Ion Irradiation Effect on the In-Field Performance of MOD-REBCO Coated Conductors

C. B. Cai; N. ZHANG; Z. Y LIU; R. T. HUANG; Y. LI

Shanghai Key Laboratory for High Temperature Superconductors, Shanghai University

Shanghai Creative Superconductor Technologies Co., Ltd

Outline

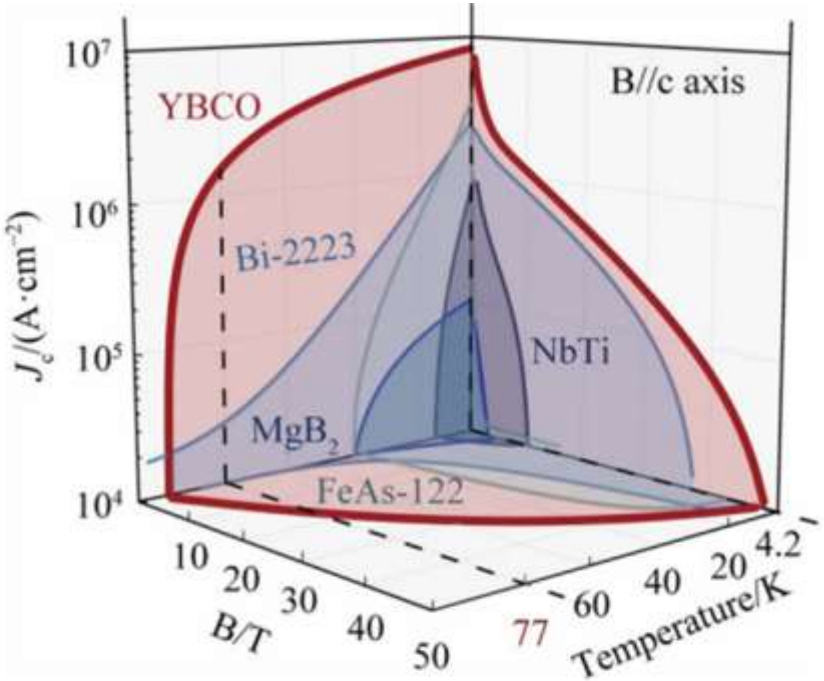
- Research Background
- Research Contents
- Conclusion

Outline

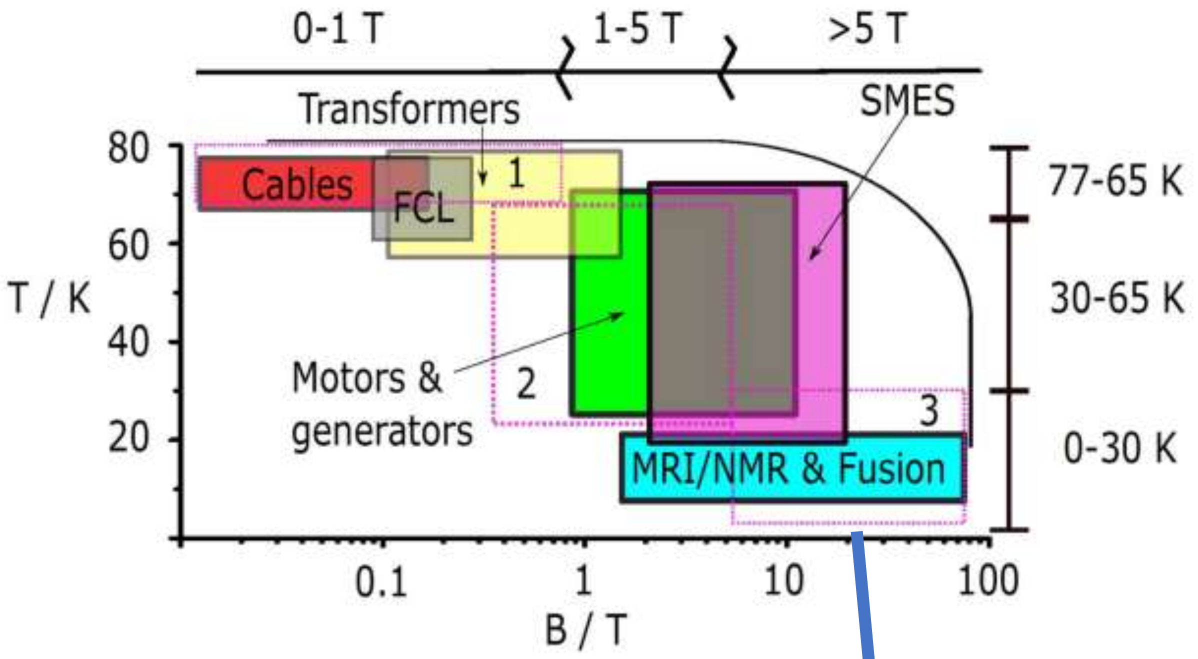
上海大学 Shanghai University　上创超导 Shanghai Creative SuperConductor

- **Research Background**
- Research Contents
- Conclusion

Introduction



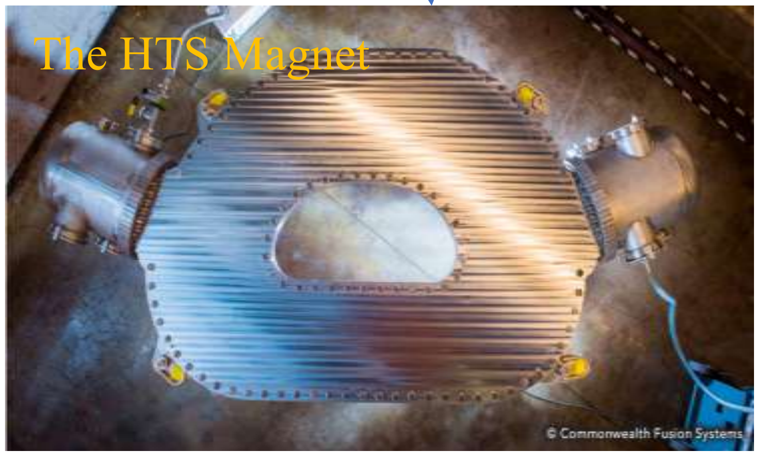
D.X. Wang., et al. ADV MANUF. 11.3 (2023): 523-540.



Characteristics of REBCO:

- High T_c
- High H_{irr}
- High J_c

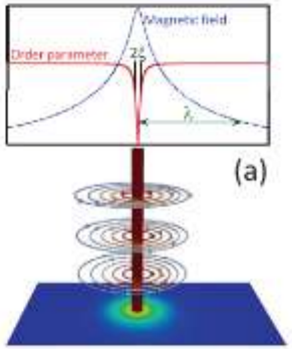
High research value & Broad application prospects



SPARC, MIT Plasma Science & Fusion Center

Defect Types VS. Methods for REBCO

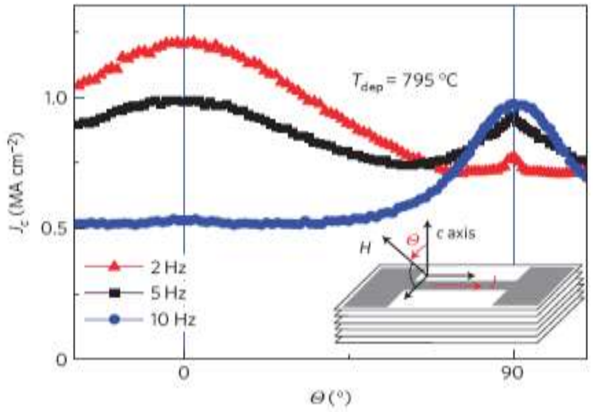
The size of magnetic core: 2ξ, ~ 1-2 nm



The effective flux pinning size：
$> 2\xi$

WK Kwok, et al. Rep. Prog. Phys. 79 (2016) 116501

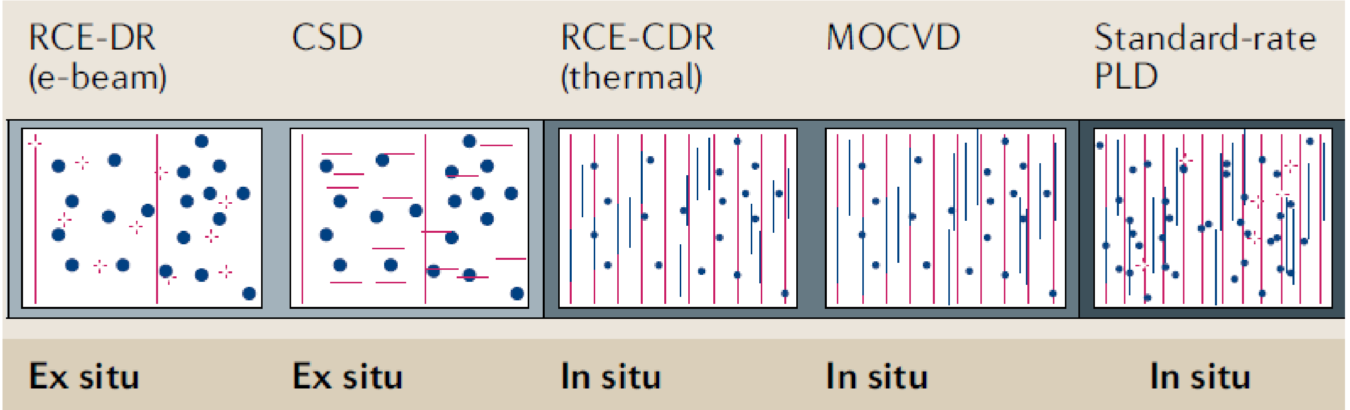
Magnetic transport anisotropy:

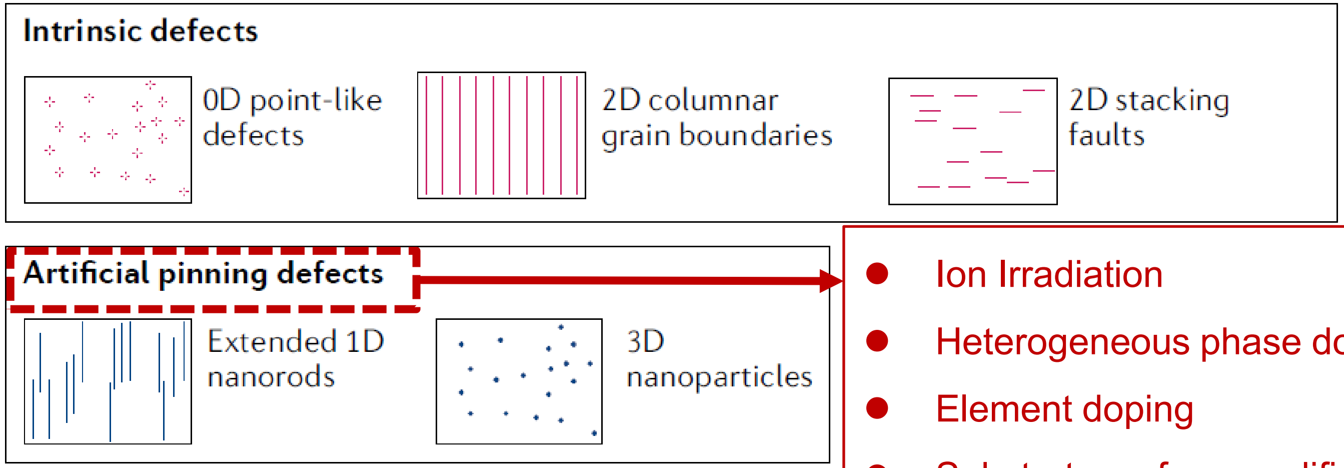


APC can reduce the magnetic transport anisotropy

B. Maiorov, et al. Nat. Mater. 8, 398 (2009)

Defect types as flux pinning centers in REBCO film:

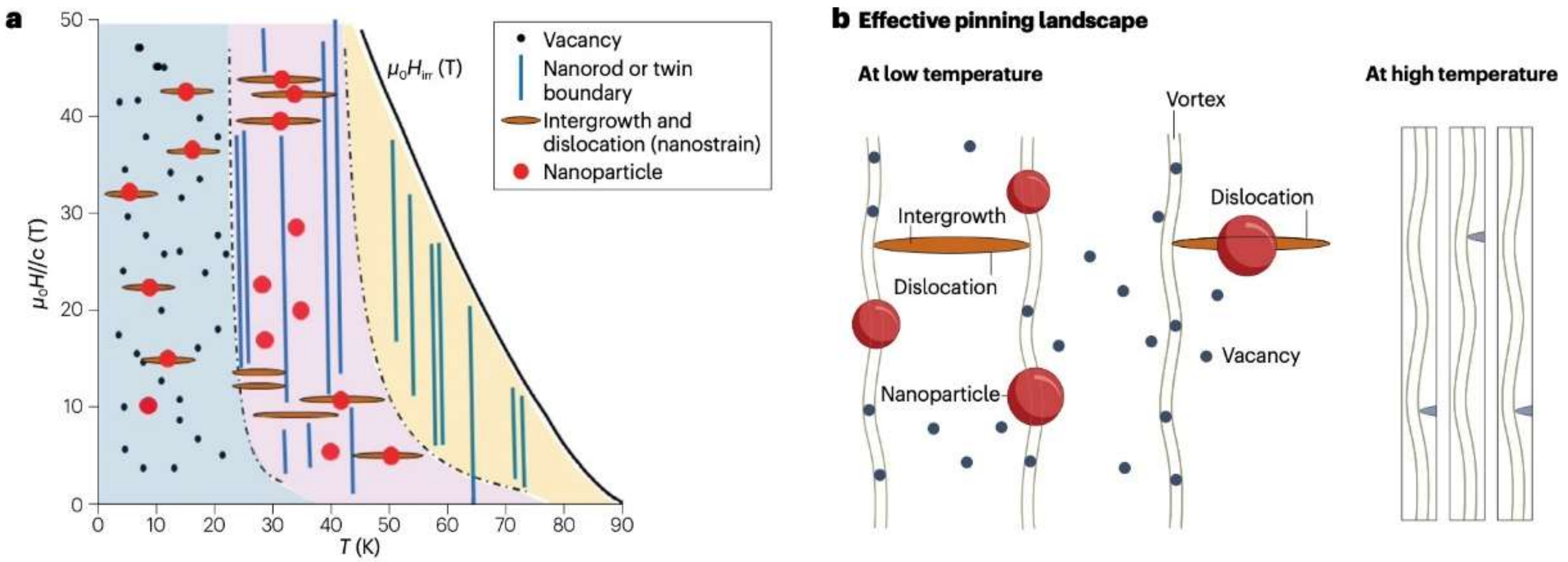




- Ion Irradiation
- Heterogeneous phase doping
- Element doping
- Substrate surface modification
- ……

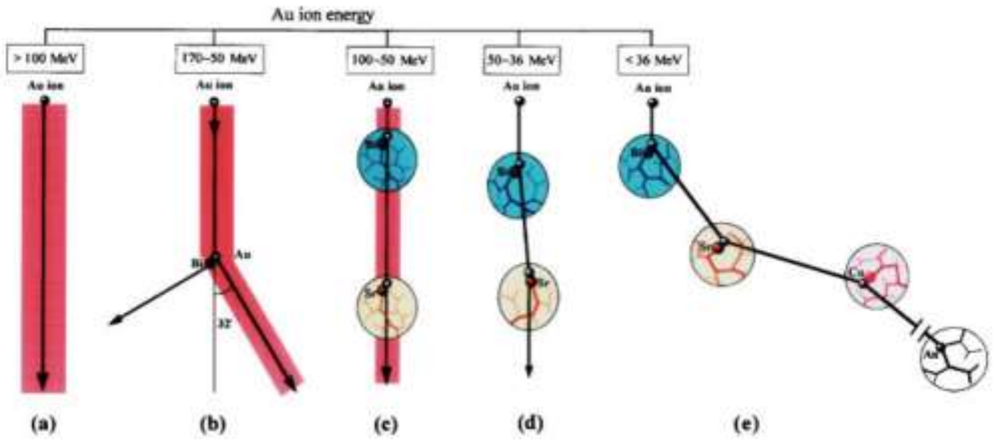
MacManus- Driscoll et, al. Nat. Rev. Mater., 2021

Mixed pinning landscape



a. *H-T* phase diagram, defects of different dimensions form different vortex states； b. effective pinning landscapes at high and low temperatures.

P Tuig, J Gutierrez, and X Obradors. "Nat. Rev. Phy. 6.2 (2024): 132-148.



D. X. Huang and Y. Sasaki, et al. Phys. Rev. B. vol.57 No.21 (1998)*

Defects of different dimensions can improve the in-field performance of REBCO in various temperature and magnetic field ranges.

