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Abstract. Internal friction and frequency measurements as a function of temperature have been carried out in Nb and Nb-Zr policrystalline samples, using a torsion pendulum in the temperature range between 300K and 700K, the heating rate was 1K/min and the pressure was kept better than $5x10^{-3}$ mbar. Metals with bcc lattice containing solute atoms dissolved interstitially often show anelastic behaviour due to a process know as stress-induced ordering, responsible for the appearance of Snoek peaks. In the Nb sample it has been identified two constituent peaks corresponding to the interstitial-matrix interactions (Nb-O and Nb-N), but for the Nb-Zr samples with interstitial solute concentrations very close to those measured for the unalloyed Nb, it was not observed any mechanical relaxation peaks due to the presence of oxygen and nitrogen in solid solution .

1. INTRODUCTION

Metals containing solute atoms dissolved interstitially often show anelastic behaviour due to a process known as stress induced ordering. One manifestation of this anelastic behaviour is the internal friction, wich was originally observed by Snoek [1] in Fe containing carbon and nitrogen as interstitial solutes. The anelasticity has its cause in the stress-induced migration of interstitial atoms in octahedral positions of bcc lattices.

Several techniques can be used to measure the internal friction [2-4], of these the torsion pendulum is best suited to the study of metal-interstitial solute interactions, such as carbon, nitrogen or oxigen. At low interstitial-solute concentrations, the relaxation strength of internal friction at a given temperature is a function of the nature, positions and concentration of the interstitial atoms.

In the present work the internal friction and frequency were measured as a function of temperature in Nb and Nb-Zr alloys.

2. EXPERIMENTAL PROCEDURE

The Nb and Nb-Zr alloys were obtained by electron-beam melting zone and were supplied in the form of swaged rods of 3mm diameter. Samples 60mm long, which had been chemically polished to 1.5mm thickness in a mixture of nitric and fluoridic acids, were used for the mechanical relaxation measurements.

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The mechanical relaxation values were obtained in the temperature range between 300K and 700K, using a torsion pendulum of the inverted Kê-type [5], applyng a heating rate of 1K/min, at a pressure near 10^{-3}mbar. A laser beam was deflected by a mirror on the pendulum bar and data on the decay of the oscillations have been collected automatically by two phototransistor connected to a computer. The internal friction was obtained from the amplitude decay.

The internal friction curve as a function of temperature for to the unalloyed Nb have been decomposed into elemental Debye peaks [6] using the method of successive subtration, and the anelastic relaxation processes have been identified comparing the calculated values with literature [7,8].

3. RESULTS AND DISCUSSION

Experimental spectra of mechanical relaxation as a function of temperature have been obtained for the Nb and for the Nb-Zr alloys. Chemical analysis of interstitial elements in the pure metal and in the Nb-Zr alloys resulted in very close values for the different samples. For the Nb sample it was found O_2 content of 50 wt.-ppm and N_2 content of 30 wt.-ppm; for the Nb-Zr alloys it was found O_2 content of 60 wt.-ppm and N_2 content of 30 wt.-ppm.

Figure 1 shows the data for unalloyed Nb; the Snoek peaks observed at 430K and 560K have been associated with Nb-O and Nb-N interactions respectively. The corresponding activation energies have been calculated as 24.5 kCal/mol for the Nb-O peak and 39.6 kCal/mol for the Nb-N peak, which are in good agreement with reported values [7,8].

Figure 2 (a) and (b) show the internal friction and frequency as a function of temperature for Nb-1.0Zr and Nb-1.2Zr alloys. These spectra did not present any mechanical relaxation peaks due to the oxygen and nitrogen in solid solution since the presence of substitutional element (Zr) affect the random distribution of the interstitial solute atoms in free solid solution, with oxygen and nitrogen atoms clustering around zirconium atoms [9,10].

Comparing Figure 1 with Figure 2 (a) and (b) can be observed that the presence of Zr really modify the spectra of mechanical relaxation with the Snoek peaks being completely removed by the substitutional solid solution.Furthermore the experimental data show that there is a very close relationship between the dissipative behaviour (internal friction) and torsional modulus (frequency) and vice versa, satisfying of the Kronig-Kramers relations[6].

