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Angular dependence of the critical current density in coated conductors with an isotropic defect structure

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CCA2016
Aspen, Colorado
Coated Conductors for Applications
September 11 - 14, 2016

CCA, Aspen, Colorado, September 13th 2016

Outline

- Motivation
  - Angular dependence of critical currents in neutron irradiated coated conductors
- Neutron irradiation
  - Introduced defect structure
- Results
  - Anisotropic scaling approach (Ba-122 single crystals)
  - Resulting angular dependence of critical currents
  - Comparison with experimental results on coated conductors
- Conclusions

Acknowledgments

This work was supported by EUROTAPES which has received funding from the European Union Seventh Framework Programme [FP7/2-7-2013] under grant agreement no. NMP-LA-2012-280432.

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

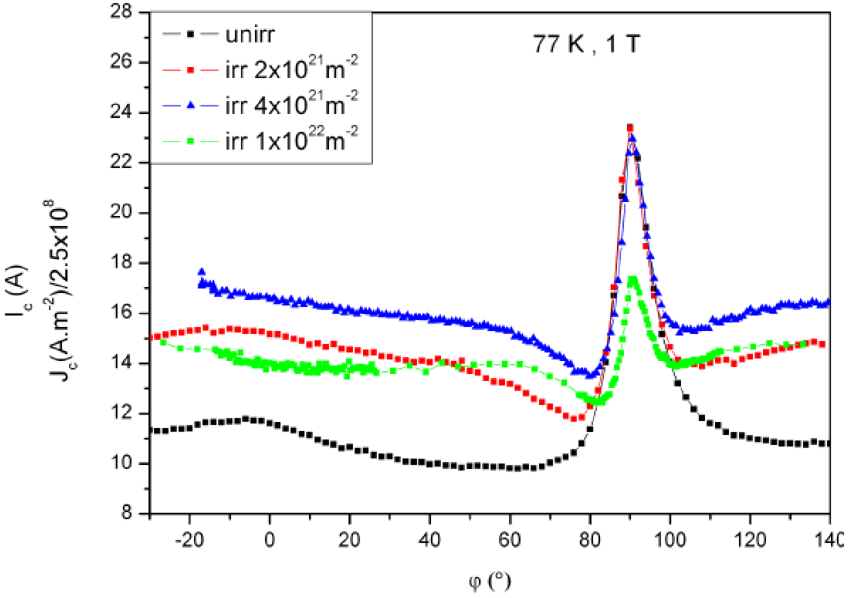
Measurements of irradiated coated conductors were performed by **Michal Chudy**.

Famous view of Maroon Bells

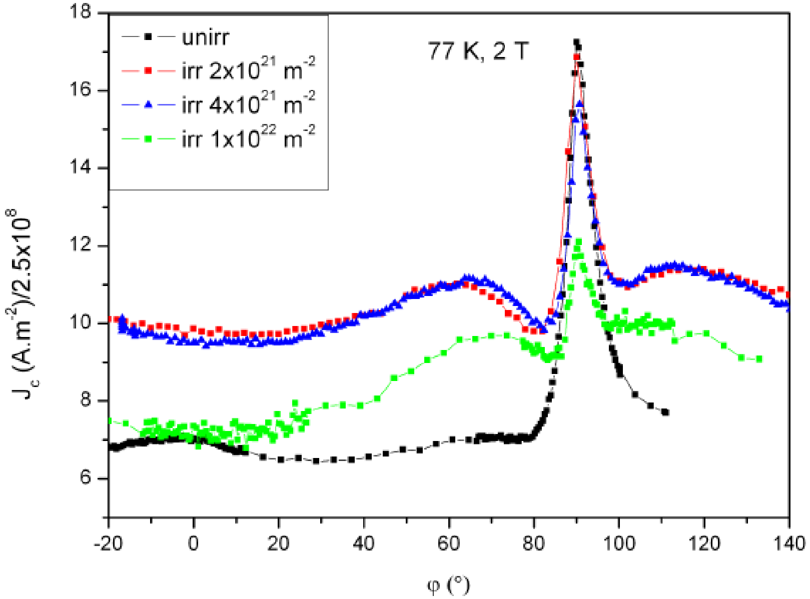
Change of perspective

may be quite rewarding!

