Upper Critical Fields of the Natural Heterostructure of Fe Pnictides and V Oxides

Ok, J.M.; Ayala-Valenzuela, O.; Kim, J.H.; Kim, J.S. (POSTECH, Physics); McDonald, R.D. (NHMFL)

Introduction

Among various Fe-pnictide superconductors, Sr_2VO_3FeAs holds a unique position. It consists of $[SrFeAs]^{+1}$ layers and $[SrVO_3]^{-1}$ layers alternately stacked, forming a naturally-grown heterostructure. While the FeAs layers host superconductivity, $SrVO_3$ layers having partially-filled $3d^2$ states of V^+ ions host the Mott-insulating phase. One of the essential questions on Sr_2VO_3FeAs is whether the FeAs layers and the $SrVO_3$ layers are coupled or not, and if so, how the mutual interaction affects the ground state of each other. The detailed investigation of the upper critical field provides an experimental clue for significant interlayer coupling between localized vanadium spins and itinerant iron electrons in Sr_2VO_3FeAs.

Experimental

The high-quality single crystals of Sr_2VO_3FeAs are used for the H_{c2} measurements. We employed the tunnel diode oscillator technique under pulsed high magnetic fields up to 65 T,

Results and Discussion

Figure 1 (a) and (b) display the tunnel diode oscillator frequency $\Delta F(H)$ in pulsed magnetic fields up to 65 T below 30 K. The estimated $H_{c2}(T)$ as a function of the normalized temperature ($t = T/T_c$) shows distinct behaviors depending on the field orientation. While $H_{c2}^{ab}(T)$ exhibits saturation due to the Pauli limiting effect, $H_{c2}^{c}(T)$ shows a strong upward curvature that can be attributed to the multi-band effect. These behaviors are similar to the $H_{c2}(T)$ of other Fe-based superconductors, but the anisotropy of $H_{c2}(T)$ is exceptionally high. As shown in Fig. 1(c), the $H_{c2}(T)$ anisotropy factor, parameterized with $\Gamma_H = H_{c2}^{ab}/H_{c2}^{c}$, reaches ~ 20 near T_c, which is the highest value found in Fe-based superconductors. This is intimately related to the pronounced upward curvature of $H_{c2}^{c}(T)$, which can be explained in terms of multiband nature with a strong disparity in different bands. The solid line in Fig. 2(c) using the two-band model agrees well with experimental data. Here we used $\lambda_{11} = \lambda_{22} = 0.5$, $\lambda_{12} = \lambda_{21} = 0.55$ and $\eta_{||c} = D_1^{ab}/D_2^{ab} = 0.035$, where D_1^{ab} and D_2^{ab} are in-plane diffusivity, λ_{11} and λ_{22} (λ_{12} and λ_{22}) are intraband (interband) coupling constants. The estimated anisotropy in the diffusivities $\eta_{||c}$ ~ 0.035 is an order of magnitude smaller than the ratio of the Fermi velocities, v_F^h/v_F^{el} ~ 0.25–0.4 for electron and hole Fermi surfaces (FSs). Hence, in order to understand the exceptionally small $\eta_{||c}$, there should be strong scattering anisotropy between two bands. This suggests that the magnetic scattering with the neighboring $SrVO_3$ layers is stronger in the hole FS than the electron FS.

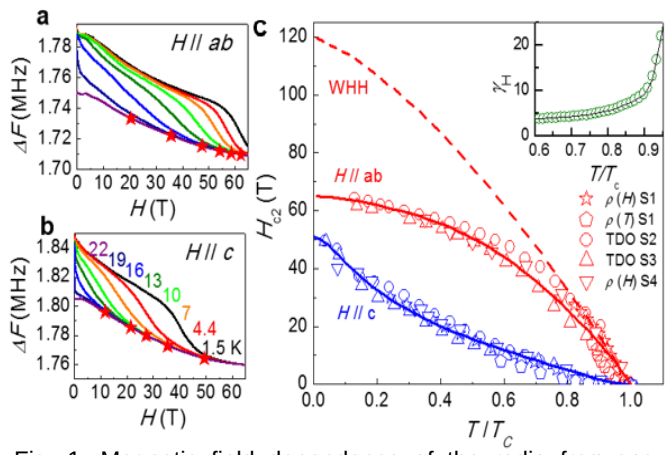

Fig. 1. Magnetic field dependence of the radio frequency magnetic penetration depth measurements of Sr_2VO_3FeAs at various temperatures for (a) $H//ab$ and (b) $H//c$. The determined $H_{c2}(T)$ is indicated by red points in (a)-(b). (c) Upper critical field $H_{c2}(T)$ for $H//ab$ (red) and $H//c$ (blue) as a function of the normalized temperature T/T_c. The inset shows the asotropy factor Γ_H.

Conclusions

We investigated $H_{c2}(T)$ for Sr_2VO_3FeAs under pulsed magnetic fields. The pronounced upward curvature of $H_{c2}^{c}(T)$ suggests that additional magnetic scattering with V spins strongly suppresses the in-plane diffusivity, enhancing the anisotropy of the upper critical fields. These findings provide experimental evidence for clear experimental evidence for interlayer coupling between localized V moments and itinerant electrons.

Acknowledgements

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References

[1] Jong Mok Ok, *et al.*, unpublished.