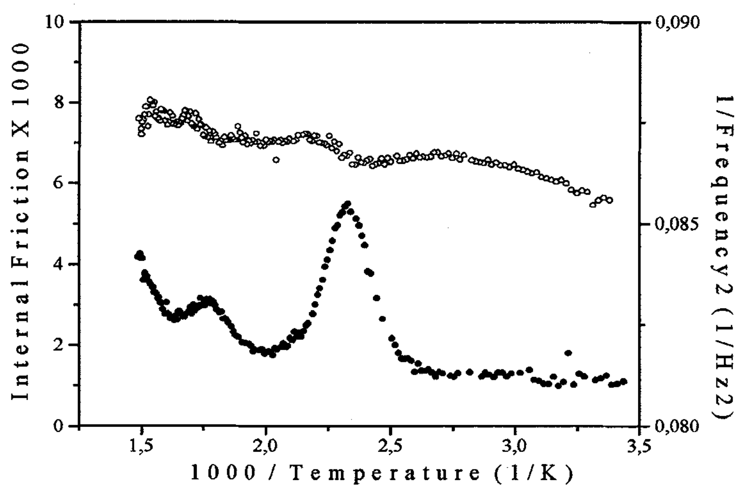
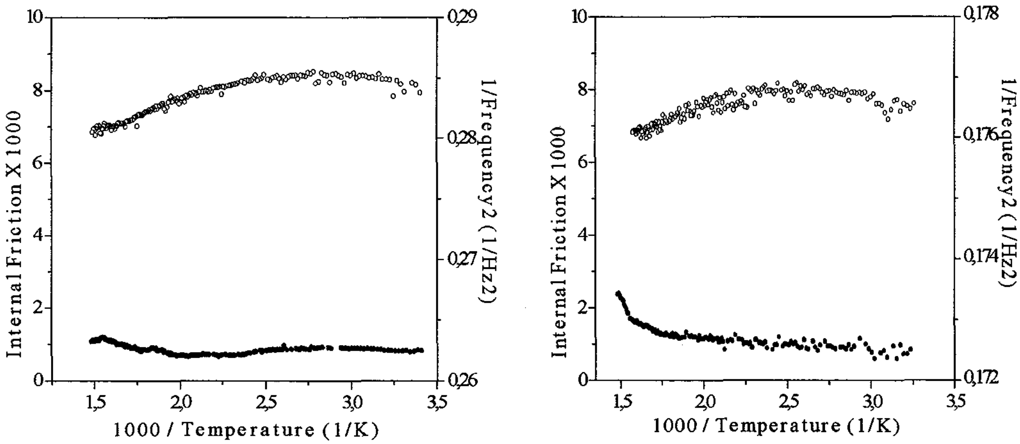


Figure 1: Mechanical relaxation [internal friction (•)and frequency(o)] as a function of temperature for unalloyed Nb show the Snoek peaks: Nb-O at 430K and Nb-N at 560K.



(a) (b)

Figure 2: Mechanical relaxation [internal friction (•) and frequency (o)] as a function of temperature for Nb-1.0Zr (a) and Nb-1.2Zr (b) alloys.

4. SUMMARY

The results of the present work concerning the influence of interstitial elements on mechanical relaxations in Nb and Nb-Zr alloys containing oxygen and nitrogen suggest that the presence of substitutional Zr modify the spectra of mechanical relaxation due to interaction of Zr with interstitial oxygen and nitrogen, and affect the random distribution of these atoms in free solid solution removing completely the Snoek relaxation peaks.

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References

[1] Snoek J L ,*Physica* **6** (1939) 591.
[2] Jordão J.A.R., Doctor of Physics Thesis, Universidade de São Paulo (1982).
[3] Florêncio O.,Pinatti D.G. and Roberts J.M., *J.Physique* **46** (1985) C10.
[4] Botta F° W.J.,Florêncio O.,Grandini C.R.,Tejima H.,Jordão J.A.R., *Acta metall. mater.* **38** (1990) 391
[5] Kê T.S., *Phys.Rev.* **71** (1947) 533.
[6] Nowick A.S. and Berry B.S., *Anelastic Relaxation in Crystalline Solids*, Academic Press, New York , 1972.
[7] Ahmad M.S. and Szkopiak Z.C., *J.Phys.Chem.Solids* **31** (1970) 1799.
[8] Powers R.W. and Doyle M.V.,*J.Appl.Phys.* **30** (1959) 514.
[9] Szkopiak Z.C. and Smith J.T.,*J.Phys.D:Appl.Phys.*, **8** (1975) 1273.
[10] Bunn P.M., Cummings D.G. and Leavenworth,H.W., *J.Appl.Phys.* **33** (1962) 3009.