Pro of ion irradiation:

- **Easy to control the size and distribution of defects**

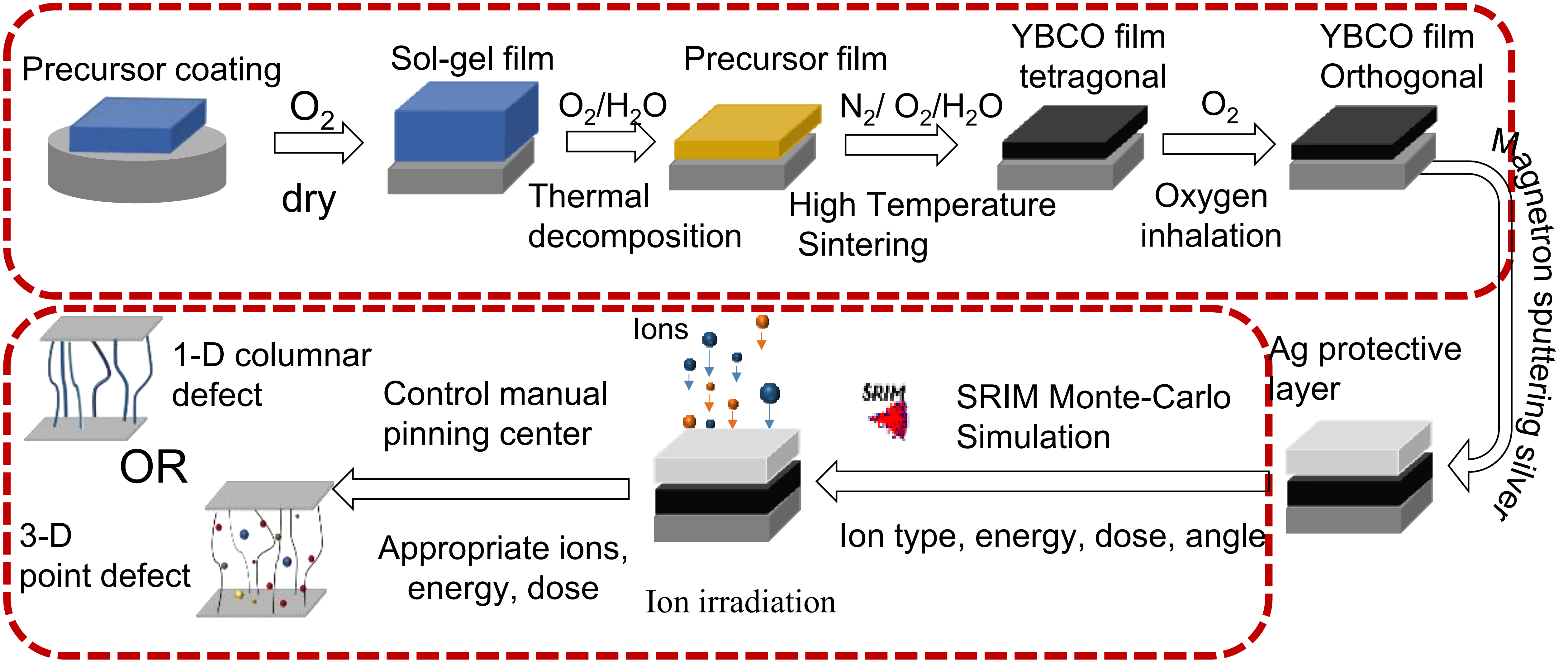
Outline

- Research Background
- **Research Contents**
- Conclusion

Experimental process

上海大学 Shanghai University 上创超导 Shanghai Creative SuperConductor

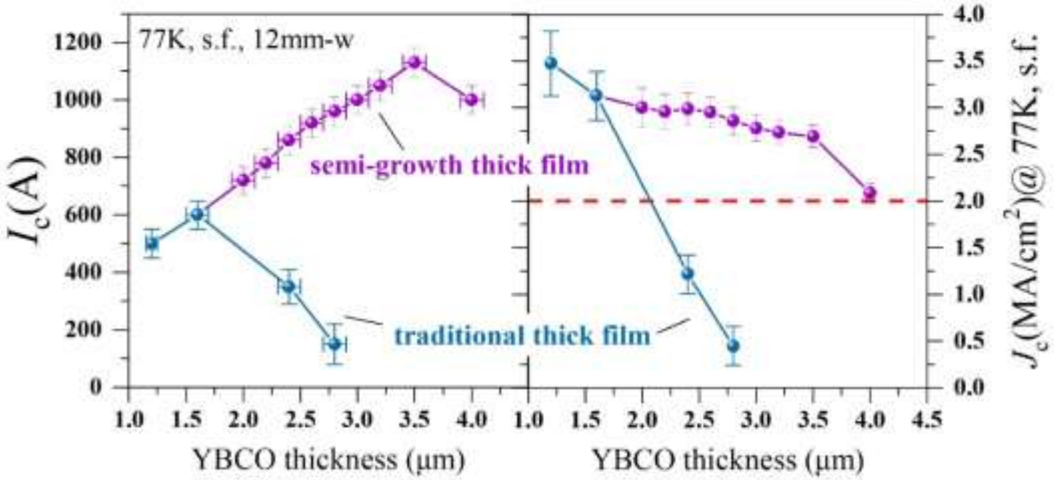
The whole process: (Preparation for REBCO + Ion irradiation)

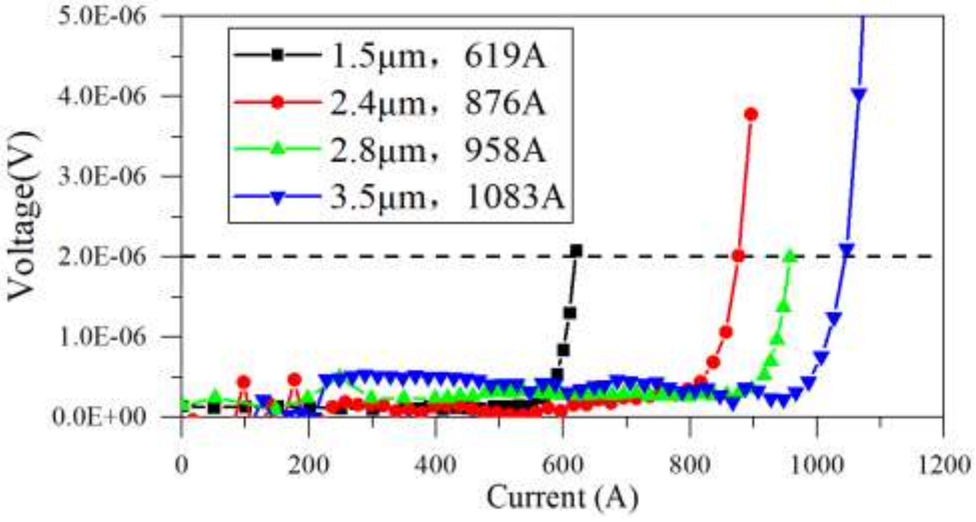


REBCO: thickening and nanocrystal

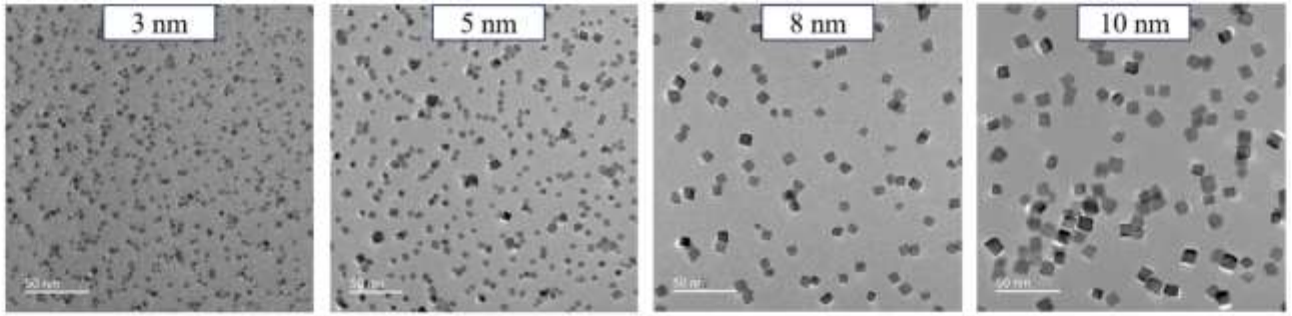
上海大学 Shanghai University　上创超导 Shanghai Creative SuperConductor

