# Neutron irradiation and thermal annealing of HTS wires

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# Neutron irradiation

Samples covered by Ag and Cu

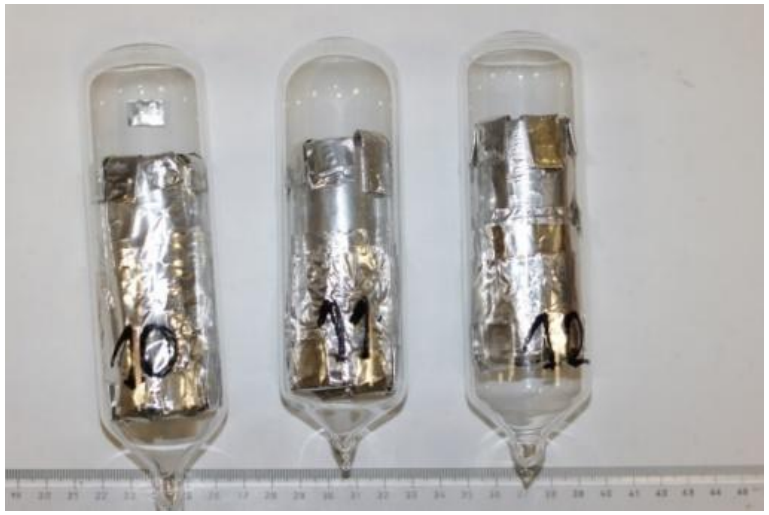
New sample holder designed:

5 ampoules with 7 samples, each ampoule irradiated to another neutron fluence

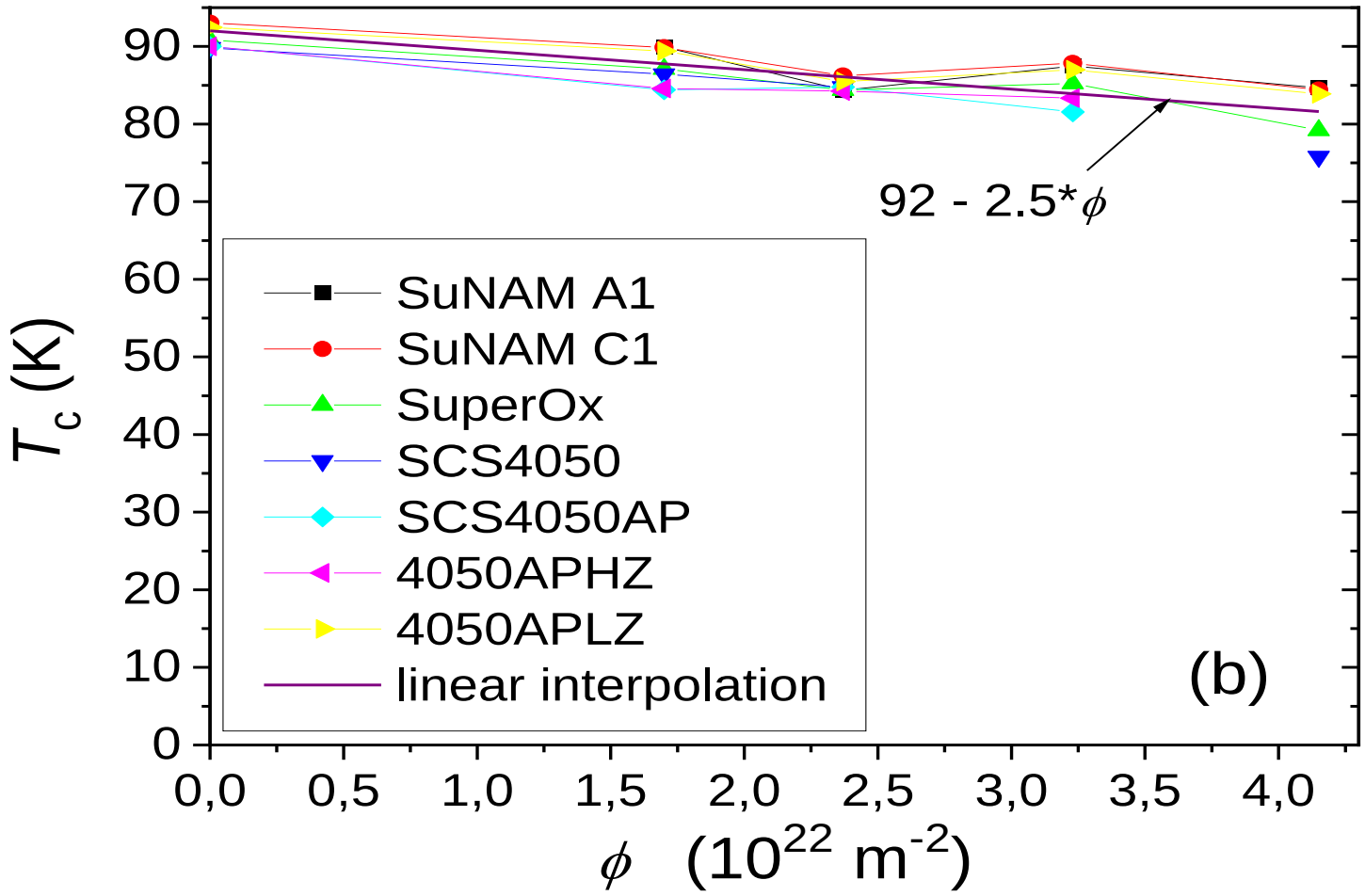
Fluences ($10^{22}$ $m^{-2}$)

