current measurements using various techniques in order to confirm the concept that E is constant during glass transformation, which has been supported by the work of many authors. In particular, isoconversional methods have been applied to evaluate E estimates at different stages of transition. DSC is the widely used technique to explore crystallization kinetics on glassy materials DSC measurements provide a precise determination of the glass transition temperature T_g .

In this study, we report the preparation and characterization of $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glass, focusing on its structural and thermal properties. This work provides new insights into how Cd incorporation modifies the glass network, which has not been extensively investigated in previous studies. Therefore, the novelty of this work lies in the systematic investigation of Cd-doped Se-Te glasses with detailed experimental characterization, which contributes to a better understanding of dopant effects on chalcogenide glass properties. This paper used the DSC technique to test the amorphous glass crystallization kinetics of $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ at various constant heating rates. The melt-quench process was used to set the glass in bulk form for the $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses. Moreover, the DSC data were analyzed using (the Kissinger formula, Matusita method) and the isoconversion technique, through which the mechanisms of conversion growth were determined.

2 Experimental Details

2.1 Bulk Preparation of Sample

Starting elements comprising Se, Te and Cd with 99.999% purity were employed in this study and a silica cylindrical vessel, measuring 1.0 cm in diameter and 20.0 cm in length, was loaded with predetermined mass percentages of these elements. A low pressure of 10^{-4} Torr was then blown down the tube and the tube thermally sealed. It was fitted into an electric oven Heraeus (type Ro7115) programmable cylinder heater. $\text{Se}_{90}\text{Te}_{10}$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ at.% were furnace at 600°C and 50°C , respectively, for 40 h. Silica tubes were agitated at three-hour intervals throughout the heating process to ensure uniform mixture composition. The tubes were quenched in a container containing crushed ice and water after heating. The mixture was then collected and ground into small grains using a hand mortar.

2.2 Characterizations

Using a $\text{CuK}\alpha$ of $\lambda = 0.154 \text{ nm}$, the Philips 1710 type was used to measure the samples' degree of crystallinity. The samples were examined using a "Philips Paradigm" XL30 electron scanning microscope (SEM).

The compressive strength of the laboratory-prepared specimens was quantitatively determined to characterize their mechanical performance under axial loading; this critical assessment was conducted in strict accordance with the standardized test method delineated in ASTM C109/C109M, which governs the compression testing of hydraulic cement mortars. The experimental procedure was executed utilizing a (Matest C088-10N Concrete compression machine), a precision instrument configured with a 10 kN capacity load cell to ensure accurate force measurement; To guarantee quasi-static loading conditions and mitigate the influence of strain rate effects, a constant crosshead displacement rate was meticulously maintained at 1.0 mm per minute throughout the duration of each test until specimen failure was achieved.

DSC was utilized to assess the behavior of crystallization under non-isothermal conditions using the Shimadzu TA-50 instrument (Kyoto, Japan). An amount of about 5 mg of a powdered sample was loaded into the benchmark aluminum pan and dried in a nitrogen-free environment; heating rates of 5, 10, 15 and 25 K/min were employed to obtain non-isothermal DSC curves. T_g , T_c , and T_p are the additional result values derived from those curves.

3 Results and Discussions

3.1 XRD Investigation

Fig. 1 displays $\text{Se}_{90}\text{Te}_{10}$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ the XRD curves which illustrate the samples' amorphous character. A hump in the baseline usually indicates the presence of an amorphous material in the sample. This feature, which appears at higher 2θ angles, is characteristic of medium-range order in amorphous chalcogenide glasses, reflecting correlations between atomic clusters that extend beyond the nearest-neighbor distances. Similar observations have been reported in Se–Te and related chalcogenide glasses, where the first broad hump corresponds to short-range order (nearest-neighbor distances) and the second broader hump reflects intermediate-range structural organization [10].

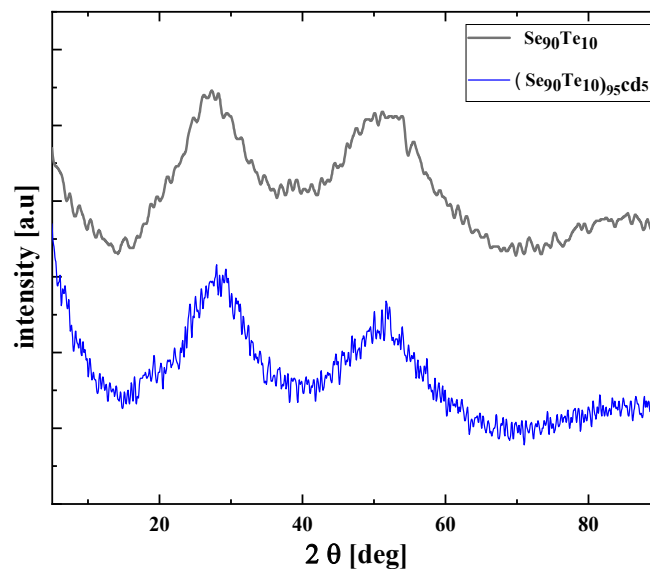


Figure 1: XRD diffraction of $\text{Se}_{90}\text{Te}_{10}$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ [9].