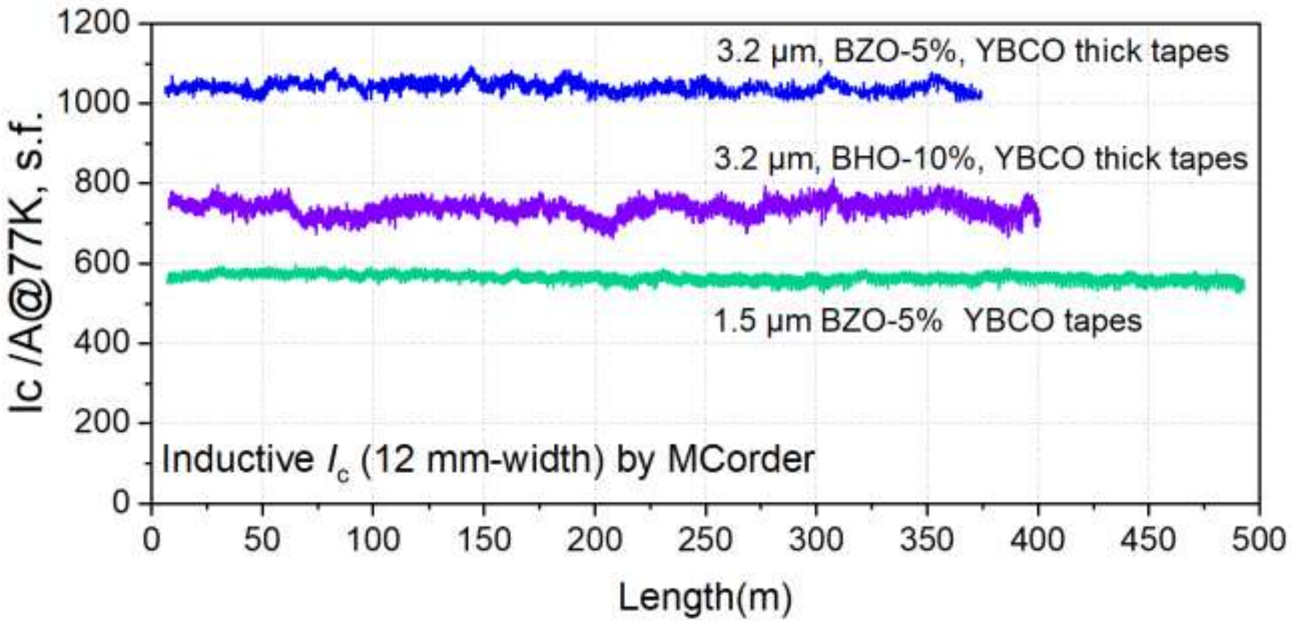
✓ Significantly improve the J_c of YBCO





Dispersion of BMO

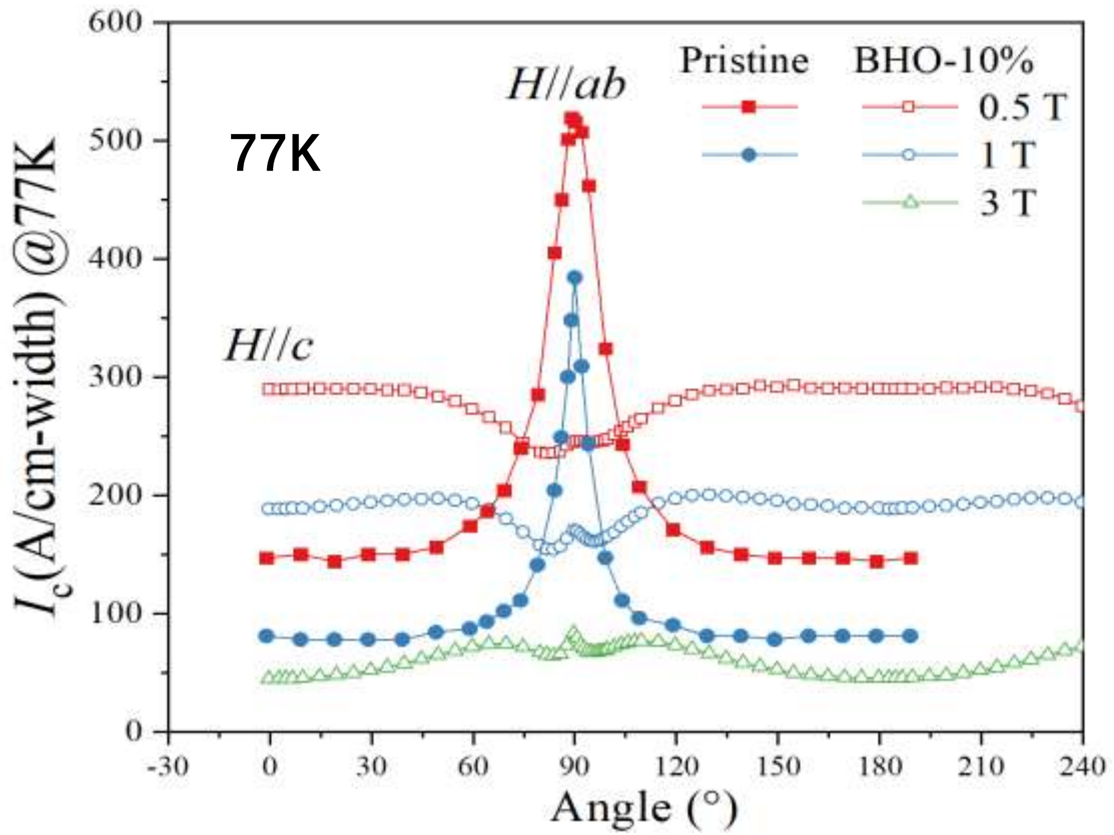


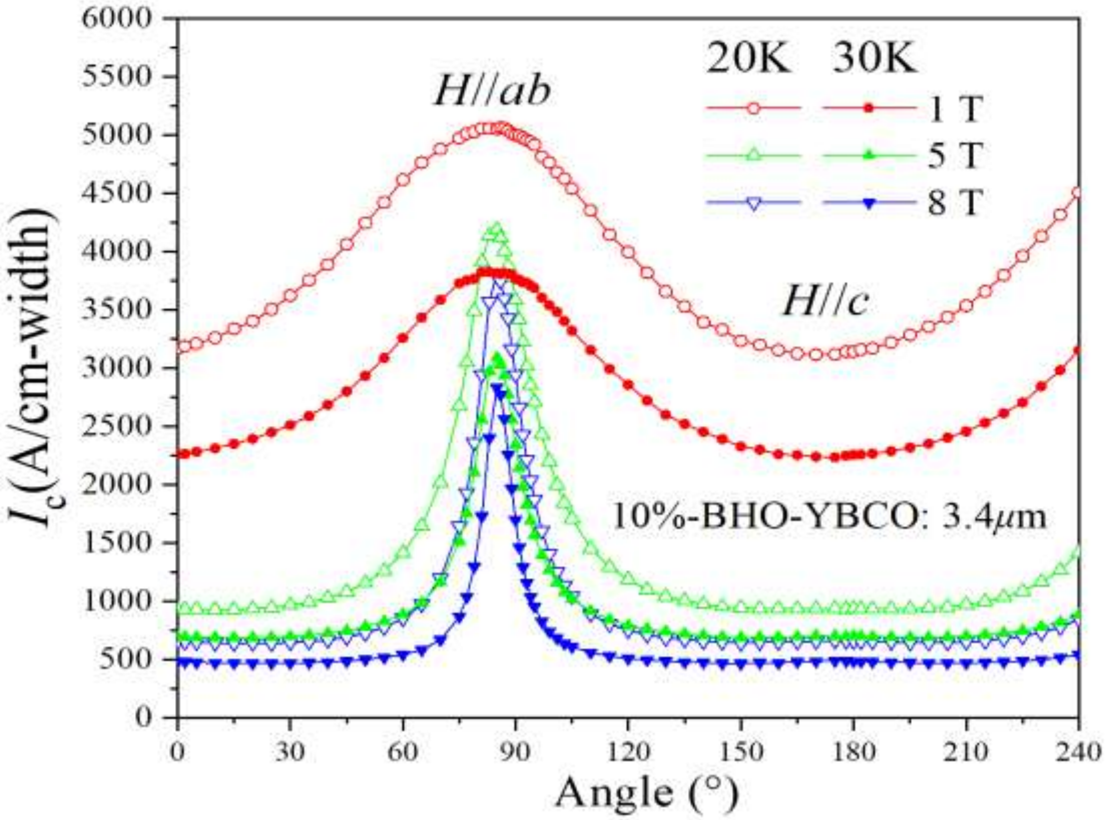


Anisotropic behavior with BMO additions

上海大学 Shanghai University 上创超导 Shanghai Creative SuperConductor

- Measured by Robinson Research Institute, NZ

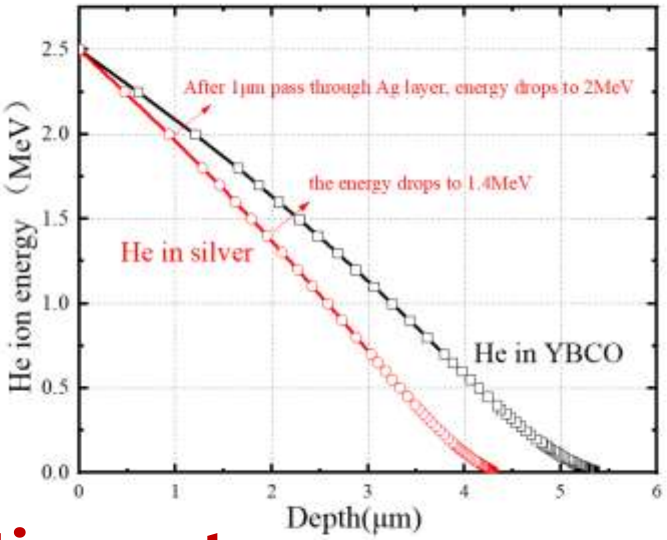


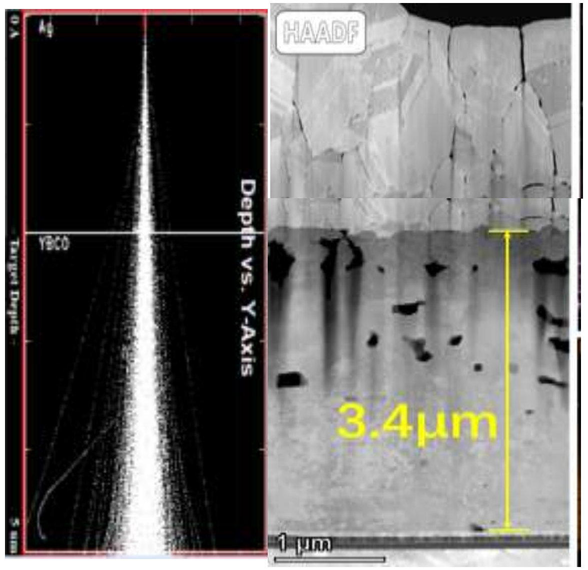


