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THE BEHAVIOR OF INTERNAL FRICTION IN METALLIC GLASSES

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Abstract - The internal friction (IF) behavior of metallic glasses Fe_{75.1}-Ni_{3.0}Mo_{1.6}Si_{6.5}B_{13.8} and (Fe_{0.6}Ni_{0.4})₈₂Si₈B₁₀ is investigated. The results suggest that the activation energy of the internal friction of these metallic glasses is distributed in a continuous spectrum which interprets the change of IF with variation of frequency and the influences of pre-annealing and deformation on IF.

INTRODUCTION

The internal friction (IF) of solid is known to be highly structure-sensitive both in crystalline metals and metallic glasses. There have been some reports [1-3] on the study of low-frequency IF of metallic glasses, but the nature and the microscopic mechanism has not been understood clearly. The present work attempts to investigate the spectral distribution of activation energies of IF in the metallic glasses Fe_{75.1}Ni_{3.0}Mo_{1.6}Si_{6.5}B_{13.8} and (Fe_{0.6}Ni_{0.4})₈₂Si₈B₁₀ so to interpret the change of IF with the variation of vibrational frequency and influences of pre-annealing and deformation of the materials on IF. The experimental procedure used in this study is similar to that in [4].

RESULTS AND DISCUSSION

The temperature dependence of IF and vibrational frequency are shown in Fig. 1(a) and (b). The phenomenologic characteristic of IF in them is similar to that of martensitic phase transition in β shape memory alloys [5], i.e. the height of the IF peak as a linear function of \dot{T}/f is observed (\dot{T} is heating rate), the IF is independent of vibrational amplitude, and during continuous heating, if the temperature is kept constant ($\dot{T}=0$) the IF decreases until a stable value is approached.

Since the amorphous structure of metallic glass possesses various topological and chemical short range order, and the structure of as-quenched metallic glass is in an unstable state, and will relaxes gradually to a metastable state. Hence the modes of the internal activation processes resulting in structural relaxation and the change of mechanical properties are of various kinds. It is shown from the results of IF that the internal processes inducing IF are not unique. It is assumed that in structural relaxation stage, the relaxation times of IF show a broad distribution to which every available process obeys Arrhenius relation

$$\tau = \tau_{\text{exp}}(E/KT). \quad (1)$$

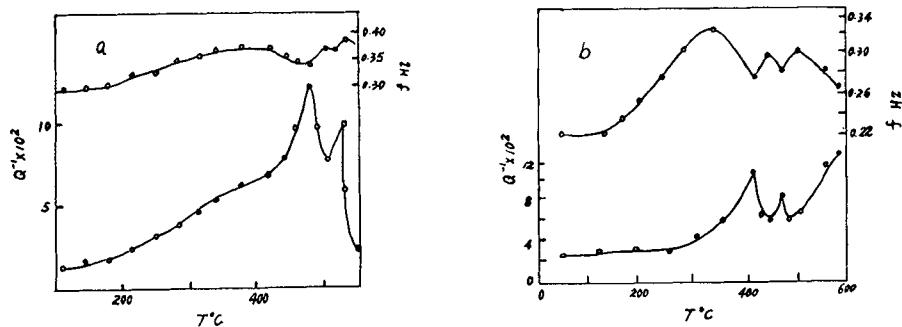


Fig. 1 - Temperature dependences of the internal friction and vibrational frequency of metallic glasses, (a) $\text{Fe}_{75.1}\text{Ni}_{3.0}\text{Mo}_{1.6}\text{Si}_{6.5}\text{B}_{13.8}$; (b) $(\text{Fe}_{0.6}\text{Ni}_{0.4})_{82}\text{Si}_8\text{B}_{10}$.

Assume that the pre-exponential factor τ is constant, the activation energies of these processes must have a distribution in a continuous spectrum $n(E)$, $n(E)dE$ is defined as a number density of processes available for IF having activation energies between E and $E+dE$. Various authors have investigated the relaxation time spectrum of IF in metallic glasses [3,6-8]. Some of them [6,7] have suggested a Gauss distribution in $\ln \tau$ to interpret their IF results, but it was not in agreement with the experimental data above room temperature. Hence the exact function of $n(E)$ have yet to be worked out. But it may be assumed that the shape of $n(E)$ is shown approximately in Fig. 2 which is similar to that suggested by Gibbs et. al. [8] and is dependent of thermal and mechanical history of the materials.

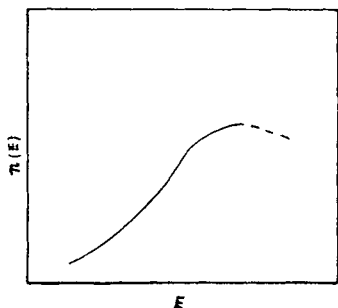


Fig. 2 - The schematic representation of the distribution of activation energy of metallic glass.

