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Improvement of the first flux entry field by laser post-treatment of the thin Nb film on Cu

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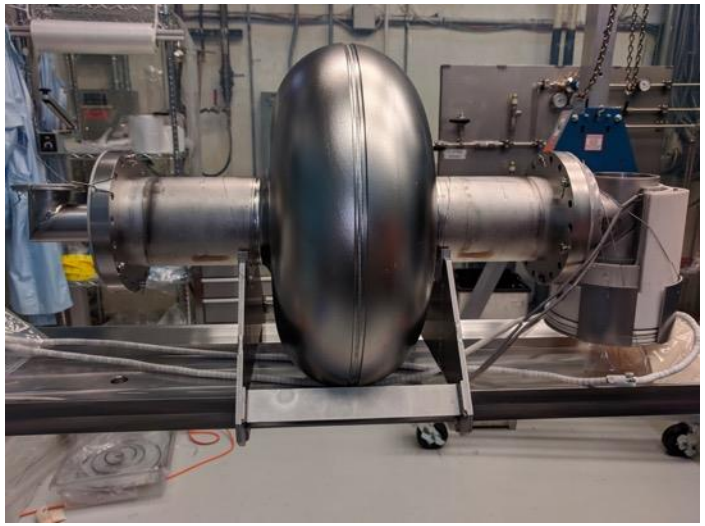
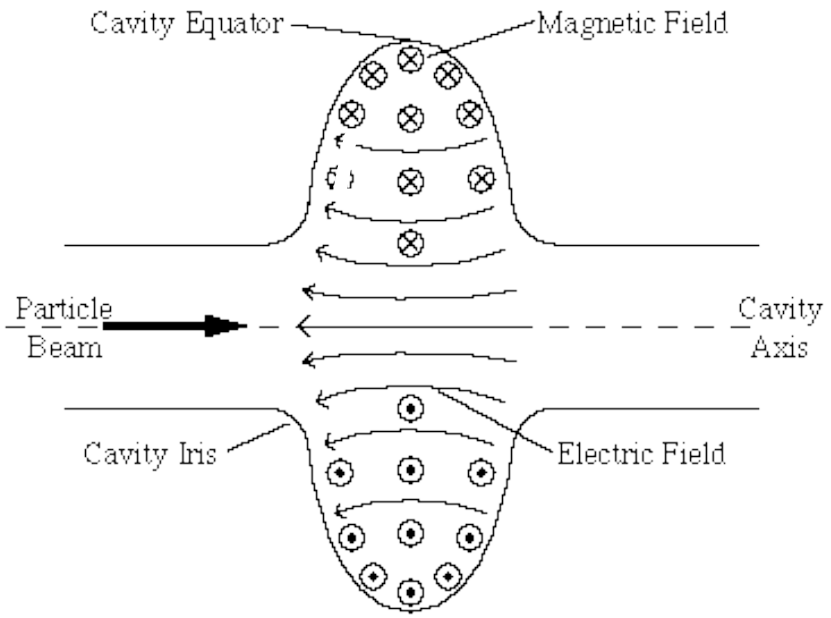
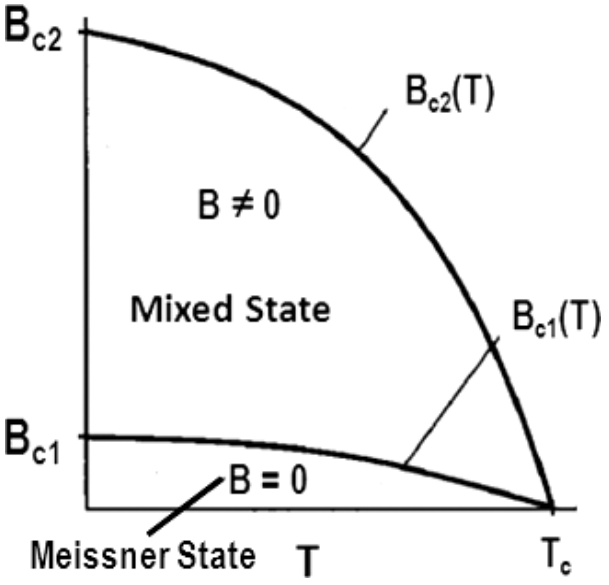
Introduction - SRF cavity