- ◆ Angular in-field I_c of BMO-added YBCO films at various high temperatures and low fields
- ◆ **Competitive flux pinning effect between the intrinsic layers and the correlated 0D/3D pinning, both affected by effective vortex potential U_{eff}(H, T)**
- ◆ depending on the applied temperatures and magnetic fields

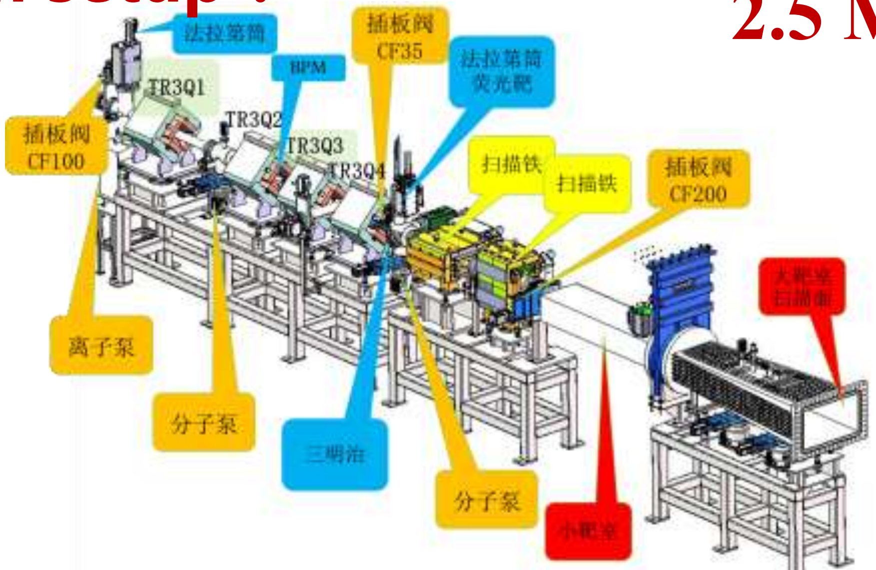
Experimental parameters

SRIM Simulation:

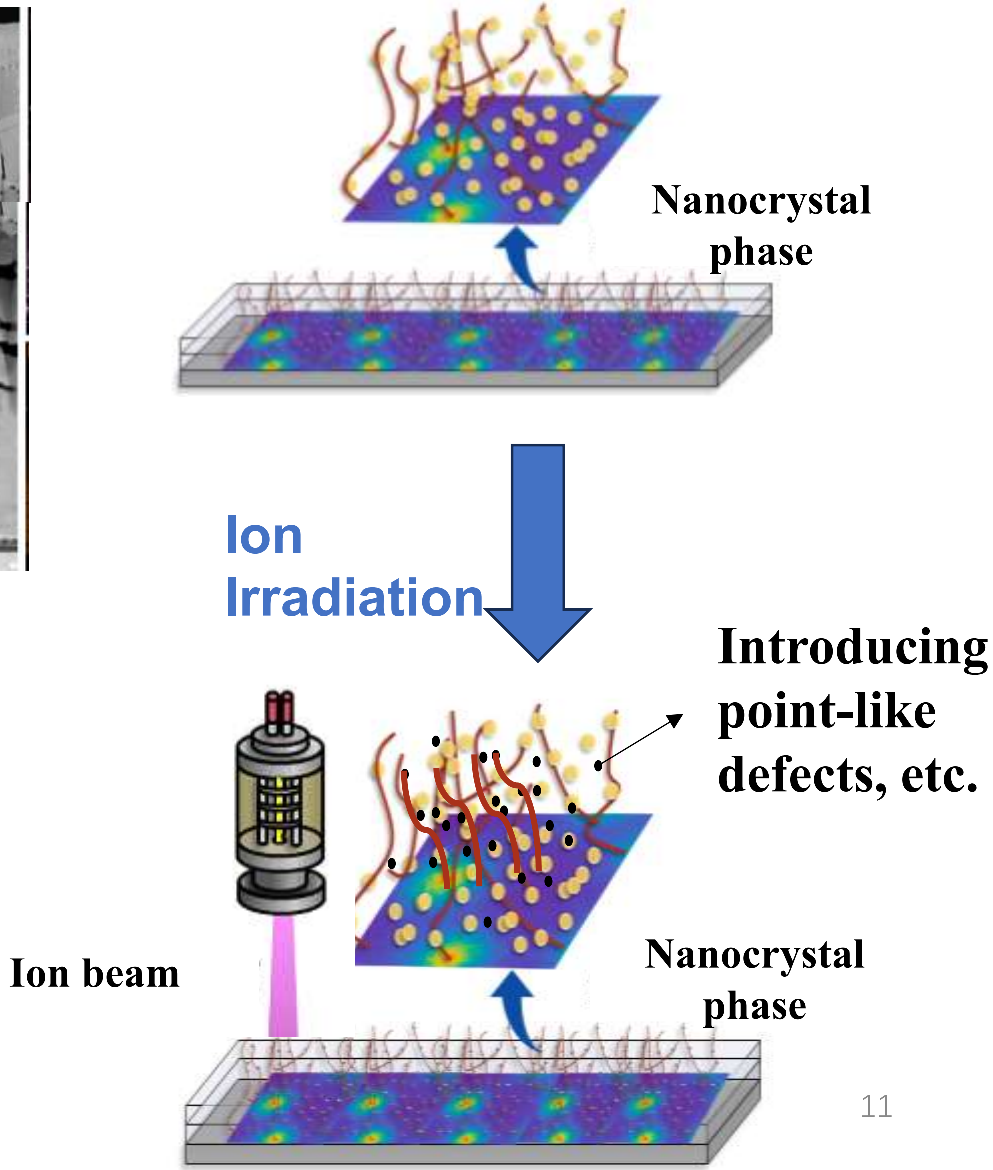




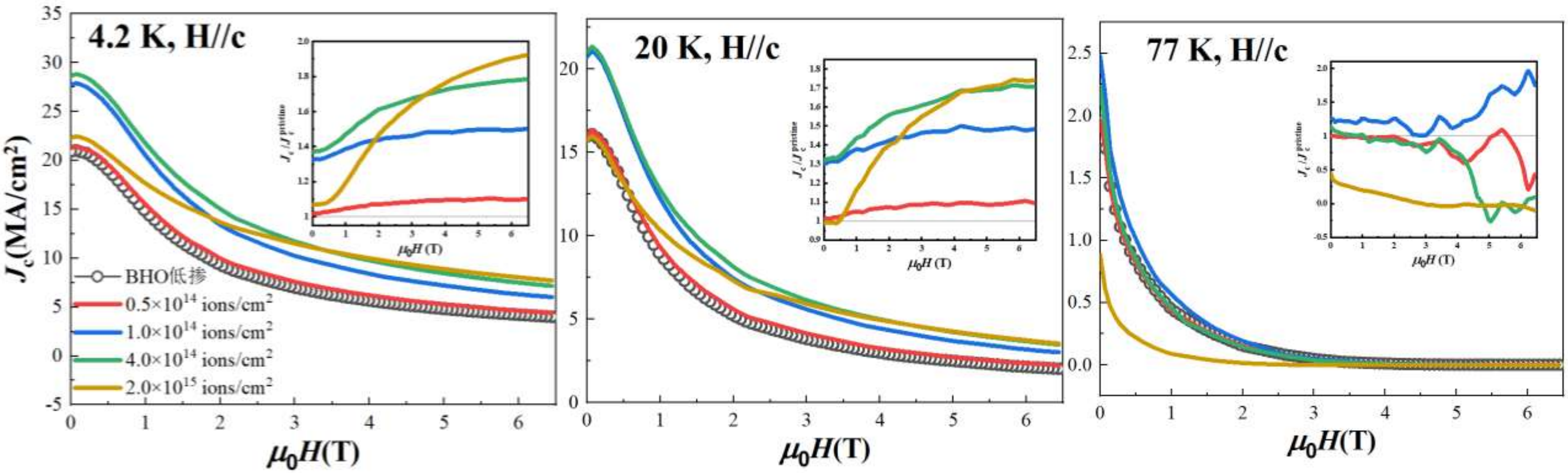
Irradiation setup：



2.5 MeV He



J_c Analysis of Low-doped BHO-YBCO



Experimental Parameters

Sample: low-doped BHO-YBCO

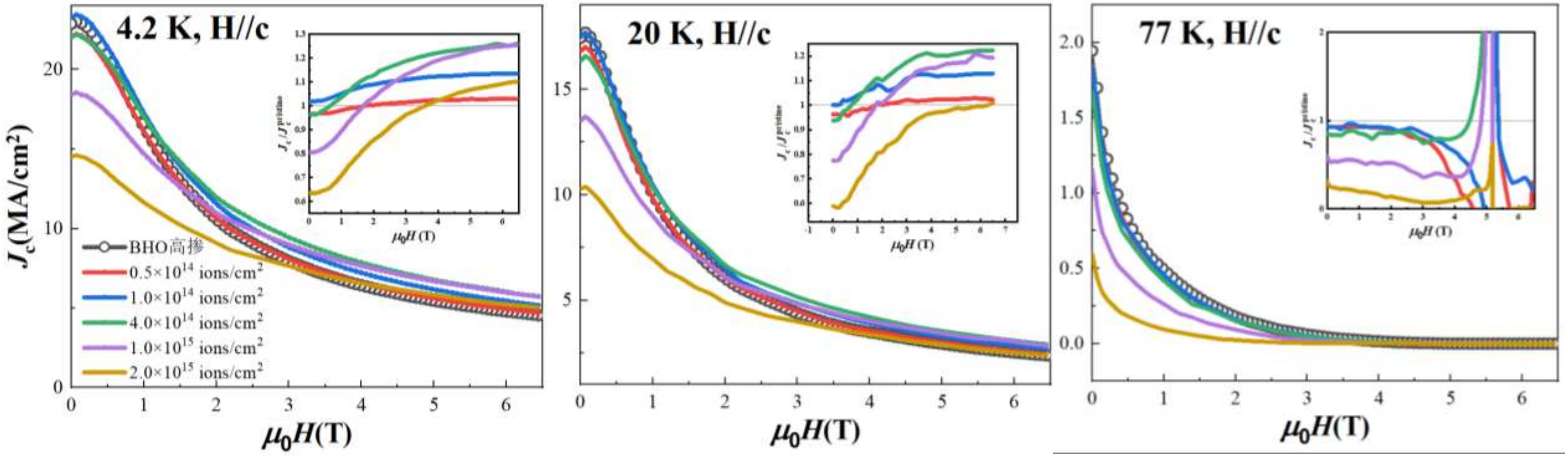
Ion type: He ion

Energy: 2.5 MeV

Dose: 5×10^{13}—2×10^{15} ions/cm²

- **At 4.2K and 20K, He irradiation can significantly improve the in-field performance of low-doped BHO-YBCO;**
- **While at 77K, He irradiation is not beneficial to improving the in-field performance.**

