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Magnetic Field Enhancement of the Hall Effect in Dilute Magnetic System $La_{1-x}Ce_xB_6$ ($x \leq 0.1$)

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Magnetic field dependences of the Hall coefficient R_{H} and resistivity have been studied in detail for dilute magnetic compounds $La_{1-x}Ce_xB_6$ ($x \leq 0.1$) at temperatures 1.8–300 K. It was established that the regime of weak localization of charge carriers, which was observed in these heavy fermion systems below 30 K destroys gradually in magnetic field up to 8 T. Moreover, in addition to the strong negative magnetoresistance ($\Delta\rho/\rho \approx 80\%$) a drastic enhancement of the negative Hall coefficient in magnetic field ($\Delta R_{\mathrm{H}}/R_{\mathrm{H}} \approx 50\%$) has been deduced at liquid helium temperatures. The results of comprehensive analysis contradict the predictions of Kondo-impurity approach for this archetypal strongly correlated electron system in the dilute impurity limit. An alternative interpretation of $La_{1-x}Ce_xB_6$ properties is developed on the basis of spin-polaron approach, Pauli paramagnetism and the density of states renormalization effects at low temperatures.

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1. Introduction

Recent discovery of quantum critical behavior in heavy fermion solid solutions $La_{1-x}Ce_xB_6$ in the range of $x \leq 0.6$ [1] has brought renewed interest to study unusual properties of these strongly correlated electron systems. Authors in [1] interpreted the experimental results in frame of the Kondo-impurity approach and pointed out that special attention should be paid to the low concentration limit $x \leq 0.1$. At the same time the results of very recent research of resistivity, thermopower, low field Hall coefficient and magnetic susceptibility studies of $La_{1-x}Ce_xB_6$ ($x \leq 0.1$) [2] contradict the predictions of Kondo-impurity approach for these archetypal strongly correlated electron systems in low impurity limit. Contrarywise, all experimental results obtained in [2] for cerium based magnetic systems $La_{1-x}Ce_xB_6$ ($x \leq 0.1$) were successfully interpreted in terms of the spin-polaron approach, developed earlier for the dense magnetic system CeB_6 [3]. To verify this approach for dilute compounds $La_{1-x}Ce_xB_6$ ($x \leq 0.1$) in detail it is promising to investigate charge transport anomalies in $La_{1-x}Ce_xB_6$ in strong magnetic fields.

2. Results and discussion

To shed more light on the nature of many-body states in the metallic $La_{1-x}Ce_xB_6$ matrix, the precision measurements of magnetoresistance and Hall effect have been carried out on high-quality single crystals of dilute magnetic substitutional solid solutions $La_{1-x}Ce_xB_6$ ($x \leq 0.1$) in a wide temperature range 1.8–300 K in strong magnetic fields up to 80 kOe. The analysis of the resistivity behavior of $La_{1-x}Ce_xB_6$ ($x \leq 0.1$) in magnetic field reveals that the weak localization regime observed

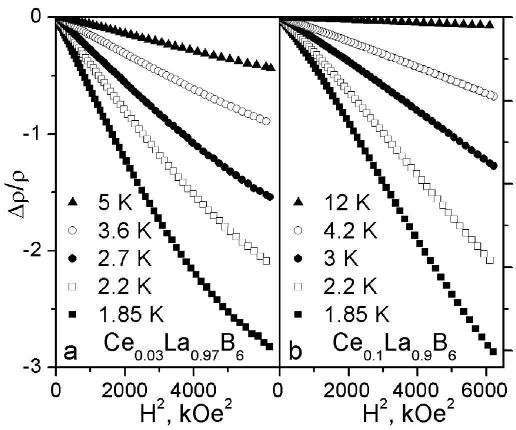

Fig. 1. Magnetic field dependences of magnetoresistance $\Delta\rho/\rho(H^2)$ of $La_{1-x}Ce_xB_6$ for $x = 0.03$ (a) and 0.1 (b).

in these dilute magnetic systems at $T < 30$ K [2] depresses drastically with H elevation above 20 kOe, resulting to the appearance of strong negative magnetoresistance ($\Delta\rho/\rho \approx 80\%$). Figure 1 shows typical magnetic field dependences of the magnetoresistance $\Delta\rho/\rho(H^2)$ for $La_{1-x}Ce_xB_6$ compounds with $x = 0.03$ and 0.1, correspondingly. The most appropriate interpretation of such negative quadratic magnetoresistance $-\Delta\rho/\rho \sim H^2$ (Fig. 1) was developed and verified earlier for dense mag-

