Effect of Frenkel defects on superconducting properties of GdBCO tapes

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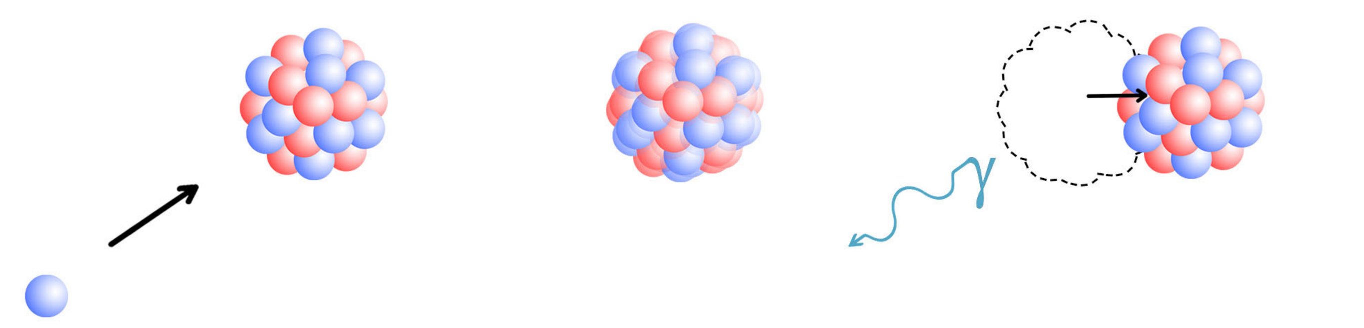
Introduction

Optimizing flux pinning is one of the current tasks in the development of second generation HTS-tapes. This is achieved by introducing nanometer sized artificial pinning centers into the superconducting layer. Using irradiation techniques further defects were added to the existing structure. This allows the investigation of their influence on the collective action of all defects on the flux line lattice. We report on the introduction of single displaced atoms into GdBCO-123 coated conductors by neutron irradiation. The gadolinium nucleus, a strong absorber of thermal neutrons, gets excited upon capture and relaxes by emitting a gamma particle with just enough recoil energy to displace its emitter. The displaced atoms or introduced vacancies significantly decrease the transition temperature. The dependence of the critical current on the applied fluence is discussed in comparison to fast neutron irradiation.

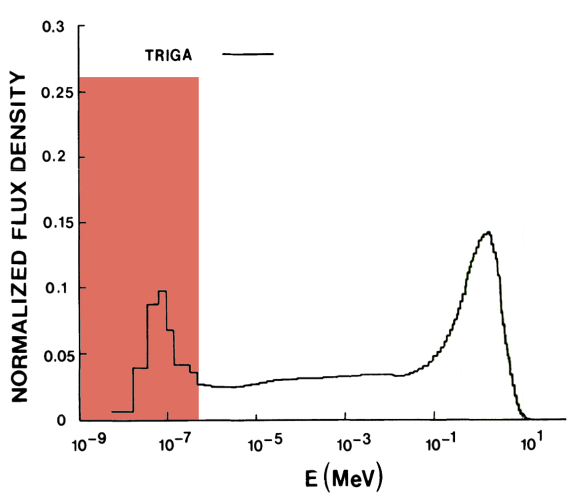
neutron capture by Gd-155 | excited state Gd-156* | relaxation knocks Gd out of lattice



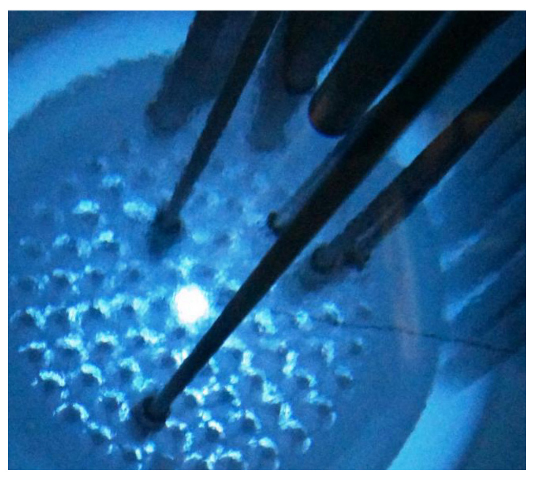
▶ 15 eV repulsion of gamma knocks Gd atom out of lattice [1]

Experiments

- ▶ Used samples: SP SCS4050 GdBCO no APCs
- ▶ Shielded tapes (st) wrapped in Cd foil are only irradiated by neutrons ***E* > 0.55 eV**
- ▶ Unshielded tapes (ut) are irradiated by whole neutron spectrum
- ▶ Tapes were irradiated up to a fast neutron fluence of **3.9 x 10^{22} m^{-2}** in a TRIGA research reactor



neutron spectrum [2]



TRIGA Mark-II core

- ▶ Transport current measurements down to T_{min} = 30 K and up to B_{max} = 15 T
- ▶ J_c via electric field criterion E_c = 1 µV cm^{-1}
- ▶ T_c via onset-criterion

