Pressure Investigation of Superconductivity of V$_3$Si

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Abstract. V$_3$Si is one of the superconducting A15 compounds and has relatively high $T_c$ of $T_c = 16.7$ K at ambient pressure. A15 compounds have another feature the martensitic cubic-tetragonal structural phase transition at $T_M$ comparatively close to $T_c$; $T_M$ of V$_3$Si is 21.5 K at ambient pressure. Interestingly, there are two types of crystals of V$_3$Si showing transformation (T) and non-transformation (NT). Here, we have revealed the pressure dependence of $T_c$ in NT V$_3$Si under hydrostatic pressures up to 14 GPa. $T_c$ monotonically increases up to 6 GPa and saturates on further compression, which is different behavior from previous report.

1. Introduction

In many superconductors including the new recently discovered new high-$T_c$ Fe based ones, a structural phase transition seems to play important roles in the appearance of superconductivity, but it is still unclear. The difficulty may be arisen from the difference between their transition temperatures, i.e. superconducting transition occurs at much lower temperature than structural phase transition temperature [1].

It has been already observed in the A15 compound V$_3$Si having relatively high $T_c$ of $T \sim 16$ K and $dT_c/dP > 0$. That superconductivity occurs also near lattice instability [2,3]. A martensitic phase transition temperature $T_M$ is quite comparable to $T_c$, promising a good example to study this problem [4]. However, there are two types of crystals in V$_3$Si transforming (T) and nontransforming (NT) ones. In previous works, for both samples the pressure dependence of $T_c$ and $T_M$ were investigated up to 3 GPa. $T_M$ and $T_c$ in the T sample merge into one point around 2 GPa. These studies reported that NT samples showed a large drop of $T_c$ above 2.5 GPa. In this paper, we investigated the pressure dependence of $T_c$ of NT polycrystalline sample, which shows no anomaly above $T_c$ in the specific heat, by the ac-susceptibility under hydrostatic pressure up to 14 GPa.

2. Experimental details

The small polycrystal of V$_3$Si was used in this work. High pressure was applied by using a diamond anvil cell (DAC) and pressure was up to 9.2 GPa (Run 1) and up to 14 GPa (Run 2). The culet diameter of the anvils were 1 mm. The pressure transmitting medium was liquid argon. Pressure was changed in the refrigerator and determined by the ruby fluorescence method at low temperature [5].

For ac-susceptibility measurement, we put a micro-coil with 300 μm in diameter, which was a pick-up coil and wound 10 turns with 12 μm insulated copper wire in 300 μm, into a pressure...
chamber [6,7]. $V_3Si$ and lead were put inside the pick-up coil. The lead was the marker to check whether the ac-susceptibility measurement was going well, and also used as a manometer [8].

3. Experimental results

Figure 1 presents temperature dependence of magnetic susceptibility $\chi'(T)$ of $V_3Si$ at several pressures in Run 1. There are three anomalies corresponding to superconducting transitions. At ambient pressure two clear drops of the $\chi(T)$ are observed around 7.2 K and 17 K. The low temperature anomaly monotonically decreases, indicating that the drop is due to the superconducting transition of Pb in the pressure chamber and that the measurements is working well. The anomaly at higher temperature is corresponding to $T_c$ of $V_3Si$. $T_c$ was determined from the peak of the temperature derivative of the susceptibility as shown in the inset of Fig. 1 and in agreement with previous works. With increasing pressure, $T_c$ of $V_3Si$ initially increases with a slope of $dT_c/dP = 0.18$ K/GPa. This value was slightly smaller than previous works [2,3].

From this experiment $T_c$ of NT sample continues increasing with applying pressure up to $\sim 6$ GPa and saturates on further compression. However the data of Run 2 were not systematically-changed and difficult to determine the $T_c$ of $V_3Si$, the onset of superconductivity seemed to decrease for higher pressures.

We show the pressure dependence of $T_c$ and $T_M$ for T and NT samples of $V_3Si$ in Fig. 2. Our results are different from previous works. Though the various works on $V_3Si$ had been previously reported, it is still unclear that how $T_c$ depends on the type (T or NT) of sample. SC transition of NT sample occurs without any changes in its cubic structure. These results suggests SC transition doesn’t depend on the crystal structure, which may result in that the weak pressure dependence of SC in $V_3Si$ as seen in Fig. 2. In order to clarify the more detail, the other physical properties such as the pressure dependence of the jump of specific heat at $T_c$ with the both T and NT samples are required.

![Figure 1. Magnetic susceptibility of $V_3Si$ under pressure: SC transition of (1) lead manometer, (2) solder, (3) $V_3Si$. The inset shows temperature derivative of the susceptibility. At all pressure range, we determined $T_c$ by its peak.](image-url)
Figure 2. The pressure dependence of $T_c$ and $T_M$ for T and NT samples of $V_3Si$. Open triangles show T sample, open and solid circles show NT sample.

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5. References

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