Grain Boundary Flux Penetration in Niobium Sheet Sampled Across the Cavity Production Route

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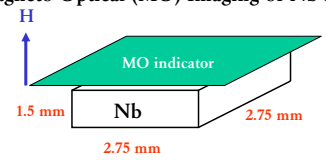
Issue

Cavity performance is very sensitive to Nb surface quality and preparation. Premature flux penetration is one mode of cavity degradation – here we focus on how the cavity preparation route impacts flux penetration properties.
Does the existing process optimize grain rather than grain boundary properties?

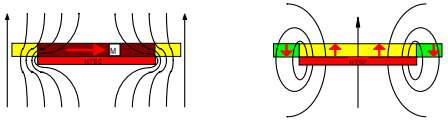
Experiment

Magneto optical (MO) and magnetization measurements were used to study the global and local magnetization of Nb samples taken through a cavity "optimization process" on cavity-quality fine grained (regular) sheet and on weld regions (large grains) samples.
All measurements were made at 7K.

Magneto Optical (MO) Imaging of Nb Samples



Two types of MO imaging



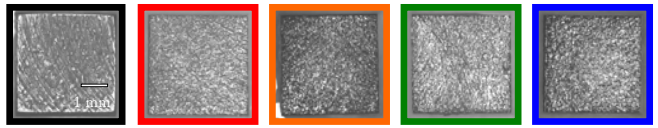
Zero field cooled (ZFC) to the superconducting state, then field applied.

Field cooled (FC) into the superconducting state, then field reduced to zero.

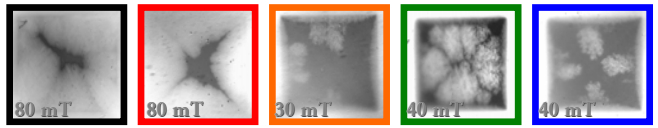
Process sequence

Cold work + degrease | ... + 100 min etch | ... + 750°C HT | ... + 20 min etch | ... + 120°C bake

Regular samples



Optical images of surface and machine marks on samples

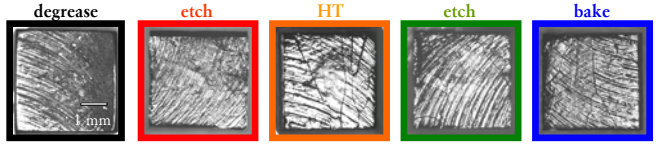


ZFC images show increasingly irregular flux penetration

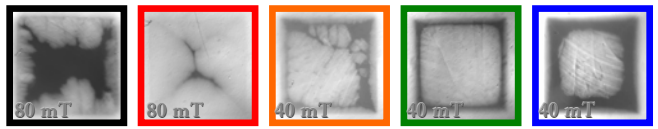
H=0 FC images after cooling to 7 K in H ≥ H_{c2} = 110 mT show rather uniform flux distribution

Weld samples

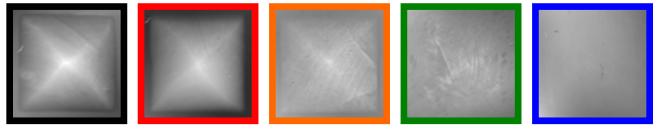
Cold work + degrease | ... + 100 min etch | ... + 750°C HT | ... + 20 min etch | ... + 120°C bake



GBs are visible through the surface machining marks

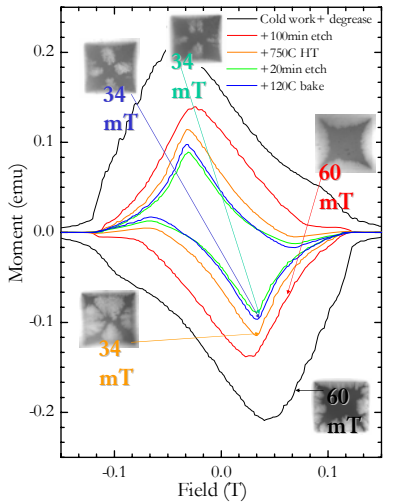


ZFC images show increasingly irregular flux penetration



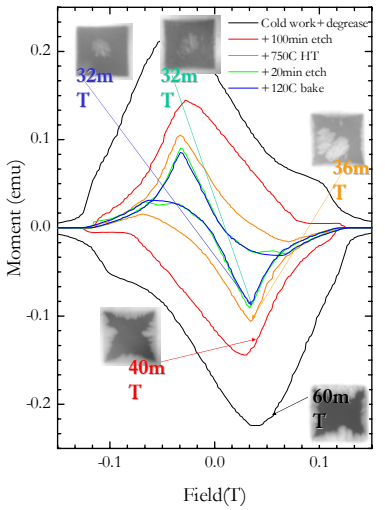
H=0 FC images after cooling to 7 K in H ≥ H_{c2} = 110 mT show initially uniform flux distribution, which is progressively more perturbed in later process steps

Regular samples (small grains)



Magnetization curves with MO images taken at marked fields

Weld samples (large grains)



Summary

1. FC flux penetration state is much more uniform than when field is applied from the ZFC state – the sample surface is clearly implicated for locally varying flux penetration in the superconducting state.
2. The "optimization" (etch, HT at 750°C, etch, bake) reduces magnetization hysteresis, much of which comes from the surface, but enhances non-uniform flux penetration.
3. Flux penetration along GBs is particularly clear in the large grain weld samples
4. Comparison of ZFC and FC images of the fully processed (120° C bake) weld samples shows perturbations of the local field in both cases – some GBs preferentially admit flux in the ZFC state and distort the induced current flow patterns which appear after reducing H to zero on field cooling.
5. The chemical etching processes developed for cavities enhance surface properties of grains but can degrade some grain boundary properties.