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INTERNAL FRICTION AND MAGNETIC LOSSES IN CoPt ALLOY DURING PHASE TRANSITION

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Summary

The variations of internal friction, magnetic susceptibility and loss angle with time and temperature of disoredered CoPt equi - atomic alloy, during annealing induced phase transition from cubic to tetragonal are shown.

The paper presents results of investigation of magnetic and anelastic relaxation of "as-quenched" CoPt alloy measured from 300 K to 840 K versus annealing induced ordering starting from 460 K.

Internal friction and magnetic susceptibility/ time and temperature signatures can enable a better understanding of ordering processes and mechanisms.

1. INTRODUCTION

Atomic ordering can affect the anelastic and ferromagnetic properties of metals and alloys. The internal friction (**IF**) level, the initial magnetic susceptibility, its magnetic after-effect (**MAE**) and magnetic loss angle can be used as an indication of the degree of order.

CoPt has a cubic (A1) structure in the "as-quenched" (disordered) phase. It transforms during annealing into the tetragonal ($\mathrm{Ll_0}$) phase. The transformation is of diffusion like type and can be attributed to the ordering processes and establishing of short - range order.

In the disordered phase CoPt exhibits a high level of **IF** (magneto- elastic damping) and soft ferromagnetic properties, while in the ordered phase it show a low magnetic susceptibility and **IF** level.

The aim of the present paper is to investigate the change of **IF**, magnetic susceptibility and loss angle during continuous or successive annealing of disordered samples from the room temperature up to 840K. Reason for this type of research is to study the magnetic and anelastic properties of pure, equi-atomic CoPt alloy by controlling the heat treatment and temperature during the ordering and phase transition processes.

2. EXPERIMENTAL PROCEDURE

The measure of **IF** in the case of a wire is the logarithmic decrement δ of free torsional vibrations of a CoPt sample:

$$Q^{-1} = \frac{\delta}{\pi} \tag{1}$$

The inverted torsion pendulum is working at low frequency, f_0=60 Hz, and at strain amplitude of 2.0×10^{-3}.

Electronic timer with the accuracy of the order of 10 μs has been used.

Magnetic measurements - performed by differential ac technique based - on a Wilde bridge [1] at a frequency of 3 kHz in a field directed parallel to the wire has been also done.

After demagnetization of the sample at t_1=30 s in ac field of about $10^3\mathrm{Am}^{-1}$, MAE measurements started at t_2=32 s and are continued up to 1800 s. The measuring field amplitude of 0.24 Am^{-1} has been chosen.

Expressions for the loss angle

$$\tan\varphi = \frac{\chi''}{\chi'} \tag{2}$$

following from the complex initial magnetic susceptibility

$$\chi = \chi' - i\chi'' \tag{3}$$

and for the **MAE** :

$$\frac{\Delta r}{r_1} = \frac{r(t_2,T) - r(t_1,T)}{r(t_1,T)} \tag{4}$$

are used, where the reluctivity $r = 1/\chi'$ and χ' is the real part of the complex initial susceptibility; $t_1 = 30$ s, and t_2 varied from 32 s to 1800 s; T is the temperature of the sample.

2.1 Sample preparation

A high purity, equi- atomic CoPt (50 at % Pt) sample in the form of a wire, the diameter of 1.0 mm has been sealed off under a vacuum of 10^{-5} Pa in a quartz tube, annealed above the critical temperature of 1100 K (see Fig. 1) for five hours, and than ice - cold water quenched in order to obtain the disordered fcc phase.

IF and magnetic measurements have been taken on the "as- quenched" (disordered) samples during heating up to the Curie point. The rate of temperature change during these measurements has been 0.3 K/min.

In samples quenched from temperature $T > T_C$, a high **IF** level is observed in Fig.1. The high internal friction level in "as-quenched" samples is due to the magneto-mechanical damping of the Bloch domain walls as observed in the micro-scale, or due to the losses caused by the magneto- elastic hysteresis as measured in the macro- scale[3].