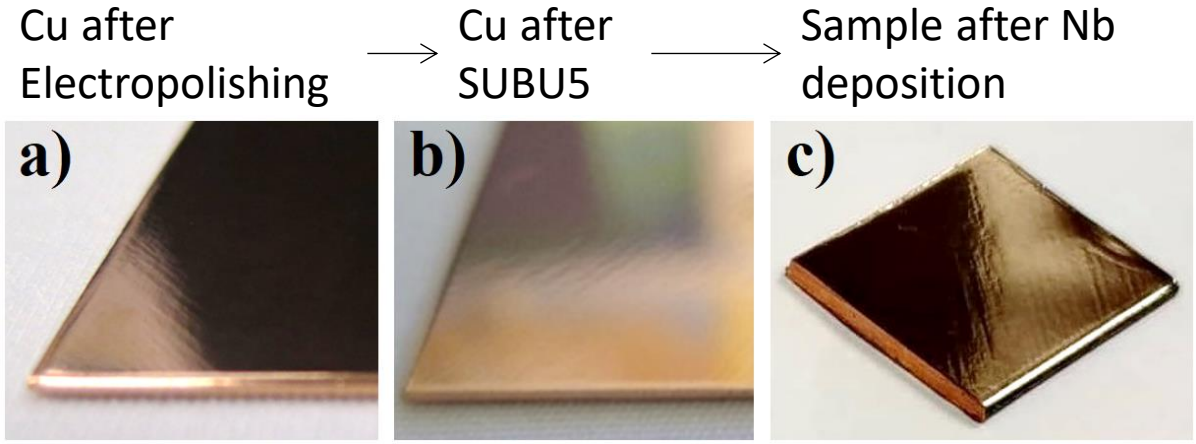


Introduction - cavity materials

- Bulk Nb - state of the art
- Thin Nb film on Cu substrate
  - advantages:
    - higher thermal conductivity (better thermal stability to avoid hot spots)
    - better mechanical stability (Cu support)
    - reduced sensitivity to Earth's magnetic field trapping
    - absence of undissolved inclusions
    - material cost (10 times cheaper)
  - has not achieved the performance of bulk Nb cavities yet
    - possible solution: laser post-treatment of Nb surface

Samples

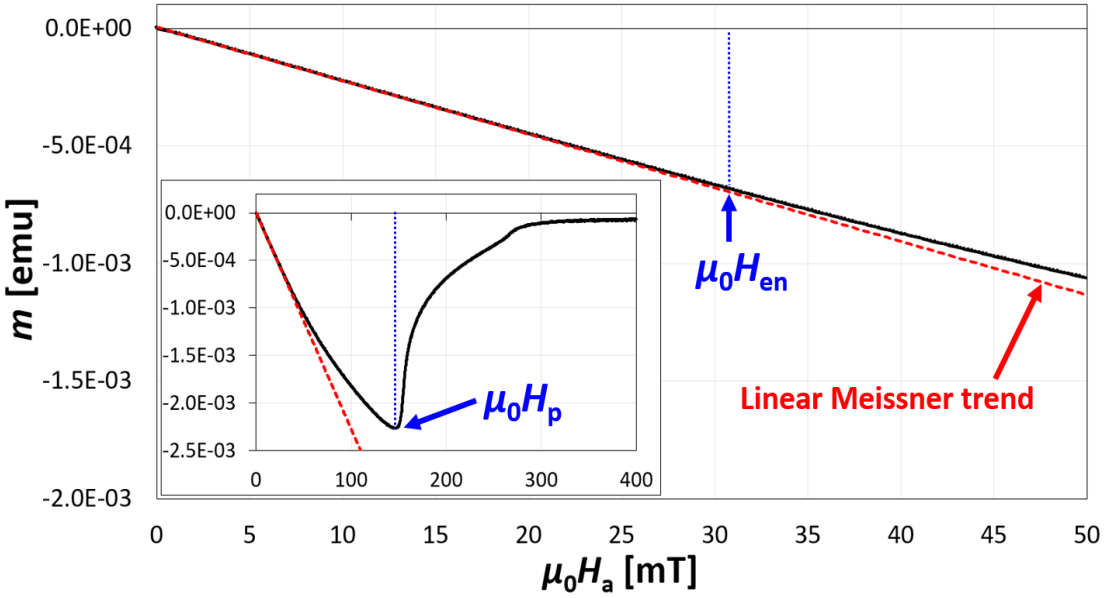
- Nb/Cu sample (Cu polished by EP+SUBU5, 3 µm thick Nb film deposited by magnetron sputtering)



- Sample cut to 5 pieces (2 x 2 mm): 1 reference and 4 irradiated by Nd:YAG laser with different energy doses (D4 = 140, D3 = 175, D2 = 233 and D1 = 350 J/cm^2).

