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# THE GLASS TRANSITION IN THE SYSTEM $Ge_{15.5-x}Te_{84.5}Sb_x$ (0.5 <x< 1.5)

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A study of non-isothermal heating for $Ge_{15.5-x}Te_{84.5}Sb_x$ (0.5 <x< 1.5) by differential scanning calorimetry (DSC) show two glass transition temperatures. The behaviour of the glass transition temperatures as a function of antimony content and aging is followed and discussed.

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*Keywords*: Chalcogenide, Amorphous, Differential Scanning Calorimetry, Glass transition, Crystallization, Thermograms

## 1. Introduction

The phase change memory (PCM) materials are of high importance for the modern recording media in CD, DVD and in the development of multistage memory films. Ovonic Universal Memory (OUM) is now under intense research in Electron Conversion Devices Company in USA, and in other companies in Japan or Korea [1]. The solid films for information recording are based on the non-crystalline, amorphous or glassy state of the complex chalcogenides. One of the most important material, which served for many years as typical, demonstrative material for phase change recording films is the ternary system Ge-Sb-Te, with its typical members $Ge_2Sb_2Te_4$, $Ge_2Sb_5Te_6$ and $Ge_5Sb_2Te_7$. The differences in the structure of these members is only in number and ordering of of stacking layers of Sb, Te and Ge and stacking defects can be probably also formed by non-equilibrium crystallization [2, 3].b Most of the research on $Ge_2Sb_2Te_5$ was mainly focused on the application side, such as design, fabrication, and performance evaluation of devices based on that material [4, 5]. Although many papers have been dedicated to Ge-Sb-Te system, there are still challenging problems related, especially, to the crystallization process and phase separation during crystallization and/or amorphization of the specific compositions of Ge-Sb-Te. In this paper we discuss the problem of the thermal properties, including the modification of the crystallographic states of the Ge-Sb-Te compositions during thermal processing.

## 2. The glass transition

The vitreous or glass transition is an endothermal reaction, specific to glassy materials. All the modifications which take place in the region of glass transition are essentials for all the processes in glasses and influence directly the glass properties.

We are interested in the effect of antimony on the region of glass transition for samples with high concentration in tellurium. This is the peritectic system $Ge_{15.5-x}Te_{84.5}Sb_x$ (0.5<x<1.5) aged for five years in ambient temperature.

On the DTA curves one observes two regions of glass transitions $T_{g1}$ and $T_{g2}$ and two exothermal peaks. There are present, therefore, two crystallization regions characterized by two $T_{c.}$(Fig. 1) with $T_{g1} < T_{g2.}$

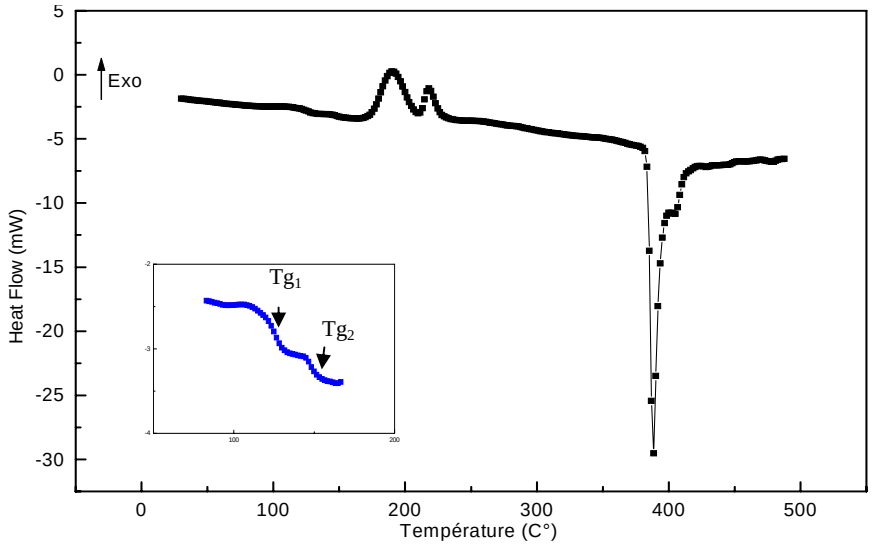


Figure 1 Differential thermal analysis (DTA) of $Ge_{15}Te_{84.5}Sb_{0.5}$ at the rate of 10 °C/min.