The nature was becoming apparent through lone-pair computations with the help of $L = V - \langle r \rangle$ [11,12], where $\langle r \rangle = \frac{\alpha N_x + \beta N_y + \gamma N_z}{\alpha + \beta + \gamma}$ and V is a valence electrons, α , β , and γ are the concentrations of $(\text{Se}_{90}\text{Te}_{10})$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$, respectively. The lone pairs were calculated 4, 3.7 for $(\text{Se}_{90}\text{Te}_{10})$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$, respectively [13]. The calculated bond stretch $N_a = \langle r \rangle / 2$ equals 1.05, bond bending $N_b = 2 \langle r \rangle - 3$ equals 1.2, and the number of concentrations $N_c = N_a + N_b$ equals 2.25 for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$. It is evident that the syntheses under study are amorphous and it was confirmed by the appearance of bumps in patterns of the amorphous material. Thus, the SEM micrograph Fig. 2, of glassy fracture lacking any layer structure confirmed the results [14].

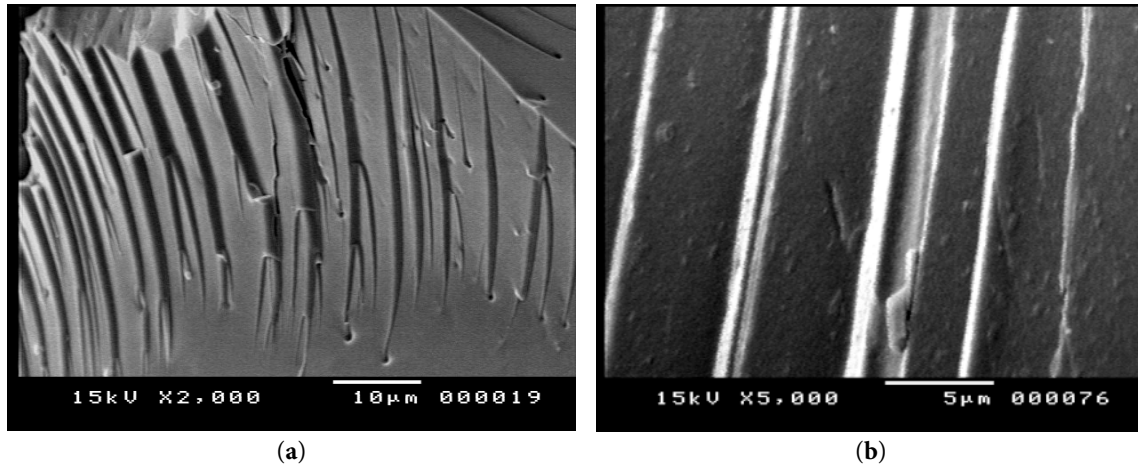


Figure 2: The SEM micrograph of as-prepared of bulk (a) $\text{Se}_{90}\text{Te}_{10}$, (b) $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ chalcogenide glasses [9].

3.2 Mechanical Performance

The mechanical behavior of the $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ alloy aligns with the typical characteristics observed in amorphous chalcogenide glasses, demonstrating acceptable intrinsic strength concurrent with restricted ductility; A measure of the failure load of 0.032 kN, presumably obtained via micro-indentation or small-scale compression testing, reflects substantial mechanical integrity within this material class: Such as value is indicative of robust resistance to deformation, consistent with the brittle fracture mode and the absence of pronounced plastic flow characteristic of vitreous alloys. Furthermore, the incorporation of cadmium into the (selenium-tellurium matrix) is designed to engineer its structural attributes, ostensibly improving thermal stability and mechanical robustness as corroborated by the aforementioned mechanical data.

The $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ alloy exhibits a high small-scale failure load (0.032 kN), indicating enhanced resistance to deformation compared with undoped Se and is consistent with reported Se-Te binaries. The presence of cadmium and tellurium increases microhardness and thermal/structural stability while retaining the brittle fracture mode typical of amorphous chalcogenide glasses, making this composition attractive where mechanical robustness and glassy optical properties must be combined: Pure amorphous Se is generally softer and more easily plastically deformed at the microscale than Se-Te alloys; showing lower hardness and lower resistance to indentation. Se $\rightarrow$ Te substitution typically increases hardness and resistance to crystallization [15]. Se-Te binary glasses exhibit enhanced mechanical properties compared with pure Se. Recent nanoindentation studies have reported a significant increase in hardness and elastic modulus with increasing Te content, confirming that Te incorporation strengthens the network structure and improves mechanical stability [16].

