Fast neutron irradiation on K-doped Ba-122 Single Crystals.

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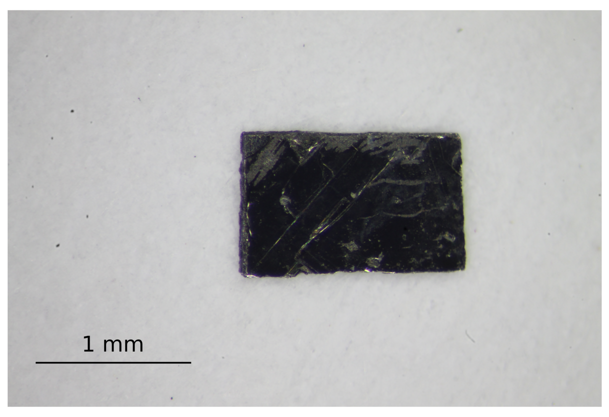
Introduction

The doping dependence of the critical current density, J_c, and the transition temperature, T_c, are qualitatively different from each other in Ba-122 single crystals. A sharp peak was observed in the doping dependence of J_c for all dopants (K, P and Co), while T_c varies much smoother around its maximum [1]. We investigated the change of this behavior in the K-doped system after fast neutron irradiation. This technique is known to introduce defects up to a size of a few nanometers, which have proven to be more efficient for flux pinning than the crystallographic defects in the pristine crystal. Therefore, the doping dependence of J_c after irradiation can help to understand the pinning behavior in Ba-122. The K-doped system was chosen since it was shown that the achievable J_cs after fast neutron irradiation are the highest [2]. This is of particular interest, because understanding the pinning behavior may enable an optimization of the defect structure for achieving even higher J_c values by introducing artificial pinning centers during the crystal growth. The irradiation shifts the peak in J_c to higher doping levels than in the pristine crystal. Furthermore, the peak broadens, but is still sharper than the variation of T_c around its maximum.

Samples

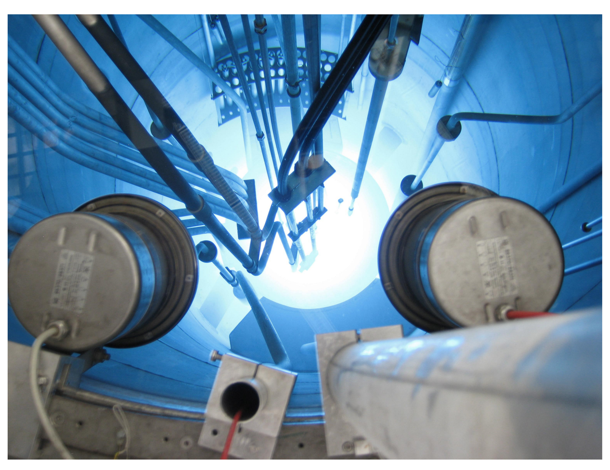
- Iron based superconductors, **K doped $Ba_1Fe_2As_2$** single crystals (Ba122): **$Ba_{1-x}K_xFe_2As_2$**



- Crystals were grown by the **self flux method** [3]
- Typical size: 1 mm x 1 mm, 30 μm thick

Experiments

- **T_c** was obtained by AC susceptibility measurements in a **SQUID** magnetometer. For the definition of T_c the 10% criterion was used.
- **J_c** was calculated from magnetization measurement performed in a vector **VSM**. A self field correction was performed for the calculation of $J_c(B)$.
- The samples were irradiated with fast neutrons to introduce more efficient flux pinning centers. This was performed in a **TRIGA** Mark-II **research reactor**.

