# THERMAL STABILITY OF $Ni_{40}Ti_{60}$ AND $Cu_{43}Ti_{57}$ METALLIC GLASSES: A COMPARATIVE STUDY

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## ABSTRACT

*The thermal behaviour of metallic glasses namely Cu43Ti57 and Ni40Ti60 glasses has been studied. The prepared glasses have been thermally scanned using Differential Scanning Calorimetry (DSC) at four heating rates under non-isothermal conditions. DSC thermograms were used to determine on-set and peak crystallization temperatures. Further, the obtained parameters have been used to determine the activation energy for crystallization employing different theoretical models. The results obtained for both glasses were compared in terms of thermal stability.*

**Keywords**: *DSC thermograms, crystallization temperatures, activation energy for crystallization.*

## INTRODUCTION

In materials science, metallic glasses, also known as amorphous metals, represent a fascinating departure from the crystalline structure that characterizes most conventional metals. Unlike their crystalline counterparts, metallic glasses possess a disordered atomic arrangement, akin to the structure of glassy substances. This unique atomic configuration imparts remarkable properties to metallic glasses, making them a subject of intense study and technological interest. Generally, crystallization kinetics of amorphous alloys, and glasses are studied in two ways (i) non-isothermal dynamics crystallization [1-3] and (ii) isothermal crystallization kinetics. In cases of metallic glasses, the first one is preferred over the second as non-isothermal experiments can be performed over a shorter period and wider temperature range.

Many studies have been reported on Cu- and Ni-based metallic glasses regarding their structure, crystallization behaviour, stability, etc.[4-7]. Among various Cu- and Ni-based metallic glasses Cu-Ti and Ni-Ti glasses gained more attention owing to their unique characteristics. Both glasses exhibited chemical short-range order (CSRO) with some differences. The difference is due to their different crystal structure. The Cu-Cu correlation in Cu-Ti glasses arises from the nearest neighbour position available for direct contact as found in the Cu-Ti crystal structure, while the Ni-Ni correlation in Ni-Ti glasses does not exist at the direct contact position. Further, the shift in characteristic crystallization temperature with Cu-content in Cu-Ti glasses is also reported [8], which implies a correlation of on-set crystallization temperature (Tc) with CSRO. The $T_c$ is a direct measure of the amorphous state's thermal stability, and CSRO is also a factor in thermal stability. Thus, it will be interesting to compare their different thermal behaviour owing to their different structure. A study of the thermal behaviour of the $Cu_{43}Ti_{57}$ and $Ni_{40}Ti_{60}$ glasses has been undertaken in terms of crystallization temperature, glass transition temperature, activation energy, etc. The composition of Ti in both glasses differs by 3%. That difference can be ignored for study purposes. The parameters of both glasses have been compared in terms of stability as there is not so much difference in the concentration of Ti component in both glasses.

## EXPERIMENTAL

The metallic glasses namely $Cu_{43}Ti_{57}$ and $Ni_{40}Ti_{60}$ have been prepared by the melt quenching technique under identical conditions. Differential Scanning Calorimetry (DSC) was performed on a Rigaku 8230B model attached with a thermal analysis (TAS 100) at four heating rates viz. 5K/min., 10K/min.15K/min, and 20K/min under non-isothermal conditions. The temperature precision of the equipment is 0.1K, with an average standard error of about ±1K in the measured values. The samples with masses of 3-4mg were continuously heated from room temperature to $500^0$C.

## RESULTS AND DISCUSSION

The metallic glasses $Ni_{40}Ti_{60}$ and $Cu_{43}Ti_{57}$ were scanned at four different heating rates; 5K/min, 10K/min, 15K/min, and 20K/min. Figs. 1 and 2 show the DSC thermograms of both glasses at the heating rate of 10K/m. as a representative curve.

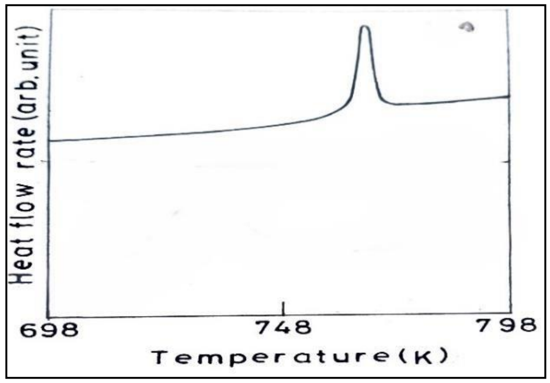


**Fig.1: DSC scan of $Ni_{40}Ti_{60}$ glass at 10K/m heating rate.**

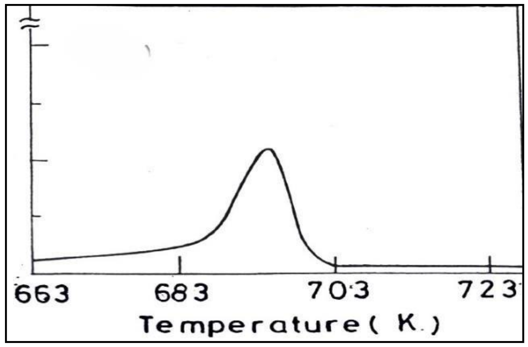


**Fig.2: DSC scan of Cu43Ti57 glass at 10K/m heating rate**

A well-defined single exothermic region corresponding to crystallization temperature is observed. The values of the on-set crystallization temperature ($T_C$) and peak crystallization temperature ($T_P$) of both glasses respectively are listed in Table 1