3.3 Kinetics of Phase Transformation

A DSC scan of the multi-component chalcogenide glasses $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ at heating rates of 5, 10, 15 and 25 K/min is displayed in Fig. 3 whereas a variation in temperature under consideration is given, the DSC thermogram distinctly reports the presence of two different phenomena, namely endothermic and exothermic peaks. Analytically, DSC thermograms are divided into two segments. The exothermic segment of the DSC curve shows the crystallization process, and the first part associated with glass transition which is depicted by an endothermic reaction. Temperature points where endothermic and exothermic peaks, corresponding to dual linear sections defining DSC trace transition elbows, intersect are designated as Glass transition temperature (T_g) and onset crystallization temperature (T_c) terminology. Peak crystallization temperature (T_p) represents the maximum temperature of exothermic peak occurrence during crystallization processes. Table 1 indicates that an increase the peak crystallization temperature (T_p) which corresponds to the exothermic peak in the crystallization region, shows that T_g , T_c , T_p , and $(T_c - T_g)$ increase with heating rate. The same observation was recorded by Mehta et al. [17] in terms of adding certain metallic additives (Ag, Cd and Sb) to the $\text{Se}_{80}\text{Te}_{20}$ alloy glass, and similar effects have also been observed in other chalcogenide systems [18,19].

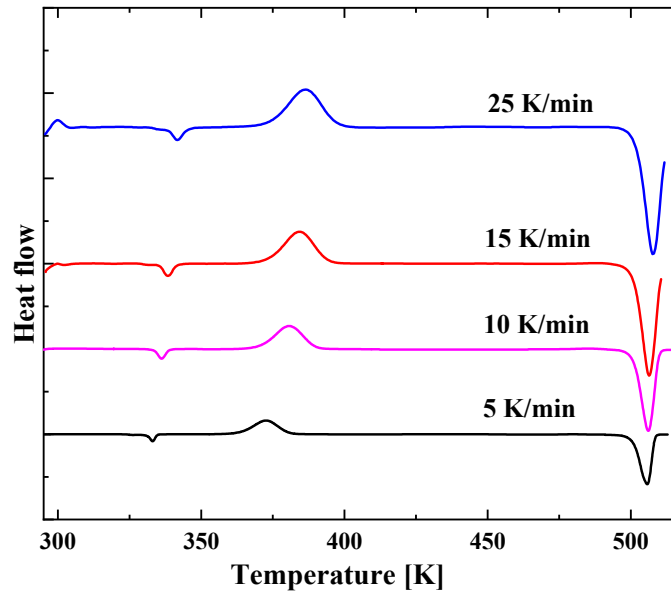


Figure 3: Typical DSC trace of the $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses measured at different heating rates.

Table 1: The values of glass transition temperature T_g , onset crystallization exothermic T_c , and the peak crystallization temperature (T_p) at the heating rate $\alpha = 5, 10, 15$, and 25 K min^{-1} for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glass.

Heating Rate (α) K/min	T_g (k)	T_p (k)	T_c (k)	$T_c - T_g$ (k)
5	328.1	372.3	363.13	35.03
10	330.9	380	368.01	37.11
15	333.1	384.2	372.18	39.08
25	335.6	386.9	374.92	39.32

The small deviation appearing at the initial part of the DSC curves for the higher heating rates (15 and 25 K/min) can be attributed to thermal response delay and baseline instability inherent to fast heating

scans. At elevated heating rates: the temperature difference among the sample and the reference increases, leading to a slight distortion in the heat flow signal before thermal equilibrium is established; This effect is absent or significantly reduced at lower heating rates (5 and 10 K/min), confirming its instrumental origin rather than a physical transition, the dip observed in all DSC curves after crossing approximately 500 K is associated with an endothermic structural relaxation process occurring in the vicinity of the glass transition temperature (T_g). The relaxation process within the amorphous phase has several features: the reason is of twofold: (1) it is non-exponential in its time dependence; (2) it is non-linear in its structural state dependence. This feature arises from atomic rearrangement and the release of frozen-in stresses within the amorphous chalcogenide network as the material approaches the supercooled liquid region. Similar relaxation endotherms near T_g have been widely reported for chalcogenide glasses and are considered a characteristic signature of glassy systems, rather than evidence of crystallization or a first-order phase transition [20,21].

3.4 Glass Transition

The glass transition zone of the materials has been verified and the thermal stability of the glassy alloy may be put as the change of glass transition temperature T_g against heating rates [22]. The T_g heating rate dependency can be discussed in three respects: “Kissinger formulation”, Lasocka and Augis and Bennett models [23]. To begin with, it can be stated that “Kissinger formulation”: is one of the most widely used methods for non-isothermal stage transition researches in thermal DSC curves study [24]: This arrangement is meant to discuss the kinetics of transformation in an isothermal state, as well as to give a generalization of the formal Avrami phenomenon equations to be applied in continuous (or non-isothermal) conditions of crystallization. Kissinger notes that activation energy value of E_c should be calculated according to the following formula [9]:

$$\ln(\alpha/T_p^2) = -E_c/RT_p + \text{const} \quad (1)$$

where α ; Heating rate used in DSC scans, R is the constant of generic gas ($R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$). Soliman was applied Kissinger’s theoretical ideas to calculate the energy value by replacing a peak temperature with glass temperature and an activation energy with the energy value thus this results in the glass transition kinetics equation, Eq. (2) as follows [9]:

$$\ln(\alpha/T_g^2) = -E_g/RT_g + \text{const} \quad (2)$$

E_g : energy activation values for the glass transition. Figs. 4 and 5 refer to $\ln(\alpha/T_p^2)$ versus $1000/T_p$ for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses and $\ln(\alpha/T_g^2)$ versus $1000/T_g$ for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$, respectively, The E_c and E_g values were deduced from Eqs. (1) and (2) in Table 2.

