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Abstract. The measurements were made in a torsional pendulum at about 0.1 cps using longitudinal stress (5 - 150 MPa) in the temperature range 20 - 600 ^{0}C. The internal friction (i.f.) decreases and the modulus increases monotonously with increasing longitudinal stress in the amorphous state. This i.f. change is more pronounced in the temperature range of structural relaxation. Changing the stress at constant temperature the changes of the measured parameters were time and temperature dependent. These effects can be explained by the diffusion controlled reversible ordering of the atoms due to the applied stress. Also the isothermal crystallization was accelerated by the stress.

Measuring structural changes during increases in temperature, (structural relaxation and crystallization) in metallic glasses using internal friction proved to be effective [1]. In general the i.f. measurements are made using low stress. One method of measuring the influence of mechanical stress is the determination of the dependence of i.f. on relative deformation. A disadvantage of this method is the fact that the stress changes with time. We examined the influence of tensile stress on the internal friction using constant relative maximal stress in torsion during measurements.

Experimental methods

The i.f. was measured with a torsional pendulum in which a mirror was fastened on the moving element and the light reflected on it was registered by a light-spot following recorder. The relative deformation of the 40 mm long, 1 mm wide and 20 - 40 μ thick specimens was $\varepsilon \approx 10^{-5}$ during the measurements. The pressure was $P = 10$ Pa, the temperature range 20 - 600 ^{0}C, and the frequency about 0,1 cps. The mass of the moving element was 25 grams. Using a manipulator we were able to put five further masses on it. This meant 5 - 150 MPa stresses in the samples of a typical cross-section. The changed moment of inertia can be reproduced with the increase of the mass of the vibrating element which must be taken as a correction. A further correction is needed because of the additional torsional stress caused by the applied tensile stress which can be calculated from the geometry of the sample.

Results and discussion

The i.f. and dynamic modulus (d.m.) changes caused by tensile stress were found to be similar for two-or multicomponent alloys. The stress dependence for an FeCoNiCrBSi metallic glass is shown in Fig.1. It can be seen that the i.f. decreases and the d.m. increases with increasing applied stress. The equilibrium values of i.f. and d.m. shown in Fig.1

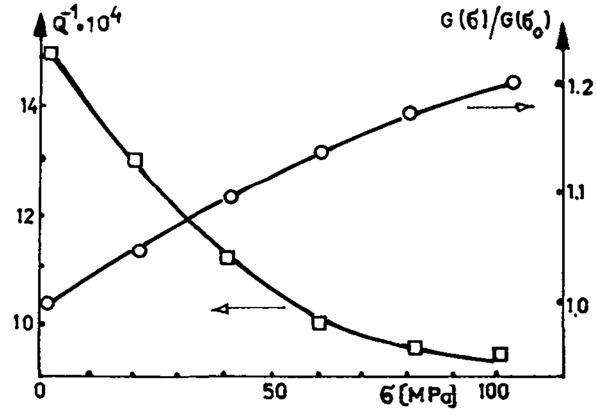
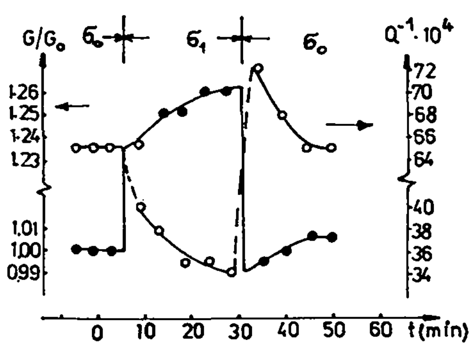


Fig.1.

The i.f. and d.m. versus tensile stress for FeCoNiCrBSi metallic glass at room temperature

were achieved after a transient process (Fig.2.).

At the transition between the different stress states i.f. showed an extra damping which ceased after a while. Moreover in connection with this the modulus showed a decrease, too. This transient process depended to a great extent on the temperature (Fig.3.). The extra damping was greater at higher temperatures and the process was faster.



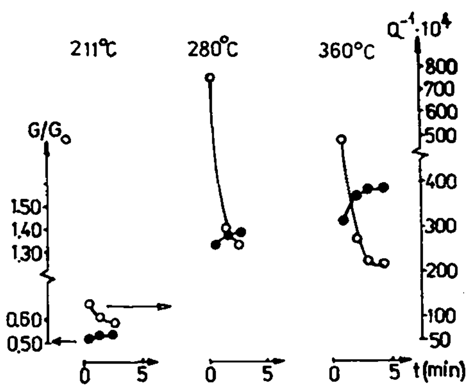


Fig.2. The time dependence of i.f. and of d.m. after stress changes for FeCoNiCrBSi metallic glass at room temperature. (σ_0 = 5 MPa, σ_1 = 90 MPa)

Fig.3. The changes during the $\sigma_1 \to \sigma_0$ transition at different temperatures.

