Enhancement of the Kondo effect in a mechanically deformed Cu(Mn) alloy

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Abstract

We have studied the Kondo effect in a mechanically deformed Cu(Mn) alloy, through measurements of the temperature dependence of the resistivity. The logarithmic Kondo slope at low temperature became a little larger than not deformed one. The temperature of maximum resistivity due to spin glass transition seems to be slightly larger than not deformed one. We suppose that the origin of these phenomena is the enhancement of the Kondo effect due to increase of Mn atoms trapped in dislocations.

Key words: Kondo effect; Cu(Mn); dislocations; resistivity

It is well known that the resistivity of a metal doped with dilute magnetic impurity has minimum at low temperature and it increases logarithmically with decreasing temperature. The effect is called the Kondo effect [1], and

$$\rho = \rho_0 + \rho_p(T) - B \ln T.$$

Here, $\rho_p(T)$ is the resistivity due to the contribution of phonon. B is called (logarithmic) Kondo slope frequently. How is the resistivity when the sample is mechanically deformed? The following result is supposed easily. Many lattice defects and dislocations are produced in the sample, and the electronic mean free path is decreased due to scattering by them. Consequently ρ_0 increases. In this case the Kondo slope has no change from Matthiessen's rule. However, the other effects of mechanical deformation exist. The effects are the contributions to the resistivity due to week localization, electron-electron interaction [2], and possibly Kondo size effect [3].

We found the change of the temperature dependence of the resistivity caused by mechanical deformation. However, we could not explain the change using above effects. We suppose that the origin of the change is the enhancement of the Kondo effect due to increase of Mn atoms trapped in dislocations.

Starting material is a Cu wire doped with Mn. The wire diameter is 100μm, the concentration of Mn is 91ppm, and the mean free path is 0.59μm. From now on we call the sample '100μm sample'. We made a thin sample by cold rolling the above sample. The thickness is 9μm and the mean free path is 0.51μm. From now on we call the sample '9μm sample'. Of course, the concentration of Mn has no change after mechanical deformation in comparison with the starting material. The resistivity of these samples was measured using four-terminal resistance bridge. The results are shown in Fig.1. We found that the Kondo slope increased due to mechanical deformation.

We also measured the resistivity of a thinner sample for studying the influence of Kondo size effect. The thickness is 4μm and the mean free path is 0.49μm. From now on we call the sample '4μm sample'. The results are shown in Fig.2.

From Fig.2 no significant change between the 4μm sample and 9μm sample was found, so that the samples seem to have no size effect. We suppose that the influence of week localization and electron-electron inter-

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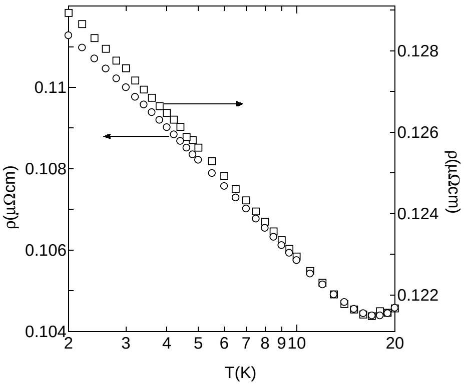

Fig. 1. Resistivity of the 100μm sample (circle) and 9μm sample (square).

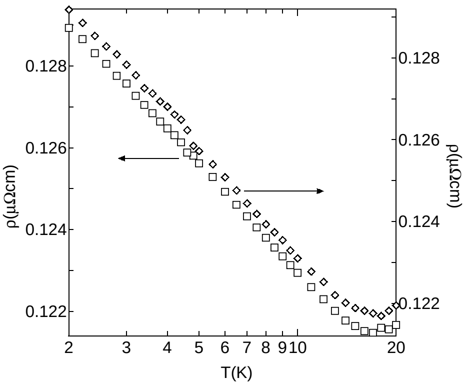

Fig. 2. Resistivity of the 4μm sample (diamond). We also show the data of the 9μm sample (square) for comparison.

action are negligible due to nearly three-dimensional system and long mean free path.

In consideration of the above results we supposed the following possibility: The suppressed Kondo effect due to Mn-Mn RKKY interaction recovered due to short mean free path [4]. To check the possibility, we measured the resistivity at lower temperature using a dilution refrigerator, and we intend to observe the peeks due to spin glass transition. We used the 100μm sample and 9μm sample. The results are shown in Fig.3.

From Fig.3 the temperature of the peek seems to be enhanced slightly due to mechanical deformation. This means that the RKKY interaction is, if anything, enhanced, so the above possibility is small.

Therefore, all of the above possibilities are unfavorable. Then we supposed the following qualitative scenario. When dislocations move and increase by mechanical deformation, some dislocations are pinned by Mn atoms. Because the radius of Mn atom is smaller than that of Cu atom, the Cu atoms surrounding a Mn atom located at a dislocation approach the Mn atom. The hybridization of 3d and conduction electron becomes large. As a result, the Kondo effect is

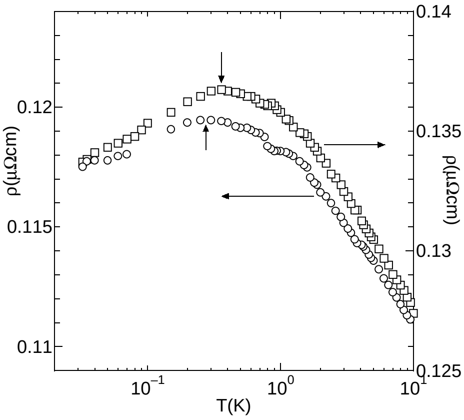

Fig. 3. Resistivity of the 100μm sample (circle) and 9μm sample (square) at lower temperatures. Two vertical arrows show the temperatures of maximum resistivity due to spin glass transition.

enhanced. The RKKY interaction is enhanced due to the enhanced Kondo effect.

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