Superconducting properties of LiFe$_{1-x}$Cu$_x$As single crystals

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1. Introduction

Since the discovery of the iron-based superconductor La[O$_{1−y}$F$_y$]FeAs [1], series of iron arsenide superconductors have been discovered, which can be classed into three types: “1111”-type [1], “122”-type [2] and “111”-type [3]. Although the mechanism of the superconductivity is still unclear, some common characters can be found in the three systems. The crystal structures are similar to each other which belong to the tetragonal structure and all consist of the two dimensional [FeAs] layers which are considered as the main part related with superconductivity. Both parent compounds of “1111” and “122” types are not superconducting but bad metallic. There exists an anomaly at $T_N$ temperature in their $p$-$T$ curves which is associated with spin-density-wave (SDW) transition. When these parent compounds are doped with electron or hole charge carriers or applied external pressure, the SDW transition temperature is suppressed gradually and the superconductivity appears [4]. However, the parent of LiFeAs is superconducting and $T_c$ is suppressed linearly with applying pressure [5]. In fact LiFeAs can be considered as an electron over-doped superconductor [6]. So it is benefit for studying the effect of 3-d transition metal doping effect on the superconductivity of LiFeAs. In this work, we report the Cu-doping effect on the property of LiFeAs.

2. Experimental

Single crystals of LiFe$_{1−x}$Cu$_x$As were synthesized by the self flux method. Li$_2$As were pre-sintered by reacting high purity Li lump and arsenic powder in an evacuated quartz tube at 650 °C for 10 h. Fe$_{1−x}$Cu$_x$As was prepared by sintering the element powders at 750 °C. Li$_2$As, Fe$_{1−x}$Cu$_x$As and As powder were mixed together according to the nominal composition Li(Fe$_{1−x}$Cu$_x$)$_{0.3}$As. The powder mixture was then pressed into a pallet in an alumina tube and sealed in Nb tube at 1 atm Argon gas before sealed in an evacuated quartz tube. The sealed quartz tube was heated up to a high temperature to 1100 °C for 50 h and then cooled to 750 °C by a rate of 4 °C/h in order to grow single crystal.

These single crystals were characterized by X-ray diffraction. The dc magnetic susceptibility was measured with a magnetic field of 30 Oe using a superconducting quantum interference device (SQUID).

3. Results and discussion

Fig. 1 shows the Cu-doping level $x$ dependence of lattice parameter c. The inset presents the typical X-ray diffraction pattern of single crystal LiFe$_{1−x}$Cu$_x$As. The reflections are indexed with 00l, indicating the c-axis orientation. The lattice parameter c calculated from the XRD patterns decreases with increasing Cu-doping level, which demonstrates that Cu is doped into the crystal lattice.

Fig. 2 presents the magnetic susceptibility of LiFe$_{1−x}$Cu$_x$As ($x = 0$, 0.01, 0.02, 0.03, 0.04, 0.06 and 0.07). For the undoped LiFeAs sample, it shows a sharp superconducting transition at the temperature of ~16.2 K and a completely diamagnetic shielding, which suggests bulk superconductivity and a high quality of our sample. When Fe is partially substituted by Cu, $T_c$ decreases gradually and is suppressed to 2.5 K at the Cu-doping level of 7%.

To investigate the suppression of $T_c$ by Cu-doping, we plot the $T_c$ data as a function of doping level, as is shown in Fig. 3. From Fig. 3 we can see that $T_c$ was almost linearly suppressed when Cu is doped into LiFeAs on the Fe cite. The red line is a linearly fitting line for the magnetic data and the slope is about −190, which...
demonstrates $T_c$ decreases about 1.9 K per 1% Fe in LiFeAs being substituted by Cu.

4. Summary

In conclusion, we successfully synthesized the LiFe$_{1-x}$Cu$_x$As single crystal with the Cu-doping level $x$ from 0 to 0.07. The superconducting transition temperature $T_c$ decreases linearly with a rate of 1.9 K per 1% Cu-doped.

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References