J_c Analysis of High-doped BHO-YBCO



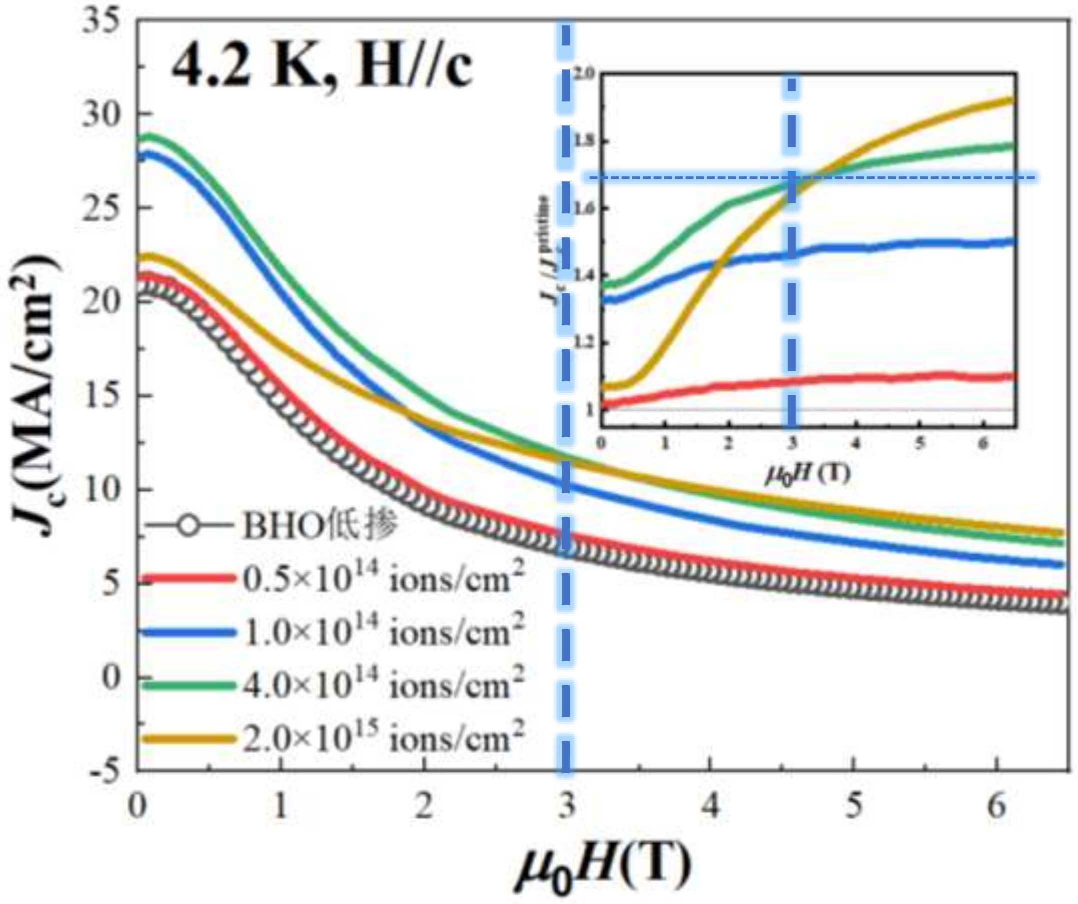
Experimental Parameters

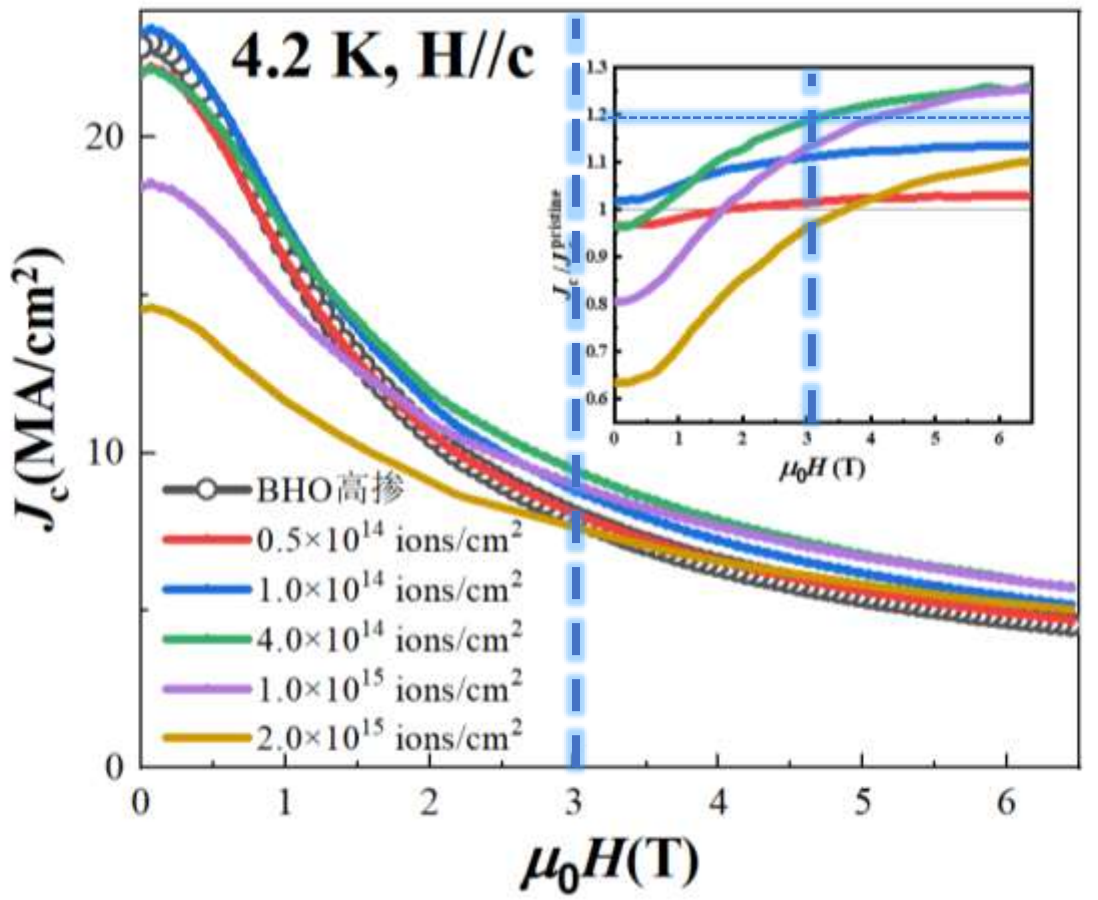
Sample: high-doped BHO-YBCO
Ion type: He ion
Energy: 2.5 MeV
Dose: 5×10^{13}—2×10^{15} ions/cm^2

- **At 4.2K and 20K, He irradiation can significantly improve the in-field performance of high-doped BHO-YBCO;**
- **While at 77K, He irradiation has no positive effect on the in-field performance.**

J_c Analysis of different-doped BHO-YBCO

上海大学 Shanghai University 上创超导 Shanghai Creative SuperConductor



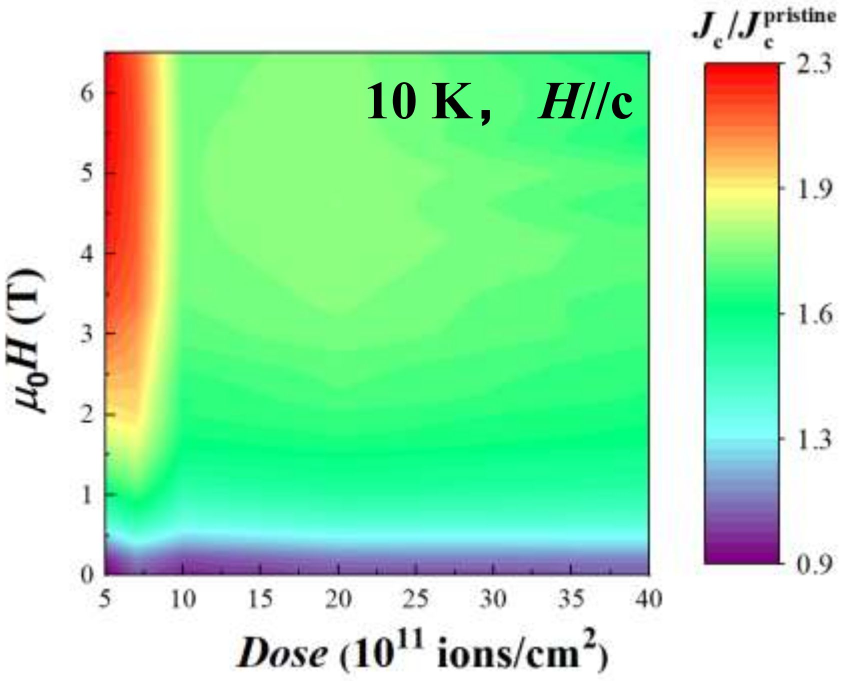


- **At 4.2 K, 3 T, compared with the original sample, He irradiation can improve the J_c of low-doped BHO-YBCO by up to about 1.7 times, while that of high-doped BHO-YBCO is only about 1.2 times.**

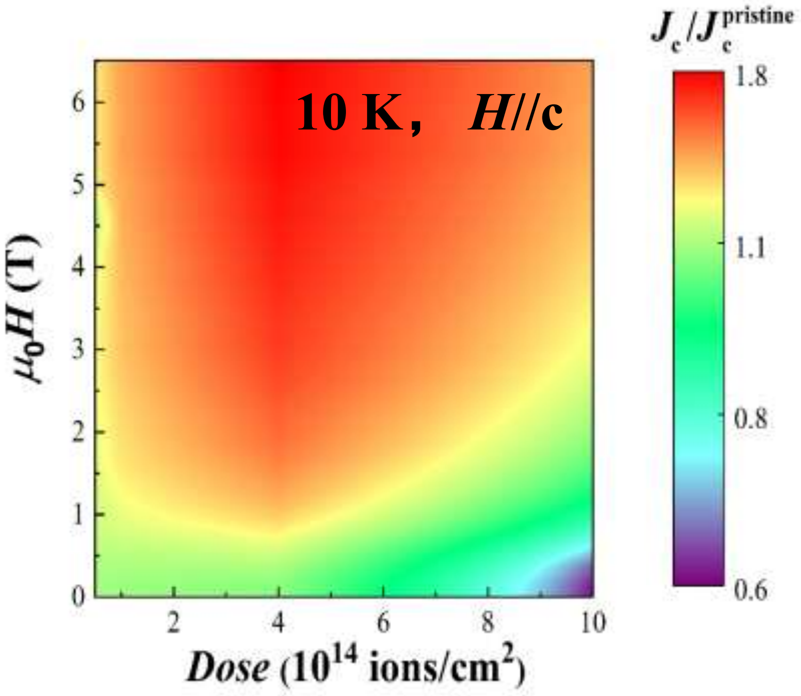
Other works: Ar ion VS He ion irradiation

