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To cite this version:

K. Kojima, K. Shimomura, Y. Chang. DISPERSION ANOMALY OF ULTRASONIC WAVE IN Cu-Zn CRYSTALS AND V3Si CRYSTALS. Journal de Physique Colloques, 1981, 42 (C5), pp.C5-989-C5-994. 10.1051/jphyscol:19815152. jpa-00221025

HAL Id: jpa-00221025
https://hal.archives-ouvertes.fr/jpa-00221025
Submitted on 1 Jan 1981

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DISPERSION ANOMALY OF ULTRASONIC WAVE IN Cu-Zn CRYSTALS AND V₃Si CRYSTALS

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Abstract. In quenched β'-Cu-Zn alloy which undergoes the first order martensitic transformation, although the small anomalous dispersion was observed in the frequency of MHz, the magnitude of dispersion did not depend on the temperature. It was suggested that the well known anomalous behavior of elastic constant in this alloy could not explain in terms of the deviation of phase velocity. On the other hand, in case of V₃Si crystal which undergoes the second order martensitic transformation at lower temperature, the anomalous dispersion of ultrasonic wave strongly depended on temperature. These results are reported in this paper.

1. Introduction.
Both of the quenched and annealed Cu-Zn alloys show the well known anomalous behavior of the temperature dependence of the shear elastic constant, C'. This behavior has been interpreted in terms of the vibrational entropy of the B.C.C. lattice.[1] However, recently, Presepyo, Reynaud and Warlimont [2] have pointed out the possibility that it may be related to the presence of the mottled structure of the W-like phase. Therefore, in this paper, we will attempt to clarify whether this effect is due to the deviation of the phase velocity or not. On the other hand, V₃Si crystal which undergoes the second order martensitic transformation at near 21 K, also indicates the drastic anomalous behavior of the temperature dependence of C'. [3] Another aim of this paper is to investigate the dispersion of ultrasonic wave in this crystal.

2. Experimental Procedure.
Single crystals of β brass with a diameter of 25 mm and a length of 70 mm were grown by Bridgman technique. These crystals were cut parallel to the (110) plane to investigate the elastic constant and the dispersion of ultrasonic wave in the frequency range of 1 - 50 MHz. The chemical analysis of these crystals showed Cu-46.5 at%Zn as the composition of used alloys. The dimension of specimens for ultrasonic experiments were about 5 mm in thickness and 10×10 mm² in area.
The specimens were homogenized at 1073 K for 24 hrs and then one of them was quenched into water. The other was cooled to room temperature for 2 days. On the other hand, V3Si single crystals used in this experiment were grown by a floating zone process in Oak Ridge National Lab. The plane parallel face, (110), was prepared on the specimen. The dimension of specimen was 2.9 mm in thickness and 6.0 x 7.5 mm^2 in area. The block diagram for the equipment used in the ultrasonic dispersion experiment is shown in Fig. 1. An electric pulse is sent from the pulse generator to one of the transducers. The longitudinal or shear waves are transmitted through a specimen and received at another transducer. These repeated signals are transformed by a sampling oscilloscope into a single wave train which sweeps at very slow rates. The output of it is fed into a slow digital wave memory device, which has a capacity of recording up to 1024 words of digitally converted data of ultrasonic response. The ultrasonic response of the specimen with a duration of 1 μs can be recorded with an effective time resolution of 1 ns. These digitally recorded data are transmitted to a computer by use of a paper tape or a magnetic tape. These data are analyzed by the computer to obtain the dispersion of an ultrasonic wave. The detailed method of numerical calculation of the deviation of phase shift and phase velocity has been already published. [4,5]

3. Experimental Results and Discussion.

The quenched Cu-Zn crystals: The deviation of the phase shift in Cu-Zn alloy for the ultrasonic waves corresponding to C_L, C_44 and C' as a function of temperature was measured in the frequency 1-50 MHz. Hereafter, the ultrasonic waves corresponding to C_L, C_44 and C' are designated as a [110] longitudinal wave, LA, a [110] shear wave with a [001] polarization, TA_1 and a [110] shear wave with [110] polarization, TA_2, respectively. Fig. 2 shows that the typical curves of phase shift at various temperatures in quenched specimens. In case of LA wave, the phase shift increases with the increasing frequency and reaches the maximum about 30 MHz and then stays constant with weak fluctuation. The maximum phase shift at near 30 MHz shows little temperature dependence. The curves of phase shift of TA_1
Fig. 2. A deviation of phase shift for LA, TA₁, and TA₂ waves in the quenched Cu-Zn alloy at various temperatures.