1.7
2.37
3.23
4.15
4.14

samples packed in the upper rim of the Al foil

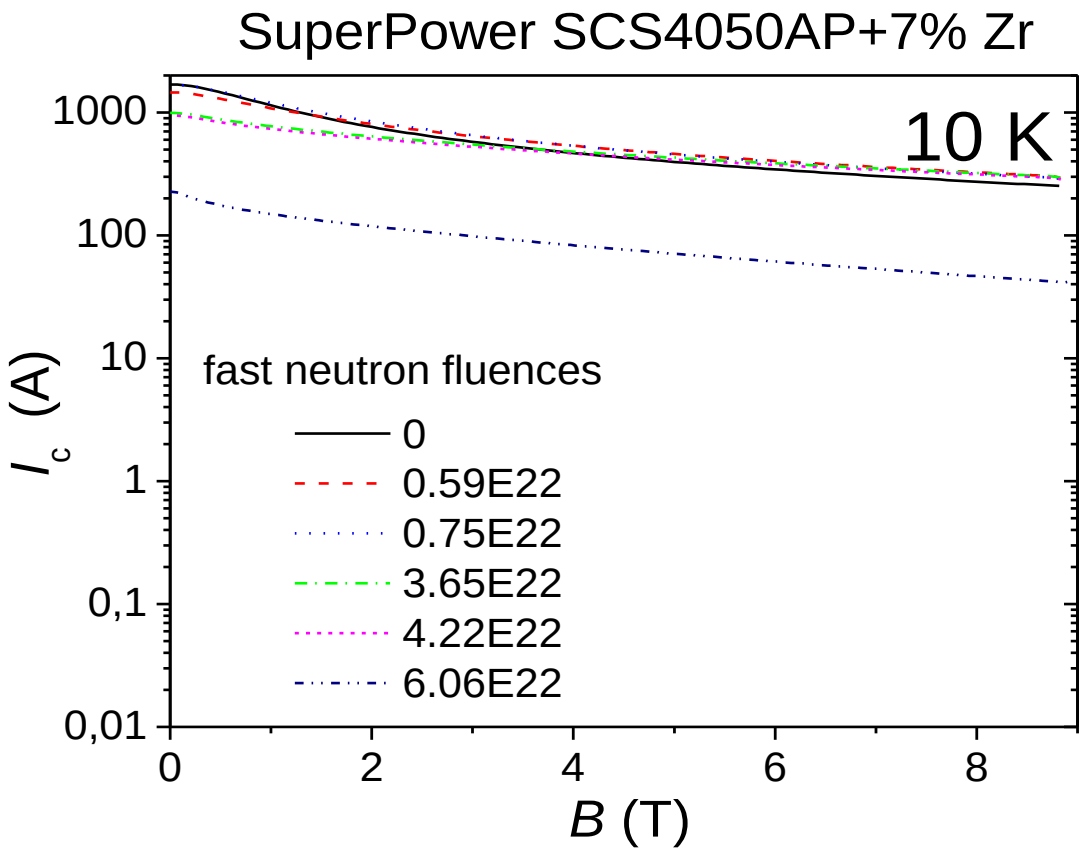


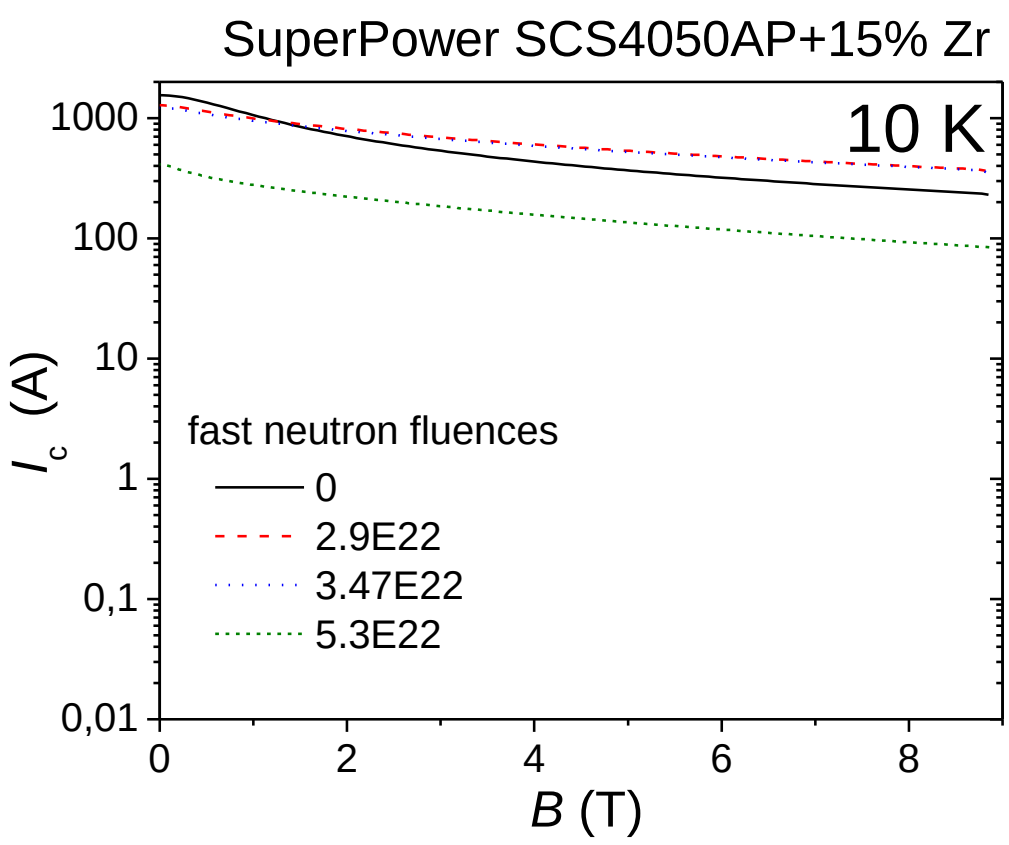
# $T_c$ of irradiated tapes



# $I_c$ of irradiated samples:

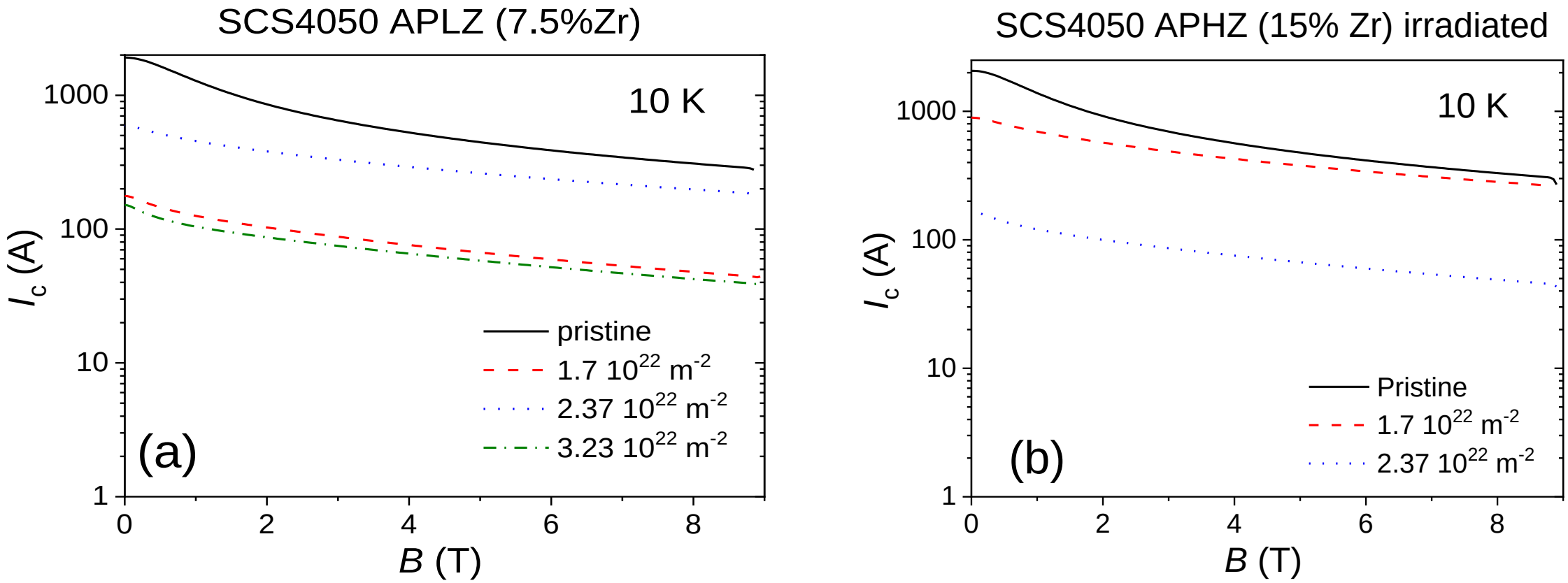