The $Q^{-1}(T,\sigma)$ and $G/G_0(T,\sigma)$ measurements of metallic glasses were carried out on the same sample during continuous heating with periodical loading - unloading. This was necessary because $G/G_0(T)$ showed rather marked differences in the relaxation range even in the samples taken from the same material. As can be seen in Fig.4. $Q^{-1}(T)$ decreased

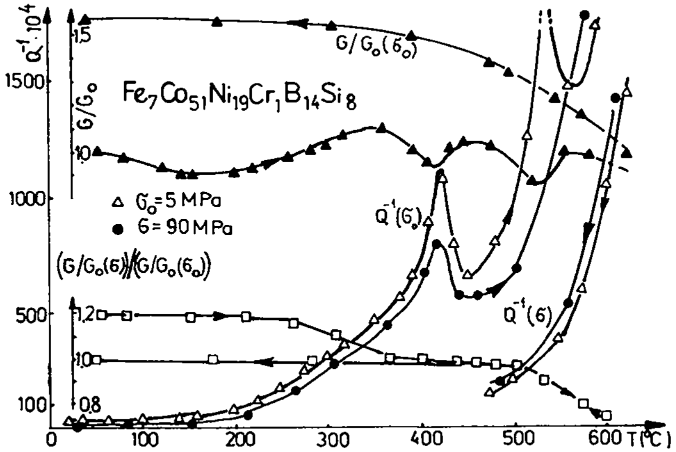


Fig.4.
The temperature dependence of i.f. and d.m. at different stresses.

with stress; we had the greatest difference during the structural relaxation and crystallization. The modulus increasing effect of the stress ceased after either the crystallization or the phase-transformations following the crystallization. The extent of the modulus increase caused by the stress showed differences in the relaxation range in the samples taken from the same material similar to the above mentioned dependence on temperature. The stress induced d.m. changes are greater for the sample having higher relaxation.

During continuous heating measuring of a sample under stress we did not find any change in the crystallization temperature. However, during isothermal testing the stress accelerated the crystallization although it did not change the extent of the modulus change during crystallization.

We also examined a few metal wires. We chose the diameters so that their moments (i.e. the frequencies) would be characteristic of metallic glasses. Our results obtained in some samples can be seen in Fig.5. The i.f. increased and d.m. decreased with the stress in the steel

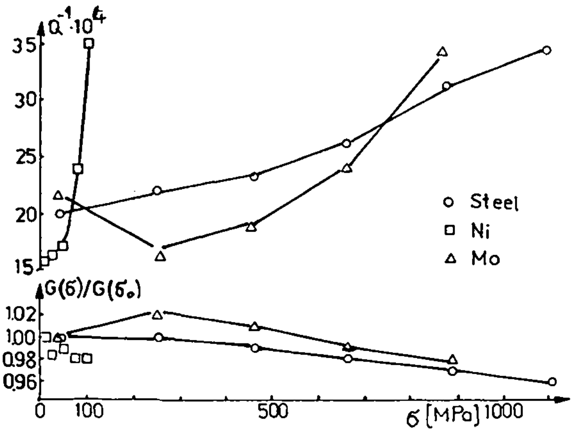


Fig.5.
The stress dependence of i.f. and d.m. for steel, Ni and Mo wires at room temperature.

wires of 0.12 mm diameter and in the Ni wires of 0.35 mm diameter. The behaviour of the sintered Mo wire of 0.10 diameter was different at lower stresses. However these d.m. changes are rather small, maximum 2-3%.

We must try to find the reasons for the behaviour of metallic glasses contradicting the crystalline metals in their amorphous structure. Under the influence of mechanical stress they show reversible ordering [2]. This ordering can have a time and temperature dependent part controlled by diffusion which causes i.f. increase and d.m. decrease. The dependence of the stress-effect on temperature shows that the influence of stress is greatest where other (thermally activated) structural changes also take place in the material: during structural relaxation and crystallization. It can be seen clearly in Fig.6. where we compared the $Q^{-1}(T,\sigma)$ and $Q^{-1}(T,\dot{T})$ curves belonging to the FeB metallic glass. The acceleration of crystallization can be explained by this stress-induced ordering.

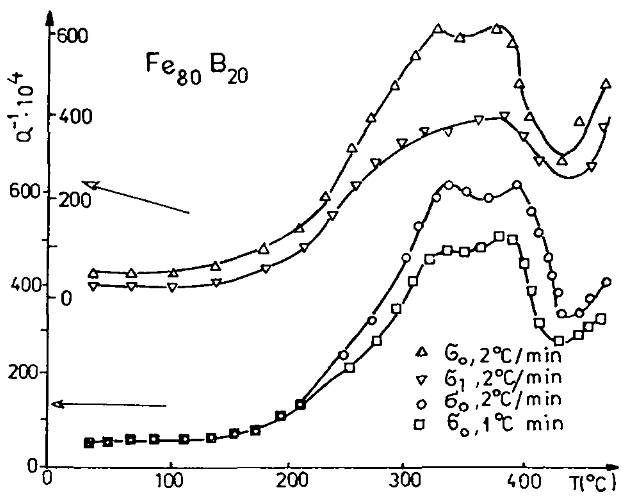


Fig.6.
The i.f. behaviour is similar (decrease) for lower heating rate or for higher stress (σ_o= 10 MPa, σ_1 = 150 MPa)

References

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