Neutron irradiated coated conductors



Peak at H||c



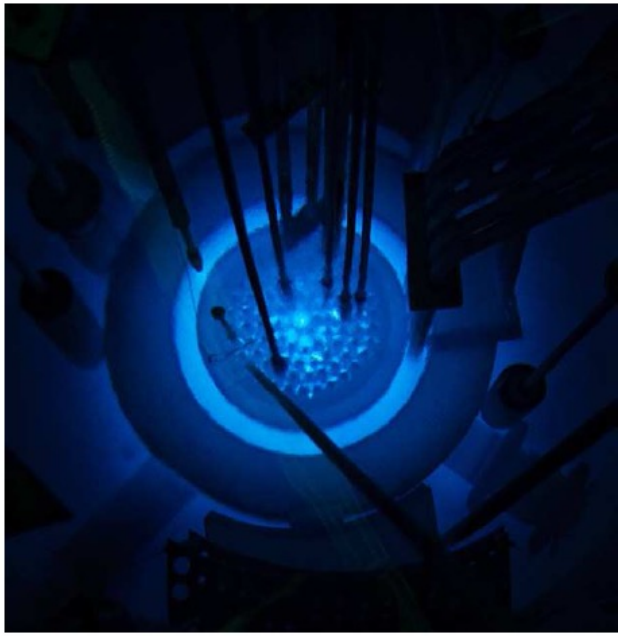
Peak at intermediate angles

Resulting from isotropic defects?

NEUTRON IRRADIATION

TRIGA MARK-II reactor

Fast (>0.1 MeV) neutron flux density: $4.5 \times 10^{16}\ \mathrm{m}^{-2}\mathrm{s}^{-1}$



Neutron Irradiation: Created Defects

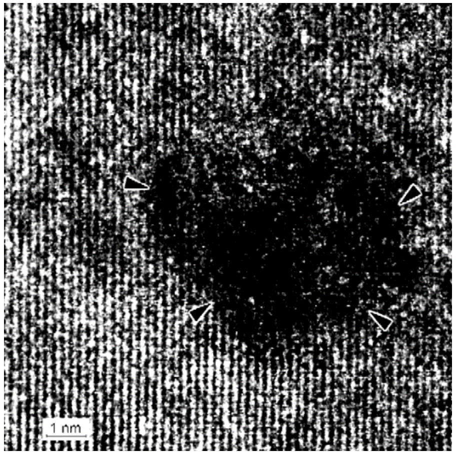
Direct collisions (high energy neutrons)

Defect cascades (E > 0.1 MeV)

Ø ~ 5 nm

Density: 10^{22} m^{-3} at a fluence of 2×10^{21} m^{-2}

(d_{av}~ 46 nm, B_f~ 1 T)



Smaller defects:

Single displaced atoms, clusters of point defects….

Randomly distributed, NOT correlated, nearly spherical

RESULTS

Anisotropic scaling approach

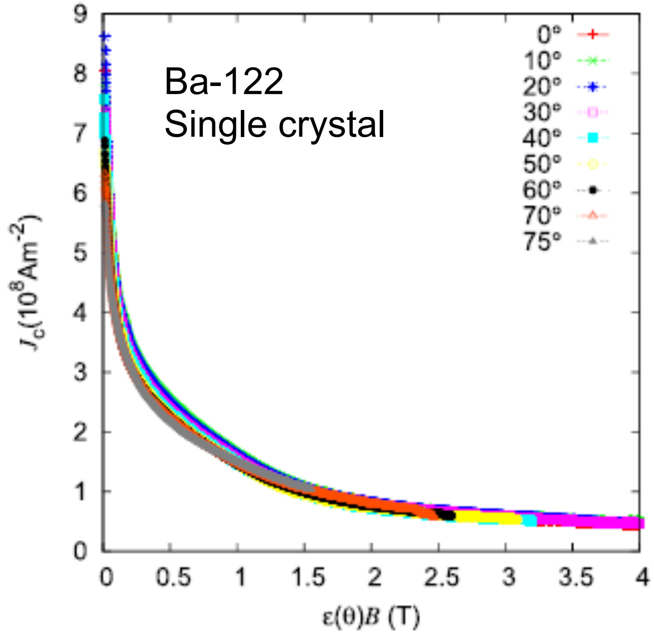
$$J_c(B,\theta)=J_c(B\epsilon(\theta))$$

