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ULTRASONIC ATTENUATION AND OCCURENCE OF THE MARTENSITIC TRANSFORMATION IN THE HIGH T_c A15 COMPOUND V_3Si

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Abstract - The [100] shear modulus C_{44} is known to be nearly temperature independent in the case of V_3Si , an extensively studied compound for which many authors tried to associate the lattice instability and the high superconducting transition temperature.

We report new sound velocity and attenuation measurements of this [100] shear mode. The temperature change of the sound velocity displays a 6 % relative decrease while a large increase in the attenuation of this mode occurs for T decreasing from 80 K to $T_c = 17$ K.

This new observation gives a strong support for a very recently proposed approach to the occurrence of the structural transformation in V_3Si .

1. Introduction

The V_3Si A15 compound is known to undergo a structural transformation from a cubic symmetry to a tetragonal one at $T_m = 21$ K, a few degrees above the superconducting transition temperature ($T_c = 17$ K.).

Furthermore this compound exhibits an anomalous elastic behaviour as a strong softening of the acoustic shear mode $C_s = \frac{1}{2} (C_{11} - C_{12})$ [1] occurs on cooling despite the structural transformation is observed or not. Non transforming samples are believed to have a "defect perturbed lattice" [2,3].

The lattice softening of V_3Si has been studied by sound velocity and attenuation measurements by Testardi and Bateman [4], the softening of the transforming samples being stronger than that of the non transforming ones.

As shown by these authors, the attenuation α_s of the shear mode C_s increases as temperature decreases below 100 K, while the attenuation of other acoustic modes increases only near $T_m = 21$ K.

Sound velocity and attenuation measurements have been performed on several V_3Si single crystals (both transforming and non-transforming). Shear waves being generally more sensitive to a symmetry break-down, even local one, than longitudinal waves, we investigated particularly the shear waves along [100] axis (C_{44}).

The new results, reported below, allow us to specify the common feature of the two kinds of V_3Si samples and to propose a new significance for T_m .

2. Experiment

All V_3Si samples studied have been prepared by the high frequency floating zone method and submitted to specific heat analysis [5]. Two of these samples (S_2 and $S_5 M$) exhibit the specific heat anomaly at $T_m = 21$ K commonly associated with the occurrence of the transformation. The third one denoted $S_4 M$ ($V_{3,2} Si$) does not show such an anomaly and, therefore, it is considered as non transforming. It becomes superconducting at 15 K while for the stoichiometric samples S_2 and $S_5 M$ the critical temperature is near 17 K. Ultrasonic experiments were performed as a function of the temperature using an Y-cut quartz transducer (10 MHz) bonded to the sample with Nonaq, the pulse-superposition method of Mc Skimin [6] being used to measure the wave velocities.

3. Results

3.a - The velocity V_S and the attenuation α_S of the acoustic shear mode C_S along $[110]$ polarized $[\bar{1}\bar{1}0]$ measured on the sample $S_4 M$

The results of velocity measurements obtained in this case are displayed on Figure 1 and compared with previous results obtained by Testardi and Bateman [4] on transforming and non transforming samples denoted respectively "T" and "NT".

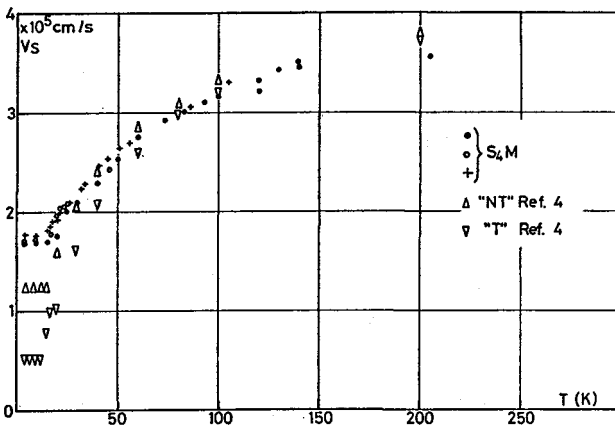


Figure 1 - Comparison of the velocity V_S of the acoustic shear mode C_S along $[110]$ polarized $[\bar{1}\bar{1}0]$ measured on $S_4 M$ with the results of Testardi (4) obtained respectively on transforming "T" and non transforming samples "NT"

As the temperature decreases, it appears clearly that the 3 samples $S_4 M$, "T" and "NT" behave similarly until 80 K is reached.

The attenuation α_S (Figure 2) measured on $S_4 M$ shows approximately the same relative variation with the temperature as that displayed by sample "T" [4]. Unfortunately the corresponding results were not reported for the sample "NT" and thus complete comparison cannot be achieved.

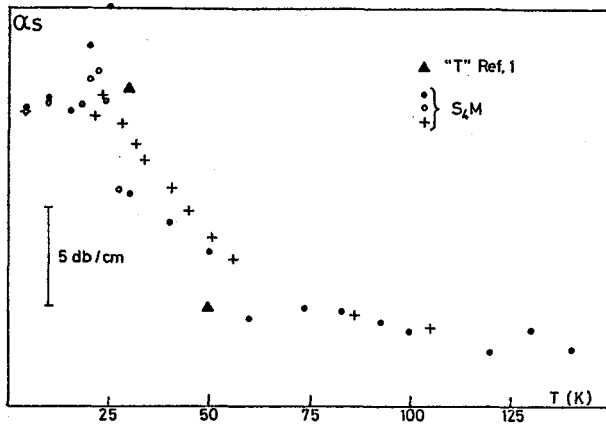


Figure 2 - Several measurements of the attenuation α_S of the shear mode C_S obtained on S_2M and compared with the results of Testardi (4) for a transforming sample "T"

3.b - The velocity V_T and the attenuation α_T of the acoustic shear mode C_{44} along [100] measured on the samples S_2 , S_4M , S_5M

The ultrasonic velocity V_T of this mode show a slight relative decrease of 4-7 % between room temperature and 4.2 K in agreement with previous results obtained in [4]. The results of the ultrasonic attenuation α_T measured on the three studied samples and on different parts of them, are displayed on Figure 3.