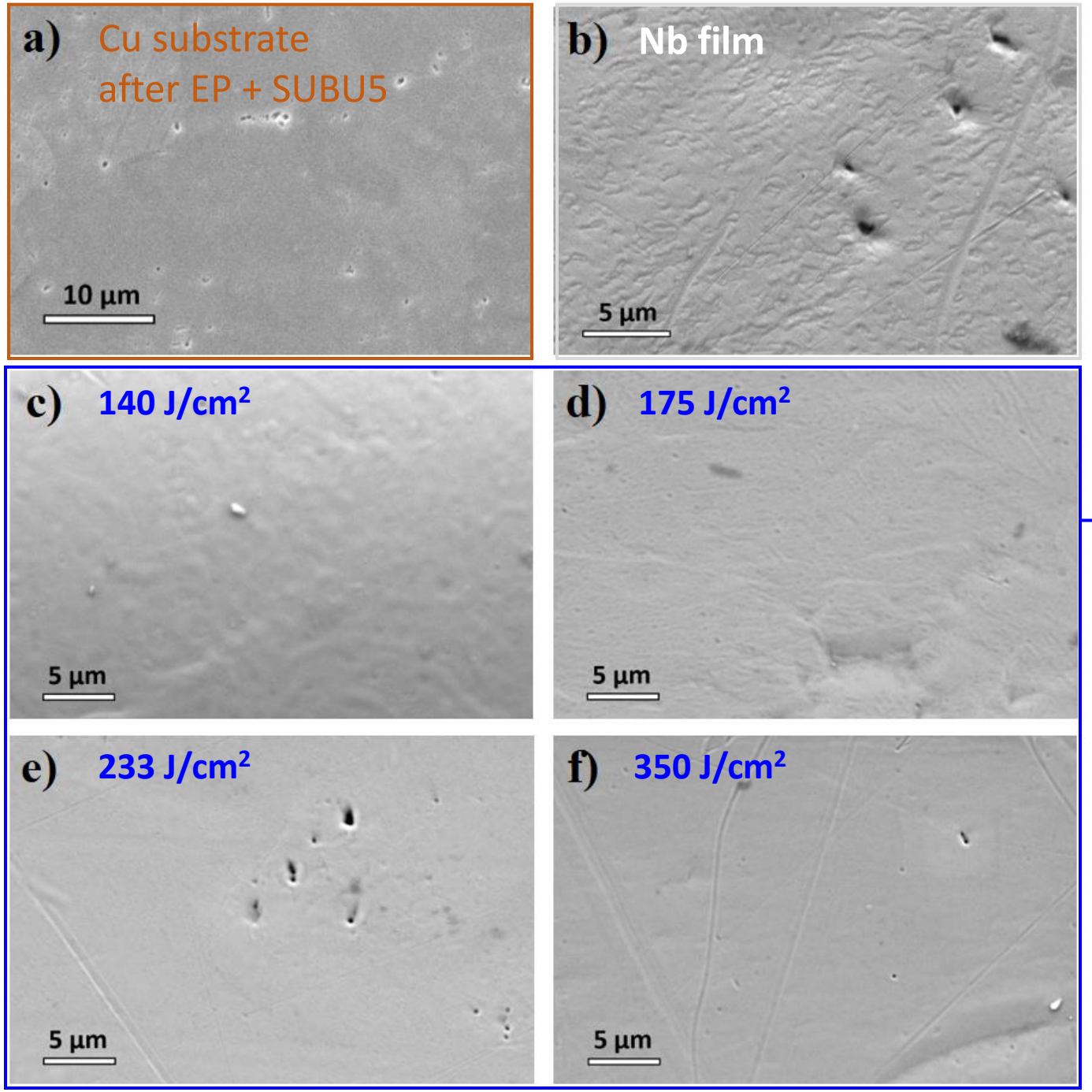
Measurements

- The structural properties were determined using SEM, AFM and XRD
- The SC properties were measured at 4.22 K in a DC parallel magnetic field using VSM



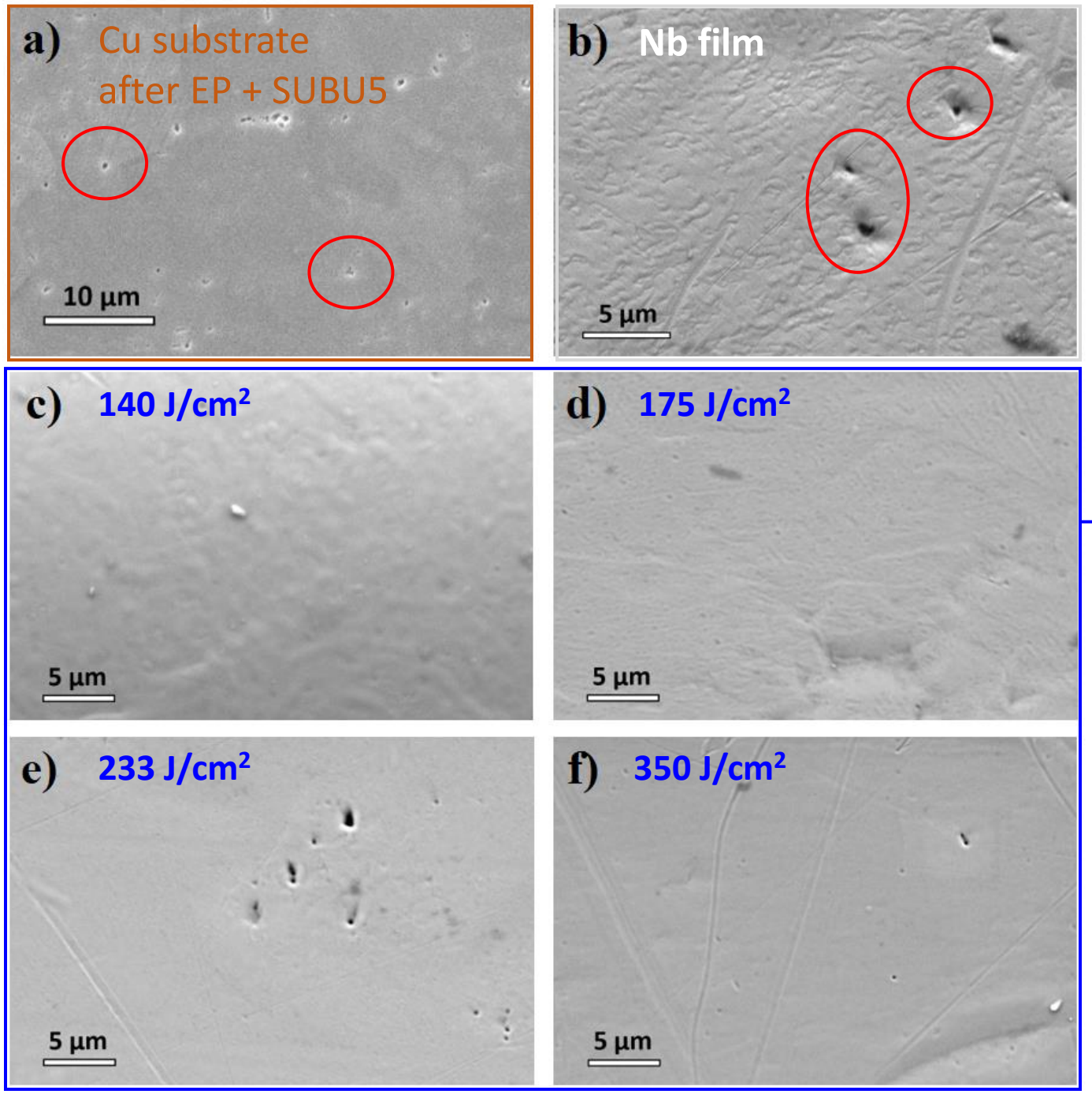
H_{en} - first magnetic flux entry field
- determined as a field at which relative difference between initial mag. curve and LMT reaches 2%

