# EFFECT OF ALUMINIUM ADDITION ON CRYSTALLIZATION ACTIVATION ENERGY OF GeSbTe THIN FILMS

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$Al_x(Ge_2Sb_2Te_5)_{1-x}$ materials with different Aluminium contents are studied for applications in phase change random access memory (PCRAM) device. The crystallization of the amorphous films was investigated by electrical resistance measurement. Resistance measurement with temperature shows that crystallization temperature increase with increase in Al content. The resistance variation study at different rates of heating and applying Kissinger's equation to the results show activation energy for crystallization also increases with increase in Al content.

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*Keywords*: Chalcogenides, Electrical properties, Optical properties, Phase-change materials, Phase transitions, Ge-Sb-Te

## 1. Introduction

Phase-change random access memory PRAM has attracted attention as a promising device for the next-generation non-volatile data storage[1]. $Ge_2Sb_2Te_5$ is one of the most successful materials with its prototypes also being developed. But still few challenges are being faced. These involve stability of amorphous phase, retention time and crystallization speed. To overcome them many attempts have been made to develop new phase change materials [2]. Doping is the most commonly used method to tailor the properties optical response band gap etc. We too have tried the same. Many dopants are being studied till date with changing one or the other parameters either favorably or adversely. In this quest doping by various elements, such as N[3], O[4] ,Si[5] ,SiO2 [6] ,Bi[7] ,Ag[8] ,Sn[9], Ce[10] and so on are studied. Al addition theoretically studied in [11] suggest increase in crystallization temperature. Also Al addition experimentally studied by [12,13] hint at favorable optimization of required properties. Therefore we chose to add Aluminium. The crystallization temperature and activation energy are the basic parameters used to estimate the physical and chemical features of optical and electrical phase-change (PC) films. In this paper these two parameters are studied using resistance variation with temperature under vacuum.

## 2. Experimental details

Bulk samples of $Al_x(Ge2Sb2Te5)_{1-x}$ with x=0,0.25 and 0.30 were prepared using a conventional melt-quench technique. The 5N constituent elements were sealed at given atomic-weight percentage ratios in an evacuated quartz ampoule with a diameter of 8 mm. The sealed quartz tube was then placed in a furnace and heated at 1223 K for 48 h. The ampoule was frequently stirred in order to achieve a homogenization of the constituents in the melt, and then the sample was subsequently furnace cooled. The amorphous thin films (~100 nm) were deposited by thermal evaporation of the bulk kept in a vacuum of $2x10^{-5}$ Torr. The film deposition was carried out in HIND HIVAC coating unit. The film deposition was carried out on well cleaned glass slides kept at room temperature as substrate and with source material taken in a molybdenum boat. The

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resistance-temperature measurements were carried out in running vacuum at different heating rates (β).

### 3. Results

XRD output of the bulk for all three compositions is checked for formation of GST. The peaks obtained confirms formation of GST. [14] Further thin films prepared were checked for presence of crystalline structure but XRD output confirms the amorphous nature as no clear peak is obtained.

