Anomalies of electro- and magnetotransport in Heusler-like alloys $Fe_{2-x}V_{1+x}Me$ (Me = Al,Ga)

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Abstract

Electro- and magnetoresistivity, Hall effect, magnetic and optical properties of Heusler-like alloys $Fe_{2-x}V_{1+x}Me$ ($-0.2 \le x \le 0.2$; Me = Al,Ga) were studied in the temperature range from 1.4 K to 400 K and in magnetic fields up to 150 kOe. The anomalies in the temperature dependence of the resistivity and the Hall coefficient were observed, which correlate with the peculiarities of the optical properties. These anomalies can be caused both by Fermi level position in a low state density region and by strong scattering of current carriers.

Key words: Heusler-like alloys; electro- and magnetoresistivity; Hall effect

1. Introduction

The electronic properties of the Heusler-like alloys $Fe_{2-x}V_{1+x}Me$ (Me = Al,Ga) attracted considerable attention after the appearance of reports on their unusual resistive characteristics, metal-isolator concentration transition and negative giant magnetoresistance [1]-[3]. The physical reasons of these singularities are still unclear. The aim of this paper is to obtain new information on the electronic structure of $Fe_{2-x}V_{1+x}Al$ and $Fe_{2-x}V_{1+x}Ga$ ($-0.2 \le x \le 0.2$) alloys by measuring their electrical, galvanomagnetic, magnetic and optical properties.

2. Experimental and results

$Fe_{2-x}V_{1+x}Al$ and $Fe_{2-x}V_{1+x}Ga$ ($-0.2 \le x \le 0.2$) alloys were melted in an induction furnace in a purified argon atmosphere and were remelted three times. The alloys have $L2_1$ structure. The electroresistivity and the galvanomagnetic properties were studied in the temperature range from 1.4 K to 400 K in magnetic fields up to 150 kOe. The magnetic measurements were carried out using the Quantum Design SQUID magnetometer at 4.2-300 K in magnetic fields up to 50 kOe. The optical properties were measured with the ellipsometric Beattie technique in the spectral range $\lambda = (0.25 - 40)\,\mu$m at room temperature.

Electroresistivity. Figure 1 shows the temperature dependence of the electroresistivity ρ(T). One can see the maximuma of ρ(T) and the portions with a negative temperature coefficient of the electroresistivity. A semiconductor-like behavior of ρ(T) is observed in $Fe_{1.9}V_{1.1}Al$ with very high magnitude of the resistivity at T = 1.4 K ($\rho_{1.4\,K} = 12750\ \mu$Om×cm).

Magnetoresistivity and magnetic properties. The maximum value for the transverse magnetoresistivity $-\Delta\rho/\rho(0)$ was obtained for Fe_2VGa alloy (Fig. 1, inset). According to magnetic measurements this alloy is non-magnetic. For other compounds the maximuma of $-\Delta\rho/\rho(0)$ are observed at temperatures near magnetic transformations temperature. "Ferrimagnetic-

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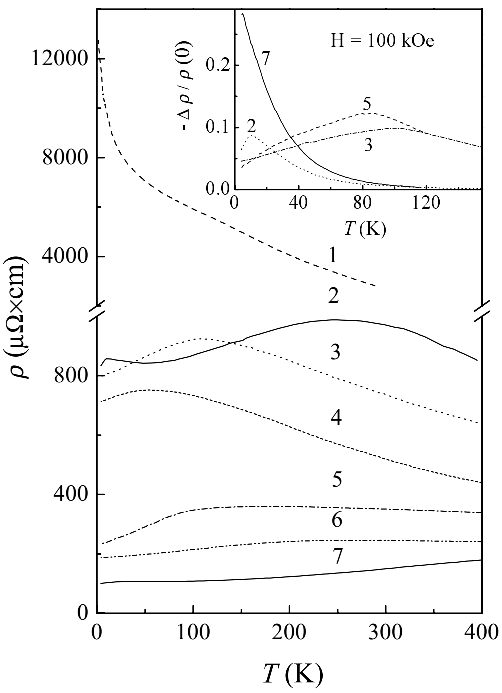

Fig. 1. Temperature dependence of the electroresistivity ρ and the transverse magnetoresistivity -$\Delta\rho/\rho(0)$ (inset). 1 - $Fe_{1.9}V_{1.1}Al$, 2 - Fe_2VAl, 3 - $Fe_{2.2}V_{0.8}Al$, 4 - $Fe_{1.8}V_{1.2}Ga$, 5 - $Fe_{2.2}V_{0.8}Ga$, 6 - $Fe_{1.9}V_{1.1}Ga$, 7 - Fe_2VGa.

paramagnetic" is for Fe_2VAl. Heterogeneous magnetic state is realized for $Fe_{2.2}V_{0.8}Al$ and $Fe_{2.2}V_{0.8}Ga$.

Hall effect. Figure 2 presents the temperature dependence of the Hall coefficient R_H and the current carriers concentration n for Fe-V-Al alloys. The Hall coefficient is negative, which corresponds to the electron-type charge carriers. The magnitude of n is changed strongly from $n = 6.94 \times 10^{19}$ cm^{-3} for $Fe_{1.9}V_{1.1}Al$ to $n = 1.05 \times 10^{21}$ cm^{-3} for Fe_2VAl at T = 4.2 K.

Optical properties. An anomalous behaviour of the real part of the dielectric constant $\varepsilon_1(\omega)$ of alloys was observed in the IR range, i.e. $\varepsilon_1(\omega)$ is either positive or negative for $\lambda > (10 - 35.7)\mu$m [4]. This correlates with the appearance of portions with a negative slope in the temperature dependence of ρ(T). The high level of optical absorption in the IR range (coefficient $\alpha = 2.7 \times 10^4$cm^{-1}) may indicate that the semiconductor-like state is not realized for $Fe_{1.9}V_{1.1}Al$ alloy.

3. Conclusion

An analysis of obtained data allows us to conclude that a behaviour of the electrical, galvanomagnetic and optical properties for $Fe_{2-x}V_{1+x}Al$ and $Fe_{2-x}V_{1+x}Ga$

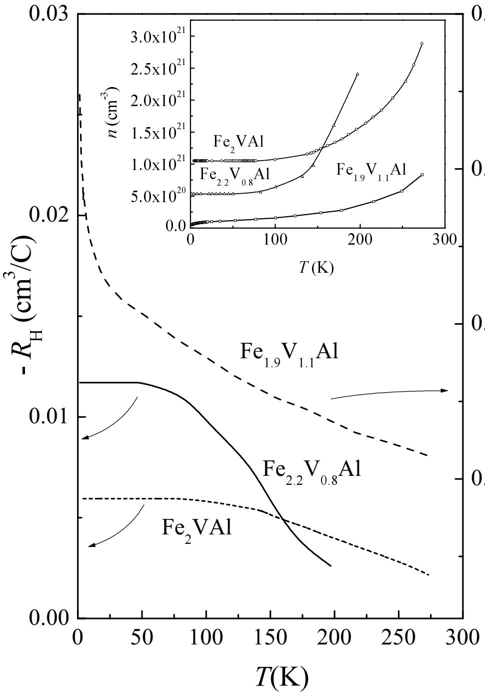

Fig. 2. Temperature dependence of the Hall coefficient in a field of 50 kOe and the current carriers concentration n (inset).

($-0.2 \leq$ x ≤ 0.2) compounds satisfies neither typical metals nor typical semiconductors. The observed anomalies of physical properties can be caused both by Fermi level position in a low state density region and by strong scattering of current carriers.

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