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STUDY OF CRYSTALLIZATION KINETICS OF AMORPHOUS $FE_{76}TM_4B_{20}$ALLOY USING DIFFERENTIAL SCANNING CALORIMETRY (DSC)

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ABSTRACT

Crystallization kinetics of amorphous $Fe_{76}Tm_4B_{20}$ alloyhas been studied using Differential Scanning Calorimetry (DSC). Calculation of activation energy(E_a) and frequency factor (k_0) of amorphous $Fe_{76}Tm_4B_{20}$ alloy has been doneusing Kissinger, Matusita-Sakka and Augis-Bennet methods.Using. The average value of activation energy (E_a) of crystallization is found to be equal to 430.85kJ/mol. Similarly, the Frequency factor(k_0) is calculated using Kissinger and Augis-Bennet methods which is found to be 5.39 $x10^{17}$ sec^{-1}, and 2.51 $x10^{19}$ sec^{-1}, respectively.It can be concluded that the Kissinger, Matusita-Sakka and Augis-Bennet relations are applicable to calculate the activation energy and frequency factor to explain the thermal stability of the sample.

Keywords: Crystallization, Differential Scanning Calorimetry, Activation Energy, Frequency Factor,

I. INTRODUCTION

Investigation of crystallization kinetics of amorphous materials was done by explaining the crystallization mechanism and the crystallization activation energy in terms of isothermal and non isothermal methods with different approaches. Differential thermal analysis (DTA) techniques used in crystallization kinetic studies were reported and a correlation between kinetic and structural investigations were made to determine the crystallization mechanism . Thus, the theory of crystallization in amorphous materials can be explained by considering the structure and the kinetics of the crystallization. The investigation of crystallization kinetics is important since it quantifies the effect of the nucleation and growth rate of the resulting crystallites [1,2].In this paper, we presented the study of crystallization kinetics of amorphous $Fe_{76}Tm_4B_{20}$ alloy using Differential Scanning Calorimetry (DSC).

II. EXPERIMENTAL

Amorphous $Fe_{76}Tm_4B_{20}$ alloyribbons prepared by single roller melt spinning technique under inert atmospherewere procured from our other researchers. The alloy ribbon was about 1 mm wide and about 30 µm thick. The amorphous nature of ribbons was confirmed by X-ray diffraction (XRD).The as-quenched sample of$Fe_{76}Tm_4B_{20}$ribbon was heated in DSC (DSC-50, Shimadzu, Japan) at three linear heating rates (5, 10, and 15

Kelvin/min) from room temperature to 1200 K. The DSC scans were recorded by a thermal analyzer interfaced to a computer.

III. RESULTS AND DISCUSSION

According to Kissinger's method [3,4], the transformation under non-isothermal condition is represented by a first-order reaction. More over, the concept of nucleation and growth has not been included in Kissinger equation. Matusita et al.[5] have developed a method on the basis of the fact that crystallization does not advance by an n^{th} order reaction but by a nucleation and growth process. They emphasized that crystallization mechanism such as bulk crystallization or surface crystallization should be taken into account for obtaining activation energy. Augis and Bennett method [6] is helpful in obtaining kinetic parameters such as frequency factor (k_0) along with activation energy

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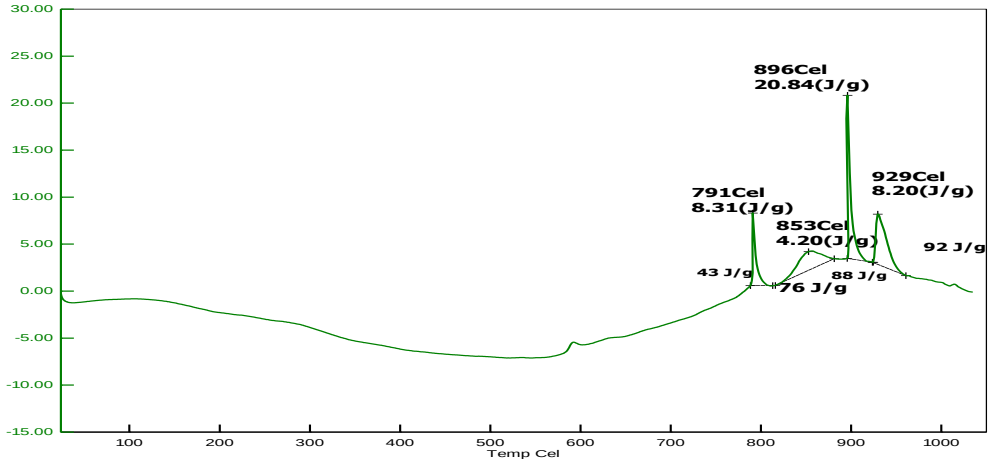

