Superconductivity at 36 K in Gadolinium-arsenide Oxides GdO$_{1-x}$F$_x$FeAs

Peng Cheng, Lei Fang, Huan Yang, Xiyu Zhu, Gang Mu, Huiqian Luo, Zhaosheng Wang and Hai-Hu Wu

National Laboratory for Superconductivity, Institute of Physics and Beijing National Laboratory for Condensed Matter Physics, Chinese Academy of Sciences, P.O. Box 603, Beijing 100190, People’s Republic of China

In this paper we report the fabrication and superconducting properties of GdO$_{1-x}$F$_x$FeAs. It is found that when $x$ is equal to 0.17, GdO$_{0.83}$F$_{0.17}$FeAs is a superconductor with the onset transition temperature $T_{c0}$ ≈ 36.6K. Resistivity anomaly near 130K was observed for all samples up to $x = 0.17$, such a phenomenon is similar to that of LaO$_{1-x}$F$_x$FeAs. Hall coefficient indicates that GdO$_{0.83}$F$_{0.17}$FeAs is conducted by electron-like charge carriers.

PACS numbers: 74.20.Mn, 74.20.Rp, 74.25.Bt, 74.70.Dd

I. INTRODUCTION

Since the discovery of superconductivity in iron-based layered quaternary compound LaOFeP$_4$, extensive efforts have been devoted to find new superconductors among this system. It is found that with the replacement of $P$ by As and partial substitution of O with F, LaO$_{1-x}$F$_x$FeAs changes into superconducting state below $T_c ≈ 26$. Subsequently superconducting state at 25 K was also observed in La$_{1-x}$Sr$_x$OFeAs in which no F was added into the sample, therefore it was a hole-doped superconductor. More recently, superconductors LnO$_{1-x}$F$_x$FeAs with light rare-earth substitution (Ln=Ce, Pr, Sm) were realized and superconducting transition temperature($T_c$) was raised to 52K. As to the heavy rare-earth element, however, single phase could not be easily formed and no superconducting state was observed below 2K. As to the element Gadolinium which locates near the heavy rare-earth element, experimentally a drop of resistivity was observed below 10 K but with a residual resistivity down to 2 K. So it is worth exploring further that whether GdO$_{1-x}$F$_x$FeAs is also a superconductor with much higher $T_c$. In this study, we report the superconducting properties of GdO$_{0.83}$F$_{0.17}$FeAs, the onset transition temperature $T_{c0}$ is about 36.6 K.

II. EXPERIMENT

Polycrystalline samples GdO$_{1-x}$F$_x$FeAs ($x=0.12$, 0.15, 0.17) were synthesized by conventional solid state sintering method. The raw materials are all with high purity(Gd$_2$O$_3$ 99.99%, GdF$_3$ 99.99%, Fe 99.95%, As 99.99%, Gd 99.99%). The detailed synthesis method is the same as that in the papers we reported previously. The as-sintered pellet is concrete ceramic-like with dark-brown surface. X-Ray diffraction measurement was performed at room temperature using an MXPI8A-HF-type diffractometer with Cu-K$_\alpha$ radiation from 10° to 80° with a step of 0.01°. The magnetization measurements were carried out on a Quantum Design superconducting quantum interference device (SQUID) magnetometer. The electrical resistivity and Hall coefficient were measured by a Physical Property Measurement System (PPMS, Quantum Design) with a standard six-probe method.

Fig.1 shows the X-ray diffraction (XRD) pattern of the sample GdO$_{0.83}$F$_{0.17}$FeAs. The pattern can be indexed in tetragonal space group with $a = b = 4.001$ Å and $c = 8.650$ Å. Obviously the phase is dominated by GdO$_{1-x}$F$_x$FeAs. The asterisks mark the peaks from the impurity phase.
shown in Fig. 4. The transverse resistivities of GdO$_{1-x}$FeAs were doped into GdO$_x$ near 130 K is also observed in resistivity curve, it suggests the transition temperature of about 36.6 K for x = 0.15 and x = 0.17 samples exhibit superconducting transitions and zero-resistance at a lower temperature. From the inset of Fig. 3 we can see the onset drop of resistivity about the straight line here. 