SEM



→ Nb film after Laser irradiation

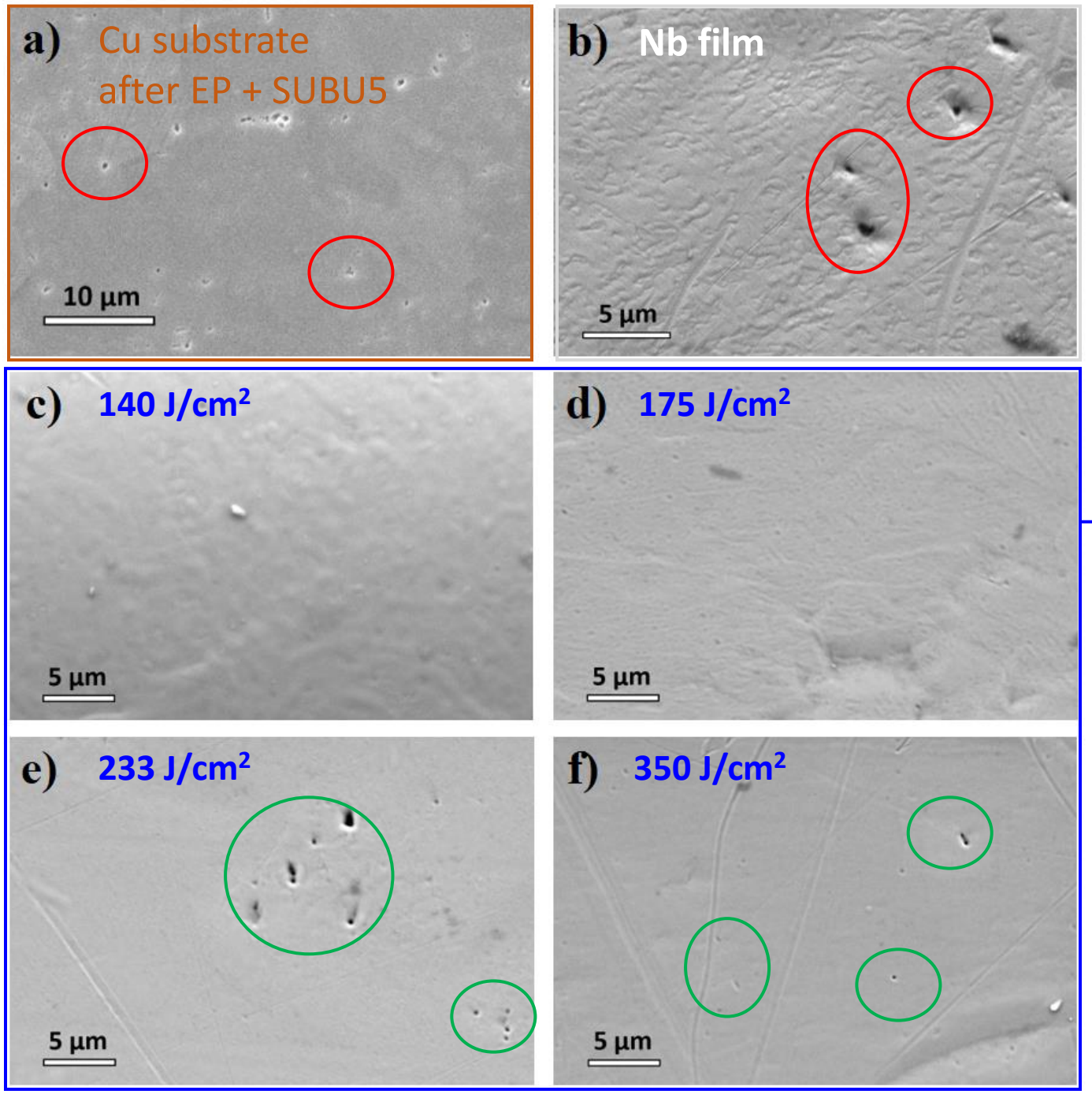
SEM



SUBU5 action

Nb film after
Laser irradiation

SEM



SUBU5 action

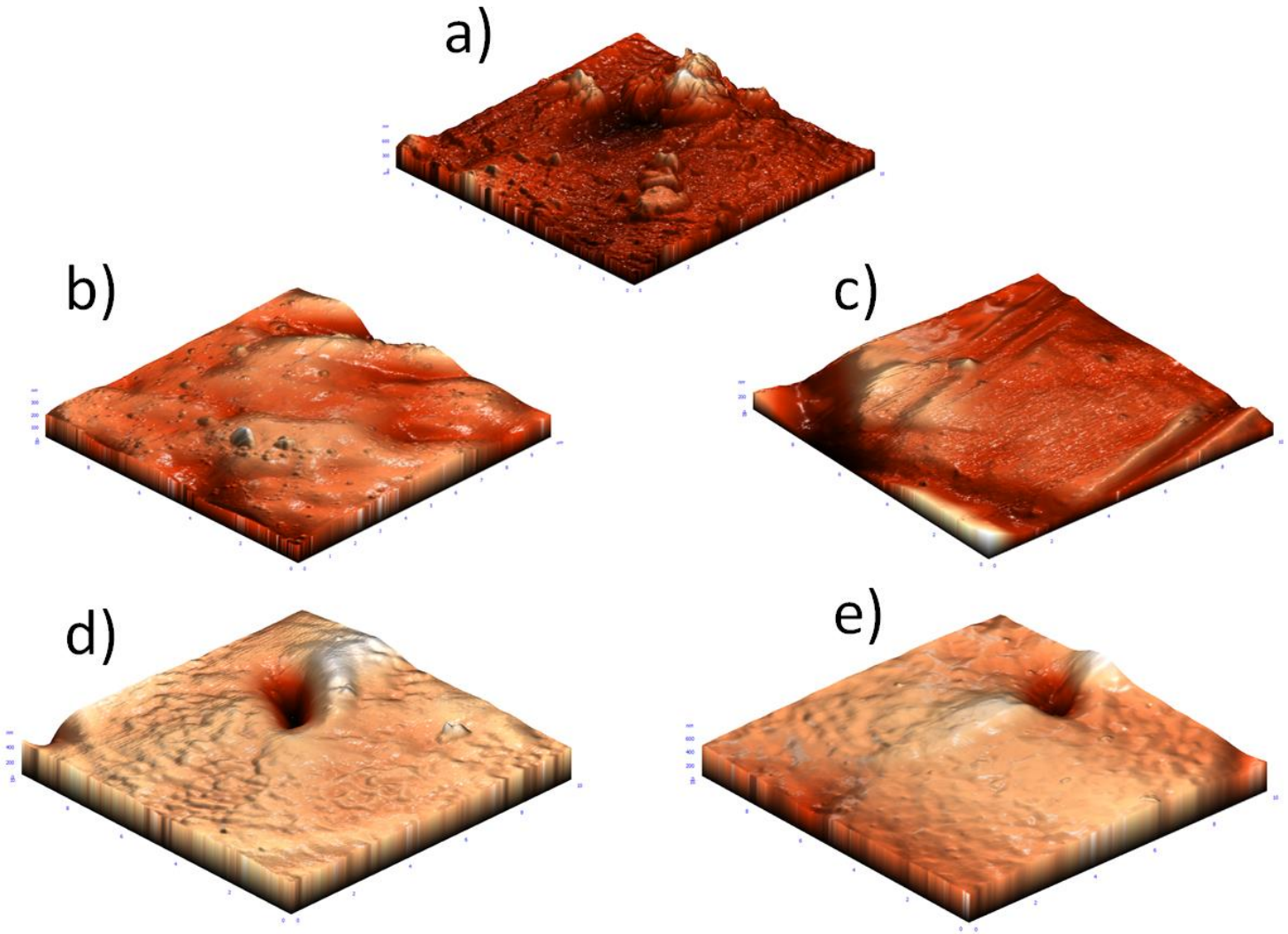
Nb film after Laser irradiation

Subsurface melting action

Surface roughness (AFM)

	Energy dose	R_a (nm)
a)	Non-irradiated	14.9 ± 2.1
b)	$D4 = 140\ \mathrm{J\ cm^{-2}}$	8.8 ± 1.9
c)	$D3 = 175\ \mathrm{J\ cm^{-2}}$	6.4 ± 1.3
d)	$D2 = 233\ \mathrm{J\ cm^{-2}}$	8.3 ± 1.5
e)	$D1 = 350\ \mathrm{J\ cm^{-2}}$	7.5 ± 2.0