Figure 1(a) DSC curve of Amorphous $Fe_{76}Tm_4B_{20}$ alloy at a heating rate of 20^0C/min.

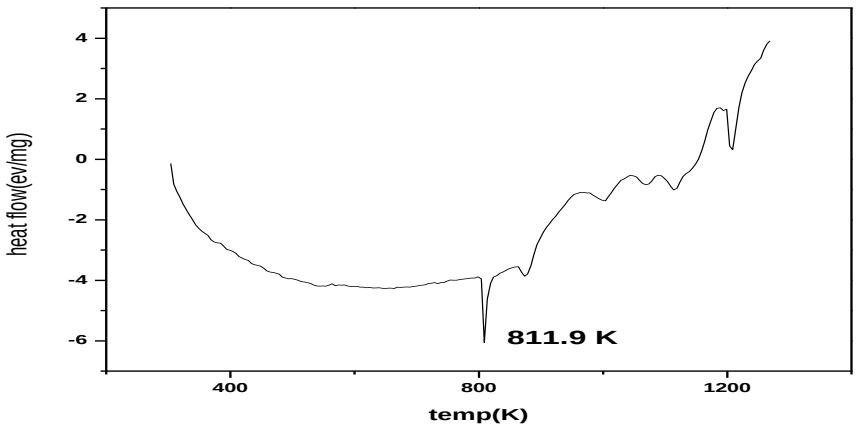

Figure 1(b) DSC curve of Amorphous $Fe_{76}Tm_4B_{20}$ alloy at a heating rate of 15^0C/min.

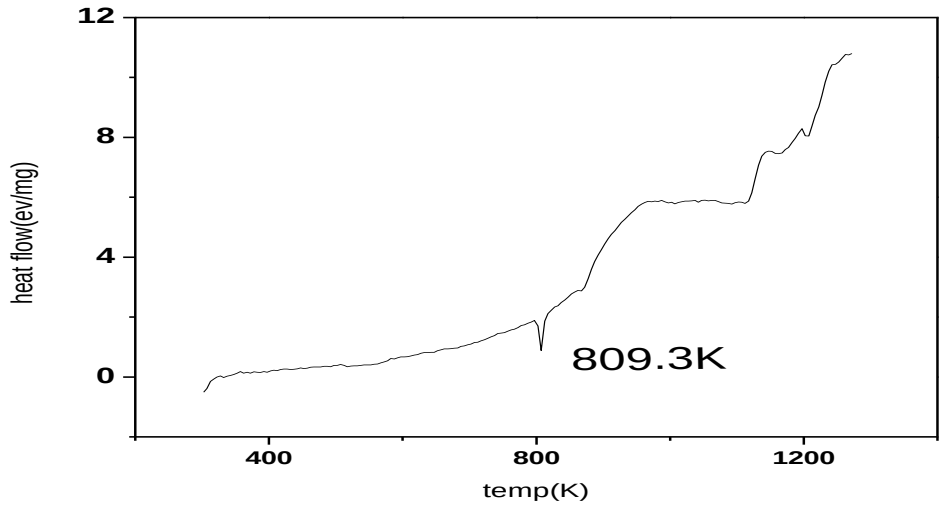

Figure 1(c) DSC curve of Amorphous $Fe_{76}Tm_4B_{20}$ alloy at a heating rate of 10^0C/min.