The following observations can be drawn :

- The increase of α_T between 80 K and 25 K appears to be a common feature for all the samples investigated independent of their state whether transforming or not.
- For $T < 25$ K, the results are depending on the samples and are related to the scanned part of the sample.

Thus the general behaviour of α_T differs markedly from that measured by Testardi which reported a marked increase between $T_m = 21$ K and T_c .

4. Discussion

Two important features arise from the results presented above :

- the attenuation α_T behaves same as α_S (see figures 2 and 3).
- the increase of α_S and α_T starts at the same temperature 80 ± 5 K.

The increase of α_T cannot be explained by the following classical mechanisms :

- attenuation due to electrons appears not suitable to explain such an increase considering that α_T remains nearly constant in the superconducting state.
- according to the classical treatment [7] the reduction of the velocity V would imply an increase of the attenuation proportionnal to $1/V^3$.

If $1/V_S^3$ scales roughly the attenuation α_S , the change of V_T is too small to explain, within this treatment, the large increase of α_T .

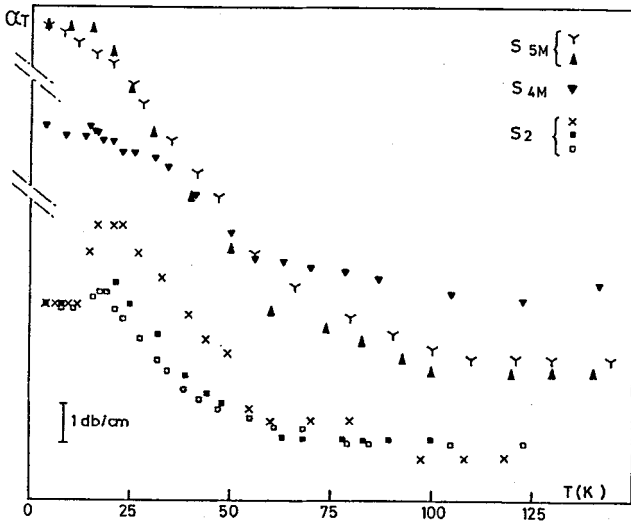


Figure 3 - The attenuation α_T of the shear mode C44 along [100] for the 3 samples S2, S4M and S5M

Recent thermal conductivity measurements [8] on the two class of V_3Si samples show a common behaviour in the temperature range 1.2 - 5 K of both samples, which was interpreted by the existence of planar defects associated in the case of non transforming samples with the boundary between the tetragonal domain and the cubic matrix.

For transforming samples, anomalies of thermal expansion [9,10,11] extending up to at least 60 K were interpreted as evidence for tetragonality.

The anomalous increase of the attenuation α_T between 80 K and 20 K can be explained by losses resulting from the diffraction of the ultrasonic waves by the tetragonal domains developing below 80 K. This temperature can be associated with the onset of sensitivity of ultrasonic attenuation to tetragonality, implying that the nucleation temperature would be higher than 80 K. The increase of the attenuation on cooling depends also on the level of tetragonality which would be lower in the case of non transforming crystal as shown by sample S4M.

The upper part of the attenuation α_T for temperature lower than 25 K displays quite a different behaviour (Figure 3).

In most cases a hump is observed in cooling and could be interpreted as a reduction of the effective area of the boundary of tetragonal domains scanned by the ultrasonic beam. The decrease of the attenuation must be then a consequence of the collapse of some domains in a single one and would be related to the anomaly observed in specific heat measurements near $T_m = 21$ K. Consequently the meaning of T_m would be quite different from the onset of the lattice transformation.

In another case α_T increases continuously (see S_5M) indicating an extent of the tetragonal domains even in the presence of superconductivity. This observation is in agreement with the results of Gibbs et al [11] and Fawcett [12].

The same kind of analysis based on the occurrence of tetragonality at higher temperature may account for different anomalous effects observed previously as the second harmonic conversion in ultrasonic wave propagation reported by Testardi [13]. The discontinuous behaviour of $\frac{\partial C_S}{\partial P}$ ($C_S = 1/2 (C_{11} - C_{12})$) as a function of pressure observed by Larsen and Ruoff [14] near 90 K for a non transforming sample and the existence of a minimum of $\frac{\partial C_S}{\partial P}$ reported by Garcia and Barsch [14] near 80 K for a transforming sample could be explained within the scope of tetragonality.

5. Conclusion

Anomalous attenuation of the ultrasonic shear mode C_{44} along [100] was interpreted as the occurrence of tetragonality at temperatures extending up to and a minimum of 80 K, where it is in agreement with other observations.

The difference between transforming and non transforming samples can be explained by the level of tetragonality occurring in each sample.

Studies are underway to achieve a better understanding of the development of tetragonality according to a recently proposed approach to the occurrence of the structural transformation in V_3Si [16].

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