Singularities of magnetic susceptibility of V_3Si

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We investigated the temperature dependence of the magnetic susceptibility $\chi(T)$ of V_3Si single crystals with different resistivity ratios. The following were observed for the first time: a singularity on the $\chi(T)$ curves near 70°K, and differences in the laws governing the variation of χ in the temperature intervals above and below 70°K.

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V_3Si is a high-temperature conducting compound with A15 structure. The special interest in this compound is due also to the fact that it undergoes a structural transition from the cubic into the tetragonal phase at a temperature T_M only several degrees higher than the critical superconducting transition temperature T_c. Numerous attempts have been made to establish a correlation between the high value of T_c and the presence of lattice instability in this compound. Most results, both experimental and theoretical,[1–5] give grounds for assuming that the instability of the V_3Si lattice is due to the anomalously high density $N(\epsilon_F)$ of the electron states at the Fermi level. The shift of the Fermi level relative to the peak of the density of the electronic states can lead to a vanishing of the structural transition.[5] Great interest attaches therefore to experiments on those physical properties of V_3Si which yield direct information

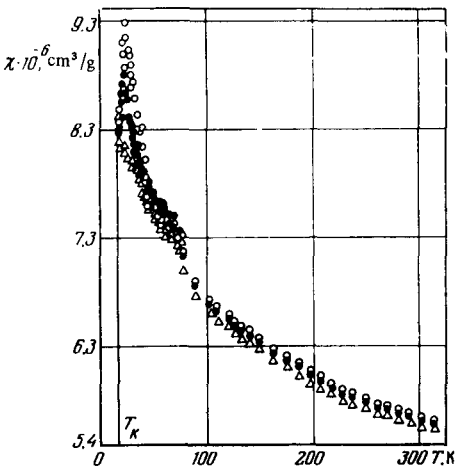

FIG. 1. Temperature dependences of the magnetic susceptibility of V_3Si: ○—$\alpha = 34$, ●—$\alpha = 25$; Δ—$\alpha = 13$.

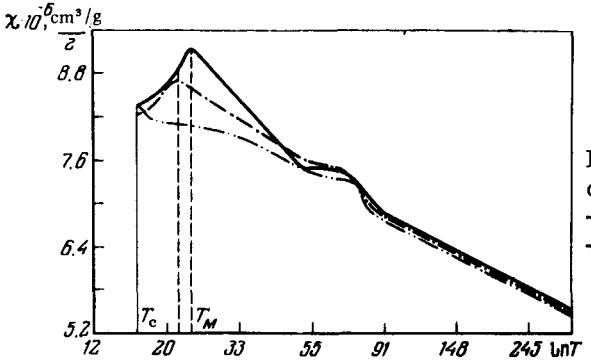

FIG. 2. Plots of the magnetic susceptibility of V_3Si against ln T: —— —$\alpha = 34$; -·-·-·- —$\alpha = 25$; ------ —$\alpha = 13$.

on the variation of $N(\epsilon_F)$. These experiments include measurements of the temperature dependence of the magnetic susceptibility.

The purpose of the present study was to investigate the variation of $\chi(T)$ of V_3Si single crystals with resistivity ratios $\alpha = \rho_{300K}/\rho_{18K} = 13$, 25, and 34 in the interval 4.2—3.4 °K. The investigated samples had a near-stoichiometric composition. The rocking curve of the (200) reflection, obtained with the DRON-1 diffractometer in Cu-K_α radiation, have shown that the width of the rocking curve decreases with increasing α from 10′ at $\alpha = 13$ to 2′ at $\alpha = 34$. We obtained $T_C = 17 \pm 0.1$ °K for all the samples. The values of χ were measured by the relative Faraday method using an electronic microbalance with automatic compensation.[6] The measurement error did not exceed 1%.

Figure 1 shows plots of $\chi(T)$ for samples with $\alpha = 13$, 25, and 34. As seen from the diagram, the $\chi(T)$ plots of V_3Si samples with $\alpha = 25$ and 34 have maxima at $T_M = 22$ °K and 23.7 °K, respectively.

A similar singularity on the plot of $\chi(T)$ was observed in[4] near $T_M = 21$ °K. The presence of a maximum of χ at T_M is attributed to a structural transformation.

At $T < T_M$ the value of χ decreases with decreasing temperature, down to $T_c = 17$ °K. At $T \leq T_c$, the $\chi(T)$ plot has a sharp break, namely a transition into the diamagnetic region as a result of the Meissner effect. There is no maximum corresponding to a structural transition for samples with $\alpha = 13$.

We have observed that at low temperatures (below 70 °K) the value of χ decreases with decreasing α, and is practically independent of α in the interval 100—314 °K, in the range of the investigated $\alpha = 13$—34.

Figure 2 shows plots of χ against ln T. As seen from the figure, the temperature dependences of χ in the region 100—314 °K are close to logarithmic.

A $\chi(T)$ dependence in this form was predicted by Gor'kov[5] for quasi-one-dimensional strings with allowance for the str interaction between strings. According to[5], for strings of transition-element atoms, when account is taken of interaction between them, the electron energy spectrum leads to a fine structure in the density of the states of the d band, with a logarithmic dependence. This results in a logarithmic temperature-dependent increment to the magnetic susceptibility at $T > T_M$.

A singularity was observed on the $\chi(T)$ curve of all the investigated samples

near 70 °K. At $T_M < T < 70$ °K (Fig. 2), an increase in the slope of the $\chi(T)$ curve is observed for the crystals undergoing a structural transformation. With increasing α, the slope of $\chi(T)$ increases in this temperature region and the temperature T_M of the structural transformation rises.

The presence of a singularity of $\chi(T)$ near 70 °K, as well as the difference between the growth rates of $\chi(T)$ of samples with different α at $T < 70$ °K, are apparently due to the fact that the density of the electronic states in V_3Si is more complicated than predicted by the theory[5].

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