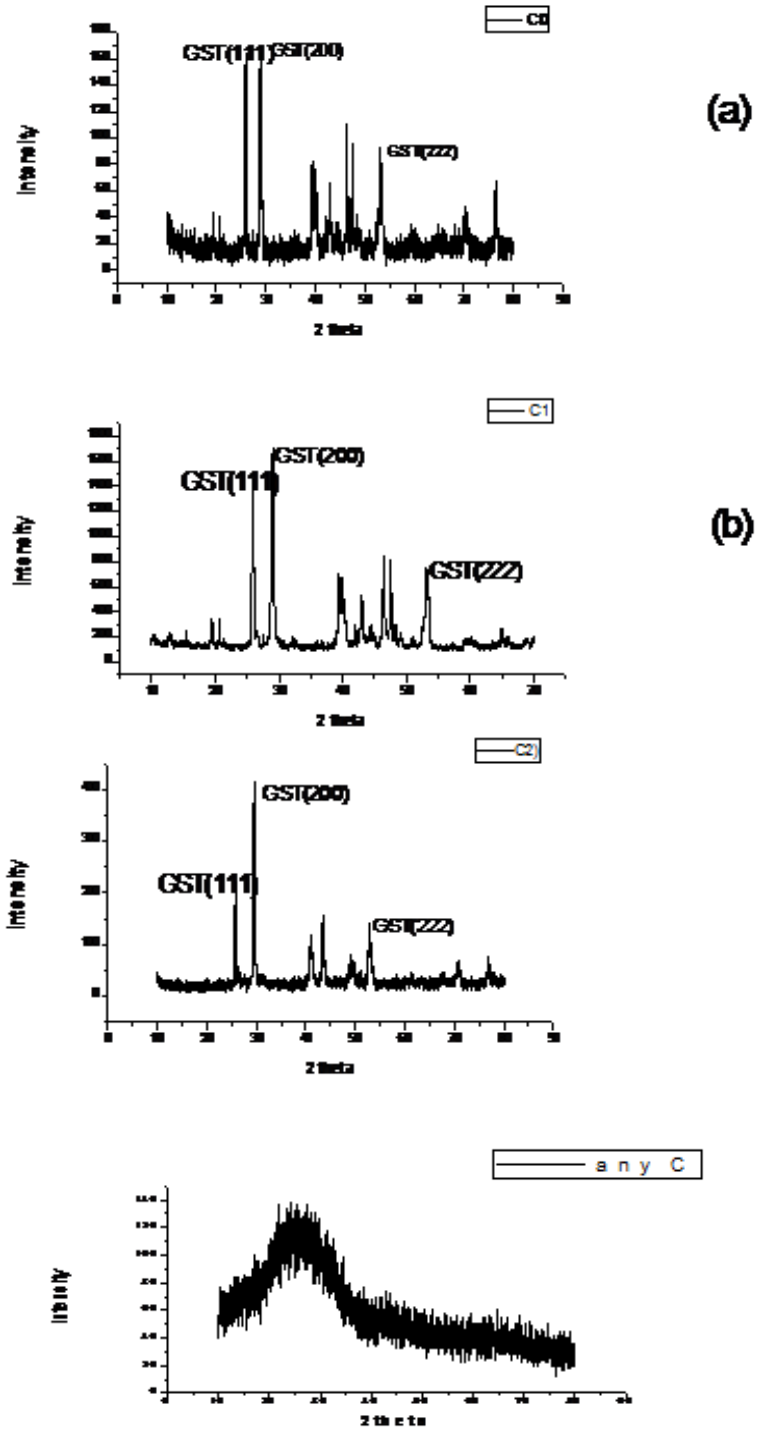



*Fig (1) (a),(b),(c) shows the GST peaks in compositions C0 ,C1, C2 respectively.*
*(d) shows the amorphous nature of thin films formed*

The result of the temperature vs resistance measurements are shown in fig 2.

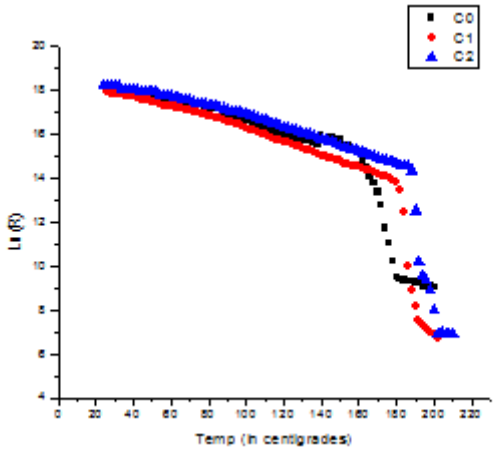
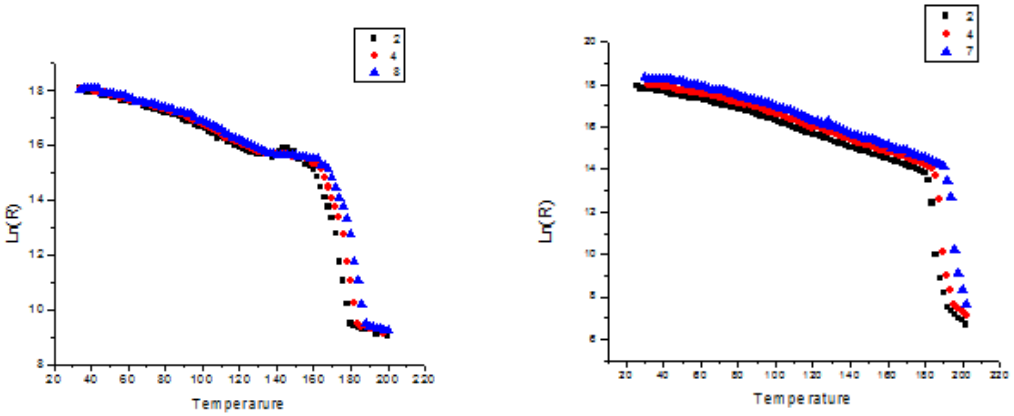