Next, Lasocka proposed an empirical relationship in the following form [25]:

$$T_g = A + B \ln \alpha \quad (3)$$

The third estimation by Augis and Bennett [23] is referred to as “a streamlined version of Kissinger’s technique”, as detailed [25]:

$$\ln\left(\frac{\alpha}{T_g}\right) = -\frac{E_g}{RT} + \text{const} \quad (4)$$

$$\ln\left(\frac{\alpha}{T_p}\right) = -\frac{E_c}{RT} + \text{const} \quad (5)$$

In Fig. 6, we can observe a linear relationship amidst $\ln(\alpha)$ and T_g for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses, A and B act as constants determining the composition of the glass. A and B values were thoroughly analyzed in Table 2. Values obtained from A and B are considered perfect for all samples for both glass transition temperatures [26,27].

Figs. 7 and 8 display the relationship between $\ln(\alpha/T_g)$ and $1000/T_g$ for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glass and $\ln(\alpha/T_p)$ and $1000/T_p$ for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glass, respectively. The values of E_g and E_c could be found in Table 2.

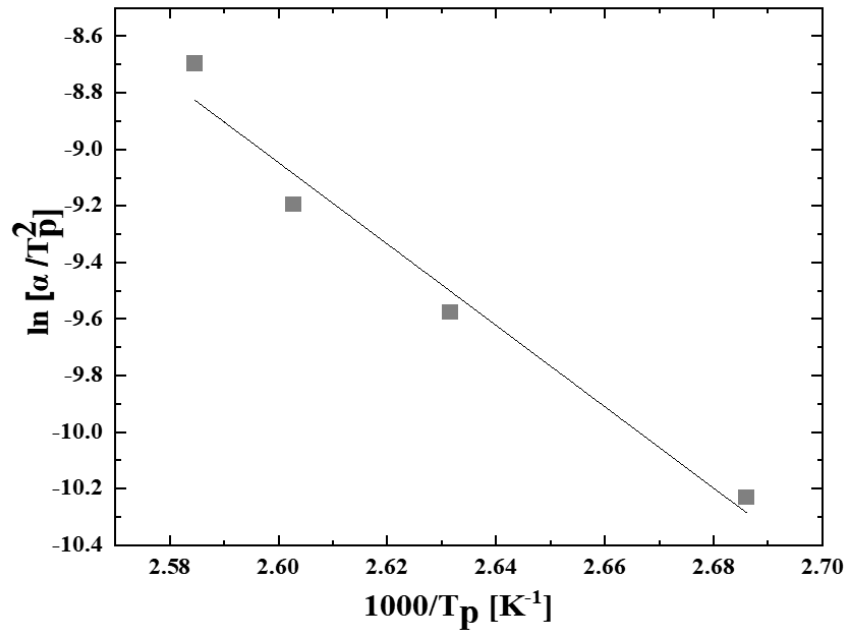


Figure 4: $\ln(\alpha/T_p^2)$ versus $1000/T_p$ for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

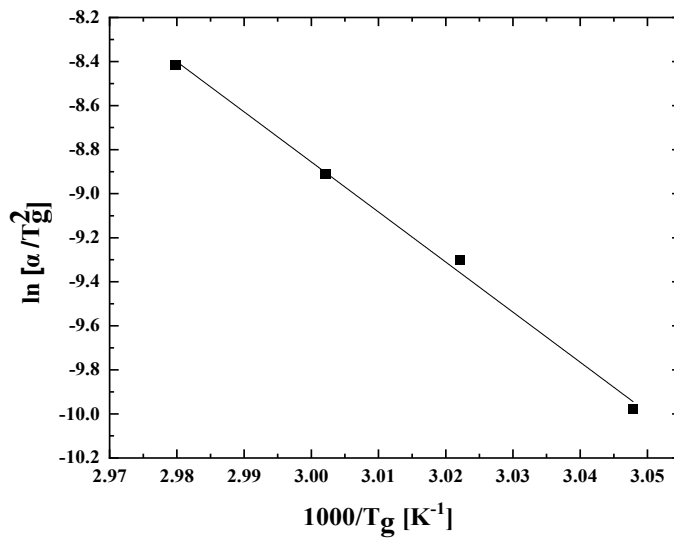


Figure 5: $\ln(\alpha/T_g^2)$ versus $1000/T_g$ for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

Table 2: Values of E_g , E_c (kJ mol^{-1}) for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses deduced from different methods, and values of A and B, E_c and avrami (n, m).