originally, the $I_c(B)$ curves crossed the pristine curve and merged at high fields



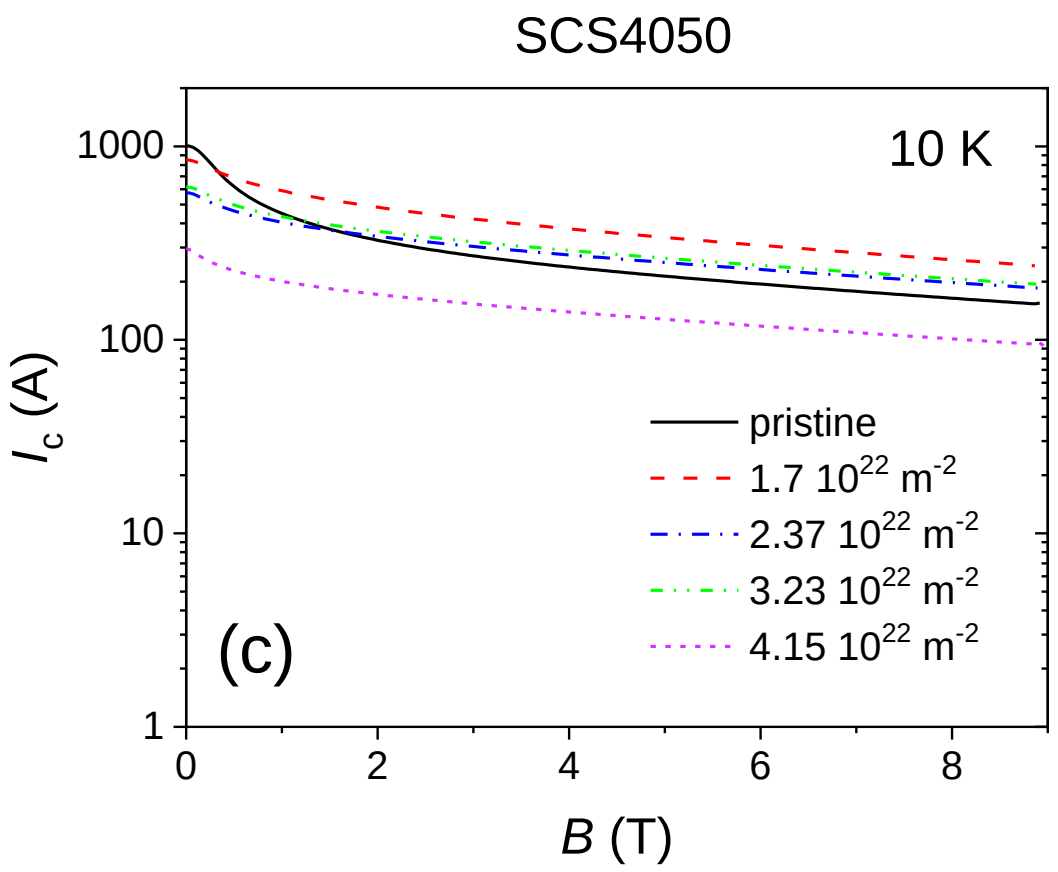
After the last irradiation (end of 2024), $I_c(B)$ curves disordered, did not merge at high fields.

