Transition from Slow Abrikosov to Fast Moving Josephson Vortices in Iron-Pnictide Superconductors

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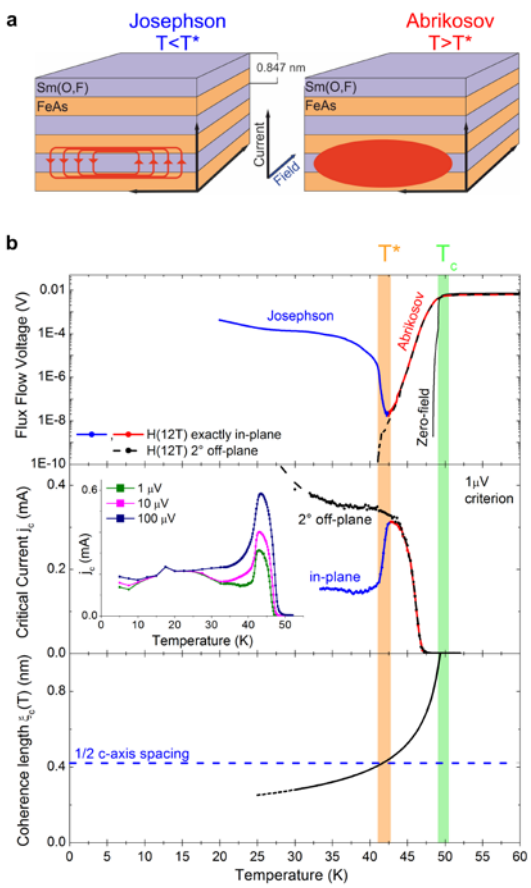
Introduction

Magnetic flux may penetrate anisotropic superconducting systems, such as artificial Josephson junctions or the more anisotropic cuprate superconductors, in the form of a Josephson vortex instead of Abrikosov vortices, which occur in more isotropic systems. Typically these two phenomena are clearly separated by the materials anisotropy; either one or the other is observed. We have investigated the vortex matter of the pnictide superconductor SmFeAs(O,F) with T_c~48-50K and found the superconducting parameters to conspire in such a way that both kinds of vortices exist in the same material in different temperature regimes, Abrikosov at high and Josephson at low temperatures [1]. Superconducting applications based on these compounds will always operate deep in the Josephson regime, thus the particular pinning of pancake segments in the iron-pnictides is found to be technologically most relevant.



***a)** Sketch of a Josephson-vortex below T* and an anisotropic Abrikosov-vortex above T*. **b)** Flux-flow (FF) voltage and critical currents along the c-axis at 12T, well aligned and 2° misaligned with the FeAs layers. These two cases are almost identical in the Abrikosov regime, but strongly differ in the Josephson regime: A sharp jump in FF voltage and a drop in critical currents signals the transition into the Josephson state.*

Experimental

We have investigated the critical currents and flux flow voltages perpendicular to the FeAs layers in fields up to 35T in a resistive magnet at the NHMFL in Tallahassee. Two main experimental challenges had to be overcome to observe Josephson vortex motion in the system: (1) Reliable transport measurements perpendicular to micron-sized crystal platelets had to be performed using the FIB technique (as reported in ref [2]) and (2) precise and stable field alignment (<0.05°) with the FeAs layers is essential to observe the effect. This has been well achieved using the Cell 12 rotator.

Results and Discussion

We discovered a distinct change in the nature of the vortices from Abrikosov-like to Josephson-like upon cooling below a temperature T*~41-42K well below T_c~48-50K, despite its moderate electronic anisotropy γ~4-6. This transition is hallmarked by a sharp drop of the critical current and accordingly a jump of the flux flow voltage in a magnetic field precisely aligned along the FeAs layers, indicative of highly mobile vortices. T* coincides well with the temperature where the coherence length ξ_c perpendicular to the layers matches half of the FeAs-layer spacing. For fields slightly out-of-plane (>0.1°-0.15°) the vortices are completely immobilized as well-pinned Abrikosov segments are introduced if the vortex crosses the FeAs layers. We interpret these findings as a transition from well-pinned, slow moving Abrikosov vortices at high temperatures to weakly pinned, fast flowing Josephson vortices at low temperatures.

Acknowledgements

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References

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[2] P.J.W. Moll, *et al.*, Nature Materials **9**, 628-633 (2010)