Outlook

- ▶ Further experiments have to be conducted in order to better understand impact of a large number of small defects on T_c and J_c
- ▶ Single atom displacements do not pin efficiently at temperatures ≥ 30 K
- ▶ Methods for measurements at low temperatures T_{min} = 4.2 K are being developed

References

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Neutron irradiation of coated conductors.
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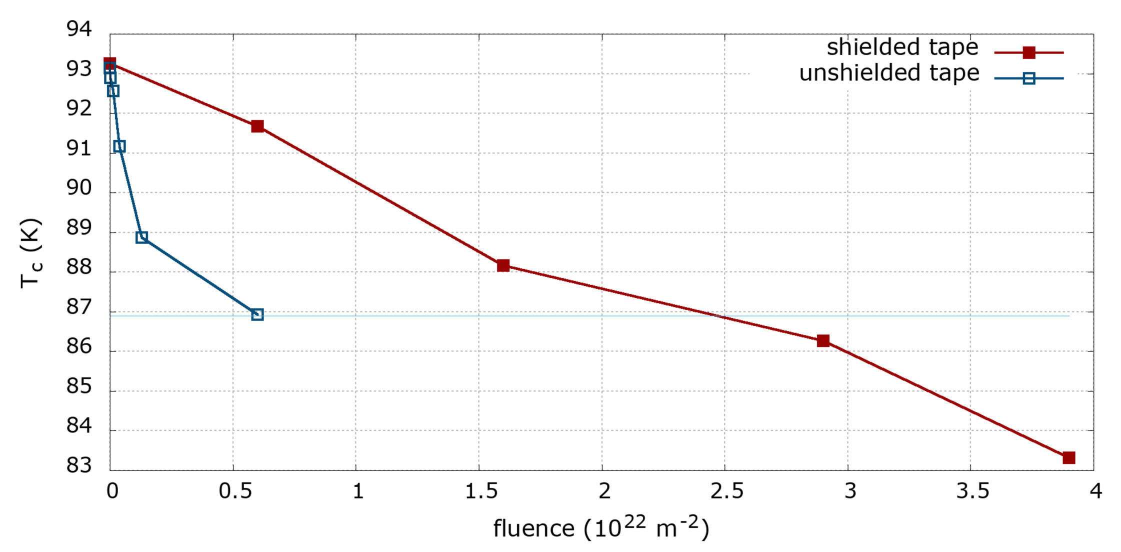
Results

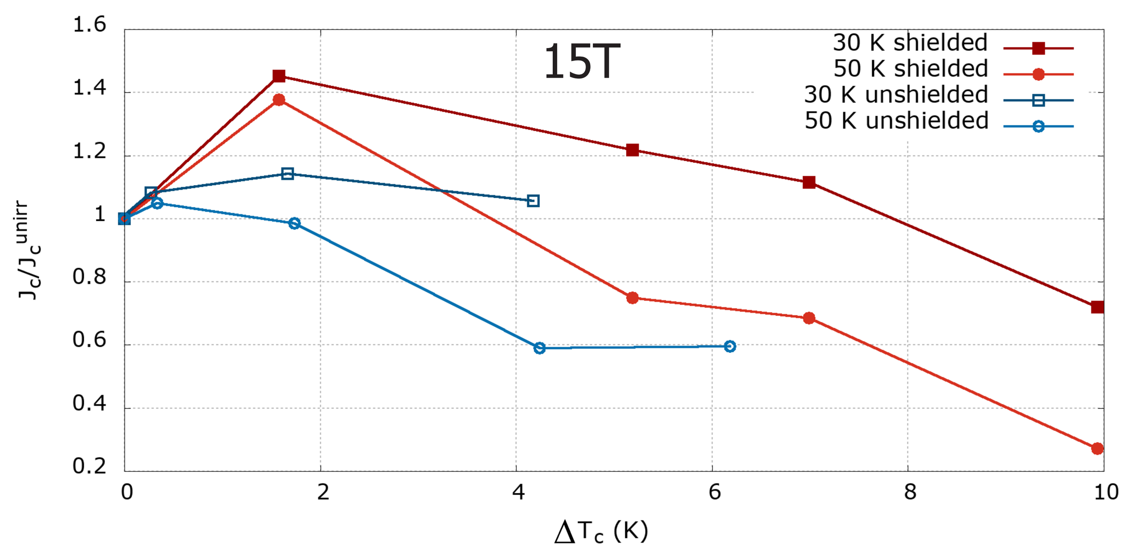
Critical temperature

- ▶ T_c^{ut} declines much faster than T_c^{ut} and shows non-linear behavior (?)
- ▶ T_c^{st} declines linearly with irradiation
- ▶ Experiments show strong dependency of T_c on single atom displacements
- ▶ Irradiation reduces T_c^{ut} to 87 K at ~20 % of the fast neutron fluence needed to decrease T_c^{st} to the same level