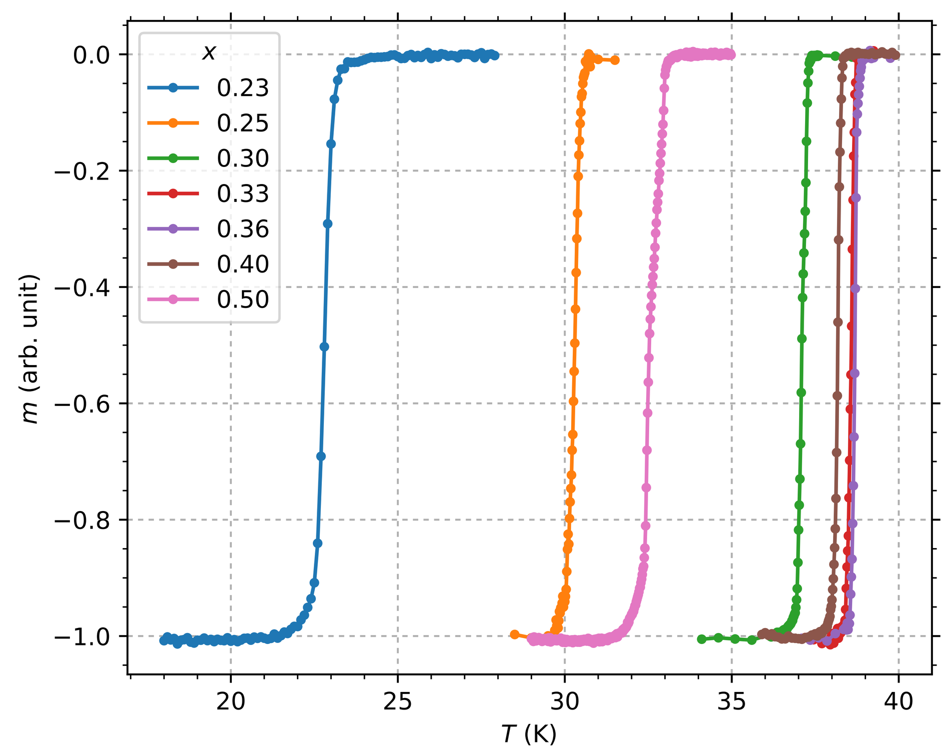


- The measurements before and after irradiation were done on the same crystals to avoid sample variations.