Fig. 3. A deviation of phase shift for LA, TA₁, and TA₂ waves in the annealed Cu-Zn alloy at various temperatures.
show the weak periodic fluctuation around zero as shown in Fig.2(b). This small amount of phase shift is comparable with errors so that it seems that the deviation of the phase shift of $T_A_1$ is quite small. On the other hand, the behavior of phase shift of $T_A_2$ wave is quite different from LA and $T_A_1$ waves as shown in Fig.2(c). The amount of the phase shift successively increases with the increasing frequency at every temperature. Concerning the temperature dependence of it, there is little temperature dependence of the phase shift. The maximum relative deviation of phase velocity, $\delta v/v_0$, of the LA and $T_A_2$ waves leads to about 1% and 0.5%, respectively. These results suggest that there are small dispersion in LA and $T_A_2$ waves without large temperature dependence of the dispersion of the ultrasonic waves.

The annealed Cu-Zn crystals: The characteristics of the phase shift in the annealed Cu-Zn crystals are shown in Fig.3. At the lower temperature, the phase shift occurs in all of ultrasonic waves. Especially, about $T_A_1$ wave, although the phase shift was not observed in the quenched specimens, the phase shift took place in the annealed specimens at every temperature. In contrast, at the higher temperature, the phase shift for LA and $T_A_2$ waves was getting small. It should be pointed that there is no relationship between this phase shift and the anomalous behavior of elastic constant, since the shear elastic constant, $C_{44}$, in annealed Cu-Zn crystals showed the normal temperature dependence of it, in spite of large phase shift for $T_A_1$ wave. In conclusion, it seems that our results suggest that the anomalous shear elastic constant in the $\beta$ type Cu-Zn alloy is not due to the deviation of phase velocity with scattering dispersion but due to the vibrational entropy of B.C.C. lattice. However, the dispersion of ultrasonic wave due to the scattering still exists in both specimens.

$V_{3}Si$ crystals: The sound velocity in $V_{3}Si$ crystals has shown that the elastic constant $C'$ for $T_A_2$ wave falls from a value at room temperature to near zero at the transition temperature.

![Fig.4. Temperature dependence of the velocity of shear wave, $T_A_2$.](image-url)
It was measured that the sound velocity for TA\textsubscript{2} wave as a function of the temperature. The temperature dependence of the sound velocity for TA\textsubscript{2} wave as shown in Fig.4. Our result is quite in good agreement with that of Testradi and Bateman.[3] The heavy damping of TA\textsubscript{2} arose from a large reduction in sound velocity so that we were not able to observe the first echoes below 240 K and also the second echoes below 273 K. The diagram for the phase shift is shown in Fig.5 at 360 K and 290 K, respectively. The deviation of the phase shift in V\textsubscript{3}Si at 290 K increases with the increasing frequency. On the other hand, the curve of phase shift at 360 K is getting small on the magnitude of the phase shift. It should be pointed out that the temperature dependence of the phase shift for TA\textsubscript{2} wave shows the anomalous dispersion of ultrasonic wave in the frequency range of MHz. The maximum relative deviation of phase velocity, ΔV/V₀, for TA\textsubscript{2} wave gave about 6%. This value is large enough to interpret the anomalous temperature dependence of elastic constant \textquoteleft C\textquoteleft. The more detailed work is in progress.

Acknowledgement: We would like to thank Prof. Teturo Suzuki at Tsukuba University for stimulating discussion. This work has been partially supported by the Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture.
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