X-RAYS AND MAGNETS TEAM UP TO PROBE SUPERCONDUCTORS

Aside from their fundamental importance and interest as physical phenomena, magnetic fields can also be quite handy for practical experimentation. In materials science, the application of just the right sort of magnetic field can create effects and reveal changes in a material that provide key insights into its properties and structure, all without any direct physical contact. Researchers from Argonne, Stanford University, the SLAC National Accelerator Laboratory, and Tohoku University (Japan) combined a pulsed magnetic field with x-ray diffraction (XRD) studies at XSD beamline 6-ID-B at the APS to investigate anisotropic magnetic susceptibility behavior in an iron arsenide superconductor. This work opens the door to greater characterization of iron arsenide superconductors.

Fig. 1. High-resolution x-ray diffraction shows the (2, 2, 0) Bragg peak splitting at the structural phase transition ($T_s \sim 70$ K). Figure this page and next from J.P.C. Ruff et al., Phys. Rev. Lett. 109, 027004 (2012). © 2012 American Physical Society
Previous experiments have demonstrated a strong electronic anisotropy within the \( a-b \) plane in these materials. While it has been speculated that this anisotropy may be the impetus for the tetragonal-to-orthorhombic phase transition, transformational twinning effects mask detection of the anisotropy by resistivity and susceptibility measurements, unless they are performed under significant applied uniaxial stress.

The current work illuminates a new way to probe the iron arsenide phase transition without any kind of physical contact, thus avoiding secondary symmetry-breaking effects. Through the application of pulsed magnetic fields under XRD, magnetic detwinning measurements can provide unique information about the evolution of susceptibility anisotropy.

Studying a single crystal of under-doped \( \text{Ba(Fe}_{1-x}\text{Co}_x\text{)}_2\text{As}_2 \) at the 6-ID-B beamline, the experimenters first observed the tetragonal-to-orthorhombic phase transition at 70 K (Fig. 1). The evolution of Bragg scattering from structural twins during the application of pulsed magnetic fields up to 27.5 T show complete detwinning in the orthorhombic phase, which the authors ascribe to anisotropy in magnetic susceptibility between the \( a \) and \( b \) axes (Fig. 2). The detwinning effects set in immediately as the temperature drops below the critical temperature of the structural phase transition, as a precursor to magnetic order. The detwinning effects also accompany the anisotropy down to the superconducting transition temperature and then, surprisingly, disappear, signifying either kinetic inhibition or a return of susceptibility isotropy.

After application of magnetic field pulses to 27.5 T at low temperatures, a residually detwinned state remains that is quite similar to the detwinning induced under uniaxial strain and seems quite stable, lasting for at least several hours. Improved crystal quality is also seen in this remnant phase. This opens the possibility that the use of magnetic fields might provide a new "hands-off" treatment for the creation of superior detwinned iron arsenides without the use of uniaxial pressure treatment.

The pulsed-magnet x-ray diffraction technique demonstrated here offers numerous experimental possibilities for the investigation and characterization of iron arsenide superconductors. Because it can be applied over a wide range of temperatures and magnetic field strengths, it provides a valuable window into the magnetic anisotropy of iron arsenides throughout their various phase transitions.

The next step will be to develop more-accurate models of how twin domains behave in magnetic fields, which will lead to more accurate measurements of magnetic susceptibility. Further development and refinement of pulsed-magnetic XRD techniques will make possible exciting new inroads in both experiment and theory.

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See also:


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