HIGH TEMPERATURE CREEP OF $Fe_{40}Ni_{40}B_{20}$ AMORPHOUS ALLOY UNDER NONISOTHERMAL CONDITIONS

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The high temperature creep behaviour of $Fe_{40}Ni_{40}B_{20}$ amorphous alloy is significantly affected by isothermal pre-annealings at different elevated temperatures. In the low temperature region (350-425°C) an anomalous behaviour of the viscosity temperature dependence different for the various pre-annealings is observed which is most probably due to amorphous phase separation in the amorphous alloy studied.

INTRODUCTION

The atomic structure of the as-quenched amorphous alloys is metastable with respect to the crystalline equilibrium state and with respect to the partially relaxed structural states reached after different relaxation pre-annealings. A special kind of relaxation is the decomposition of the initial one-phase glass into two amorphous phases which differ with respect to the short range order (1). The $Fe_{40}Ni_{40}B_{20}$ amorphous alloy is one of the glassy alloys for which amorphous phase separation is experimentally established by direct observation in an atom probe field ion microscope (2). The annealing of this alloy below the temperature of crystalization leads to further development of chemical inhomogeneity on an atomic scale from its state after quenching. This decomposition consists of phase separation of the amorphous matrix into amorphous cementite-like $(Fe,Ni)_3B$-particles and an amorphous (Fe,Ni,B) solid solution, for which the boron content decreases with increasing volume fraction ξ of the cementite-like particles. The aim of this article is to describe the viscous flow features of $Fe_{40}Ni_{40}B_{20}$ glassy alloy studied with the aid of a nonisothermal dilatometry with particular attention to possible phase separation.

EXPERIMENTAL PROCEDURE

The amorphous $Fe_{40}Ni_{40}B_{20}$ ribbon used was 1 mm wide by 0.03 mm thick. Creep measurements were carried out using a Hereaus TMA 500 silica glass dilatometer. In order to study the influence of different heat treatments

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on the creep behaviour of the alloy studied isothermal pre-annealings for 50 min at 275, 300, 325, 359 and 370°C were carried out under applied loads. The annealed samples were cooled down to room temperature and without replacing the load (0.5 or 1.0 N) the strain-temperature (time) curves $\varepsilon_{0.5}$ and $\varepsilon_{1.0}$ respectively, were monitored up to temperatures higher than the temperature of crystalization. In a previous paper (3) we showed that the strain difference $\Delta\varepsilon_{0.5}$ of the strains $\varepsilon_{1.0}$ and $\varepsilon_{0.5}$ is due to the viscous creep of the specimens only, and that the viscosity η of amorphous alloys could be calculated at different temperatures according to Newton's equation:

$$\eta = 3\Delta\delta_{0.5}/\Delta\dot{\varepsilon}_{0.5} \tag{1}$$

where $\Delta\delta_{0.5}$ and $\Delta\dot{\varepsilon}_{0.5}$ are stress and strain rate differences respectively (3). The value of $\Delta\delta_{0.5}$ was 167 MPa.

EXPERIMENTAL RESULTS AND DISCUSSION

The temperature (time) dependence of strain $\Delta\varepsilon_{0.5}$ and strain rate $\Delta\dot{\varepsilon}_{0.5}$ -differences are shown in Fig.1 and Fig.2 respectively.

According to (4), the temperature dependence of the viscosity coefficient of glassy alloys could be represented as:

$$\eta = \eta_o \exp(B/T-T_o)\exp(Q/kT) \tag{2}$$

where η_o, B and T_o are empirical constants, and Q is the activation energy for viscous flow. Eq.(2) links together a Fogel-Fulcher-Tamman-type and Arrhenius-type temperature dependences of η. At lower temperatures ($T<T^g$) the Arrhenian term in eq.(2) is predominant, whereas at temperatures higher than the glass transition temperature T^g predominant is the VFT-term. Fig.3 shows the temperature dependence of η in a plot of $\ln(\eta)/(1000\ T^{-1})$. The viscosity exhibits a complex behaviour with four different stages. In the low temperature region the apparent activation energy Q for viscous flow increases significantly from 95 to 234 kJ/mol with increasing the pre-annealing temperature. This is due to the annealing out of the flow defects with low activation energy of rearrangement. The second plateau-like stage is most probably due to the suspected amorphous phase separation with deviation of η from the Arrhenian temperature dependence towards higher values as predicted by the Einstein equation for flow of dispersions:

$$\eta_{app} = \eta(1 + 2.5\xi) \qquad (3)$$

As shown in (2), in this temperature range amorphous $(Fe,Ni)_3B$ - particles with viscosity much higher than the viscosity η of the parent amorphous matrix are separated. With increasing the volume fraction ξ of these particles the apparent viscosity η_{app} of the suspension increases too. On reaching approximately 425°C the glass transition temperature of $(Fe,Ni)_3B$ is most probably reached resulting in rapid decrease of the viscosity and disappearence in the differences due to the different pre-annealings (see also Fig.2). This region of the viscosity temperature dependence is described by a Vogel-Fulcher-Tamman temperature dependence with η_o = 0.0013 Pa s, B = 2880 K, and T_o = 640 K. At the end of this temperature range the rapid crystallization of the amorphous alloy begins with maximal rate of this process at approx. 450°C. On reaching this temperature η_{app} of the alloy goes over a minimum and increases rapidly with increasing temperature. This is again explained with the aid of eq.(3). At temperatures higher than the temperature of maximal crystallization rate the volume fraction ξ of the crystalline particles suspended in the undercooled liquid matrix increases rapidly with consequent rapid increase of the apparent viscosity of heterogeneous liqiud-solid mixture.

CONCLUSIONS

The high temperature viscous creep of the amorphous $Fe_{40}Ni_{40}B_{20}$ alloy studied exhibits complex behaviour represented with Arrhenian type temperature dependence at lower temperatures. The activation energy for viscous flow increases with increasing the pre-annealing temperature due to the annealing out of the flow defects with lower activation energy of rearrangement.

The plateau-like region of the viscosity temperature dependence is most probably due to amorphous phase separation. The glass transition temperature of the separated cementite-like amorphous particles is 425°C. Viscous flow measurements could be used as a sensitive tool for detecting possible phase separation phenomena in amorphous metallic alloys.

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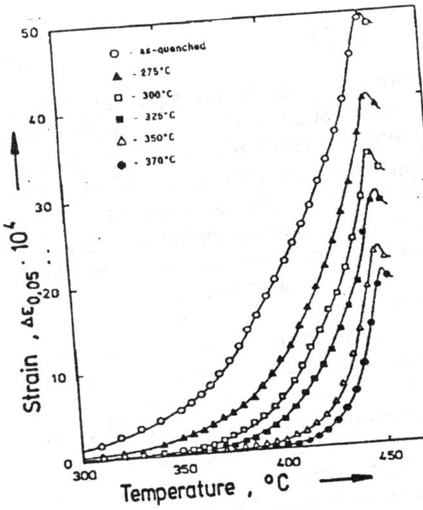

Fig.1 Temperature dependence of the strain.

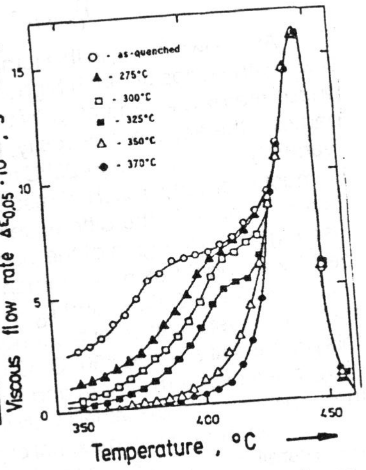

Fig.2 Temperature dependence of the strain rate.

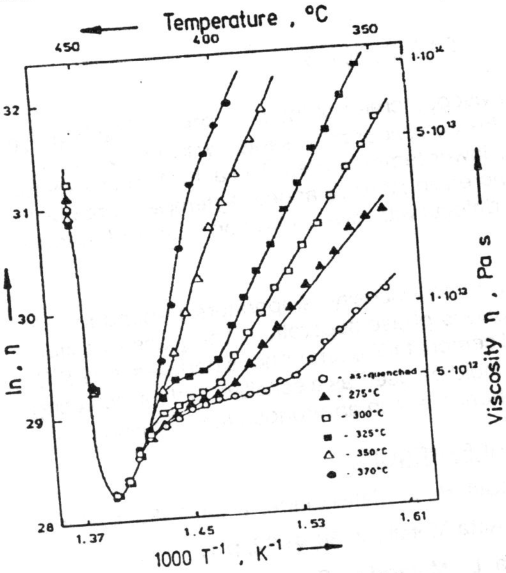

Fig.3 Temperature dependence of the viscosity.