ELECTRIC AND MAGNETIC PROPERTIES OF Vₓ Ti₁₋ₓS₂
A. Chang, P. Molinié, M. Sienko

To cite this version:

HAL Id: jpa-00217955
https://hal.archives-ouvertes.fr/jpa-00217955
Submitted on 1 Jan 1978

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
ELECTRIC AND MAGNETIC PROPERTIES OF $V_{x}Ti_{1-x}S$

A.T. Chang, P. Molinié and M.J. Sienko
Cornell University, Ithaca, New York 14853, U.S.A.

Several studies /1,2/ have been carried out on $Ti_{1-x}S_{2}$ to determine conditions for obtaining stoichiometric $TiS_{2}$. The $TiS_{2}$ is complicated by possible existence of vacancies at titanium sites and interstitial titanium. All these studies have attempted to explain the discrepancy between the resistivity data (metallic behavior with $T^{2}$ dependence) /1/, the photoemission work /3/, and the band structure calculation /4/ which gives an indirect gap of 0.2 - 0.3 eV. The present work was undertaken to investigate the effects of vanadium substitution.

Vanadium concentration was determined by neutron activation. Electrical conductivities and Hall effect were measured on single crystals by conventional methods. Magnetic susceptibility measurements were made using the Faraday method.

Room temperature values of $\mu$ and $\rho$ are linearly dependent on composition. Resistivity as a function of temperature is shown in figure 1. At low vanadium concentration, $T^{2}$ dependence is observed with resistivity minima at 18 K and 22 K, respectively. At 3.7 % V there is practically no temperature dependence of $\rho$ except for the anomaly at 30 K. The more heavily substituted crystals behave like semiconductors. These are not conventional semiconductors; the "band gap" diminishes with decrease in temperature. Anomalies were also observed at $\sim$ 30 K.

The Hall constants in figure 2 show that the metallic samples are insensitive to variation in temperature. 8.0 % V and 6.2 % V show an increase with falling temperature, indicating decrease of the conduction electron density in the semiconducting crystals. For 3.7 % V, the anomaly in the resistivity can be seen as partially due to sudden increase in the conduction electron concentration.

In figure 3, the samples show Curie-type behavior with 2.8 $\mu_{B}$ per mole of vanadium suggesting $V^{3+}$ ($d^{2}$). At low temperature (< 30 K), ferrimagnetic ordering sets in. It decreases abruptly on cooling and hence causes the observed anomalies in resistivity.
There are two existing band models for TiS₂. The semimetallic model of Thompson, Kukkonen and Maldague attributes the T² dependence of resistivity to electron hole scattering. In this model, the p and b bands are very close to each other or even overlap. According to Kukkonen and Maldague, the presence of 0.39% excess Ti (~10²¹e⁻) there is a substantial deviation from T² dependence. With 1.4% V the change in electron concentration (~2 x 10²², assuming V⁺³) is great enough to cause deviation from the T² dependence. Wilson, in his dirty semiconductor model, attributes the T² resistivity dependence to electron scattering by "Fivaz mode" optic homopolar phonons, an A₁₈ vibration in the case of TiS₂. With the "Fivaz mode", primarily due to lattice disorder, the carrier mobility was derived as μqTⁿ where n depends solely on the energy of the A₁₈ mode (n = 2 for TiS₂). In a Raman study of HfS₂, ZrS₂ and TiS₂, Smith et al. observed that the energy of the A₁₈ mode is independent of the metal ion. Hence, the replacement of Ti by V should not alter the energy of the A₁₈ mode, and consequently, the temperature dependence of the mobility. With the observed temperature-independent Hall constant for the slightly doped samples, the resistivity should obey the same T² laws as in TiS₂, which was indeed the observed case. Recent work by Friend et al. on the pressure dependence of resistivity and Hall constant of TiS₂ and TiSe₂ crystals is in agreement with the extrinsic semiconductor model.

For higher vanadium concentrations (κ > 0.04) the crystal exhibit semiconducting behavior with a varying "band gap". We suggest Anderson localization of conduction electrons due to potential fluctuations created by randomly distributed vanadium ions. The effect, however, is complicated by ferrimagnetic interaction between the vanadium ions.

References