Decrease
$\sim 50\%$



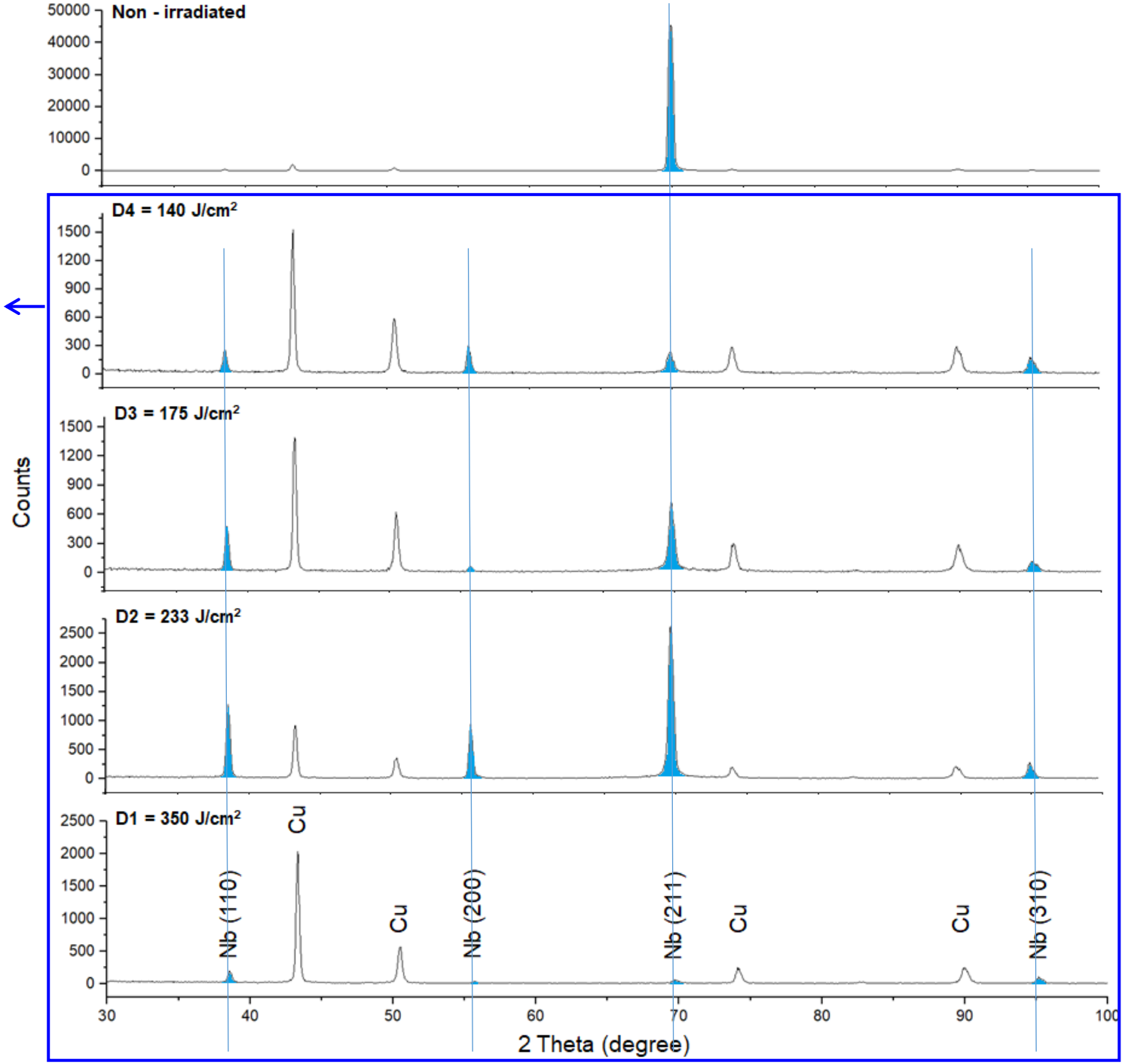
XRD

After Laser irradiation ←

Energy dose	a (nm)	Crystalline size (nm)
Non-irradiated	0.329755 ± 0.000003	26.4
$D4 = 140$ J cm^{-2}	0.32999 ± 0.00002	20.2
$D3 = 175$ J cm^{-2}	0.32998 ± 0.00001	20.6
$D2 = 233$ J cm^{-2}	0.329823 ± 0.000006	20.1
$D1 = 350$ J cm^{-2}	0.32995 ± 0.00003	19.7

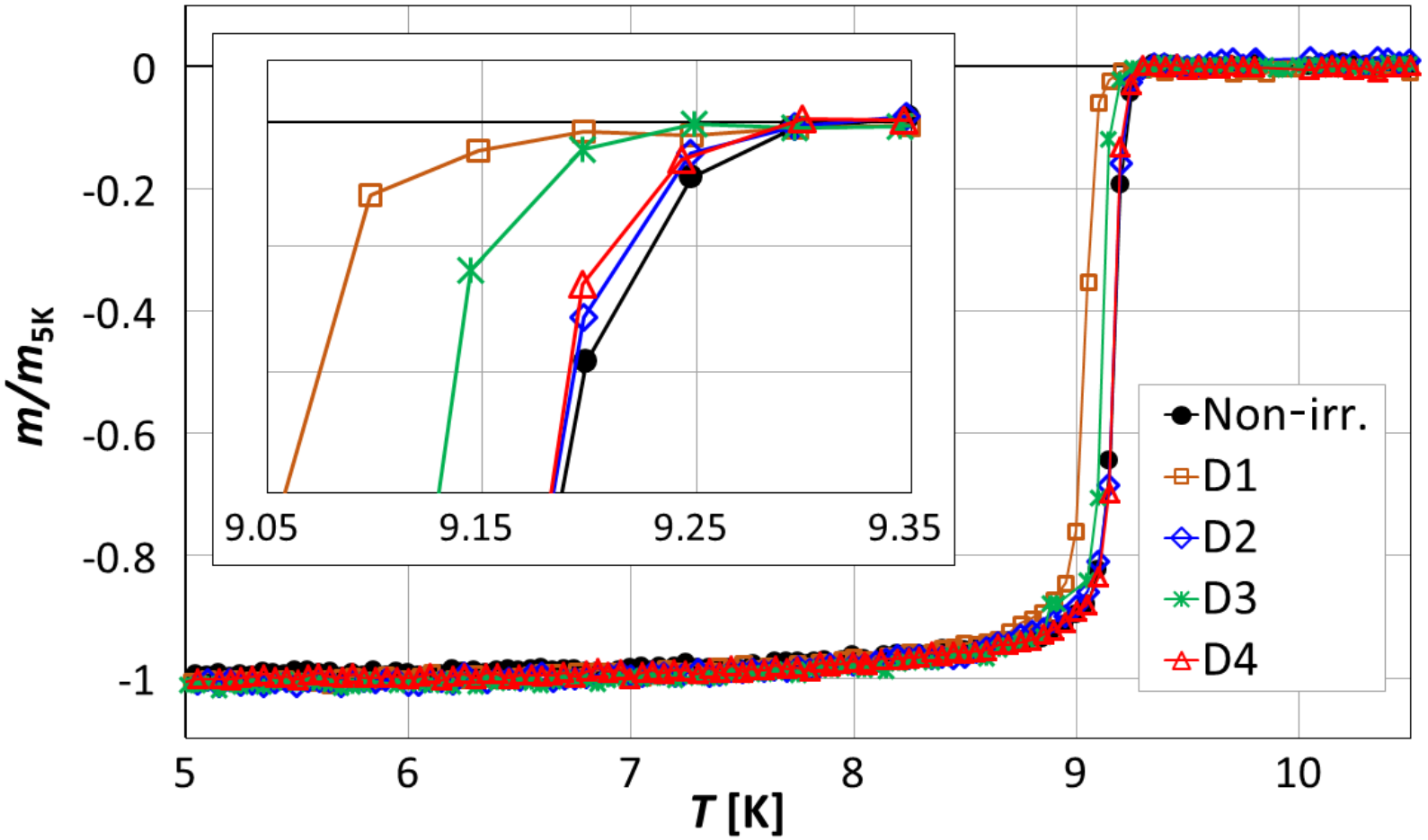
Weak increase
0.08% at max.