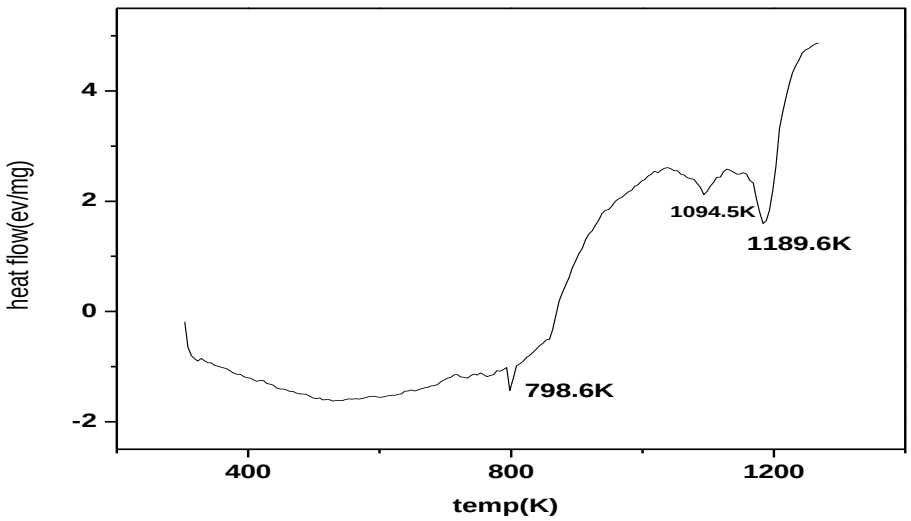

Figure 1(d) DSC curve of Amorphous $Fe_{76}Tm_4B_{20}$ alloy at a heating rate of 5^0C/min.

Figure 1 DSC curves of amorphous $Fe_{76}Tm_4B_{20}$ ribbonsat three heating rates of crystallization.

IV. DETERMINATION OF ACTIVATION ENERGY USING KISSINGER METHOD

The activation energy for crystallization of an amorphous alloy under a linear heating rate can be estimated using Kissinger's peak shift method, which relates the peak temperature, T_p, with heating rate (α) through the equation

$\ln (\alpha/T_p^2) = -(E_a/RT_p) + \ln(k_0R/E_a)$----------(1)

where$E_a$is the activation energy for crystallization, $T_p$the peak temperature and k_0 the frequency factor which is defined as the number of attempts made by the nuclei per second to overcome the energy barrier. Figure 2 shows the graph of ln (α / T_p^2) vs $1000/T_p$ for amorphous $Fe_{76}Tm_4B_{20}$alloy. The activation energy, E_a and the frequency factor k_0 for crystallization peak are given in Table 1.

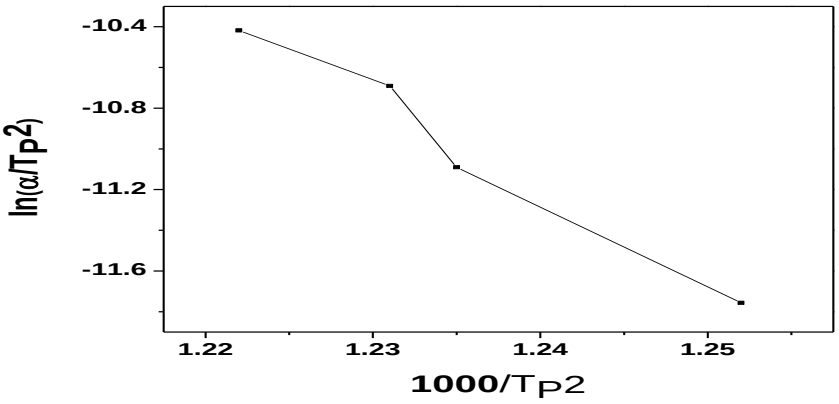

Figure 2ln (α/T_p^2) vs. (1000/ T_p) ofamorphous $Fe_{76}Tm_4B_{20}$alloy (Kissinger Plot)

Table1 The activation energy (E_a) and frequency factor (k_0)of amorphous $Fe_{76}Tm_4B_{20}$ alloy

COMPOSITION	Activation Energy, E_a (kJouls/mole)				Frequency factor, $k_0(sec)^{-1}$	
	Kissinger's Method	Augis-Bennet's Method	Matusita-Sakka's Method	Average (kJouls/mole)	Kessinger's Method	Augis-Bennet's Method
$Fe_{76}Tm_4B_{20}$	422.70	429.83	440.06	430.85	$5.39x10^{17}$	$2.51x10^{19}$