$$\epsilon(\theta)=\sqrt{\gamma^{-2}\sin^2(\theta)+\cos^2(\theta)}$$

G. Blatter et al., Phys. Rev. Lett. **68** (1992) 875

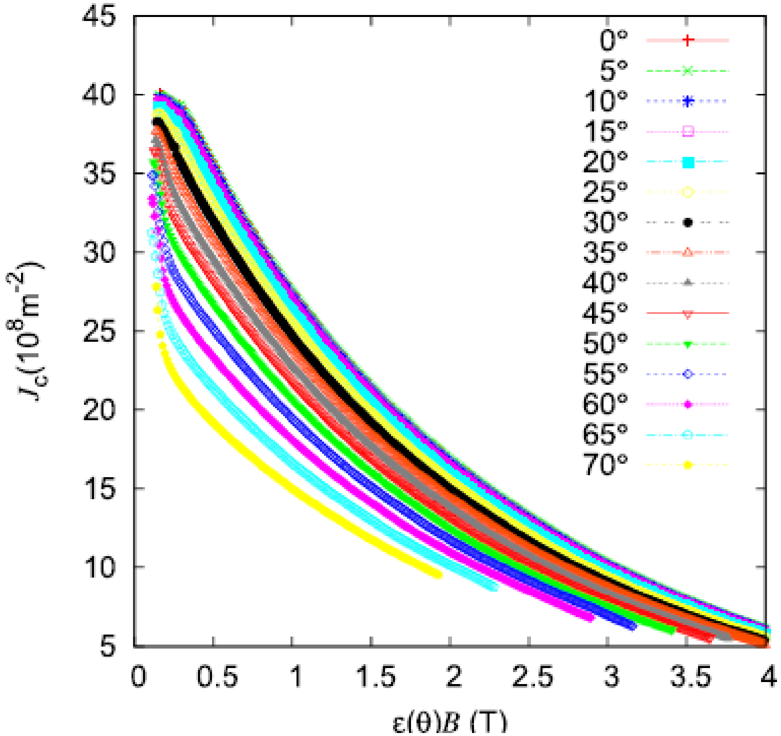
Collective pinning theory, single vortex pinning regime (weak pinning, low fields)

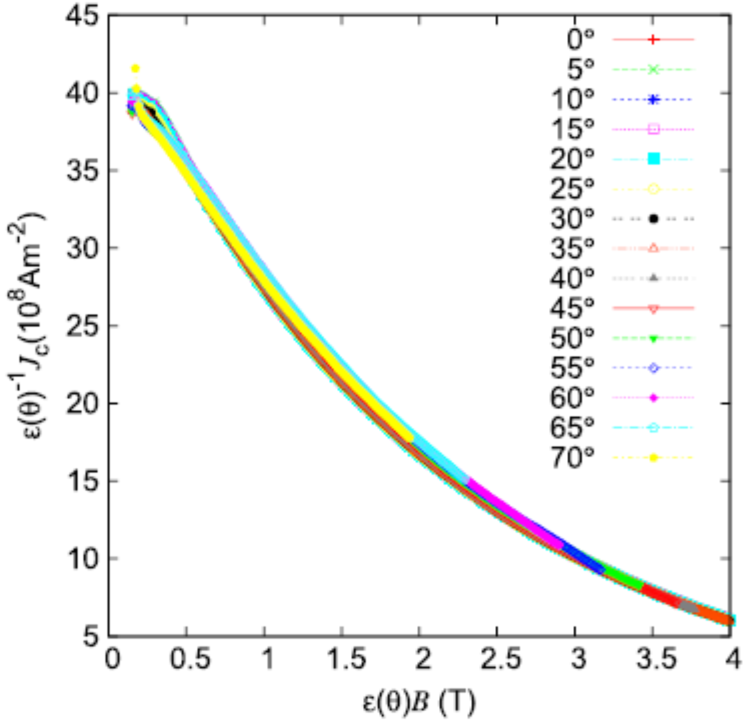
Angle-resolved magnetization measurements



