Electron Irradiation of Polycrystalline Bulk FeSe Superconductors

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Critical state model for polycrystalline FeSe

- By removing both diamagnetic and ferromagnetic signal, we can see that a polycrystalline FeSe sample show an asymmetric magnetization loop function of the grains size and the grains coupling.

![Magnetization loop of a FeSe polycrystalline sample at 2K](Image)

- For an external magnetic field B(T), we can see that: \(|\text{Magnetization} |(B)| \) = \(|\text{Magnetization} |(B)| \) which means 50% of the superconducting volume is allocated for the intragrain current

![Magnetization loop of a FeSe polycrystalline sample at 2K](Image)

- This magnetization is created by the sum of an intergrain moment (with a total reversibility) and an intragrain moment (with an horizontal symmetry).

![Intragrain and intergrain magnetization loops of a polycrystalline sample](Image)

Electron irradiation using Sirius facility

- Irradiation experiments were done on small cut fragments (around 1 x 1 x 0.01 mm2)
- Samples were irradiated using SIRIUS, an EMIR’s facility based at Laboratoire des Solides Irradiés.
- Electron energy of 2.5 MeV and a beam current of 4.6 μA for a total dose of 0.655 C and 1.27 C.
- An electron irradiation adds point-like defects such as voids and interstitial atoms which are useful to trap vortices.

A polycrystalline iron-based superconductor

- Iron-selenide superconductors:
  - Discovered in 2008 [1]
  - Variable critical temperature: 9 K using bulks, up to 36.7 K under 8.9 GPa [2], above 103 K as monolayer [3]
  - Rare-earth free and non-toxic materials

- Polycrystalline FeSe:
  - Ball milling and sintering at 950 °C
  - Critical current: 8 K
  - Well coupled and randomly oriented grains of the order of 1 μm
  - Presence of a FeSe ferromagnetic phase (40% of the volume)

Effect of electron irradiation

- We extract the intragrain moment on 5 samples:
  - 2 irradiated with 4 x 10^19 e^- (1.27 C): “1.27A” and “1.27B”.
  - 2 irradiated at 2 x 10^19 e^- (0.655 C): “0.655A” and “0.655B”
  - 1 unirradiated sample: “Unirr”.

![Intragrain magnetization loop for the 5 samples](Image)

- Using the so-called extended bean model we can extract the critical current from the intragrain moment (30% of the sample’s volume). Using the following formula [Chen et al., 1989]:

\[
J_{c,\text{intragran}} = \frac{\Delta M_{\text{intragran}}}{a} \times 10^3
\]

![Critical current of an unirradiated polycrystalline FeSe](Image)

- Fig. 6 show an increasing of the critical current for a medium level of irradiation and a lower critical current for a “high” level of irradiation.

Conclusion

- We developed a new model to extract the critical current of a polycrystalline superconductor
- We have seen the influence of the irradiation on a FeSe polycrystaline sample

What next?

- A new experiment on EMIR facilities using heavy ion irradiations
- Working on the fabrication process to change the ratios FeSe/FeeSe material and intra/inter grain moments.