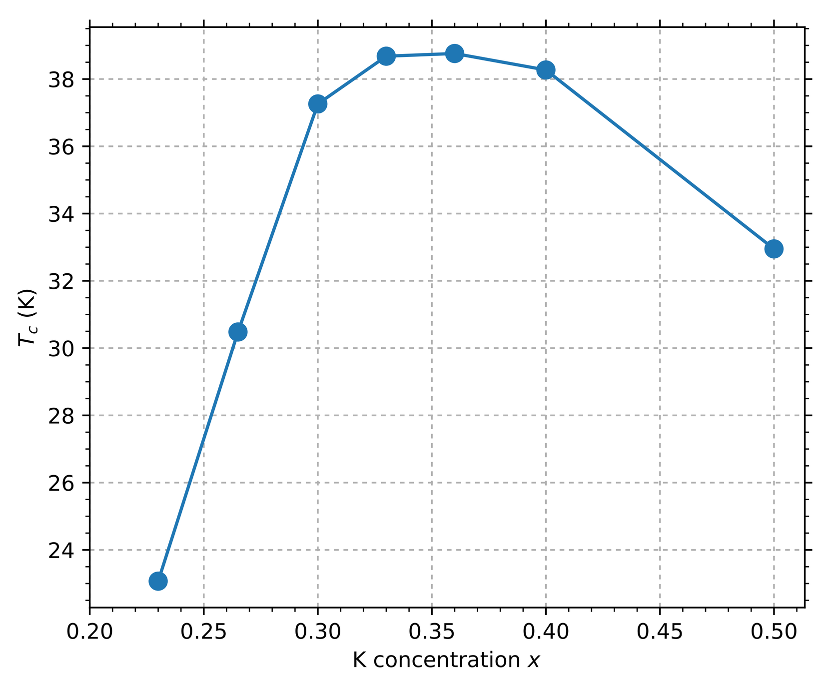
Results

Critical temperature

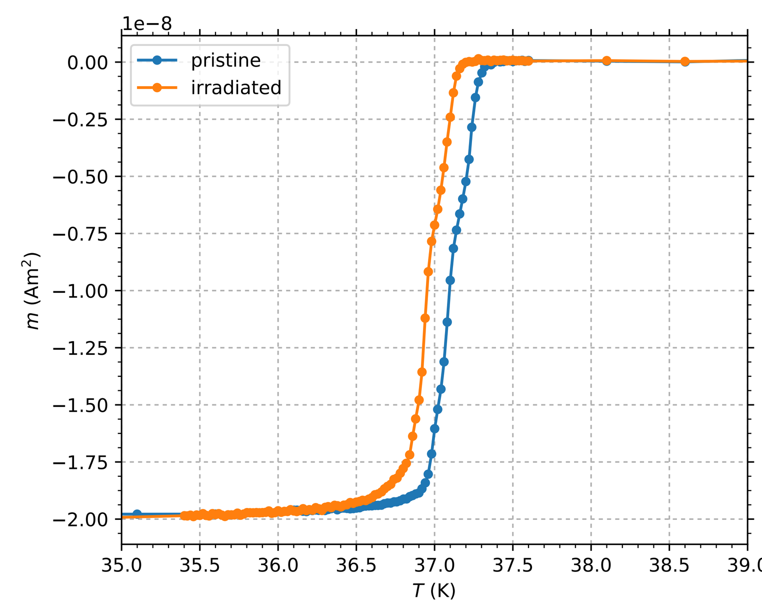
- Pristine single crystals → sharp transitions due to high sample quality:



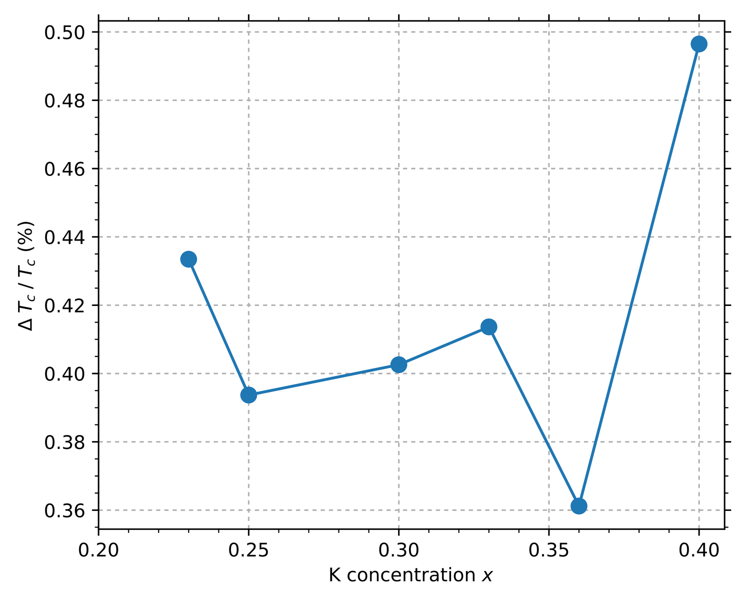
- T_c as a function of the K concentration: 1.) **smooth variation** over the whole doping range, 2.) **broad** maximum



- Fast neutron irradiation with a fluence of $\mathbf{1.7 \cdot 10^{21}\ m^{-2}}$ ⇒ T_c decreases for all doping levels.
- Transition after irradiation widens, but is still sharp → no sample damage due to the irradiation
- The crystal with **K concentration x = 0.3** before and after irradiation:

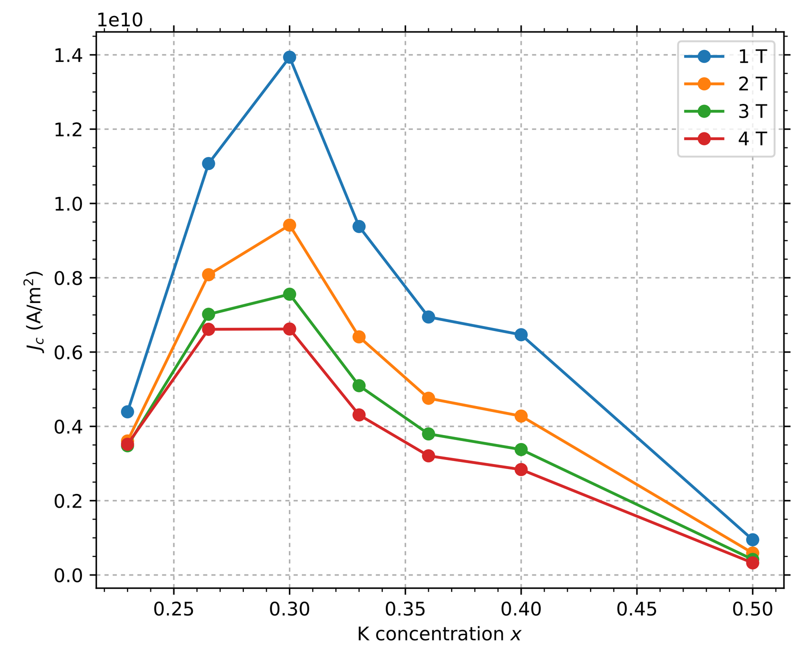


- **Similar relative change of T_c** for all K concentrations:

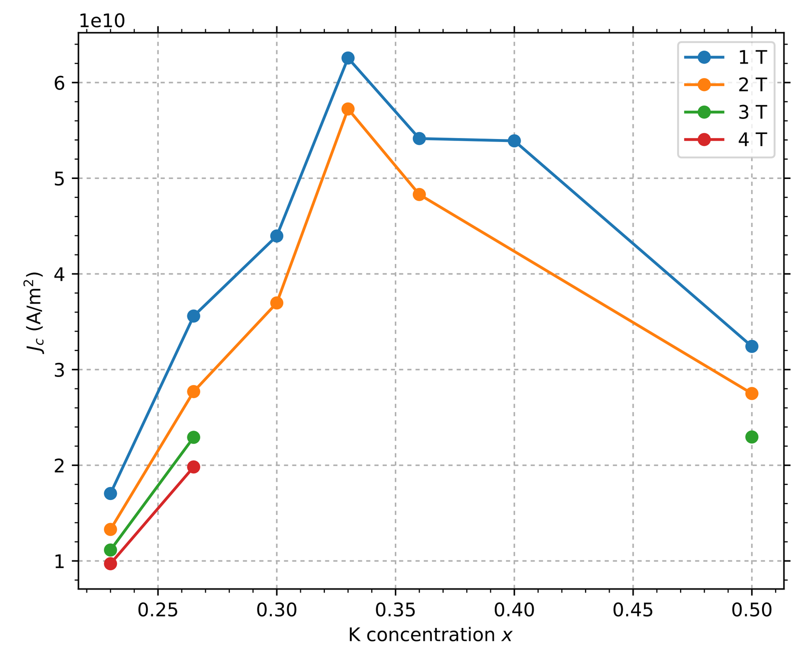


Critical currents

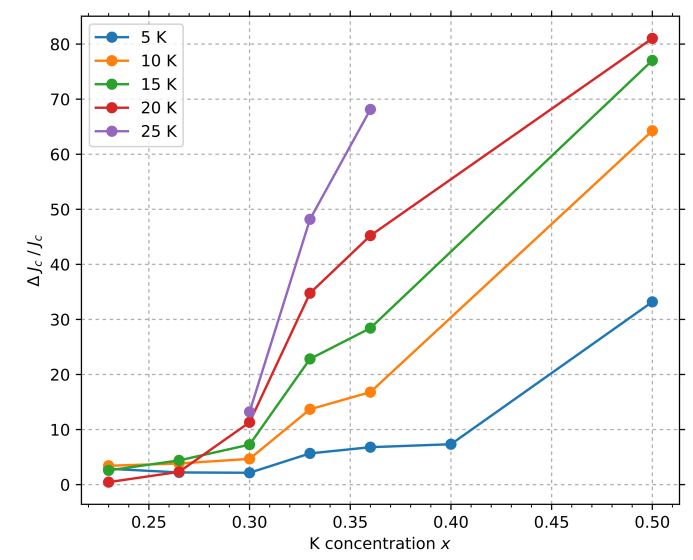
- J_c of the pristine crystals at **5 K** and different applied fields as function of the doping level → sharp peak:



- Introduction of defects from fast neutron irradiation ⇒ increase of J_c over the whole doping range. J_c at **5 K** and different applied fields:

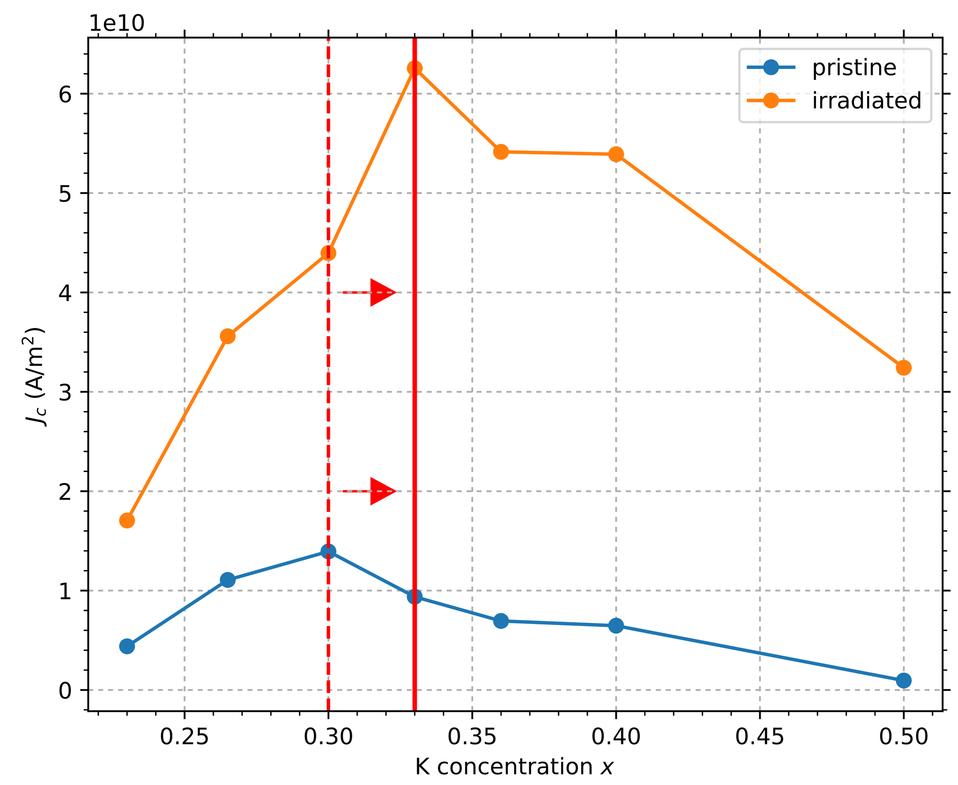


- Enhancement of J_c due to fast neutron irradiation as a function of the K concentration:



Peak position

- Position of the peak in T_c **does not change**.
- Peak in J_c **shifts** to higher doping levels:



References

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Summary and Outlook

- Pristine crystals: **smooth** variation of T_c → irradiated crystals: **decrease** of T_c → relative change **similar** for all doping levels
- Distinct **peak** in J_c → irradiated crystals: **shift** of the peak and **smoother** curve
- **Next steps:** 1.) Further irradiation of the crystals. 2.) Investigation of Ba122 with other doping atoms.

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