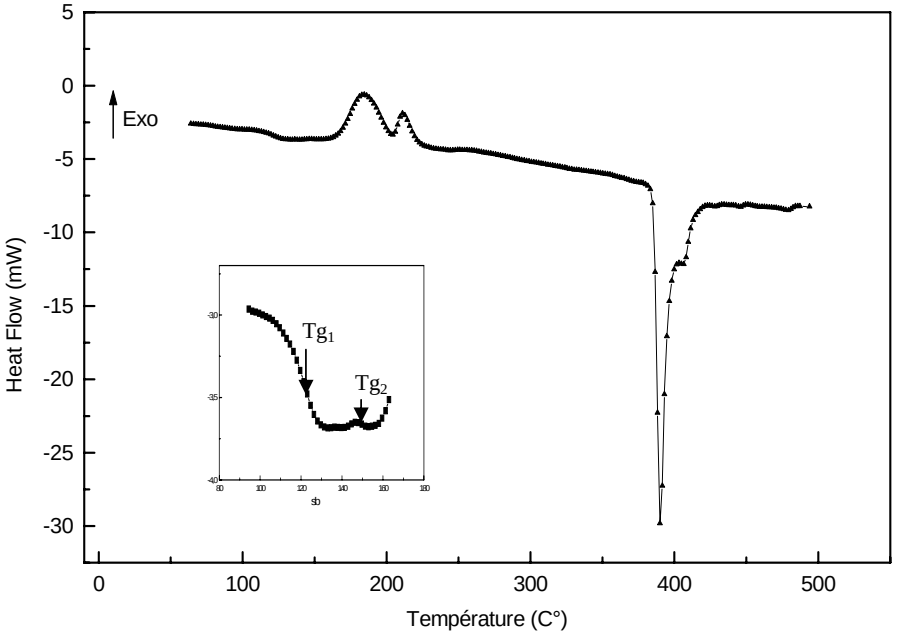


Figure 2 Differential thermal analysis of $Ge_{14.5}Te_{84.5}Sb_{01}$ at the rate of 10 °C/min.

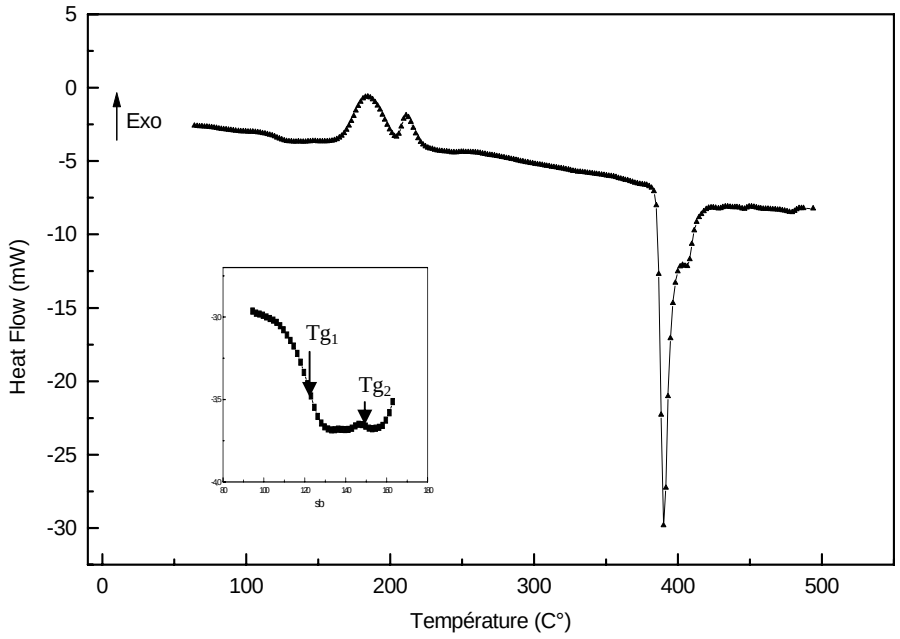


Fig. 3. Differential thermal analysis of $Ge_{14}Te_{84.5}Sb_{1.5}$ at a rate of 10 °C/min.

In the Table 1 are shown the values of the glass transition temperatures for the heating of the samples with 10 °C/min.

Table 1 : The $T_g$ values (in °C) for various compositions for the heating rate of 10 °C/min.

| x | 0.5 | 1 | 1.5 | Reference |
|---|---|---|---|---|
| $T_{g1}$ | 122 | 117 | 115 | Our results |
| $T_{g2}$ | 145 | 147 | 151 | |
| $T_{g1}$ | 120 | 116 | 114 | [1] |
| $T_{g2}$ | 144 | 148 | 150 | |

Fig. 4 shows the variation of $T_g$ with the percent of antimony starting from the reactions observed for a heating rate of 10°C/min.

