ANALYSIS OF THE TOPOGRAPHIC TRANSFORMATION OF NB SURFACE UNDER CONTROLLED EP CONDITIONS

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Abstract:

As the field requirements of niobium SRF cavities approach fundamental material limits, there is increased interest in understanding the details of topographical influences on realized performance limitations. In this study, a set of samples representing 24 different starting conditions used in cavity processing has been assembled. This set includes fine grain, large grain, and single crystal Nb samples under EBW'ed, hand ground, and CBP with a variety of stones, the latter provided by KEK colleagues. Sample topography has been carefully characterized in both the initial condition and after removal of 30 microns via controlled-parameter EP. A power spectral density (PSD) method based on Fourier analysis of surface topography [1], stylus profilometer and atomic force microscopy (AFM) is used to distinguish the scale-dependent smoothing effects. The detailed topographic transformation of Nb surface with the varied starting state Nb surface (CBP/ EBW) is reported. This study will help to identify optimum EP parameter sets for controlled and reproducible surface levelling of Nb for cavity production.

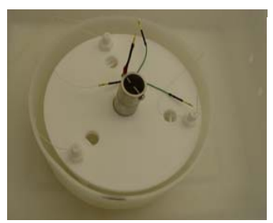
Starting Conditions Matter For SRF Nb Cavities

24 Different Material and Preparation Conditions

No.	Type	EBW	Treatment Details
Jlab-1	FG	No	Degreasing + UPW ultrasonic rinse + light BCP (~ 5 μm removal) + UPW ultrasonic rinse
Jlab-2	LG	No	Same as above
Jlab-3	SC	No	Same as above
Jlab-4	LG	Yes	Degreasing + UPW ultrasonic rinse + Iris EBW + Degreasing + UPW ultrasonic rinse+0.1μm grit grinding + Degreasing + UPW ultrasonic rinse
Jlab-5	FG	Yes	Same as above
Jlab-6	SC	Yes	Same as above
Jlab-7	LG	Yes	Degreasing + UPW ultrasonic rinse + Equator EBW + Degreasing + UPW ultrasonic rinse
Jlab-8	LG	Yes	Same as above
Jlab-9	LG	Yes	Same as above
Jlab-10	FG	Yes	Same as above
Jlab-11	FG	Yes	Same as above
Jlab-12	FG	Yes	Same as above

No.	Type	EBW	Treatment	CBP Details: Rough stone	Middle stone-1	Middle stone-2	Fine stone
KEK-1	FG	No	CBP(rough only)+degreasing	6hrs			
KEK-2	FG	No	CBP(fine)+degreasing	6hrs	6hrs	6hrs	6hrs
KEK-5	FG	Yes	CBP(rough only)+degreasing	6hrs			
KEK-6	FG	Yes	CBP(fine)+degreasing	6hrs	6hrs	6hrs	6hrs
KEK-8	LG	No	CBP(rough only)+degreasing	6hrs			
KEK-9	LG	No	CBP(fine)+degreasing	6hrs	6hrs	6hrs	6hrs
KEK-14	LG	Yes	CBP(rough only)+degreasing	6hrs			
KEK-15	LG	Yes	CBP(fine)+degreasing	12hrs*	6hrs	6hrs	6hrs
KEK-12	SC	No	CBP(rough only)+degreasing	6hrs			
KEK-13	SC	No	CBP(fine)+degreasing	6hrs	6hrs	6hrs	6hrs
KEK-17	SC	Yes	CBP(fine)+degreasing	18hrs*	6hrs	6hrs	6hrs
KEK-18	SC	Yes	CBP(rough only)+degreasing	6hrs			

