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LETTER

Magnetization Studies of $K_{0.8}Fe_{1.7}Se_2$ Single Crystals

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Abstract Magnetization measurements of the magneto-superconducting $K_{0.8}Fe_{1.7}Se_2$ single crystals ($T_C = 29.6$ K) at various applied fields and temperatures have been performed. In the superconducting range, two unusual phenomena are observed. (i) The presence of paramagnetic Meissner effect up to 20 Oe, which is revealed by the positive field-cooled magnetization curves. (ii) A double peak in the hysteresis loop at low temperatures. The isothermal magnetization measured at 35 K clearly indicates the presence of a tiny amount of a ferromagnetic substance (probably pure Fe). The two peculiar phenomena observed are attributed to this impurity.

Keywords Superconductivity · Fe-Se based materials · Paramagnetic Meissner effect

1 Introduction

Over the four last decades the ternary intermetallic compounds, which crystallize in the body-centered tetragonal $ThCr_2Si_2$ (space group *I4/mmm*), have been of great interest due to the variety of physical phenomena observed in these compounds. As early as 1975, magnetic studies suggest that in RFe_2X_2 (R = rare-earth, X = Si or Ge), the Fe ions are diamagnetic [1]. Indeed, neutron powder diffraction measurements confirmed the absence of any magnetic moment on the Fe sites, and determined that in $NdFe_2Si_2$ the Nd sublattice is anti-ferromagnetically (AFM) ordered at $T_N \sim 16$ K, with the moments aligned along the c-axis [2].

Since the discovery of superconductivity (SC) in the FeAs-based families, intensive research efforts have focused on finding new closed related Fe-based superconductors systems. Indeed, very recently a new Fe-based $K_xFe_2Se_2$ SC material with $T_C \sim 30$ K has been discovered [3], which was extended to other alkali ions families such as M = Rb and Cs. In all $M_xFe_{2-x}Se_2$ systems SC at $T_C \sim 30$ K and AFM at T_N around 500–550 K have been discovered [4–6]. In contrast to other magneto-superconducting systems such as $Ru(R,Ce)Sr_2Cu_2O_{10}$ and $RuRSr_2Cu_2O_x$ [7, 8] in which the SC and the magnetic states reside in different layers, in $M_xFe_{2-x}Se_2$ a *real* coexistence of the two states occurs, since both states are confined to the same Fe-Se crystallographic layer. This peculiar property marks the Fe-Se system is a very unique one and opens a new avenue for study the interplay between magnetism and superconductivity.

The tetragonal high-temperature crystal structure of the Fe-Se materials is the same as that of the RFe_2X_2 system mentioned above. Below a certain temperature (at or very close to T_N) a super-lattice of Fe vacancy ordering was observed (space group *I4/m*), to have a $\sqrt{5} \times \sqrt{5} \times 1$ unit cell with fully occupied Fe1 (16i) site and nearly vacant Fe2 (4d) [9].

Recent neutron diffraction measurements on $K_{0.8}Fe_{1.6}Se_2$ have confirmed the SC-AFM coexistence and revealed that the Fe moments align in a relatively complex AFM structure along the c-axis with a remarkably large moment (3.31 μ_B/Fe) [9]. Dc magnetic studies on various $M_xFe_{2-x}Se_2$ SC single crystals were able to determine precisely their the T_C values and typical isothermal field de-

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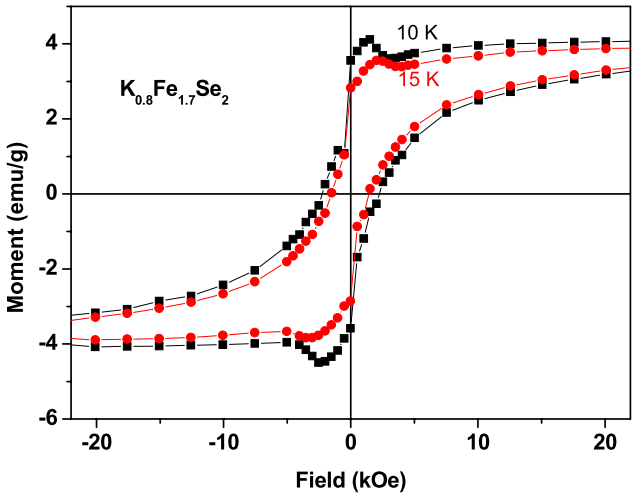

Fig. 5 Magnetic hysteresis loops of $K_{0.8}Fe_{1.7}Se_2$ measured at 10 and 15 K

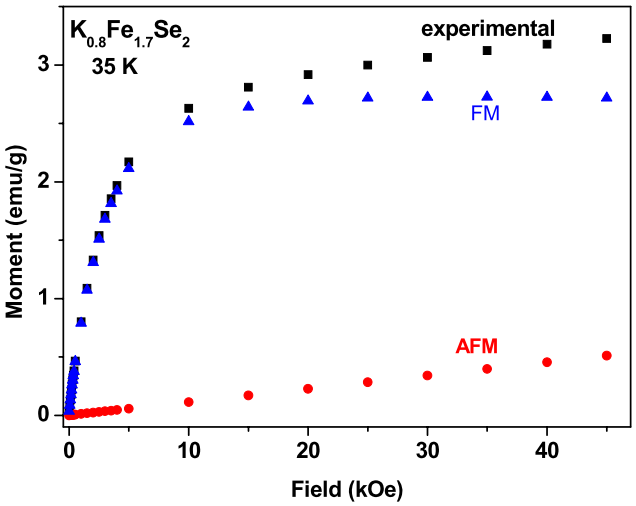

Fig. 6 Isothermal magnetization curve of $K_{0.8}Fe_{1.7}Se_2$ measured at 35 K

$H = 10$ the estimated J_C is $\sim 10^3$ A/cm^2, a value which agrees well with Ref. [10]. Of course, this estimate value is very crude, since no evaluation of the two extra contributions to the hysteresis loop was made. This low value shows that the current sample cannot support large critical currents even at low temperatures. The linear dependence of J_C is exhibited in Fig. 4 (inset).

In summary, magnetization studies of $K_{0.8}Fe_{1.7}Se_2$ single crystal exhibit two unusual phenomena. (i) the presence of paramagnetic Meissner effect (PME) which is revealed by the positive field-cooled magnetization curves. The M/H values are inversely proportional to the applied fields and PME disappears around 20 Oe. (ii) a double peak in the hysteresis loop at low temperatures. Both phenomena, not observed in other similar compounds, are probably related to the presence of a small FM extra phase (probably Fe), which obscures the SC features of the material.

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