V. Mishev et al.,
Supercond. Sci. Technol. **28** (2015) 102001C

Neutron irradiated Ba-122 (Co-doped)





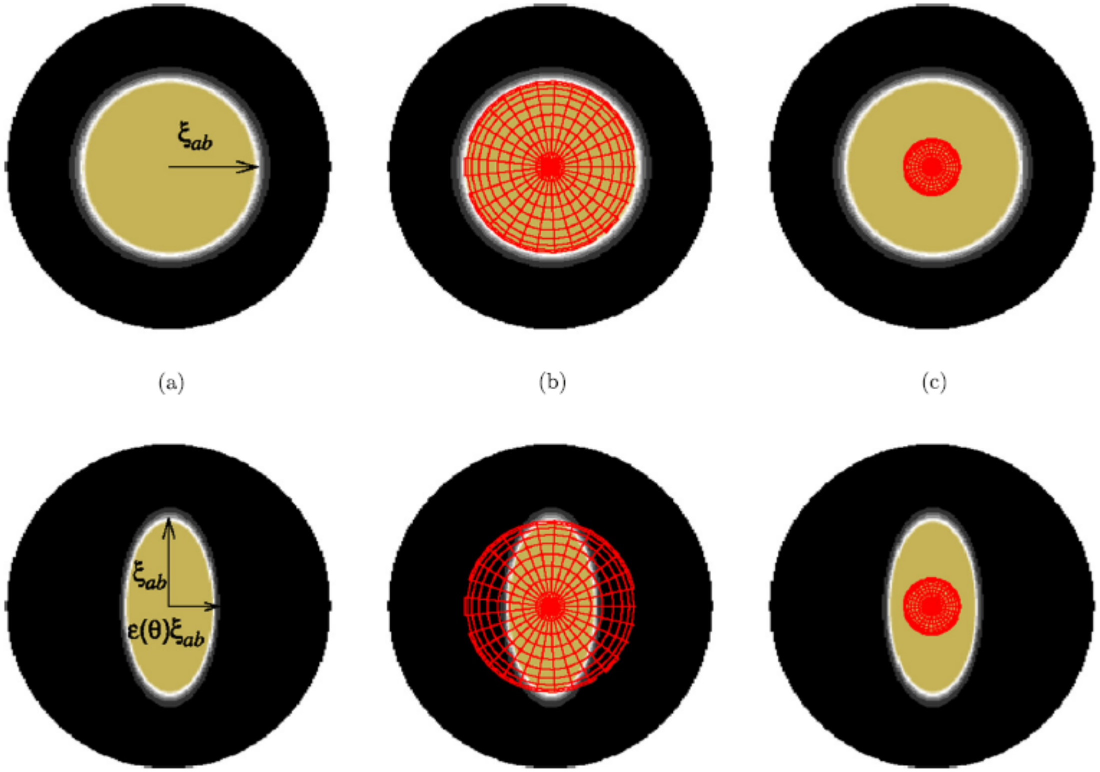
V. Mishev et al., Supercond. Sci. Technol. **28** (2015) 102001

Scaling of field **and** the critical current density is needed.

Point-like vs. spherical defects

$H||c$

θ>0



(a) (b) (c)

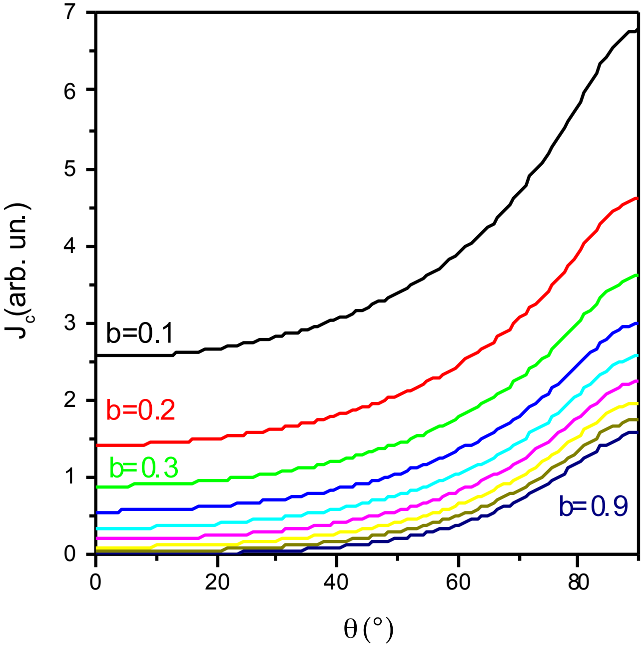
V. Mishev et al., Supercond. Sci. Technol. **28** (2015) 102001