Hall effect measurement for sample GdO$_{0.83}$F$_{0.17}$FeAs was shown in Fig. 4. The transverse resistivities $\rho_{xy}$ above T$_c$ are all negative, indicating that the normal state conduction of GdO$_{0.83}$F$_{0.17}$FeAs is dominated by the electron-like charge carriers. The Hall coefficient $R_H = \rho_{xy}/H$ changes slightly at high temperatures but drops below 100 K. The value of $R_H$ is about -1x10$^{-8}$m$^2$/C at 100 K, compared with that of LaO$_{x}$F$_{0.17}$FeAs, the value of Hall coefficient is similar. An estimation based on the single band model gives a charge carrier density of 1x10$^{21}$/cm$^3$.

III. CONCLUDING REMARKS

In this study we report the fabrication and the superconducting properties of GdO$_{1-x}$FeAs, as x is equal to 0.17, GdO$_{0.83}$F$_{0.17}$FeAs is a superconductor with the onset transition temperature of about 36.6 K. Resistivity anomaly near 130 K was observed for all samples, which is similar to that of LaO$_{1-x}$FeAs. Hall coefficient suggests that GdO$_{0.83}$F$_{0.17}$FeAs is conducted by electron-like charge carriers.

FIG. 3: (color online) The electrical resistivity vs temperature for GdO$_{1-x}$FeAs (x = 0.12, 0.15, 0.17). The inset shows the enlarged view of superconducting transition area for the sample x = 0.17. The onset transition temperature is defined at the point where the resistivity starts to deviate from the normal state background as marked by the straight line here.

Acknowledgments

This work is supported by the National Science Foundation of China, the Ministry of Science and Technology of China (973 project No: 2006CB601000, 2006CB921802), and Chinese Academy of Sciences (Project ITSNEM).

---

1 Y. Kamihara, H. Hiramatsu, M. Hirano, R. Kawamura, H. Yanagi, T. Kamiya, and H. Hosono, J. Am. Chem. Soc. 128, 10012 (2006).
2 T. Watanabe, H. Yanagi, T. Kamiya, Y. Kamihara, H. Hiramatsu, M. Hirano, and H. Hosono, Inorg. Chem. 46, 7719 (2007).
3 Y. Kamihara, T. Watanabe, M. Hirano, and H. Hosono, J. Am. Chem. Soc. 130, 3296 (2008).
4 Hai-Hu Wen, Gang Mu, Lei Fang, Huan Yang, and Xiyu Zhu, Europhys. Lett. 82, 17009 (2008).
5 X. H. Chen, T. Wu, G. Wu, R. H. Liu, H. Chen and D. F. Fang, Condmat/0803.3603v1.
6 G.F. Chen, Z. Li, D. Wu, G. Li, W.Z. Hu, J. Dong, P. Zheng, J.L. Luo, N.L. Wang, Condmat/0803.3790v1.
7 Zhi-An Ren, Jie Yang, We Lu, Wei Yi, Xiao-Li Shen, Zheng-Cai Li, Guang-Can Che, Xiao-Li Dong, Li-Ling Sun, Fang Zhou, Zhong-Xian Zhao, Condmat/0803.4234v1.
8 Zhi-An Ren, Jie Yang, Wei Lu, Wei Yi, Guang-Can Che, Xiao-Li Dong, Li-Ling Sun, Zhong-Xian Zhao, Condmat/0803.4283v1.
9 G. F. Chen, Z. Li, D. Wu, J. Dong, G. Li, W. Z. Hu, P. Zheng, J. L. Luo, and N. L. Wang, Condmat/0803.4384v1.
FIG. 4: (color online) (a) Transverse resistivity with relation of magnetic field at different temperatures for GdO$_{0.83}$F$_{0.17}$FeAs; (b) Temperature dependence of Hall coefficient for GdO$_{0.83}$F$_{0.17}$FeAs, the negative value indicates that the charge carrier is electron type.

10 Xiyu Zhu, Huan Yang, Lei Fang, Gang Mu and Hai-Hu Wen, Condmat/0803.1288v1.
11 Lei Fang, Huan Yang, Peng Cheng, Xiyu Zhu, Gang Mu and Hai-Hu Wen, Condmat/0803.3978v1.