Critical current density

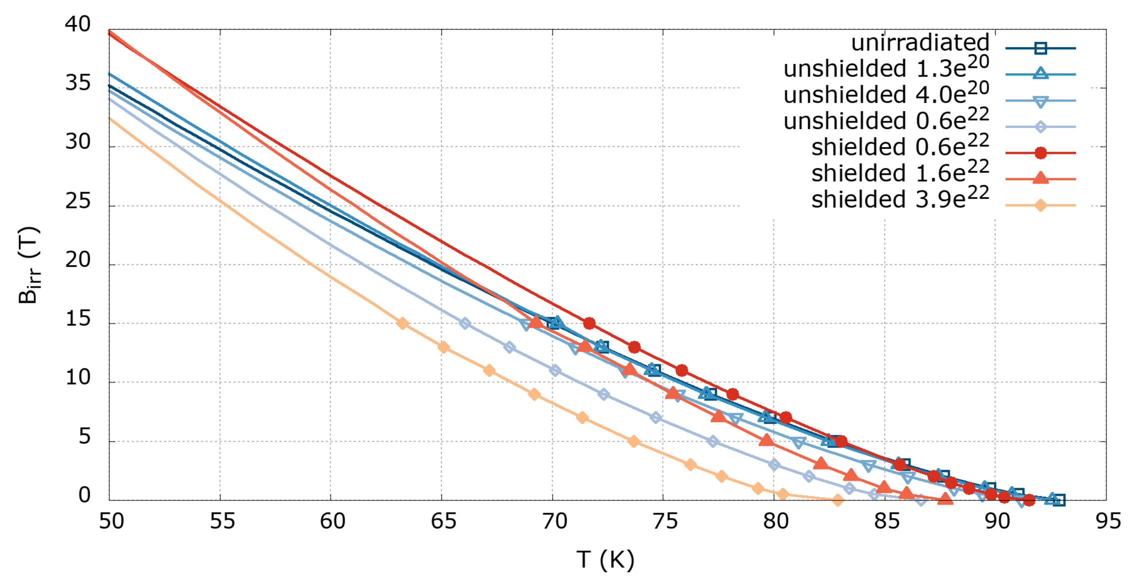
- ▶ Irradiation of unshielded samples increases J_c only by about 15 %. It stays clearly below J_c of shielded tapes which increases by up to 50 % from the initial J_c^{unirr}
- ▶ J_c does not increase as much in shielded samples, small defects therefore do not contribute to the pinning landscape as expected [3]



Irreversibility field

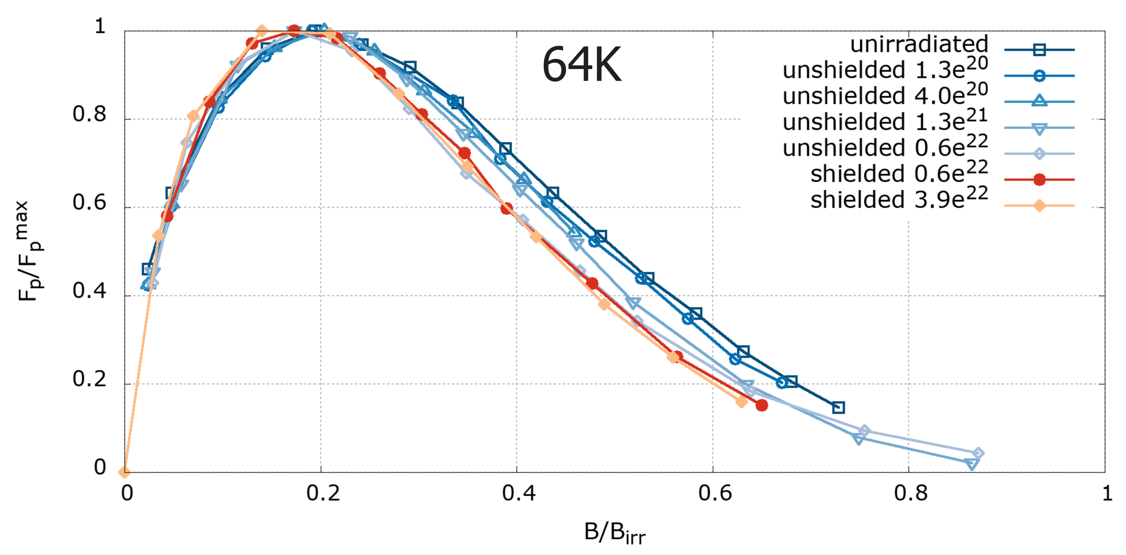
- ▶ B_{irr}^{st} (T) initially gets steeper with higher levels of irradiation
- ▶ B_{irr}^{ut} shows no sign of this behavior, this might also result from small defects
- ▶ The highest achievable field in this study was 15 T, the following function was used to extrapolate the results to 64 K

$$B_{\rm irr} = B_{\rm irr}(0)\left(1 - \frac{T}{T_{\rm c}}\right)^{\rm n}$$



Pinning force

- ▶ Extrapolated results were used to normalize pinning force curve to B_{irr}
- ▶ Irradiation changes the pinning landscape until the introduced defects become dominant for pinning at a fluence of 0.6 x 10^{22} m^{-2} [2]
- ▶ Single atom defects have no significant impact on the shape of the normalized pinning force curve at 64 K



Acknowledgements

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