Thermal Parameters at Different Heating Rate	$(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$
E_c (kJ mol^{-1}) Kissinger model	119.5
E_g (kJ mol^{-1}) Kissinger model	188.97
E_g (kJ mol^{-1}) Augis and Bennett	191.72
E_c (kJ mol^{-1}) Augis and Bennett	122.7
A	320.39
B	4.68
E_c (kJ mol^{-1}) Matusita method	114.83, 107.99, 98.37, 93.23
n	2.9
m	2.9

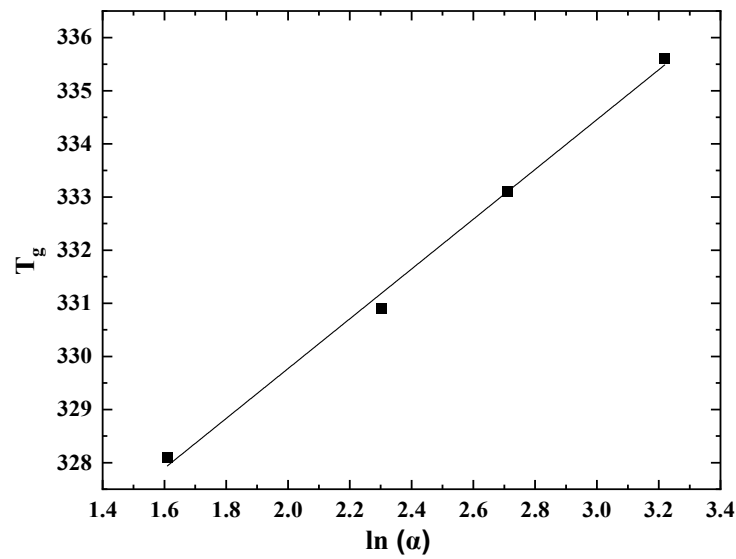


Figure 6: $\ln(\alpha)$ with T_g for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

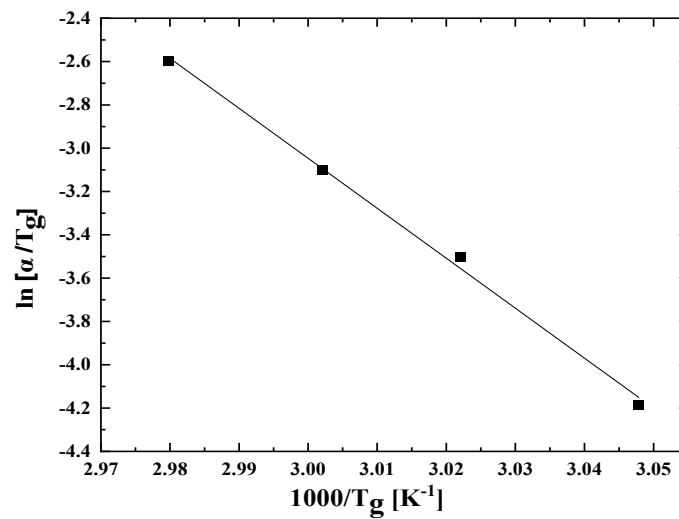


Figure 7: $\ln(\alpha/T_g)$ versus $1000/T_g$ for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

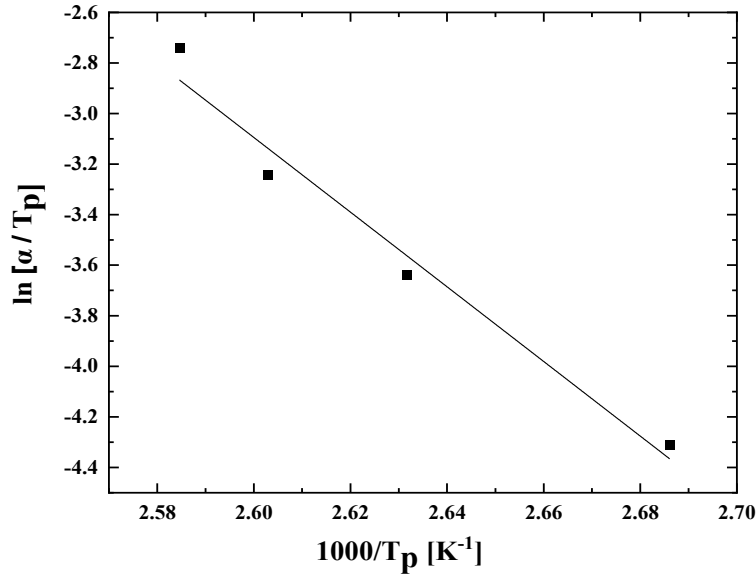


Figure 8: $\ln(\alpha/T_p)$ versus $1000/T_p$ for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