**Table 1: Values of on-set crystallization temperature ($T_C$) and peak crystallization temperature ($T_P$)**

| Heating Rate | On-set crystallization temperature ($T_C$) (in K) | | Peak crystallization temperature ($T_P$) (in K) | |
|---|---|---|---|---|
| | $Ni_{40}Ti_{60}$ | $Cu_{43}Ti_{57}$ | $Ni_{40}Ti_{60}$ | $Cu_{43}Ti_{57}$ |
| 5K/m | 745 | 673.8 | 751.8 | 682.6 |
| 10K/m | 754.3 | 684.7 | 762.3 | 693.9 |
| 15K/m | 759.2 | 690 | 766.9 | 700.4 |
| 20K/m | 760.7 | 694.8 | 770.9 | 702.4 |

It can be noticed from the table that at the outset, both temperatures; $T_C$ and $T_P$ increase with the increasing heating rate in both glasses. However, the rate of increase in temperature decreases with the increase in heating rate. It can also be seen from the table that the crystallization process in $Ni_{40}Ti_{60}$ glass occurs at a much higher temperature than that of $Cu_{43}Ti_{57}$ glass. This shows that $Ni_{40}Ti_{60}$ glass is more thermally stable than $Cu_{43}Ti_{57}$ glass.

The obtained thermograms have been further analyzed using various theoretical models to study the thermal behaviour of both glasses. The various models employed to obtain different parameters, are Kissinger Model, Matusita's Equation, and Gao and Wang model. The results obtained were reported earlier [9,10]. The activation energy of crystallization in both glasses obtained using different theoretical approaches is listed in Table 2.

**Table 2: Activation energy of crystallization ($E_C$)**

| Theoretical Models | Activation Energy ($E_C$) (kJ/mole) | |
|---|---|---|
| | $Ni_{40}Ti_{60}$ | $Cu_{43}Ti_{57}$ |
| Kissinger Eq. | 380±5 | 247±5 |
| Ozawa Model | 414±7 | 254±8 |
| Matusita Eq. | 385±10 | 250±10 |
| Gao-Wang Eq. | 393±8 | 281±5 |

From the table, it can be inferred that there is a small difference in activation energy for crystallization determined through different theoretical models in both glasses. This difference can be attributed to different assumptions involved in models. Further, it can be noted from the table that the activation energy for the crystallization of $Ni_{40}Ti_{60}$ glass is much higher than that of $Cu_{43}Ti_{57}$ glass. The higher activation energy indicates the glass's higher thermal stability, which is also distinctly visible in Table 1 and DSC scans.

## CONCLUSIONS

The above study of DSC thermograms and activation energy leads to the following conclusions (i) the DSC thermograms exhibit single crystallization temperature confirming the homogeneity of the sample and (ii) the obtained parameters indicate the higher thermal stability of $Ni_{40}Ti_{60}$ glass in comparison to $Cu_{43}Ti_{57}$ glass.

## REFERENCES


1. S. Surinach, M.D. Baro, M.T. Chavaguera-Mora, N. Claaguera, J Non. Cryst. Solids 58 (1983) 200.
2. M. Matsura, K. Suski, J. Mater.Sci. 14(1979)395.
3. E.A. Marsegila, E.A.Davis, J Non. Cryst. Solids 50 (1982)13.
4. E.F. Conde, H. Miranda, A. Conde, J. Mater.Sci. 24(1989)1862.
5. G.K.Dey, E.G. Baburaj, S.Banerjee, J. Mater.Sci. 21(1986)117.
6. Zhang Hen, Zhang Bangwei, Tan Zhaosheng Wulijun, Metall Transac.A23 (1992) 1627.
7. J.Eckert I Schultz, E. Hellstern, J. Appl.Phys. 64 (1988)3224.
8. M.Sakata, N. Cowlin, H.A. Davies, Proc. Of the IV Inter. Conf. on Rapidly Quenched Metals, edited by T. Masumoto, K. Suzuki, (Japan Institute of Metals, Sedai, 1982) Vol.1 p 327.
9. Rohit Jain, N.S.saxena, Deepika Bhandari, S.K. Sharma, K.V.R. Rao, Physica B 301 (3-4) (2001) 341 and references therein.
10. Rohit Jain, N.S. Saxena and Deepika Bhandari, Ind. J. Pure and Appl. Phys. 41(2003) 457 and references therein.