上海大学 Shanghai University　上创超导 Shanghai Creative SuperConductor

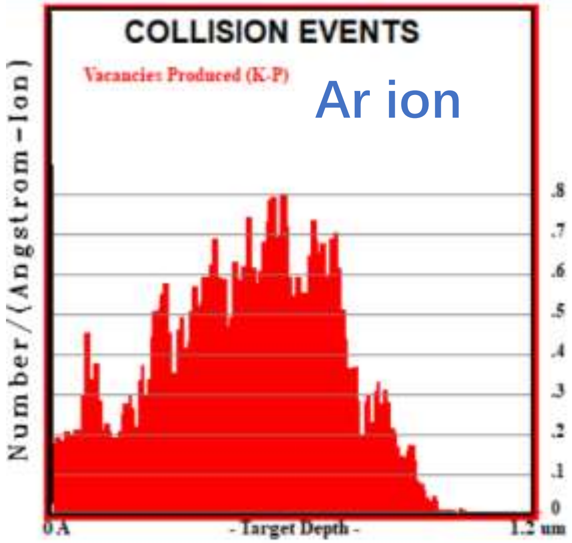
Ar ion irradiation

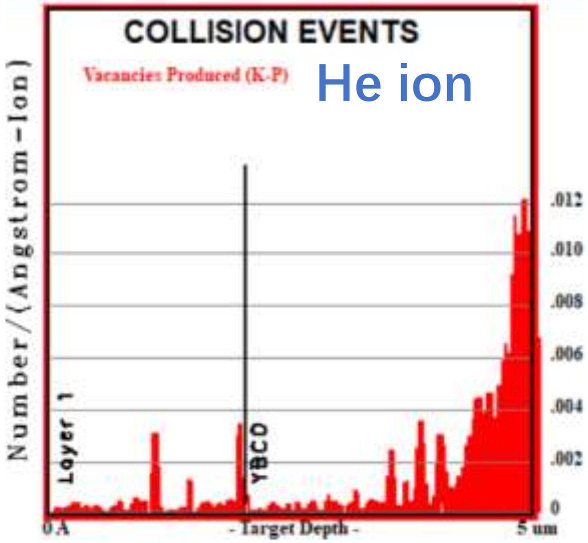


He ion irradiation



SRIM Simulation collision results：



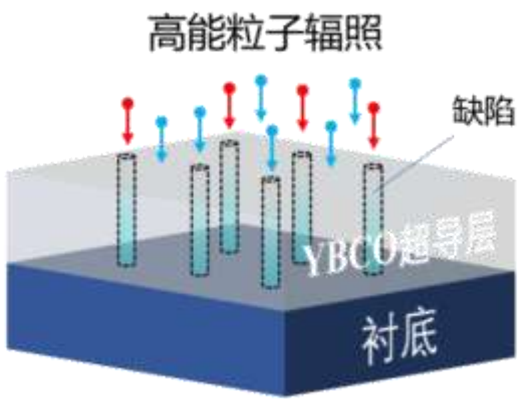


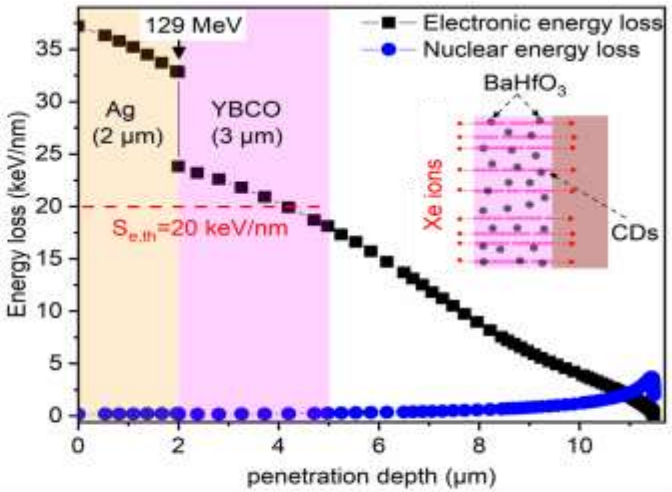
- ✓ Ar ion and He ion irradiation can significantly improve the in-field performance of YBCO at 10K ;
- ✓ The SRIM simulation collision results show that Ar ion irradiation produces more effective pinning centers than He ion irradiation.

Different energy irradiation effects of MOD REBCO

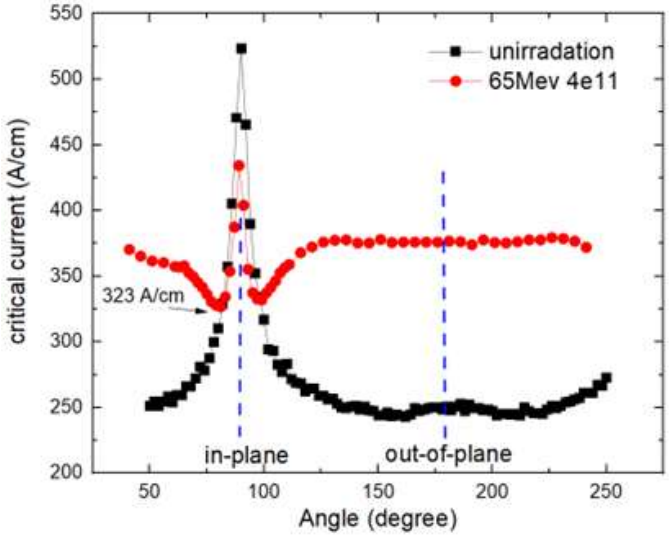
上海大学 Shanghai University
上创超导 Shanghai Creative SuperConductor

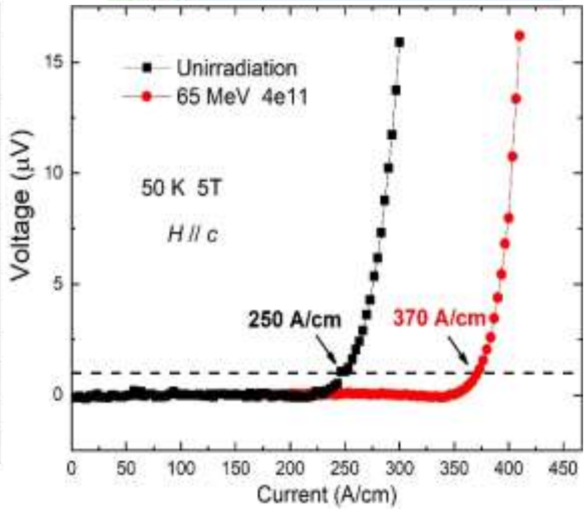
- ✓ **Xe ion irradiation at different energies significantly improves the mid-temperature field performance of the MOD-REBCO.**



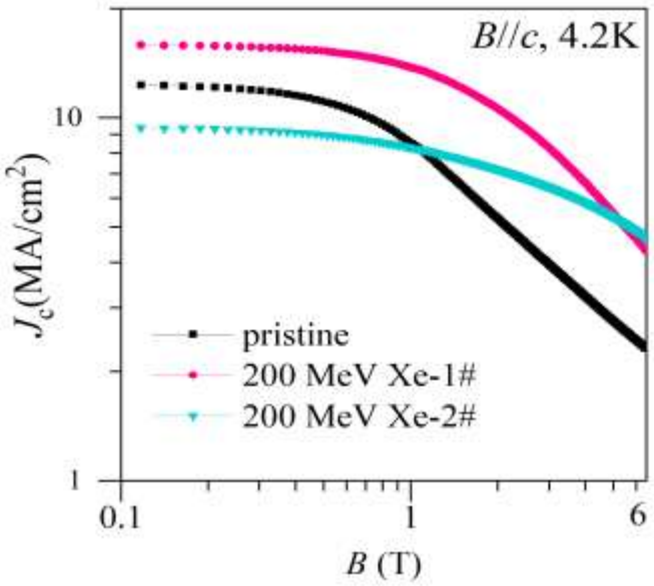


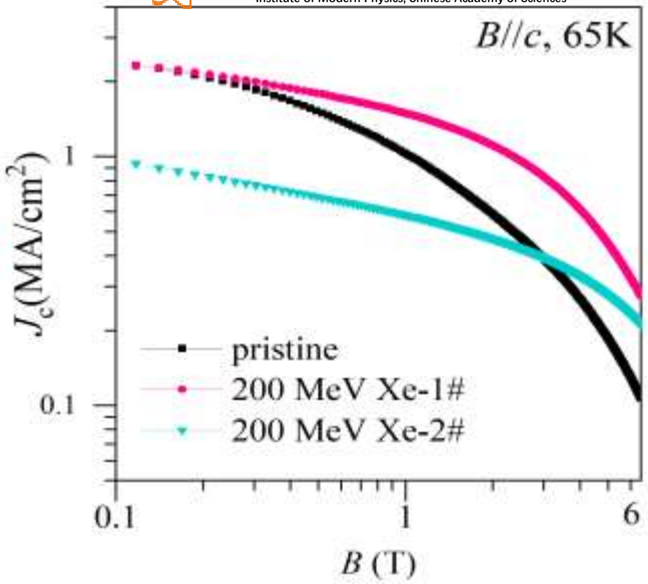
中国科学院电工研究所





中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences





Outline

上海大学 Shanghai University 上创超导 Shanghai Creative SuperConductor

- Research Background
- Research Contents
- **Conclusion**

Conclusion

- He ion irradiation can effectively improve the J_c of BHO-doped-YBCO tapes at low temperature and high field;
- At 4.2 K, 3 T, compared with the original sample, He irradiation is more effective in improving the J_c of low-doped BHO-YBCO, about 1.7 times, while high-doped BHO-YBCO is only about 1.2 times;
- Under the same irradiation dose, the effective utilization rate of irradiation defects in high-doped BHO-YBCO is low (because BHO has occupied most of the pinning sites);
- Different ion irradiation (He, Ar, Xe) has different degrees of improvement on the in-field performance of REBCO tapes.

Thanks a lot for your attention!

Welcome to visit and cooperate with SHU and SCSC

Email: cbcai@t.shu.edu.cn;   Tel: +86 13524190269