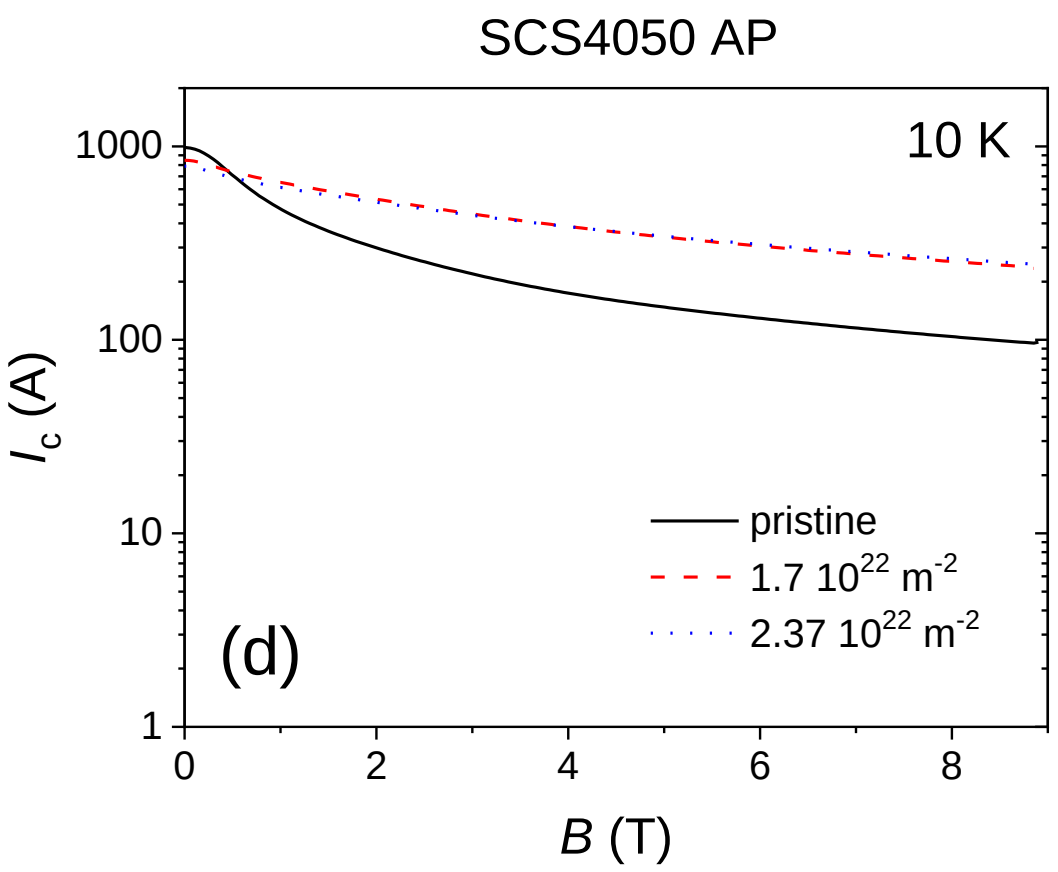
Effect of partial overheating observed




*The same for most samples without Zr*

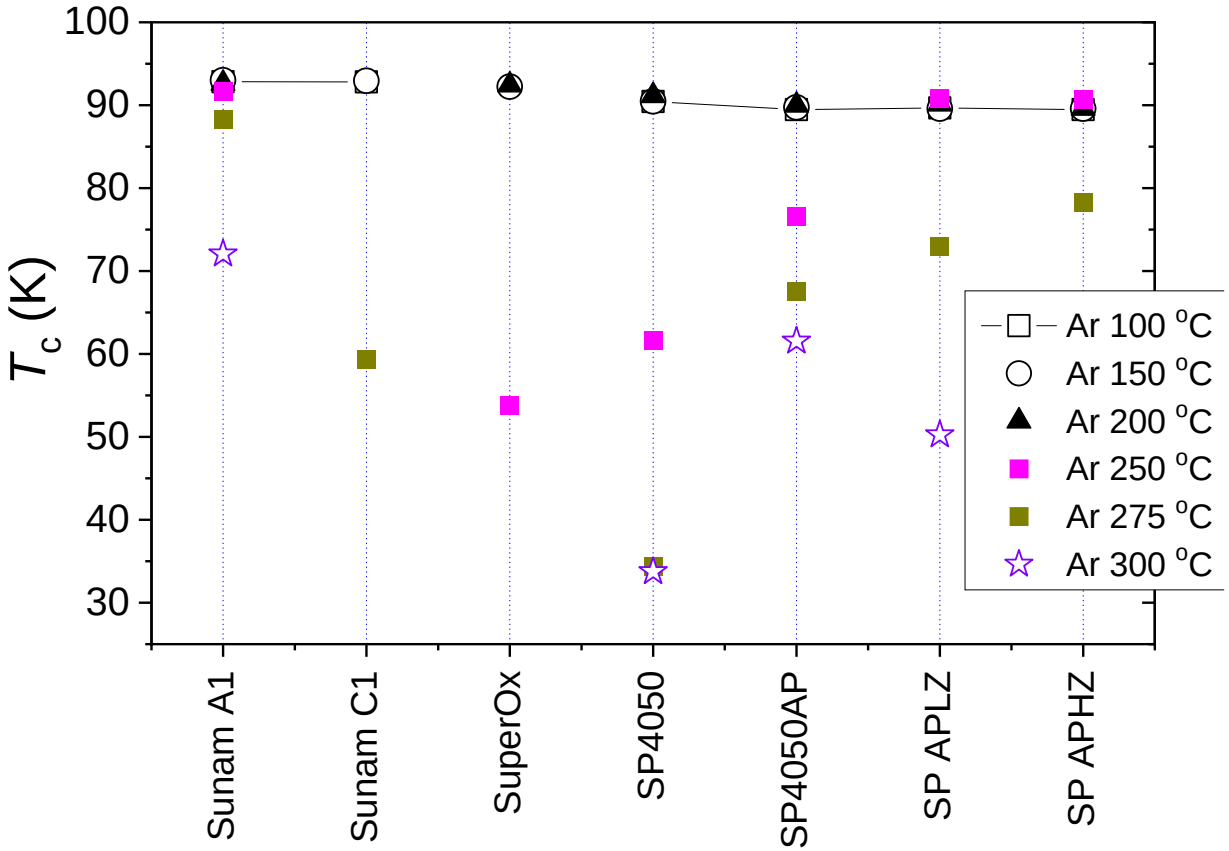
*If the curves merged at high magnetic fields, it was for too low fluences*



# Thermal annealing in Ar at temperatures 100 to 300 °C

## Samples with Ag and Cu sheath, $T_c$




1) Zr-doped samples (SuperPower)

$T_c$ stood unchanged up to 250 °C.

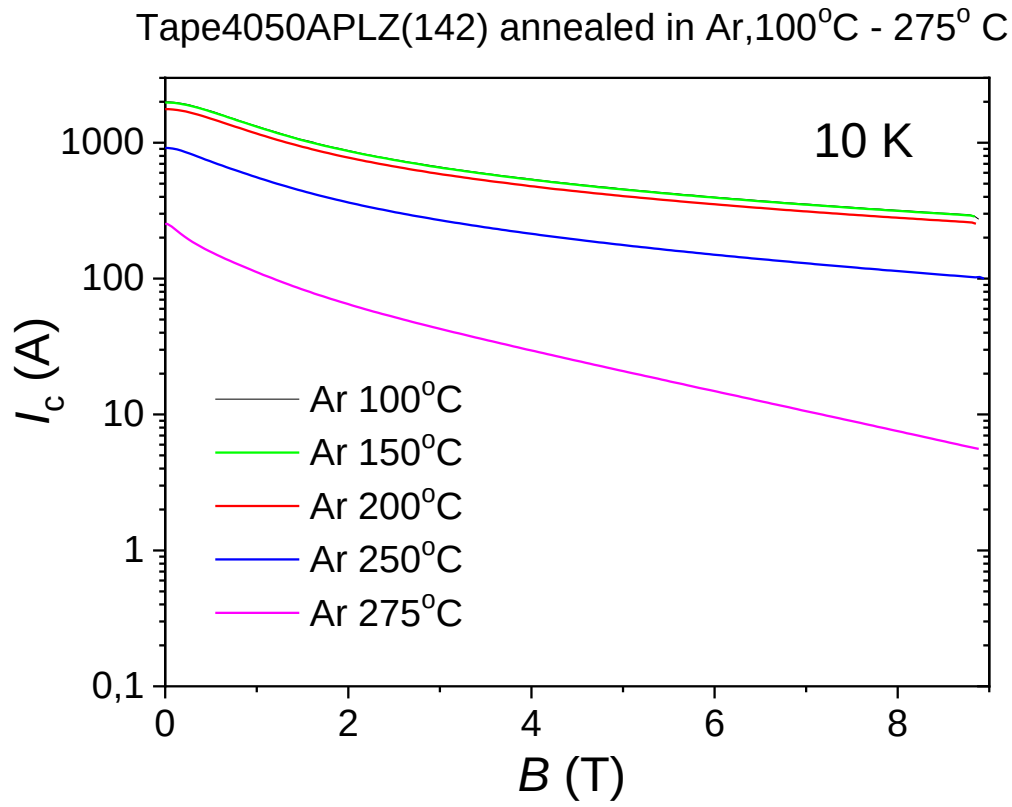
2) without Zr:

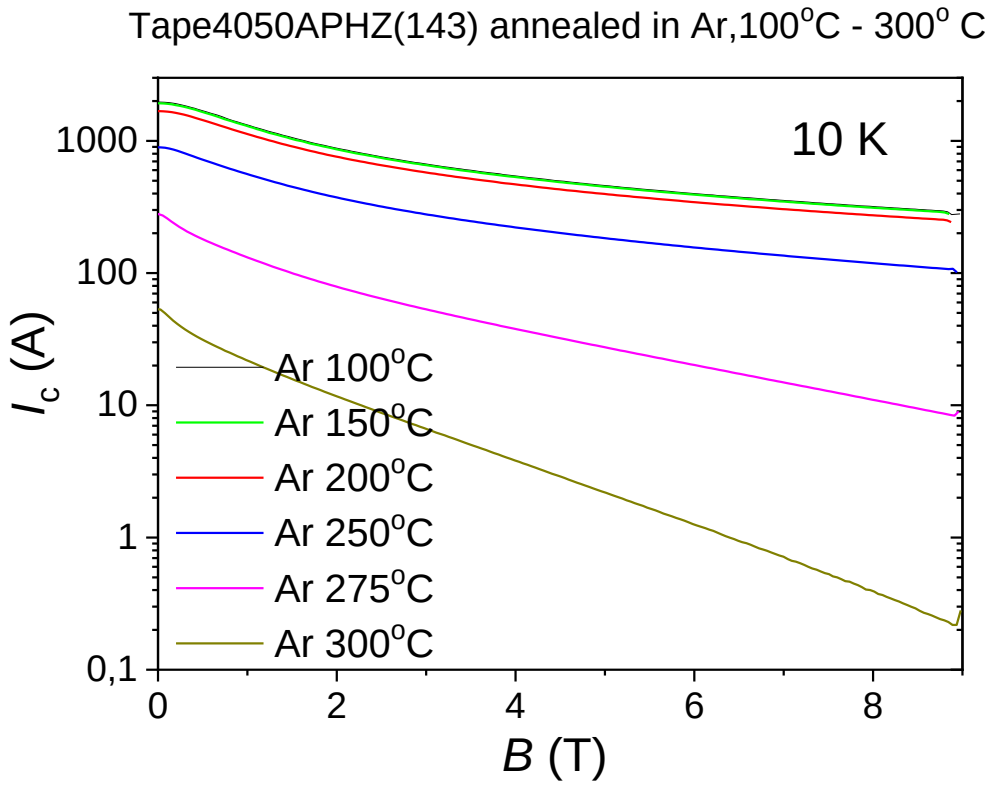
$T_c$ did not change up to 200 °C

Samples with Ag and Cu sheath, $I_c$ more sensitive to overheating than $T_c$.

1) The Zr-doped samples: $I_c$ degradation started above 200 °C (red curves), at 250 °C was still modest (blue curves).