V DETERMINATION OF ACTIVATION ENERGY USING AUGIS& BENNETT METHOD

The activation energy for crystallization of an amorphous alloy under a linear heating rate can be estimated using Augis& Bennett method, which relates the peak temperature, T_p, with heating rate (α) through the equation

$\ln(\alpha/T_p) = - E_a/ RT_p + \ln k_o$ ----------(3)

where$E_a$is the activation energy for crystallization, $T_p$the peak temperature and k_0 the frequency factor. Figure 3 shows the graph of ln (α/T_p) vs. $1000/T_p$ for amorphous $Fe_{76}Tm_4B_{20}$ alloy. The activation energy, $E_a$and the frequency factor k_0 for crystallization peak are also given in Table 1.

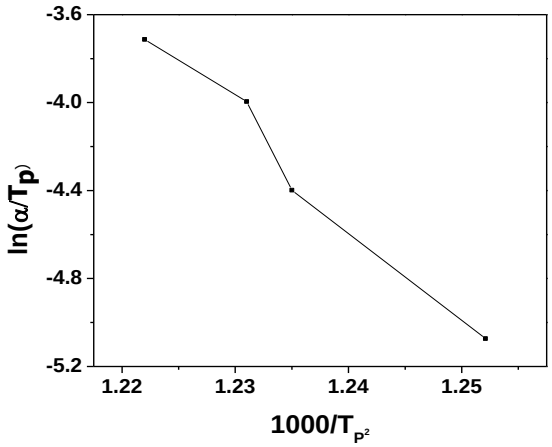

Figure 3 ln (α /T_p) vs. (1000/ T_p) of amorphous $Fe_{76}Tm_4B_{20}$alloy(Augiss and Bennet plot)

VI. DETERMINATION OF ACTIVATION ENERGY USING MATUSITA-SAKKA METHOD

The activation energy for crystallization of an amorphous alloy under a linear heating rate can also be estimated using Matusita-Sakka's peak shift method, which relates the peak temperature, T_p, with heating rate (α) through the equation

$$\ln(\alpha) = -(E_a/RT_p) + \text{constant} \text{----------} (2)$$

where$E_a$is the activation energy for crystallization, $T_p$the peak temperature and R is the universal gas constant. Figure 4 shows the graph of ln (α) vs 1000/T_p for amorphous $Fe_{76}Tm_4B_{20}$ alloy. The activation energyof amorphous$Fe_{76}Tm_4B_{20}$ alloyis given in Table 1.

It is also observed that activation energies of amorphous $Fe_{76}Tm_4B_{20}$alloy calculated by means of the different theoretical models differ slightly from each other. This difference in the activation energy as calculated with the different models may be attributed to the differentapproximations used in the models.

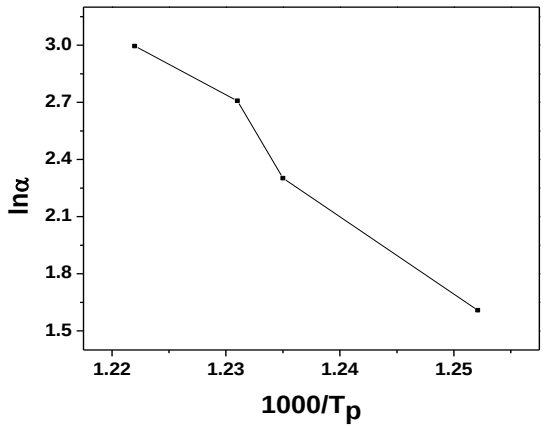

Figure 4 ln (α) vs. (1000/ T_p) of amorphpus$Fe_{76}Tm_4B_{20}$ alloy(Matusika – Sakka plot)

VII CONCLUSIONS

The average activation energy for primary crystallization of amorphous $Fe_{76}Tm_4B_{20}$ alloy using Kissinger, Augis-Bennet and Matusita-Sakka methods is found to be 430.85 kJ/mol. The frequency factor of amorphous $Fe_{76}Tm_4B_{20}$ alloy using Kissinger and Augis-Bannetmethods is found to be 5.39 $x10^{17}$ $(sec)^{-1}$and 2.51 $x10^{19}$ $(sec)^{-1}$, respectively. The above values are in good agreement with values of other similar systems.

VIII ACKNOWLEDGEMENTS

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