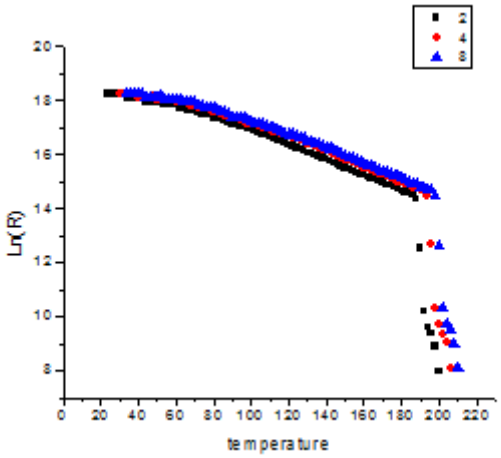

*Fig 2 : Variation of Ln( R) Vs Temperature with heating rate of $2^0$C per min.*

The variation of resistance Vs temperature by orders of magnitude shows change in phase. The crystallization temperature increases with increase in Al content. Also the resistance in amorphous phase do not change appreciably but the resistance in crystalline phase decrease with Al content. This implies resistance contrast increases with Al addition.

The variation of $T_c$ with different heating rates is studied for all there compositions and results are given in fig 3




(a) (b)




(c )

*Fig 3:Ln(R)VsT graph for compositionC0,C1,C2 in (a),(b),(c)respectively with different heating rates*

We observe that crystallization temperature increases with the heating rate for all the compositions. Activation energy is calculated from Tc variation using Kissingers relation[15].
$Ln(\beta/T_c^2) = (E_a/k_bT_c) + C$

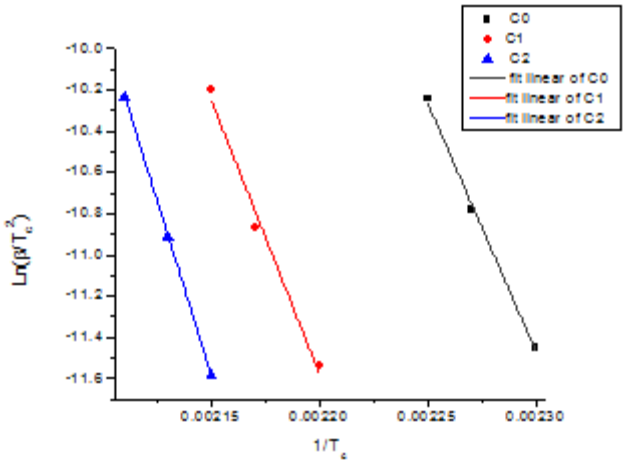



*Fig 4 : Graph of $ln(\beta/T_c^2)$ vs $1/T_c$*

$E_a$ obtained from slope of linear fit of graphs show increase of crystallization activation energy with increase in Al content.

*Table 1.Crystallization temperature variation with Temperature*

| Composition | Crystallization temperature$T_c(^oC)$ | Activation energy(eV) |
|---|---|---|
| C0 | 166 | 2.071 |
| C1 | 181 | 2.279 |
| C2 | 189 | 2.906 |

## 4. Discussion

Addition of Al increases the crystallization temperature. This can be the result of increase in heat of atomization as argued in [11]. Large variation in resistance of crystalline phase as compared to that of amorphous phase on Al addition hints that Al addition causes large change in bonding in crystalline phase as compared to that in amorphous phase. We observe that crystallization temperature increases with the heating rate for all the compositions. This increase was expected as already explained based on crystallization mechanism for GST in reference[16]. Activation energy value obtained is in agreement with reported values for GST[17]. Increase in activation energy with Al addition could be attributed to increase in thermal stability indicated by increase in crystallization temperature.

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