The curves are nearly equidistant in the semilog format or open at high fields

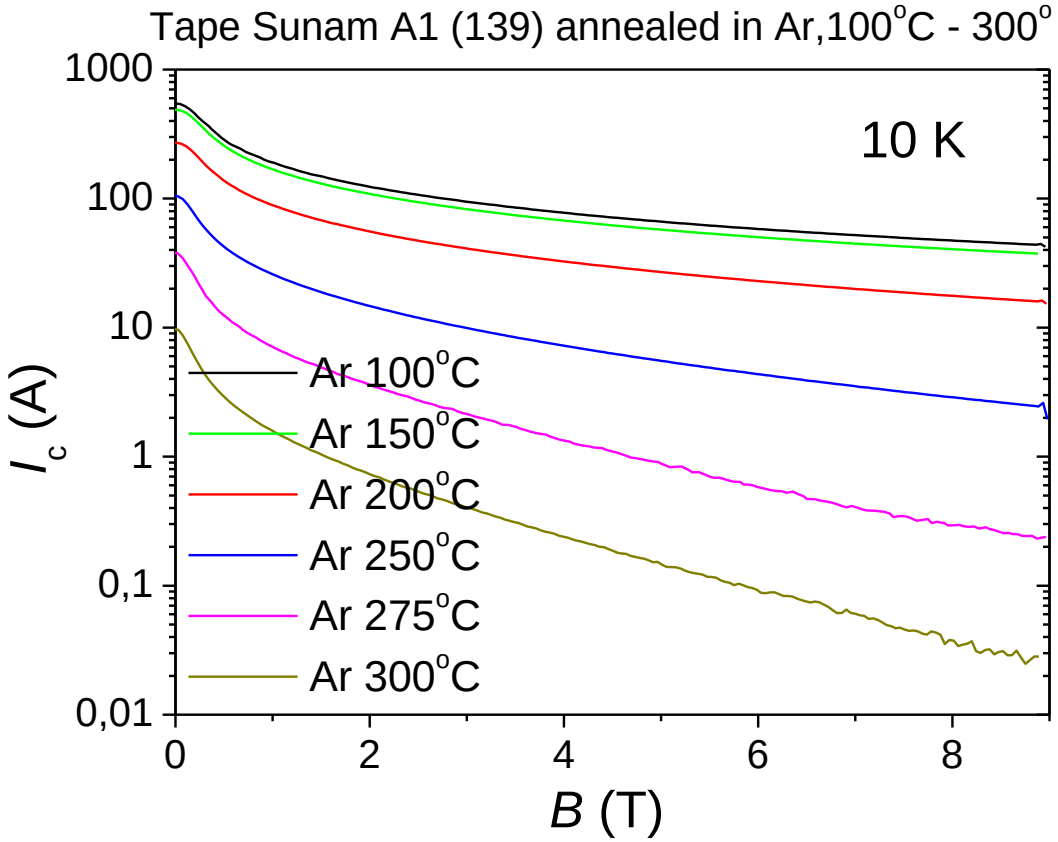


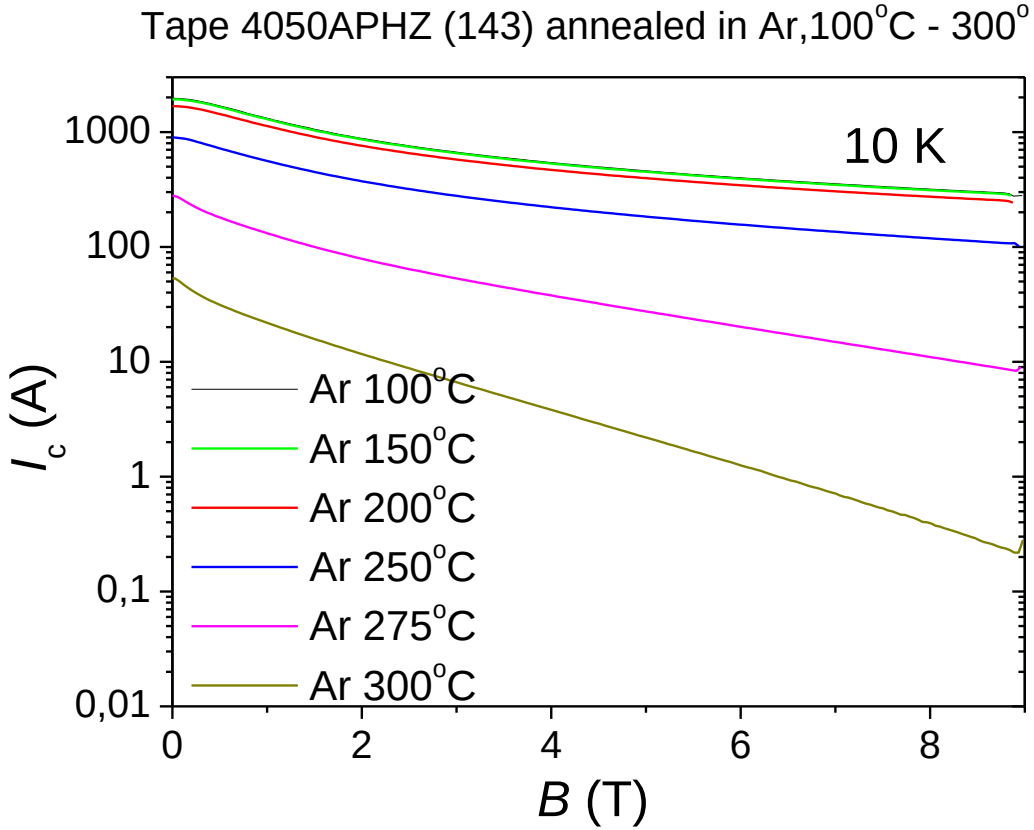



SuNAM sample A1: Ag-clad, without Zr

*In contrast to* $T_c$, $I_c$ started degrading already at 150 °C.

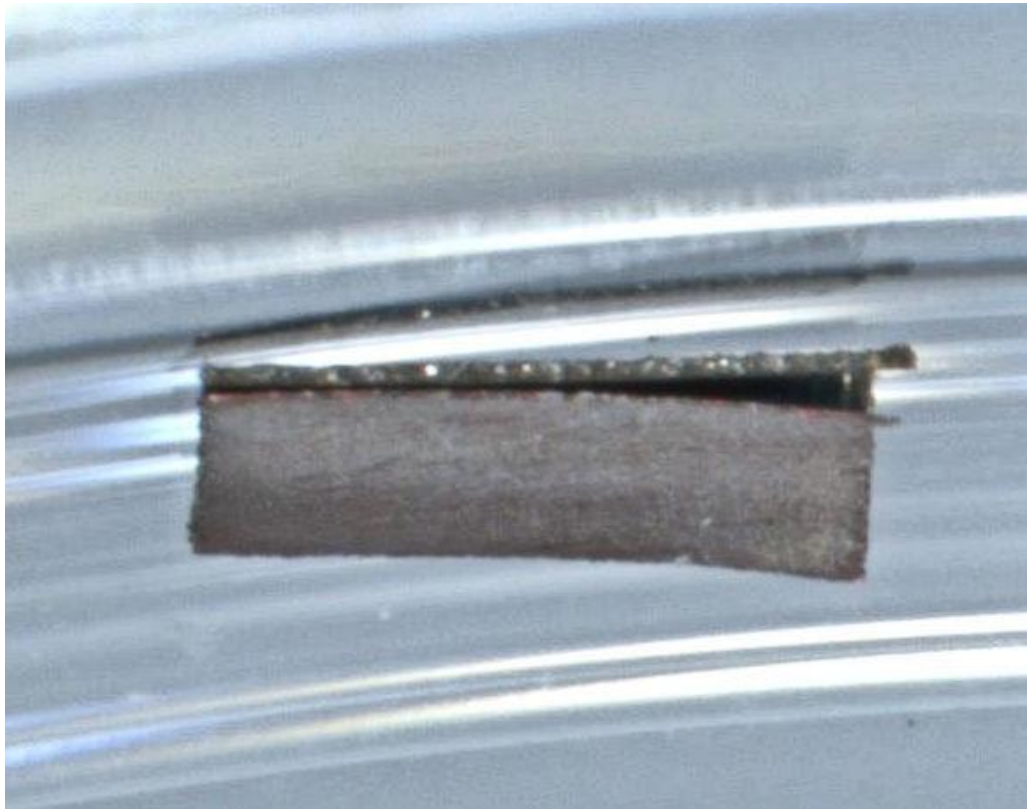
At 200 °C its degradation was comparable to Zr-doped samples at 250 °C