Decrease
20 – 25%



SC properties

Critical temperature T_c
- weak decrease after laser irradiation

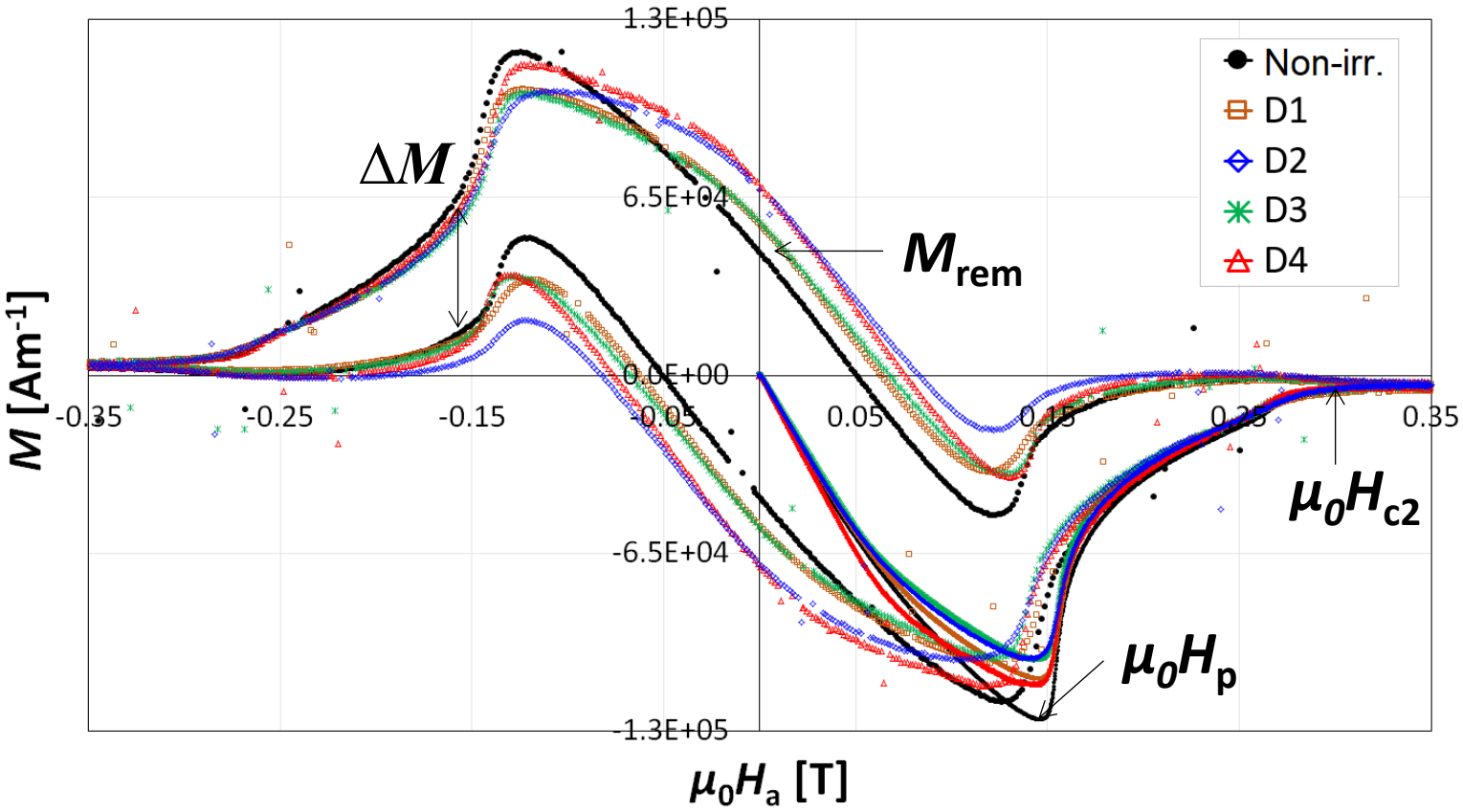


SC properties

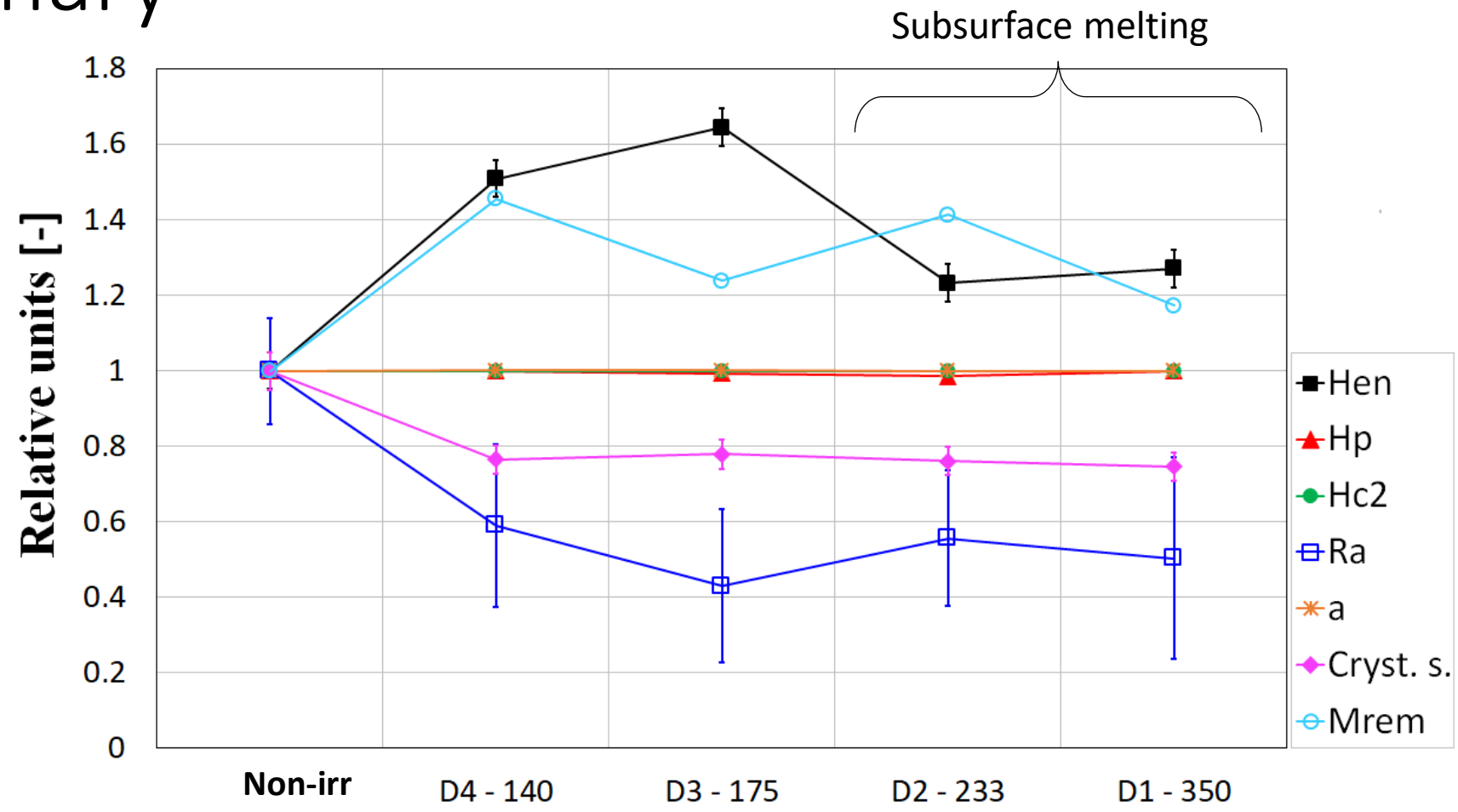
Energy dose	$\mu_0 H_{en}$ (mT)	$\mu_0 H_p$ (mT)
Non-irradiated	31.0 ± 1.5	145
$D4 = 140$ J cm^{-2}	46.8 ± 2.3	145
$D3 = 175$ J cm^{-2}	51.0 ± 2.5	144
$D2 = 233$ J cm^{-2}	38.2 ± 1.9	143
$D1 = 350$ J cm^{-2}	39.4 ± 2.0	145

Increase
D4: 51%
D3: 65%
D2: 23%
D1: 27%

practically no change



Summary



The relative comparison between H_{en}, H_p, H_{c2}, surface roughness R_a, lattice parameter a, Nb crystalline size and M_{rem} for different laser doses applied on the Nb surfaces

Highlights !

- Compared to previous studies:
  - The complex investigation of structural and SC properties of Nb/Cu samples was performed after laser post-treatment of Nb surfaces
  - 10 times higher laser energy doses were applied on Nb surfaces
- New findings provided by this work:
  - the laser irradiation is able to reduce or even remove the surface defects and increase the first flux entry field H_{en}
  - The higher energy doses causes subsurface melting and formation of hole defects resulted in stagnation of H_{en} increase
  - the laser caused reduction in surface roughness R_a, reduction in Nb crystalline size, increase in magnetization loop width ΔM and slight decrease of T_c
  - Practically no change in H_p, H_{c2} and lattice parameter was observed after laser irradiation

Thank you for attention