Superconducting behaviors of Copper-Germanium alloys

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Abstract

We have observed superconducting properties in three dimensional Cu_xGe_{100-x} samples with 38≤x≤67. Transition temperature T_c is about 0.4K. Upper critical magnetic field H_{c2} has been measured in these samples confirming that they are indeed superconductors. Near the zero field T_{co}, H_{c2} depends linearly on temperature. Our results show that the robust superconducting properties present in CuGe samples with weakly disorder.

Key words: superconductivity; weak disorder; CuGe

1. Introduction

It has been known that as the amount of disorder is increased in a superconductor, the enhanced electron-electron interaction and localization effects have deleterious effects on superconductivity leading a degradation of the transition temperature. On the other hand, it has been reported that the transition temperature of a clean bulk superconductor can be increased by introducing slight disorder in it. Moreover, superconducting properties of AuGe and AuSb were obersved.[1] However, most attention is focused on two dimensional superconductor-to-insulator transition. The question that why does the alloy of two non-superconducting elements superconduct is still not well understood yet. Here, we report the observed superconducting properties of three dimensional CuGe samples in the weakly disordered regime.

2. Experimental details

Our three dimensional amorphous CuGe samples were obtained by thermal evaporation on glass substrates at a rate 0.2nm/s in vacuum. The alloy sources were fabricated by an arc-melting method. The molar concentration ratios between Cu and Ge in all samples were examined using a SEM energy dispersion spectroscope. Film thicknesses were about 200nm, measured by surface profile probe. Four terminal AC resistance measurements were performed in a ^{3}He cryostat.

3. Results and discussion

Earlier studies of electrical transport and tunneling density of states in a series of thick CuGe samples reveal that the reduction of Cu concentration relative to Ge enhances electron-electron interactions leading to a weak-to-strong localization transition. The transition occurs around x∼0.2.[2] Figure 1 shows the evolution of the temperature-dependent resistivities for four Cu_xGe_{100-x} with 38≤x≤67. The resistive transitions are very sharp for all samples indicating the superconductivity of each sample is robust. We associate this drop with the mean-field transition of a superconductor, T_{co}. For samples with higher concentration of Cu, x≥70, no superconducting behavior above 0.28K was observed. T_{co}=0.38K for x=67 and then, T_{co} decreases with decreasing x (increasing disorder ρ).

These samples have resistivities less than 500$\mu\Omega$cm and are in the weakly disordered regime. The normal

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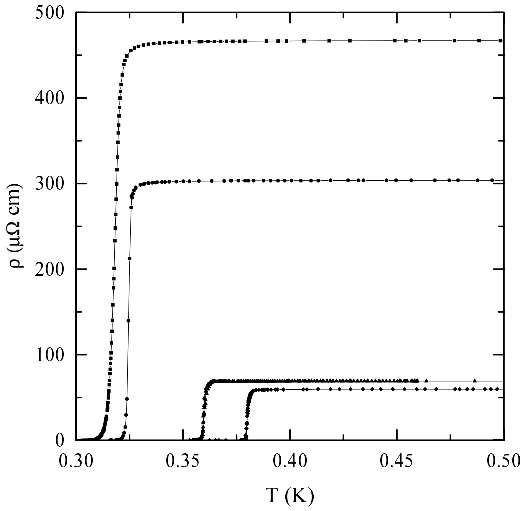

Fig. 1. Resistivity ρ versus temperature T for four Cu_xGe_{100-x} samples with x=38(□), x=45(◯), x=64(△), and x=67(◇).

state resistivity has a $T^{1/2}$ dependence at low temperatures due to the electron-electron interaction effects. It can be described by the theoretical prediction of Altshuler and coworker:

$$\frac{\Delta\rho(T)}{\rho_o} = -\frac{0.915e^2}{4\pi^2\hbar}(\frac{4}{3} - \frac{3}{2}F)\rho_o\sqrt{\frac{k_BT}{\hbar D}}. \tag{1}$$

where F present the Coulomb screening effect and D is the electron diffusion constant.

For a type-II superconductor, upper critical field H_{c2}(T) is linear in temperature near the zero field transition temperature T_{co}. We plot H_{c2}(T) of these four samples in Fig.2. All data seems fall on lines except in the regime very close to zero field for the highest disordered sample. The slope gives the information of diffusion constant,

$$D = \frac{4k_B}{\pi e}\frac{1}{dH_{c2}/dT_c}. \tag{2}$$

From fits to data we obtained D and F for these samples. As disorder increases, D changes from 6.2cm^2/s to 2.7cm^2/s(more diffusive) and F changes from -0.38 to -1.29(less screening). The result implies that disorder enhances the electron-electron interaction effects in consistent with the observed reduction of T_c in Fig.1. The slight deviation from linear relation near the zero magnetic field for the highest disorder sample may be similar to the magnetic-field-enhanced superconductivity in Au/Ge observed by Seguchi et al.[3]

In summary, superconducting properties were observed in weakly disordered CuGe samples. Disorder enhanced electron-electron interaction effects certainly degrade the superconducting properties and therefore, combination of spin-orbital scattering and weak localization may be responsible for the superconducting behaviors. That may answer why Tc is higher in both AuGe and AuSb samples than in our CuGe samples.

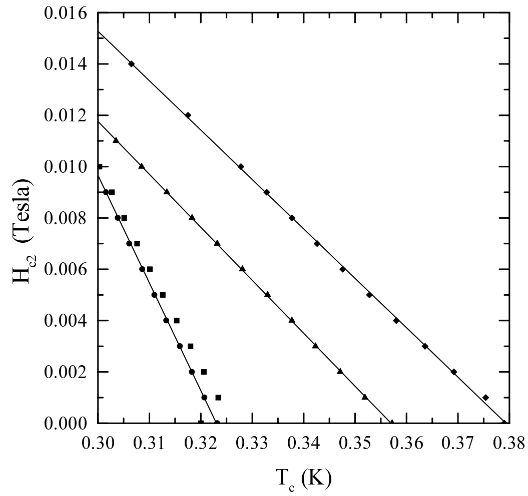

Fig. 2. Critical field H_{c2} versus T_c for four Cu_xGe_{100-x} samples. The symbols are experimental results and three lines are linear fits to data.

Acknowledgements

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