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M2Or4B-06: Rapid engineering short-segmented columnar defects in seconds for 20 MA/cmˆ2 supercurrent density in iron-based superconductors

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Realizing ultra-high supercurrent density in iron-based superconductors (IBS) is a crucial step toward practical applications at high magnetic fields. However, engineering the most effective pinning structure to maximize the critical current density (Jc) remains an open challenge. In this work, Ba1-xKxFe2As2 single crystals were irradiated by low-energy Xe ions within seconds, achieving an exceptionally high Jc of 20 MA/cmˆ2 at 2 K. Remarkably, the Jc remains 8.7 MA/cmˆ2 at 5 K and 4 T, which is the highest value ever reached at high-fields for IBS. This enhancement is attributed to the replacement of intrinsic weak collective pinning by strong pinning of segmented discontinuous columnar defects. The advantageous pinning landscape minimizes superconductivity degradation and efficiently suppresses the motion of vortex kinks across a wide temperature range, yielding an extraordinary 178-fold enhancement of Jc at intermediate temperatures. These findings pave the way for further Jc enhancement by optimizing the defect geometry and density, providing valuable insights for the development of high-performance superconducting materials.

Author: DONG, Chiheng (Institute of Electrical Engineering, Chinese Academy of Sciences)

Co-authors: ZHANG, Xianping; MA, Yanwei

Presenter: DONG, Chiheng (Institute of Electrical Engineering, Chinese Academy of Sciences)

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