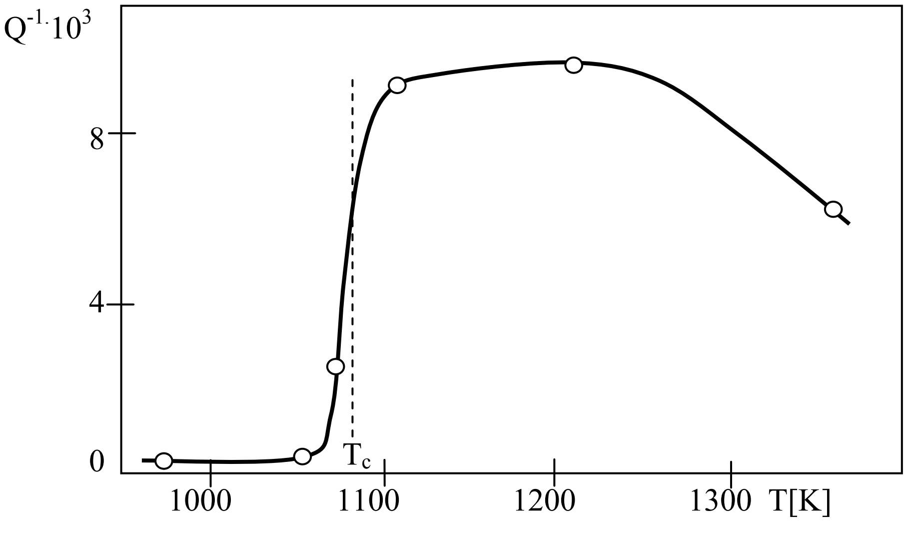

*Fig.1. The change of **IF** level of CoPt alloy as function of the quenching temperature. T_C is the critical temperature [2].*

3. RESULTS AND DISCUSSION

The **IF** measuring results for two different heating rates of CoPt during ordering are shown in Fig. 2. The high level of internal friction as seen in Fig.2 at T < 450K is observed after quenching the samples from 1430 K to 273 K.

Between 300 K and 450 K, **IF** changes only a little, but from 450K to 650 K, it decreases significantly - up to the level of partly ordered sample.

In the second temperature region, where the ordering process started, we see in Fig. 3, a maximum of $\Delta r / r_1$ and simultaneously a decrease of the real part of the initial susceptibility χ'.

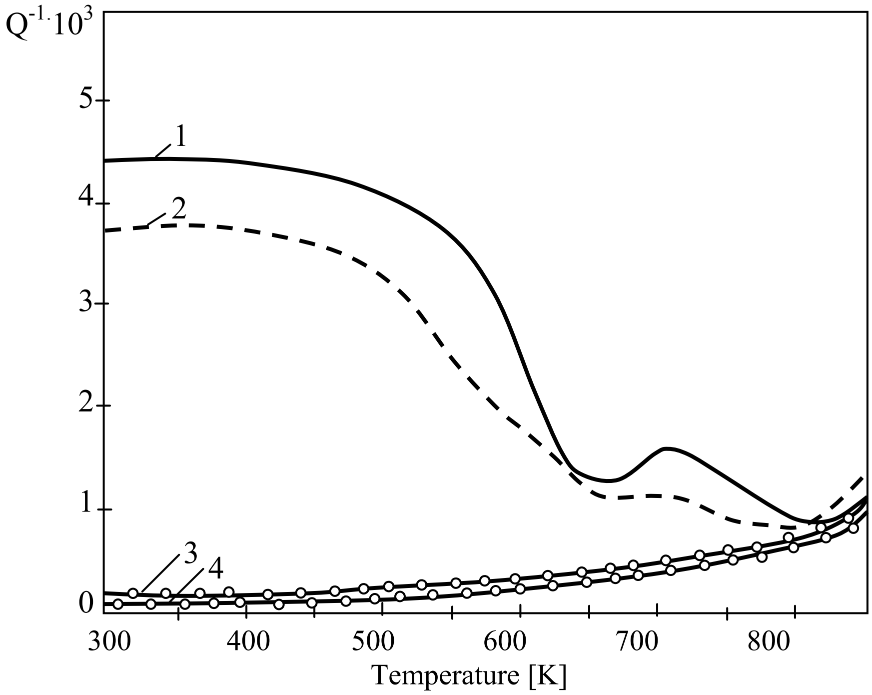

Fig.2. The temperature dependence of ***IF*** *of disordered CoPt alloy for two different heating rates: 2 K/min. - curve 1, and 6 K/min. - curve 2. Curves 3 and 4 represent damping for saturated and ordered sample respectively [6].*

