Record-high Critical Current Density in Iron-based Superconducting Wires with Strong Vortex Pinning

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Iron-based superconductors (IBS) have attracted extensive research interest due to their high upper critical field, low anisotropy, and cost-effective long wires fabricated by the powder-in-tube method[1]. Although 100-meters wires have been successfully fabricated and applied in tesla-class superconducting coils[2], the highest critical current density (J_c) of IBS wires has remained 1.5×10^5 A/cm^2 at 4.2 K and 10 T since 2018. This bottleneck arises from the long-standing challenge in introducing high-density, strong vortex pinning centers into the intrinsically rigid and brittle crystal lattice of IBS wires.

A research team led by Prof. Yanwei Ma at the Institute of Electrical Engineering, Chinese Academy of Sciences, has now demonstrated a novel extrusion-based asymmetric stress engineering strategy that directly nucleates ultra-dense dislocation arrays in $Ba_{1-x}K_xFe_2As_2$ (BaK122) superconducting wires. This approach synergistically combines triaxial compressive stresses with non-uniform shear stress fields to activate extensive lattice shearing and twisting along the (113) plane (Figure 1a). It generates a network of tilted dislocations with densities up to ~10^9 mm^{-2}, which is comparable to those in metals and alloys. These extended line defects serve as strong, quasi-*c*-axis correlated pinning centers for magnetic vortices, forming an unprecedentedly robust pinning landscape.

As a result, the IBS wires achieve an extraordinarily large irreversibility field of 120 T and an ultrahigh J_c of 4.5 × 10^5 A/cm^2 at 4.2 K and 10 T, which still maintains 2×10^5 A/cm^2 even at a high field of 33 T. This performance is five times greater than the best-reported IBS wires and outperforms Bi2223, MgB_2, and low-temperature superconducting wires at high fields (Figure 1b). Our strategy establishes a scalable route to engineer strong pinning landscapes in IBS wires, making them exceptional candidates for commercial fusion reactors, next-generation accelerators, and high-field MRI systems.

More details can be found in reference [3].

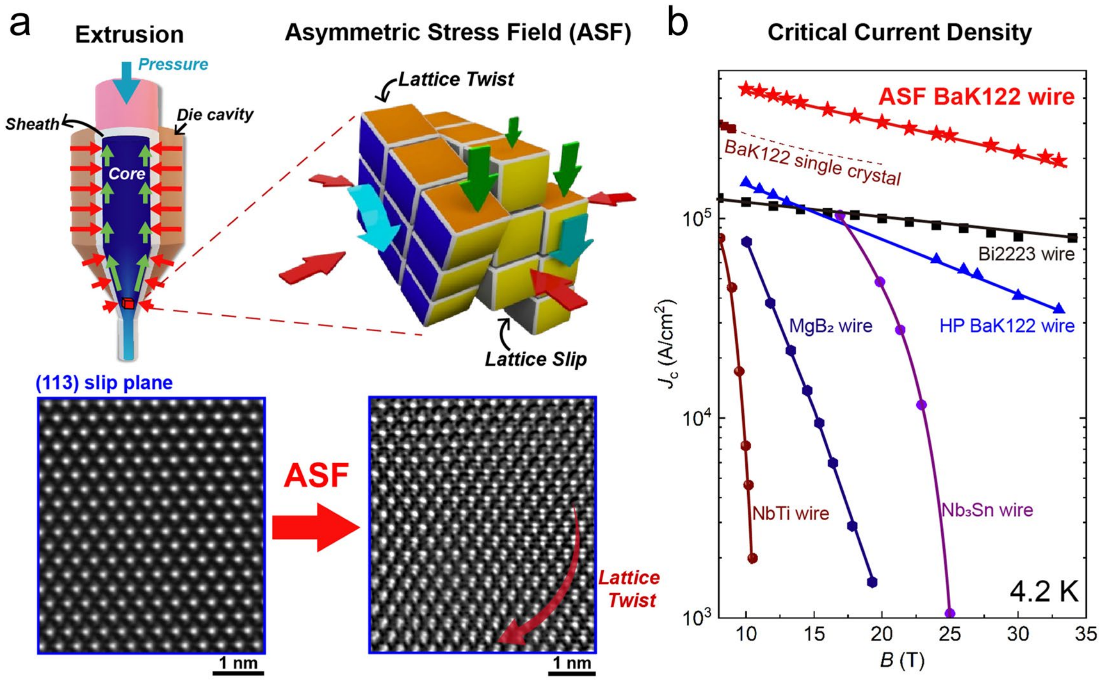

Figure 1. a, Schematic diagram of the ASF strategy. b, Magnetic field dependence of transport J_c for the ASF BaK122 wire at 4.2 K. The transport J_c of other conductors are also included for comparison.

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