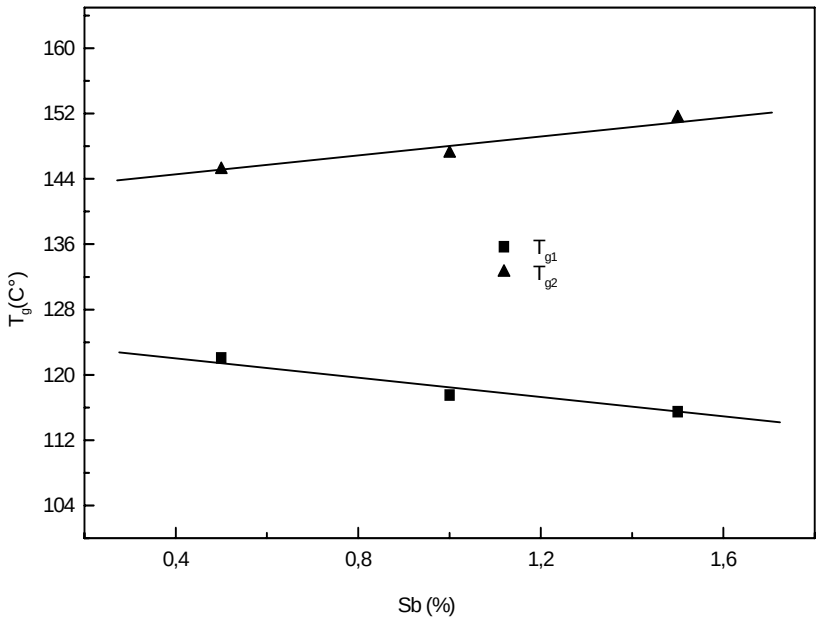


Fig. 4 The modification of $T_g$ with the percent of antimony in the sample.

It is remarkable that the value of $T_{g1}$ decreases with the increase of the percent of Sb while the value $T_2$ increases. The introduction of the antimony atoms (even in low atomic concentration) in the alloy GeTe, gives rise to a second $Tg_{2,}$ while the value of $T_{g1}$ does not change (see Fig. 5).

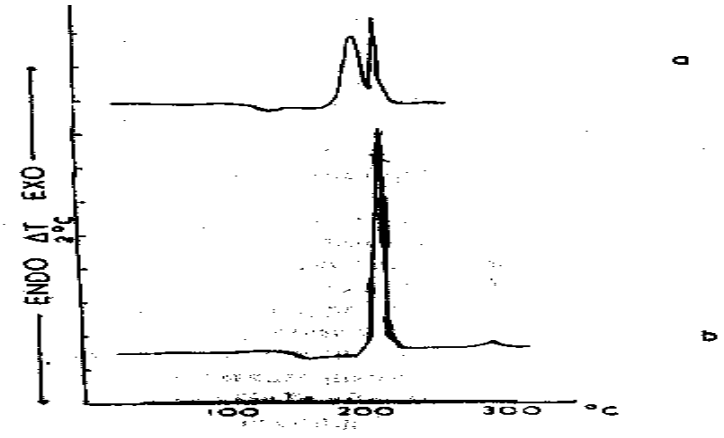


Fig. 5 Differential thermal analysis of the system GeTe: a - $Ge_{15}$ $Te_{85}$; b - $Ge_{20}Te_{80}$

The effect of aging is not influenced by the two glass transitions of the fresh system. Contrarily, if the system is subjected initially to a thermal treatment to a given temperature, and thereafter aged for three years, one gets only one $T_g$ peak with a higher area (Fig. 5).

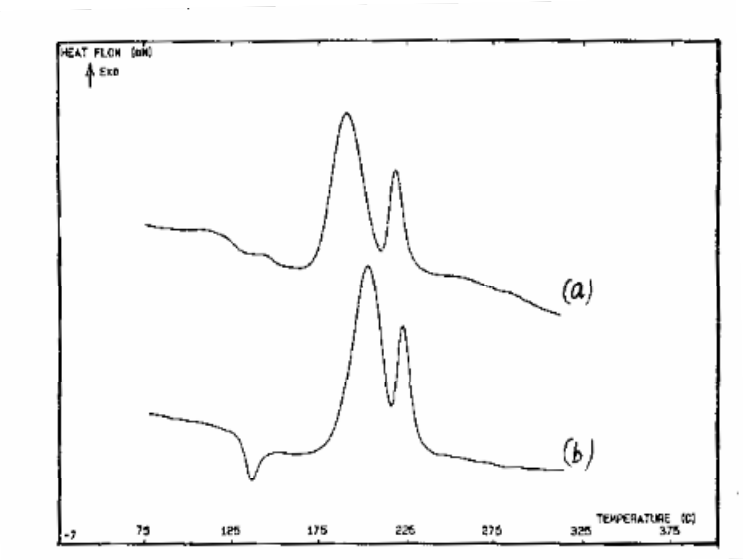


Fig. 6: The thermal differential analysis of the composition $Ge_{15}Te_{84.5}Sb_{0.5}$
a- fresh, b- aged.

## 3. Conclusions

From the thermal analysis of the Ge-Te-Sb samples there was concluded that the investigated system exhibits two glass transition temperatures in the range 115 – 151 $^oC$. The composition with x = 0.5 (i.e. 0.5 % Sb in $Ge_{15.5-x}Te_{84.5}$) show the highest glass transition temperature $T_{g1}$=122 $^oC$, and lowest glass transition temperature $T_{g2}$ = 145 $^oC$, while for x = 1.5 (i.e. 1.5 % Sb in $Ge_{15.5-x}Te_{84.5}$) exhibits the lowest glass transition temperature $T_{g1}$=115 $^oC$ and highest glass transition temperature $T_{g2}$=151 $^oC$, for the heating rate (10 $^oC$/min).

## References

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