3.5 Evaluation of an Activation Energy

3.5.1 JMA Model Calculating

The kinetic properties of crystal formation, including the activation energy (E_c) and Avrami exponent (n), during various methods by using Johnson-Mehl-Avrami model [28]. One such method, provided by Matusita and colleagues [20], is particularly useful for non-isothermal situations and can offer additional values for E_c and n . Crystal formation kinetics, including parameters like the activation energy (E_c) and the Avrami exponent (n), can be assessed [29]:

$$\ln[-\ln(1 - \chi)] = -n \ln(\alpha) - 1.052m \frac{E_c}{RT} + \text{const} \quad (6)$$

The fraction of crystals being precipitated to the glass is a , then it is heating with a constant eating speed, whereas the Avrami exponents (m and n) are the integer or half integer number based on the mechanism of growth and dimensions of the crystal. The value $n = m + 1$ dominates if a nucleus is formed by heating at a constant rate. It can be written as $n = m$; although the glass contains enough nuclei [29]. The present work assumes that values of n and m are equal. Prior to each experimental run the sample was coated at a temperature below the glass transition over a period of time. On $\ln[-\ln(1 - \chi)]$ slope against the $1000/T$, the E_c value to $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ was determined as in the Fig. 9 and Table 2, value of mE_c is calculated by slope of each side and the plot is linear at great temperature deviation. All the levels of heating exhibit interrupted linearity at higher temperatures. As it has been stated, this disorder can be an outcome of saturation of nucleation points in the final phase of crystallization [25]. In the case of constant temperature, Eq. (7) is expressed [29]:

$$\ln[-\ln(1 - \chi)] = -n \ln(\alpha) + \text{const} \quad (7)$$

Fig. 10 presents a linear plot of $\ln[-\ln(1 - \chi)]$ versus $\ln(\alpha)$ at constant values as demonstrated by Ozawa for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses. Through the transformation process, according to JMA model [30], both n and E_c should be constants, which are different from the isothermal model [31] and the non-isothermal

model [32]. The varying nucleation activity in the process of crystallization did not keep the different crystallization energy of activation constant throughout the transition.

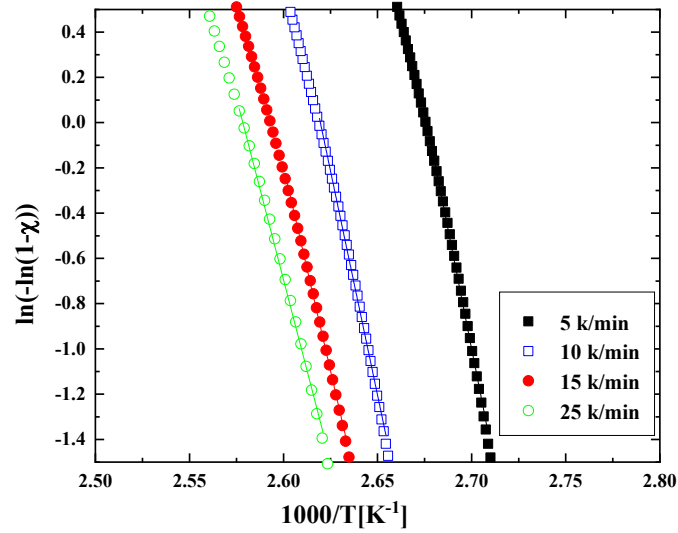


Figure 9: $\ln[-\ln(1 - \chi)]$ with $1000/T$ at different heating rates for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

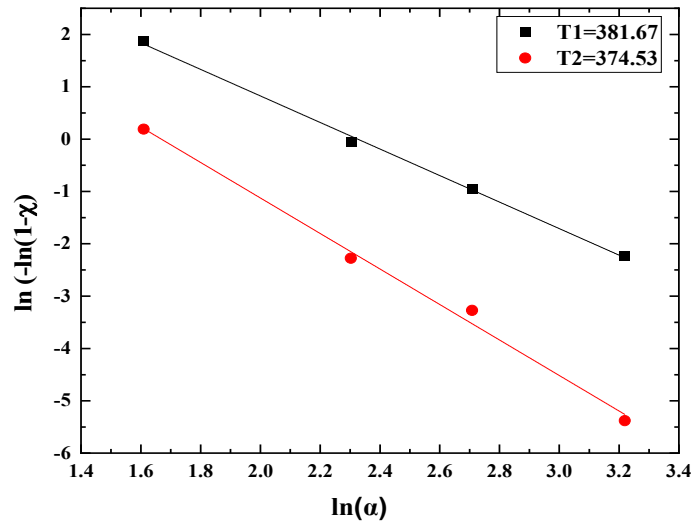


Figure 10: $\ln[-\ln(1 - \chi)]$ with $\ln(\alpha)$ at different heating rates for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

3.5.2 Isoconversion Models for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ Glasses

Conversely, the iso-conversional methods allow with determination on activation energy of the amorphous-crystalline without requiring any assumptions from the kinetic model [33–35]: One reliable method within these approaches is the Friedman technique:

$$\ln[(\Phi)]_{\alpha_{iso}} = \ln[A_{iso}\Delta H f(\alpha)]_{\alpha_{iso}} \exp[-E_{\alpha}/RT_{\alpha_{iso}}] \quad (8)$$

$$[\Phi] = [A_{iso}\Delta H] \exp\left[-\frac{E_{\alpha}}{RT_{\alpha_{iso}}}\right] f(\alpha) \quad (9)$$

A_{iso} : is an exponent frequency factor, ΔH : is a crystallization enthalpy and E_α : is local activation energy. This method can be used to calculate the local activation energy of crystallization E_α by heating through various heating rates at the heating rate of a specific α without assuming any approximations in the kinetic equation. A diagram in Fig. 11 states the relationship between the $\ln\Phi$ versus $1000/T$ that maintaining a constant value for fractional conversion for the $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ sample; by the slopes of a straight lines, the amount of activation energy of crystallization can be derived. The procedure was repeated to other values of α .