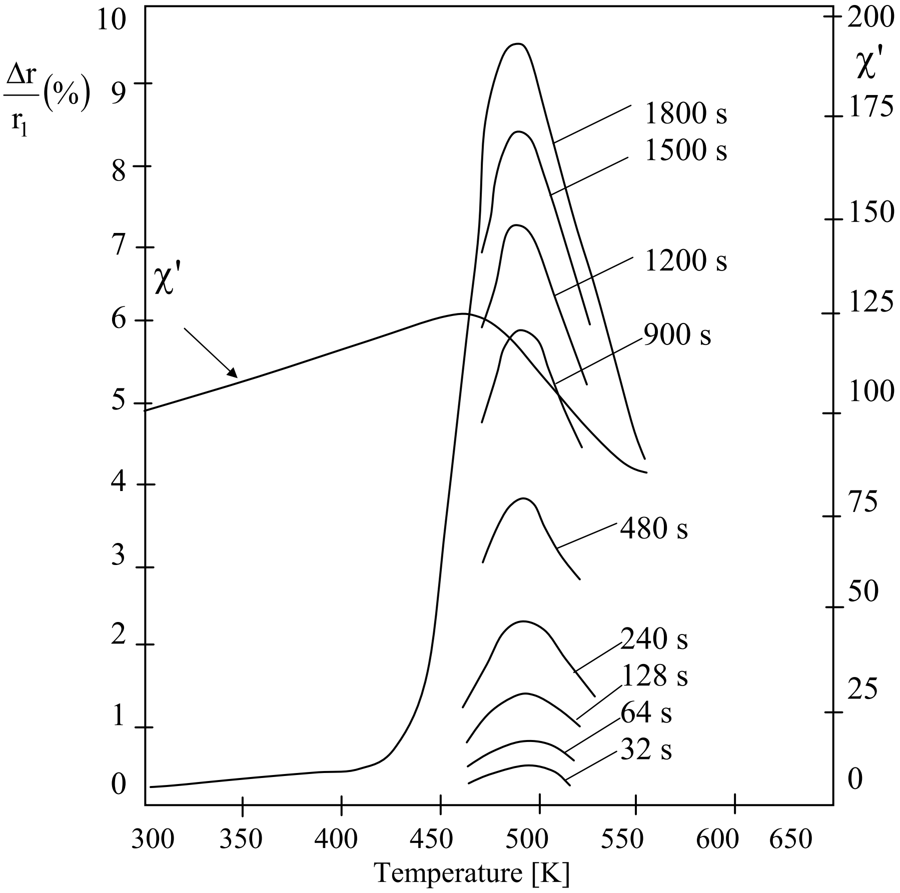

Fig.3. The magnetic after-effect and the initial magnetic susceptibility of disordered CoPt sample versus annealing temperature during a run from 300 K to 556 K, as determined at t_1=30 s after demagnetization; t_2 varied from 32 s to 1800 s.

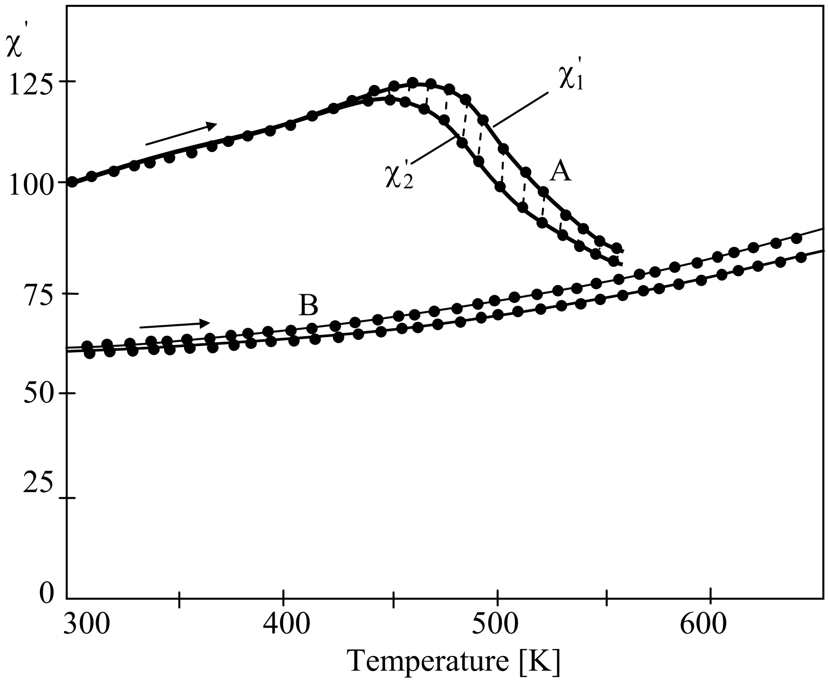

Fig.4. Variation of the real part of initial susceptibility of disordered CoPt sample, measured during two successive annealing runs A and B; χ'_1 - at t_1=1s and χ'_2 - at t_2=30min. after demagnetization [7].

We suppose that during annealing of disordered sample in this step of ordering the frozen in vacancies, produced during quenching, are moving to the partially ordered regions, increasing the level of order, as observed by the initial susceptibility measurement during two successive annealing runs: A from 3000 K to 556 K and run B from 300 K to 650 K as seen in Fig.4, and as calculated in paper [4] and [5]. The maximum of the initial susceptibility observed at about 460 K anneal and has completely annealed out by measurements in the run B.

In [5] we have shown, that the **MAE** maximum at 500 K in Fig.3 is due to the rotation of the easy magnetization vector from [111] to the [001] axis, its position depends upon the heating rate and it disappears in the course of the two successive annealing runs A and B as seen in Fig.4.

