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Internal Friction in Charge Density Wave (TaSe₄)₂ I Compound

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Abstract. The low frequency anelastic properties of CDW compounds near the Peierls phase transition are studied in a forced sub-resonant pendulum suitable for delicate (TaSe₄)₂ I samples. The influence of measurement parameters such as frequency, oscillation amplitude, temperature rate and low temperature cycles, are obtained. The principal effects found are : the Peierls transition, a higher temperature relaxation (~ 260 K) and a low temperature process (~50 K).

1. INTRODUCTION

(Ta Se₄)₂I is a well known one-dimensional charge density wave (CDW) compound but not very well studied from the point of view of its anelastic properties. Because of crystal size it was first measured in the ultrasonic frequency range by M.Saint-Paul et al [1]. Afterwards, vibrating reed experiments were performed by A.Susuki et al[2]. They measured the elastic constants in particular directions, and they obtained a reproducible reduction of the elastic stiffness constant C₄₄ and around 0.3% reduction in the Young modulus (4 kHz) at the Peierls transition.

We have measured the internal friction and shear modulus of (Ta Se₄)₂I at low frequencies (< 10Hz) in an inverted forced pendulum, in the temperature range from 25K to 290K.

We present in this paper a general overview of the elastic spectrum of (Ta Se₄)₂I between 25K and 290K taken at 1Hz and 10Hz, and some results in function of frequency between 0.05 and 10Hz.

2. EXPERIMENTAL PROCEDURE

Two batches of samples showing different Peierls transition temperatures (242 and 255K) were grown at the "Ecole Polytechnique Federale de Lausanne" by the conventional chemical transport method. These two batches showed the same overall features in the internal friction results. Three samples with sizes: 1x 1.5x 9 mm³, 1.5x 1.7x 7.6 mm³ and 1x 1x 5.4mm³, were measured.

Internal friction measurements were done in an inverted forced torsion pendulum [3] suitable for measurements between 0.001 Hz and 10 Hz. The sample temperature could be varied from 4 K to 300 K. The samples were clamped with S.P.I. silver paint in both ends and an atmosphere of 200 mmHg of helium gas was placed between the sample and the thermometer (iron-iron/gold thermocouple).

3. RESULTS

Among a set of measurements, figures 1 and 2 are selected to show the experimental data at 1 and 10Hz for comparing frequency effect on the internal friction spectra. Deformations of measurement must be in the order of 5x10⁻⁵ or less, otherwise any jumps similar to a "serrated" effect appear in the modulus.

In the figures we note three different kinds of perturbation. We can unambiguously identify the Peierls transition at 242K, which is the same temperature detected in the electrical resistivity experiment. There are two others: one at ~ 260 K which corresponds to a typical relaxation process of some entity (modulus step and an internal friction peak centered at a temperature of the maximum variation rate of the shear modulus). The other signal takes place at nearly 50 K and its characteristics is that we have a positive peak in internal friction and in the shear modulus. This corresponds to a hardening of the sample while a certain process is absorbing energy.

Figure 1: Shear modulus and internal friction at 1 Hz

Only the Peierls transition signal is always seen in any temperature scan. The two other processes depend on the thermal history of the sample. The process at 50 K is never seen when decreasing the temperature.

Figure 2 : Shear modulus and internal friction spectrum at 10 Hz

In order to prove that this signal belongs to the sample, we measured a pure aluminium wire (4N) mounted in the same conditions as the sample. In this case, no variation of the shear modulus or internal friction was detected at the same temperature.

We also made measurements at fixed temperatures (50 and 55 K) decreasing the measuring frequency from 10 Hz to 0.05 Hz. No signal was detected in this case.

The amplitude of the shear modulus or internal friction could be varied changing the temperature rate when increasing the temperature. The smaller the temperature rate, the larger the variation of anelastic properties.

The 260-270 K relaxation has a small dependence on the measuring frequency. This dependence gives an energy barrier of nearly 1 eV. Like the process of low temperature, this relaxation of 260-270K is not always seen when decreasing the temperature, and it is necessary to reach at least 100 K to observe this effect increasing the temperature.

4. DISCUSSION AND SUMMARY

An exhaustive analysis of the Peierls transition characteristics was made elsewhere[4], that we summarize as follows:

- 1) Well repetitive simultaneous effects at T_p : a sharp internal friction peak (Q^{-1} maximum $\sim 10^{-2}$) and an important elastic shear modulus variation ($\Delta G/G \sim 12\%$) are observed. The latter is greater than the Young modulus variation detected in vibrating reed experiments ($\Delta E/E \sim 0.1$ to 1%) [2] and in concordance with the fact that in ultrasonic experiments [1] the C_{44} was the stiffness constant most affected ($\sim 2.7\%$).
- 2) Their dependence with oscillation amplitude is different: the internal friction peak variation ($\Delta Q^{-1} = Q^{-1} \text{ maximum} - Q^{-1} \text{ background}$) at T_p increases linearly with amplitude ϵ between 1 to 5.5×10^{-5} , but the $\Delta G/G$ modulus variation does not change.
- 3) Successive temperature scans do not alter the effects, only a slightly decrease in T_p is observed (~ 2 K after 5 low temperature cycles).
- 4) Torsion measurement problems in this compound lead us to scan at a temperature rate $dT_p/dt = 0.1 \text{ K/min}$ in the transition temperature range (230 to 260 K).

We are still measuring the processes of lower and higher temperature than the Peierls transition. We think that the higher one may be due to a relaxation of iodine, which in this compound is very unstable. At this time we have no model of the origin of the low temperature process. Measurements are in course to deny the possibility that helium gas from the thermalization atmosphere enters the sample when we decrease the temperature and then at 50 K it comes out giving a hardening of the sample.

5. ACKNOWLEDGEMENTS

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