Fig. 12; activation energy of crystallization E is measured as a function of the fractional conversion α for the studied composition. A more pronounced variation of E (α) versus α can be interpreted as a more complex mechanism of the crystallization process for all studied compositions. Generally, the E (α) is expected to remain nearly constant within the range $0.3 \leq \alpha \leq 0.7$, while some deviations may appear at lower and higher values of α , particularly for faster processes, mainly due to baseline approximation errors at the peak tails, according to the suggestion of Malek [36].

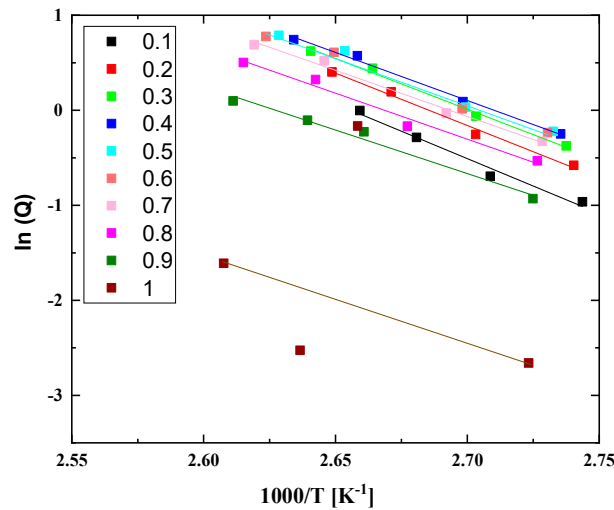


Figure 11: The plots of $\ln\Phi$ versus the reciprocal of temperature at fractional conversion $\alpha = 0.1$ to 1 for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

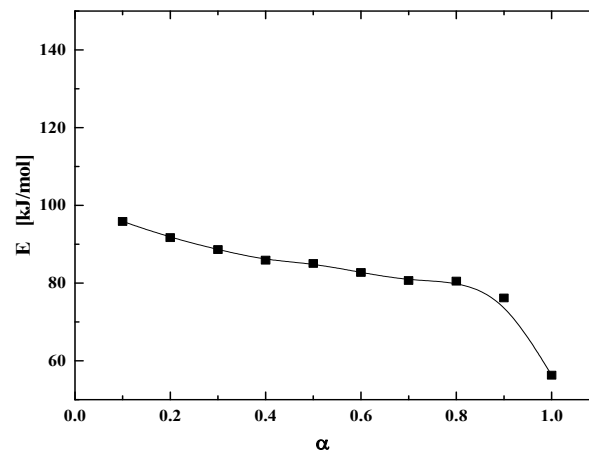


Figure 12: The activation energy for crystallization E as a function of the fractional conversion α for $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses.

JMA model validity had cleared that (the crystallization process may be tested to verify of $z(\alpha)$ at α_p^∞). In the case that fragmentary conversion of the value is associated with a limit of $z(\alpha)$ function, it lies between 0.61–0.65 and the experimental data will be explained probably with help of JMA model. When the α_p^∞ transformed into a lesser value, the condition of validity is not fulfilled. This value of $\alpha_p^\infty = 0.63$ is a characteristic fingerprint of JMA model which it may be an easy simple reliable test [33]; $y(\alpha)$ and $z(\alpha)$ functions are standardized between (0 and 1). There are maxima for these functions at α_M and α_p^∞ , respectively. These maxima are the main constituents of the test, maxima of $y(\alpha)$ for JMA model depends on kinetic exponent. As $\alpha_M = 0$ for $n \leq 1$, $\alpha_M = 1 - \exp(n^{-1} - 1)$ at $n > 1$. The kinetic exponent n may be calculated from position of maximum of $y(\alpha)$. Both $y(\alpha)$ and $z(\alpha)$ functions are studied in accordance with the following equations [37]:

$$y(\alpha) = \Phi \exp(E/RT) \quad (10)$$

$$Z(\alpha) = \Phi T^2 \quad (11)$$

Φ is the heat flow, the variations in both $y(\alpha)$ and $Z(\alpha)$ are illustrated in Fig. 13. Studying glass transition in selenium tellurium glasses doped with cadmium necessitates a comparison with undoped materials to adequately assess the novelty of results, glass transition temperature (T_g) serves as a critical marker on the thermal behavior and structural integrity of the material. During the establishment of baseline characteristics from the undoped glasses, researchers can pinpoint the specific influences of cadmium doping on the T_g and associated thermal properties. This comparative analysis not only clarifies whether the observed changes are genuinely attributable to the presence of cadmium but also sheds light on alterations in the network structure and relaxation mechanisms of the glass; The $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ alloy exhibits good mechanical performance, as indicated by a failure load 0.032 kN, which reflects substantial resistance to deformation typical of amorphous chalcogenide glasses, this behavior is consistent with its thermal properties (T_g and structural relaxation) and physical characteristics (density and composition). The addition of cadmium enhances microhardness and structural stability, improving mechanical robustness while retaining the brittle fracture mode characteristic of these glasses. These observations are in agreement with previous studies on Se–Te and metal-doped chalcogenide glasses [38]. Table 3 shows the compared values of reported activation energies for $\text{Se}_{90}\text{Te}_{10}$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glass. It can be seen from this table that the activation energy E_c of Se–Te–Cd depends on the Cd contents. Regarding the value of the present samples, it is agreed with the sequence of the reported values [9,39–42].

Table 3: The compared values of reported activation energies for $\text{Se}_{90}\text{Te}_{10}$ and $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glass.

Glass System	E_g (kJ/mol)	E_c (kJ/mol)	Reference
$\text{Se}_{90}\text{Te}_{10}$	195.99		[9]
$\text{Se}_{90}\text{Te}_{10}$	229 ± 2.5	165 ± 0.23	[39]
$\text{Se}_{95}\text{Te}_5$		99.93	[40]
$\text{Se}_{75}\text{Te}_{15}\text{Cd}_{10}$		123.8	[41]
$\text{Se}_{87}\text{Te}_{10}\text{Cd}_3$		57.02	[42]
$(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$	188.97	119.5	The present work

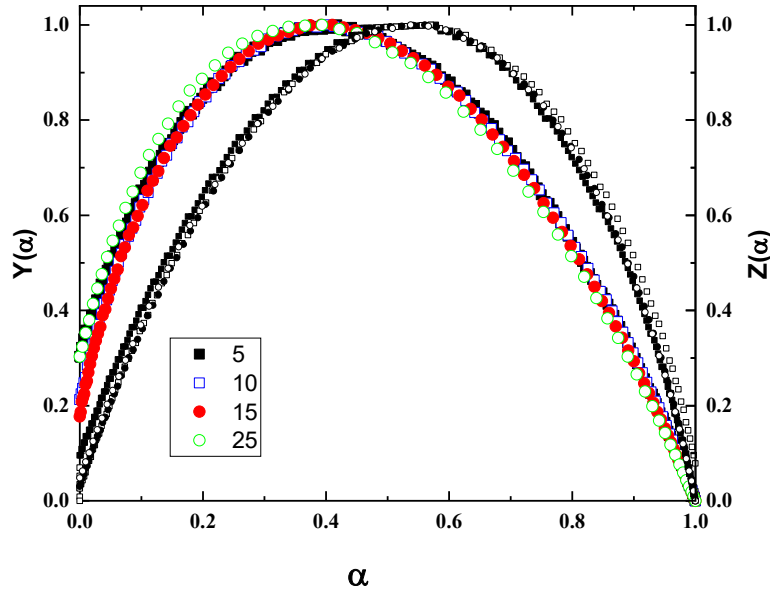


Figure 13: Normalized $y(\alpha)$ and $z(\alpha)$ functions obtained by transformation of non-isothermal data for the crystallization of $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses at different heating rates.

4 Conclusion

Using XRD, SEM and a thorough thermal analysis of $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glass was conducted; the amorphous state of as-prepared samples is confirmed by these XRD and SEM results. The $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ alloy exhibits acceptable strength with limited ductility, consistent with amorphous chalcogenide glasses. The recorded failure load of 0.032 kN substantiates the mechanical integrity, reflecting brittle fracture behavior and enhanced robustness due to cadmium incorporation. The glass transformation kinetics of Cd-doped selenium tellurium samples significantly improved compared to their undoped counterparts, indicating enhanced molecular mobility and structural relaxation within the glassy network; This enhancement suggests that the incorporation of cadmium facilitates a more efficient rearrangement of the glass structure during the transition process, ultimately leading to better thermal stability and performance. Thermal parameters of the prepared $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ glasses, i.e., T_g , T_p , and T_c , were obtained through DSC in non-isothermal conditions. Also, crystallization energy activation had been computed with different iso conversational methods. JMA model: the increase in nucleus takes a slow rate after the nucleation, and it is only applicable under the low limits of low rates of heating under non-isothermal conditions. All heating rates utilized to compute DSC curves are most compatible with the SB model. These results demonstrate that $(\text{Se}_{90}\text{Te}_{10})_{95}\text{Cd}_5$ combines favorable thermal, mechanical, and structural properties, making it suitable for applications where glassy characteristics must be maintained alongside mechanical integrity.

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