The Richter type, reversible magnetic relaxation maximum at 500 K, seen in Fig.3 has an activation energy of E_R = 1.4 eV, and is ascribed to the reorientation of Co - Pt atomic pairs [6].

The high temperature **IF** peak at 700 K, whose amplitude increase with decreasing heating rate, as seen in Fig.2, and huge increase of magnetic losses, seen in Fig.5, are due to a structural relaxation process that occur during annealing induced phase transition from cubic to tetragonal.

In Fig. 2 we observe at T> 800 K a high temperature background (HTBG) of **IF**. The HTBG is higher for higher heating rates. The characteristics of the background are basically dependent from interaction between dislocations, point defects and other defects like residual fcc-phase or stacking faults.

By applying a steady magnetic saturation field it is possible to reduce the **IF** to the level of saturated magneto-mechanical damping (curve 3 in Fig.2), which is very close to the **IF** level of ordered sample (curve 4 in Fig.2).

The background of **IF** follows the function:

$$Q^{-1}{}_{\mathrm{BG}} = a \cdot \exp\left(\frac{-E}{kT}\right) \qquad (5)$$

with E=1.5 eV for $Q^{-1}{}_{\mathrm{BG}} = 1.3\cdot 10^{-3}$ at T = 530 K, and $a = 1/\omega\tau_0$ [3] at $\tau_0 = 10^{-13}$ s and $\omega = 2\pi f_0 = 377$ Hz.

As seen in Fig.5, at T >530 K, the structural changes started influencing the increase of the magnetic losses.

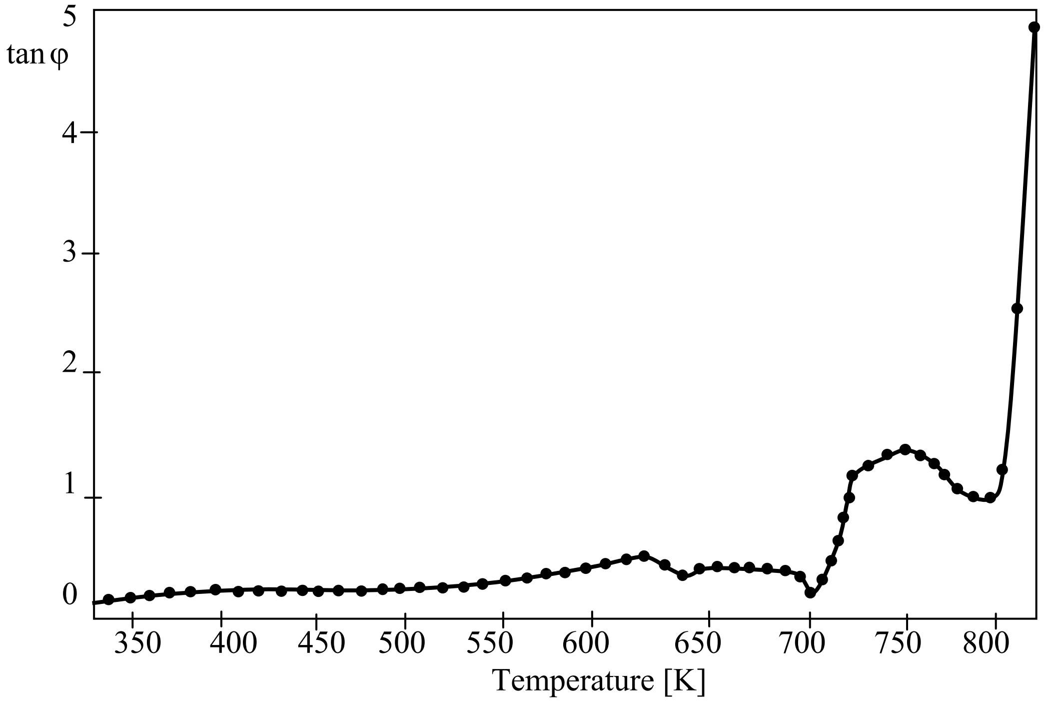

Fig.5. Loss angle versus annealing temperature of disordered CoPt alloy after quenching the sample from 1450 K to 273 K.

4. CONCLUSION

Annealing from 300 K up to 840 K of disordered by quenching equi- atomic CoPt alloy results in:

- phase transition from cubic to tetragonal,
- decrease (about ten times) of the initial magnetic susceptibility,
- rapid, thermally - activated reorientational relaxation of Co-Pt atomic pairs, leading to short- range order,
- a slower, migrational, structural ordering process, which results in reduction of Co - Co atomic pairs with ferromagnetic bonding, leading to long - range order.

Our approach could be extended up to the Curie point (T^{A1}= 830 K) [7], therefore we could observe a huge increase of magnetic losses (in Fig.5).

5. REFERENCES

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