LOW TEMPERATURE RELAXATION INVESTIGATION OF $Fe_{40}Ni_{40}P_{14}B_6$ METALLIC GLASS

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The set up for thermal dilatation measurements was modified for investigation of length change during isothermal annealing process.The free volume change was investigated for $Fe_{40}Ni_{40}P_{14}B_6$ metallic glass.It was found that the relaxation parameter R_v has a logaritmic dependence.The obtained curves which show the free volume change kinetics indicated that the process has a series of activation energies.

Introduction

The metallic glass is a metastable system in two ways, with respect to its lowest energy state and in respect to its crystalline counterpart.The free volume change investigation is the investigation of the relaxation process; during this process the samples become amorphous with the lowest energy. As proposed by Egami /1/ and Chen /2/ this low temperature relaxation process can be described by a relaxation parameter ΔR_v (in our case $\Delta R_v = 3\,\Delta l/l$), that could be

$$\Delta R_v = R_v - R_{v_o}$$

$$\Delta R_v = \frac{kT}{\alpha} \ln \left(\frac{t}{t_o} + 1 \right) \qquad (1)$$

$$t_o = \frac{kT}{c\alpha} \exp\left(\frac{\alpha R_{vo}}{kT} \right) \qquad (2)$$

where:

R_{v_o} is the amount of relative volume change that occurred during quenching resulting from finite quenching rate.

R_v is the actual relative volume change during relaxation.

k is Boltzmann constant, and c and α are constants.

T is the annealing temperature.

The term αR_{v_o} in equation (2) represents the activation energy for start of volume relaxation during annealing of as-quenched samples. This was calculated from $\ln(t_o/T)$ vs. $1/T$ plot in fig.3. to be of the order of 50 KJ/mole. Further stages of volume relaxation were found to require higher activation energy proportional to the amount of the actual relaxation, R_v i.e. increasing with amount of densification.

Experimental

The experimental set up /3/ is a modification of the apparatus constructed for dilatation measurements of amorphous samples /4/. The sample is posted in a homogeneous temperature field with the variation of ± 0.04K. Due to its low heat capacity, the samples were able to reach the surrounding temperature in 5-6s. The change in the length was transmitted to the LDTV transducer, which was in connection with a nanovoltmeter (Keithley M-180). This instrument which enabled accurate scanning of discrete displacement values, was connected with the y-axes of a chart recorder with a time base of 25 s/cm. This isothermal annealing experiment enabled direct observation of the complete process and data for further numerical analysis.

The glassy $Fe_{40}Ni_{40}P_{14}B_6$ samples were 12-16 mm long and the applied tensile stress on them was less than $4,9 \cdot 10^6$Pa. Experimental results are shown on fig.1 and fig.2. The free volume change during isothermal annealing obtained by use of the chart recorder is shown on fig.1. The same process for two different temperatures and with normalised numerical values, obtained by the nanovoltmeter are shown on fig.2.

Disscusion

The curves on fig.1 and fig.2 show that the free volume change dependence could not be approximated by an expression of type Aexp(-bt). The little peaks on fig.2 lead to the conclusion that there is not only one activation energy, but a series of them.Fig.3 shows the results plotted on logaritmic time scale. The values could be approximated to a line, what confirms the accordance with the relation (2).

The comparison with the results obtained for $Fe_{40}Ni_{40}B_{20}$ samples is given on fig.4. The substitution of boron with the $P_{14}B_6$ complex makes the metallic glass less stable, because of the more intensive relaxation process in $Fe_{40}Ni_{40}P_{14}B_6$ samples. As shown in fig.4 there is a considerable greater contraction of $Fe_{40}Ni_{40}P_{14}B_6$ metallic glass.

Acknowledgements

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References:

/1/ T.Egami, J.Appl.Phys. 50 (1979) 1564

/2/ H.S.Chen, J.Appl.Phys. 49 (1978) 4595

/3/ E.Girt, A.Kuršumović and T.Mihać-Kosanović, J.Phys.E Sci.Instr. 13 (19807 898

/4/ E.Girt, P.Tomić and A.Kuršumović, to be published

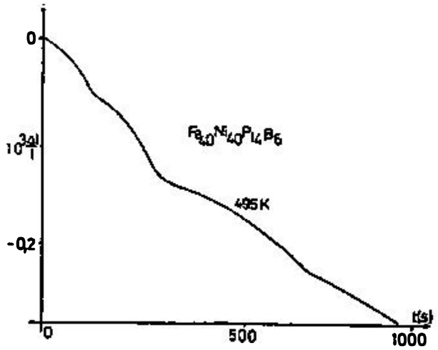

Fig.1 Free volume change during isothermal annealing in $Fe_{40}Ni_{40}P_{14}B_6$ amorphous sample

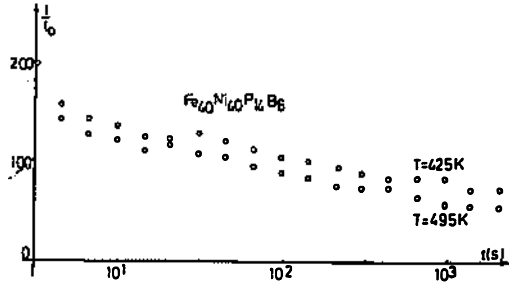

Fig.2 Free volume change during isothermal annealing of $Fe_{40}Ni_{40}P_{14}B_6$. The results are normalised values obtained by digital instrument.

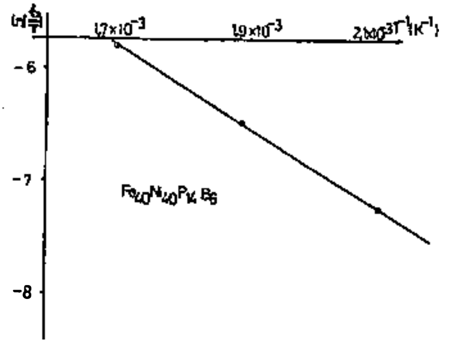

Fig.3 ln(τ_0/T) vs.1/T giving corresponding activation energy of the relaxation start of $Fe_{40}Ni_{40}P_{14}B_6$ sample

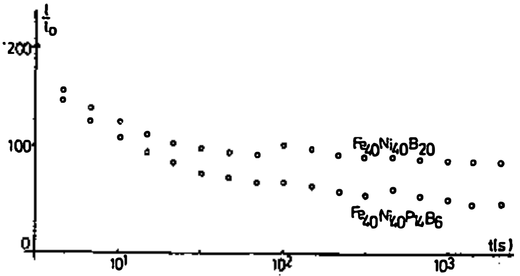

Fig.4 The comparison of the results obtained for $Fe_{40}Ni_{40}P_{14}B_6$ and $Fe_{40}Ni_{40}B_{20}$ amorphous samples.