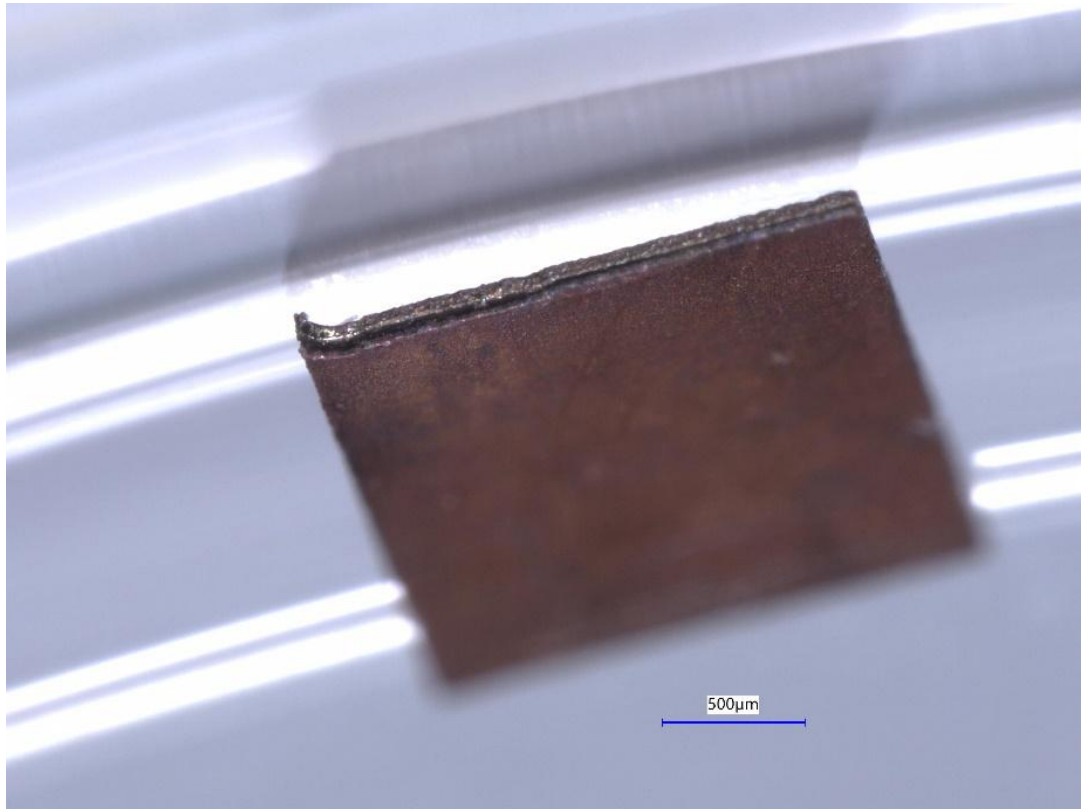


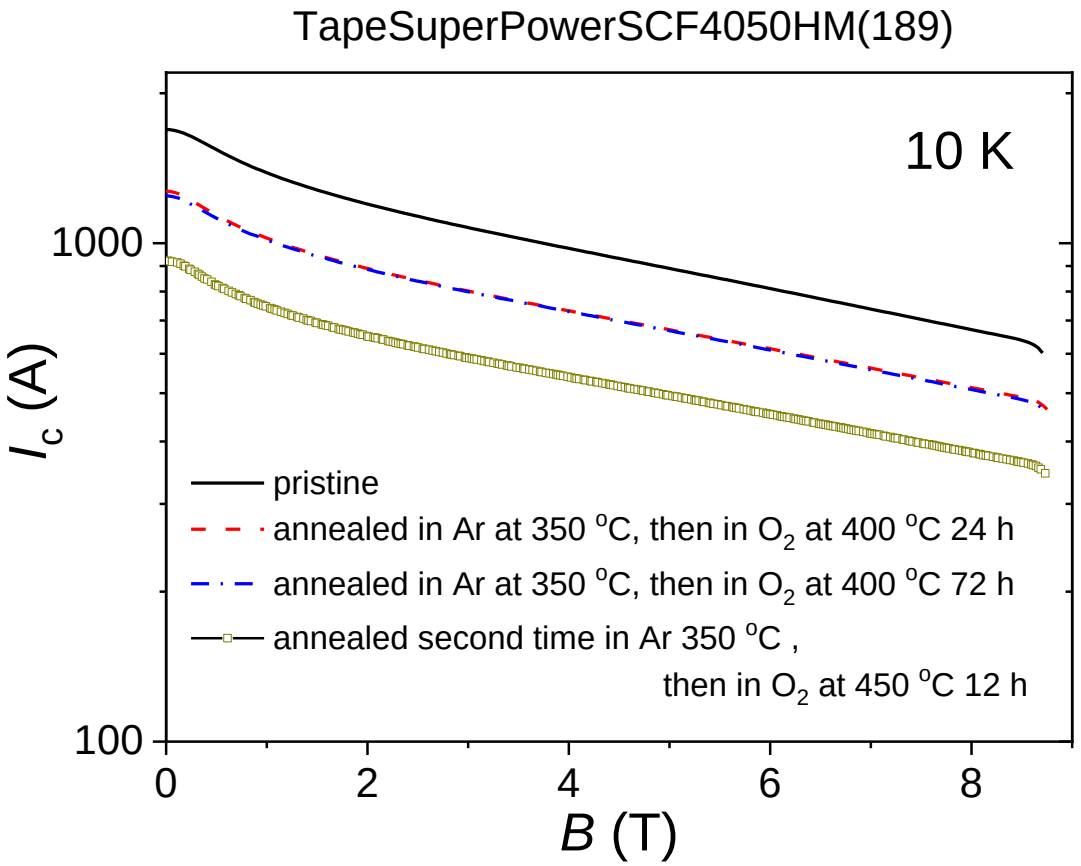

Main degradation mechanism is evidently loss of oxygen.

Samples with Ag+Cu sheaths annealed in Ar up to 300 °C were damaged also due to difference in thermal expansion of Ag and Cu, peeling off Cu.