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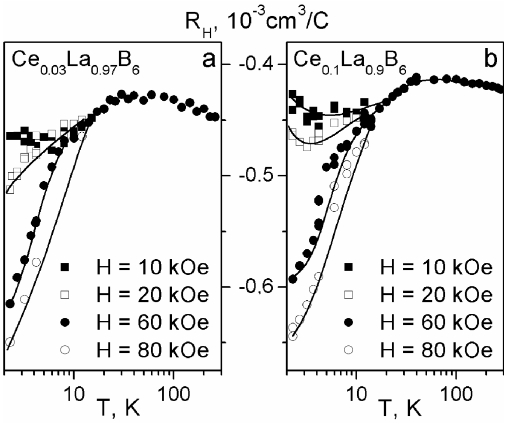

Fig. 2. Temperature dependences of the Hall coefficient $R_{\rm H}(T)$ of $La_{1-x}Ce_xB_6$ at different magnetic fields for $x = 0.03$ (a) and 0.1 (b).

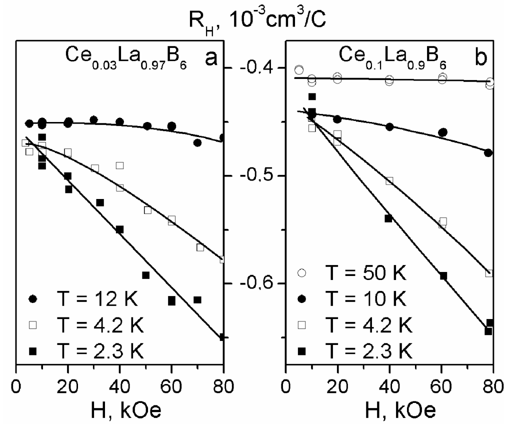

Fig. 3. Magnetic field dependences of the Hall coefficient $R_{\rm H}(H)$ of $La_{1-x}Ce_xB_6$ at different temperatures in the range 2–50 K for $x = 0.03$ (a) and 0.1 (b).

netic system CeB_6 [3] within the framework of the Yosida approach [4], and seems to be efficient for dilute magnetic alloys $La_{1-x}Ce_xB_6$ as well.

Following to the Hall effect studies of $La_{1-x}Ce_xB_6$ in low magnetic fields [2] the investigation of the Hall coefficient was developed in present studies in the range $H \le 80$ kOe. A strong enhancement of the Hall effect in magnetic field both for $x = 0.03$ (Fig. 2a, 3a) and 0.1 (Fig. 2b, 3b) at liquid helium temperatures was established evidently. The increase of the negative values of $R_{\rm H}(H)$ is almost linear in magnetic field (Fig. 3) and it reaches an amplitude $\Delta R_{\rm H}/R_{\rm H} \approx 50\%$ when H increases up to 80 kOe at temperature $T \approx 2$ K. Resulting from the strong influence of magnetic field on the resistivity (Fig. 1, see also [2]) and on the Hall coefficient (Figs. 2, 3), a drastic elevation of the Hall mobility values $\mu(H) = R_{\rm H}(H)/\rho(H)$ is observed with an enhancement factor $\mu(H)/\mu(0) = 5 \div 8$ at 2 K in magnetic field of 80 kOe. It is needless to point out that these experimental results as well as the data of [2] obtained for $La_{1-x}Ce_xB_6$ solid solutions with $x \le 0.1$ cannot be interpreted even qualitatively in terms of the skew-scattering and Kondo-lattice models [5, 6]. On the contrary, we suppose that present experimental data together with data of [2] retrieve sufficient interpretation in terms of the model, developed earlier for the dense magnetic system CeB_6 and based on spin-polaron approach, Pauli paramagnetism and DOS renormalization effects at low temperatures [3]. In the framework of this model both strong negative magnetoresistance (Fig. 1) and negative Hall coefficient enhancement in magnetic field (Figs. 2, 3) observed for archetypal strongly correlated electron systems $La_{1-x}Ce_xB_6$ in low impurity limit $x \le 0.1$ may be explained in terms of the depression of many-body states (heavy fermions) and the polarization of 5*d*-states in the vicinity of Ce centers in the metallic matrix of these hexaborides.

Acknowledgments

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