(Anisotropic scaling approach: length has to be scaled)

Implications for angular dependence of J_c

$$J_c \propto B^{-0.5}\left(1-B/B_{irr}\right)^2$$

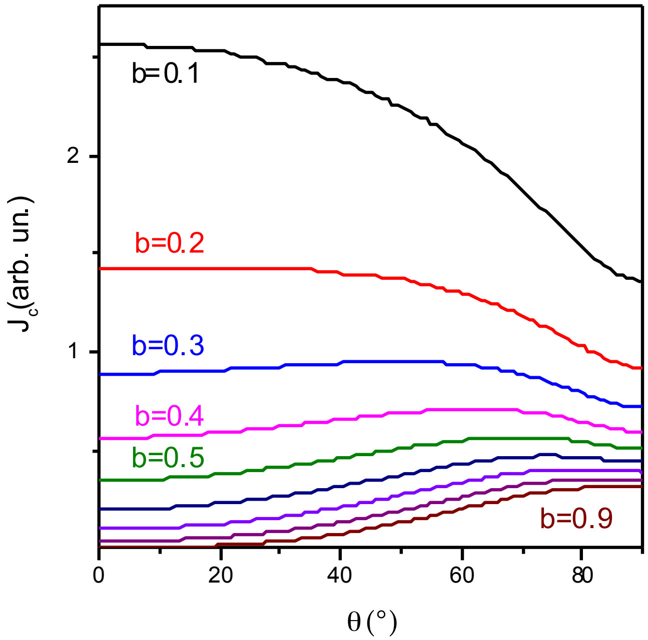
γ=5



Field scaling

$$J_c(B,\theta)=J_c(B\epsilon(\theta))$$

Peak at 90 °

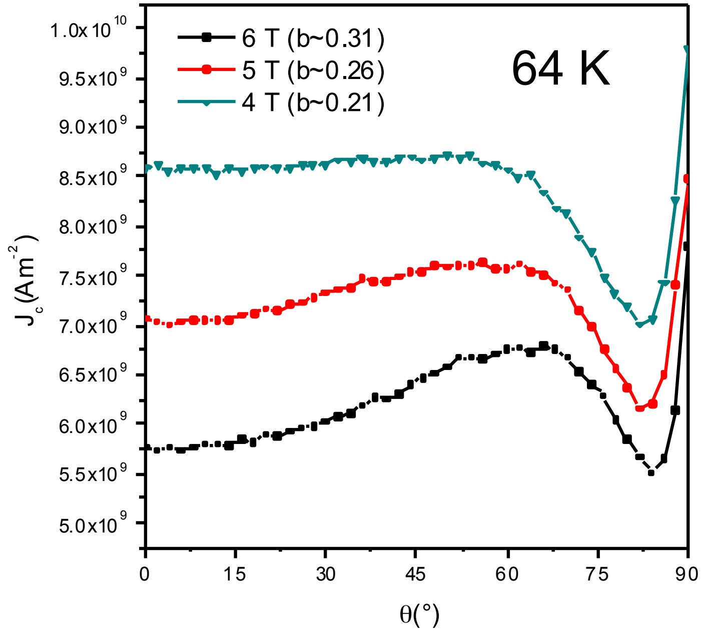


Field and current scaling

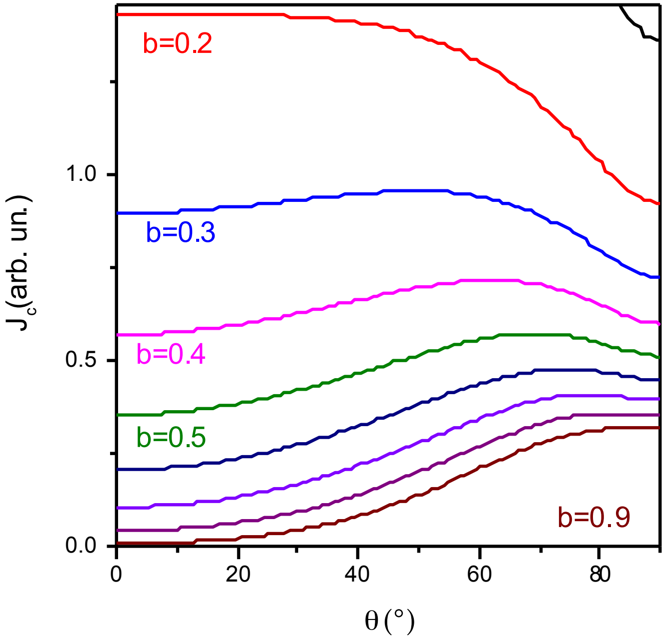
$$J_c(B,\theta)=\epsilon(\theta)J_c(B\epsilon(\theta))$$

Peak position depends on magnetic field

Angular dependence of J_c



SuperPower SCS 4050

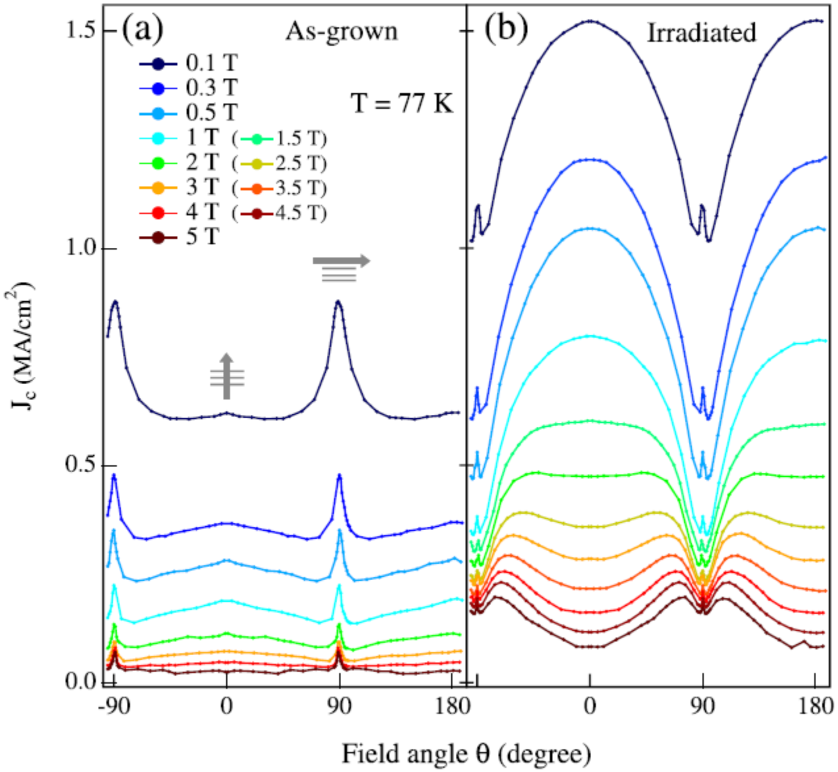


- Qualitative agreement.
- Quantitative agreement unsatisfactorily. (Pre-existing defect structure?)

Data from literature

YBCO film, 3 MeV Au-ions

Model based on flux-lattice shear (Kramer mechanism) leads to the same prediction for $J_c(\theta)$.



H. Matsui et al., J. Appl. Phys 114 (2013) 233911

Conclusions

- Peaks in $J_c(\theta)$ potentially arise from spherical defects with a size comparable to or larger than the coherence length.
- The peak is located at 0° ($H||c$) at low fields and shifts to 90° ($H||ab$) near B_{irr}.
- This qualitative behavior was found in neutron irradiated coated conductors.
- Further work is needed to establish quantitative agreement.