Morito and Egami [3] who assumed that on certain measuring temperature T_m there is only one process being available for IF. The activation energy E_m is determined by the formula

$$E_m = -KT_m \ln \omega \tau. \quad (2)$$

It suggests that the value of IF at this temperature is just the height of the Debye peak due to this process. We assume that all processes with activation energies between E_1 and E_2 may contribute to IF at T_m . The contribution of the other processes are small enough to be neglected (for example less than 1% of its Debye peak value). The IF contributed by the processes with activation energies between E and $E+dE$ may be written as

$$dQ^{-1} = C n(E) dE \omega \tau / (1 + \omega^2 \tau^2) \quad (3)$$

where C is constant, $C n(E)dE$ is the relaxation strength of this process, i.e. the more the number $n(E)dE$ of this kind of process, the greater is the contribution to IF. E_1 and E_2 may be written respectively as $E_m(1-\Delta)$ and $E_m(1+\Delta)$. If $f = 0.5 \text{ s}^{-1}$,

$\tau = 1.6 \cdot 10^{-13} \text{ s}$ and the processes, of which the contribution are less than 1% of their peak value, are not considered, then $\Delta = 0.23$. Hence the total IF at T_m is

$$Q^{-1} = \int_{E_m(1-\Delta)}^{E_m(1+\Delta)} C n(E) \frac{\omega \tau \exp(E/KT_m)}{1 + \omega^2 \tau^2 \exp(2E/KT_m)} dE. \quad (4)$$

The meaning of equ. (4) may be expressed roughly by Fig. 3. The position of a single Debye peak is T_1 determined by the value of E_1

$$T_1 = -E_1 / K \ln \omega \tau. \quad (5)$$

and the height of Debye peak is determined by the magnitude of $n(E_1)$.

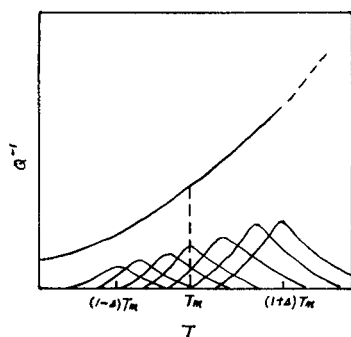


Fig. 3 - the IF at T_m is contributed by the processes with activation energy between $E_m(1-\Delta)$ and $E_m(1+\Delta)$.

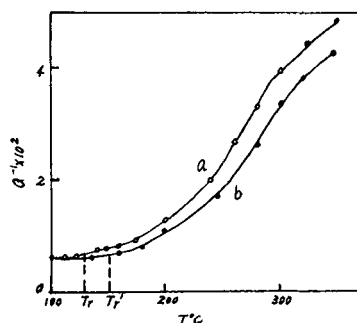


Fig. 4 - The frequency dependence of IF of amorphous FeNiMoSiB. Curve a: the frequency in room temperature is $f = 0.2 \text{ Hz}$; curve b: $f = 0.53 \text{ Hz}$.

If the frequency of the torsion pendulum is increased, the peak temperatures of all Debye peaks are also increased according to equ. (5). Since the curve of $n(E)$ is monotonously rising at low E (Fig. 2), the resultant IF curve shifts to higher temperature with measuring frequency. Thus, at a given temperature T_m , the larger the ω , the smaller the IF is. Otherwise the temperature T_r , at which IF starts to increase, increases with increasing ω . These relation are shown in Fig. 4.

If the specimen is pre-annealed, some internal modes with low activation energies vanish because of structural relaxation. Thus the function $n(E)$ descends in the region of smaller E , accordingly the value of IF at low temperature decreases and T_r shifts to a higher temperature. The effects of pre-annealing are shown in Fig. 5.

The effects of cold-rolling is contrary to that of annealing. The cold-rolling may create processes having a smaller activation energy, whereas the annealing may remove such processes. Hence the value of IF at low temperature increases and T_r shifts to a lower temperature (Fig. 6).

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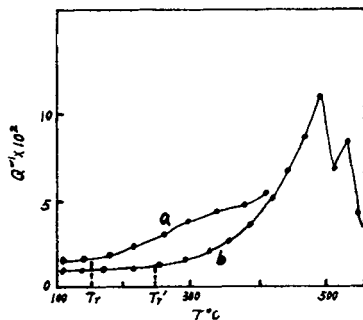


Fig. 5 - The influences of pre-annealing of amorphous FeNiMoSiB on IF, curve a: as-quenched state; curve b: pre-annealed at 400 °C.

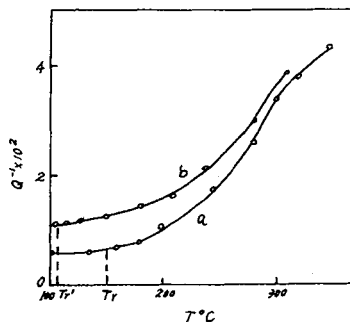


Fig. 6 - The influences of cold-rolling of amorphous FeNiMoSiB on IF, curve a: as-quenched state; curve b: cold-rolling state.

REFERENCES

- 1/ Soshiroda T., Koiwa M. and Masumoto T., J. Non-Cryst. Solids, 22 (1976) 173.
- 2/ Tyagi S. and Lord Jr. A.E., J. Non-Cryst. Solids, 30 (1979) 273.
- 3/ Morito N. and Egami T., Acta Metall. 32 (1984) 603.
- 4/ Xia Wulong, Wang Zixiao, Zhou Rusong and Shui Jiapeng, J. Physique 44 (1983) C9-111.
- 5/ Mercier O., Melton K.N. and De Preville Y., Acta metall. 27 (1979) 1467.
- 6/ Barmatz M. and Chen H.S., Phys. Rev. B, 9 (1974) 4073.
- 7/ Morito N., Mater. Sci. and Eng., 60 (1983) 261.
- 8/ Gibbs M.R.J., Evetts J.E. and Leake A., J. Mater. Sci., 18 (1983) 278.