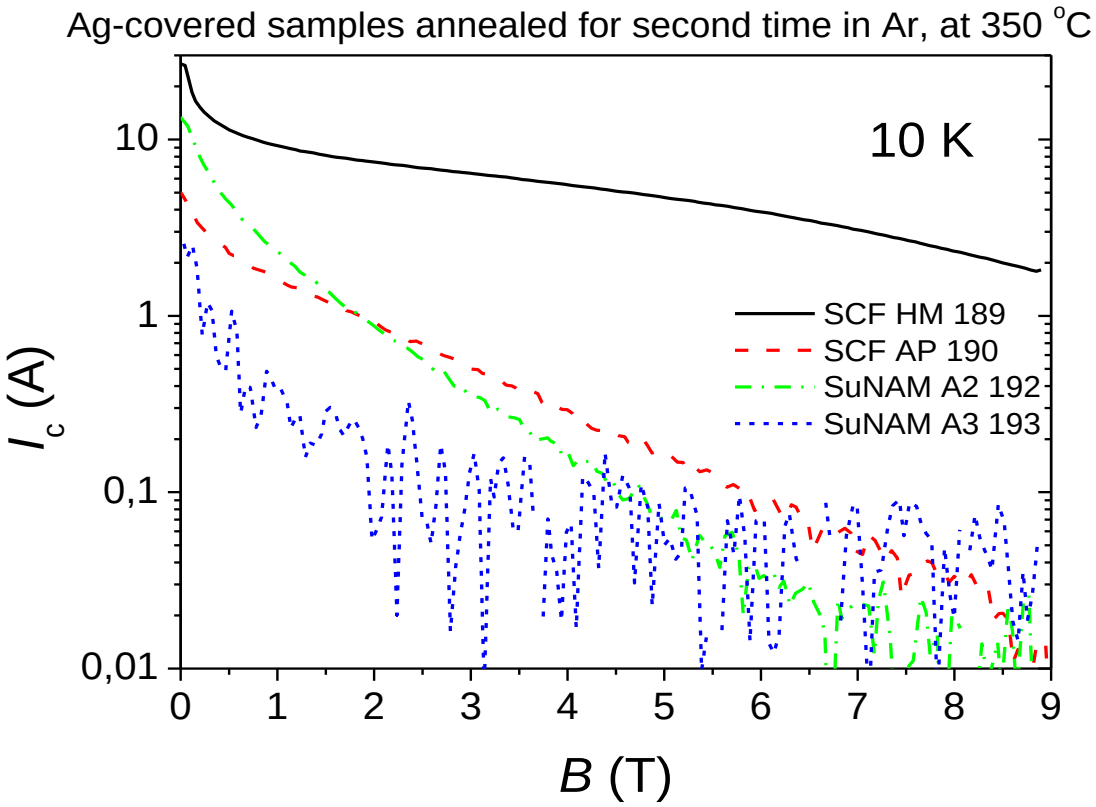


# Superconductivity recovery by annealing in $O_2$

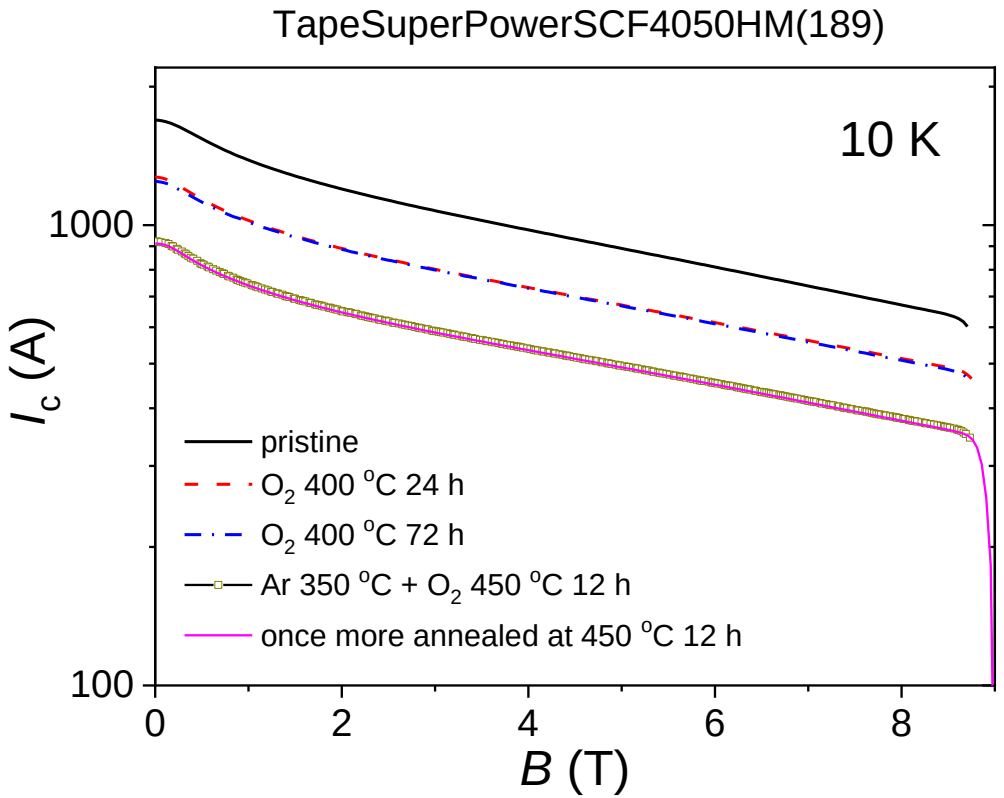



SCF 4050HM is Ag-covered, Zr- doped

## Degradation by annealing in Ar at 350 °C




## Recovery by annealing in $O_2$ at 400 °C



Oxygenation (superconductivity recovery) of Ag-clad samples degraded after heating in Ar to 350 $^{o}$C

1) Oxygenation at 400 $^{o}$C for 24 and 72 hours. In both cases identical 81 % recovery.

2) Total destruction by annealing in Ar at 350 $^{o}$C for 12 hours.

3) Oxygenation at 450 $^{o}$C for 12 and 24 hours. In both cases the same 72 % recovery.

## Conclusions :

1. In attempt to improve thermal contact of SCS samples with the cooled ampoule during irradiation experiments, the sample holder was re-designed.
2. $T_c$ indicated success (all values were above 82 K), however
3. $I_c(B)$ showed irregular thermal contact with the ampoule wall, different for each sample

4. SuperPower tapes doped by Zr and SuNAM Gd-123 tapes covered by Ag survived 250 °C.
5. At $T \geq 300$ °C, besides loss of oxygen, the Cu envelope peeled off.
6. The highest temperature for a safe use of "regular" tapes lies below 150 °C - 200 °C.
7. The tapes covered by Ag (SuperPower SCF with Zr and SuNAM A1-A4) survived annealing in Ar up to 350 °C, where the Ag layer of A4 peeled off.

## Possible tasks for 2026

1) Neutron irradiation without overheating on SCS and SCF samples

2) Correlation of magnetic measurements by SEM/TEM study.

3) Publication of the results.

Thank you for your attention.