(*) renew stone each 6 hrs



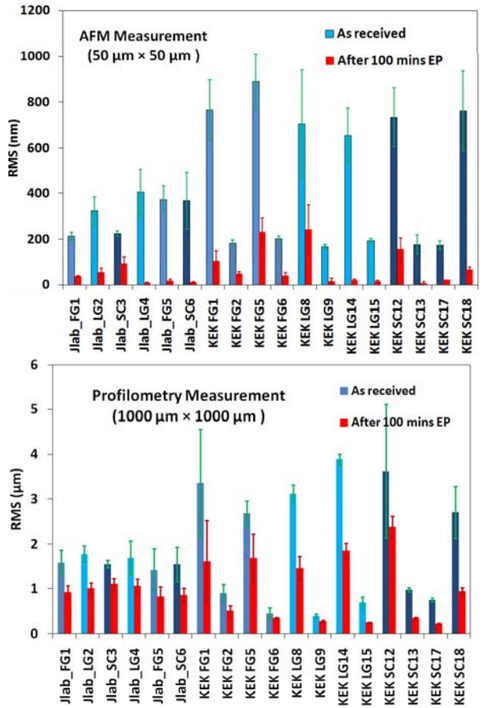
BCP : 1:1: 2 HNO_3 (69%), HF (49%) and H_3PO_4 (85%), 23±2˚C; EP: 1:10 HF (49%) and H_2SO_4 (96%), 30±1˚C, 10 volts. For EP, three Nb disk samples were mounted to a customized sample holder subjected to 100 minutes of EP (~30±3μm) at 10V simultaneously

Surface Topography I -Optical Microscopy (Fine Grain)

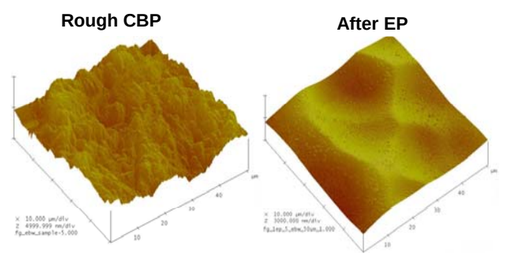
The transformation of a defect on EBW single crystal sample (KEK-17) left by CBP.

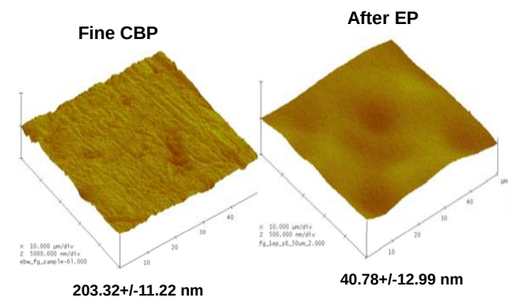
All electron beam welded CBP Nb samples have shown localized defects after EP and some of them were not observable before EP. The detailed mechanism for the appearance of those localized defects is under study. No such defects were observed from hand ground EBW Nb samples before or after EP.

Surface Topography-II
Atomic Force Microscopy and Stylus Profilometer



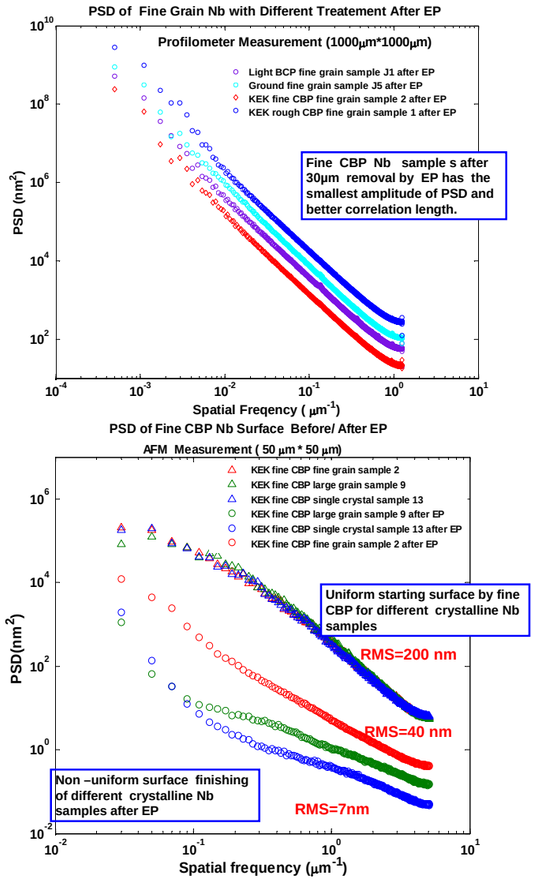
AFM images of fine grain Nb samples





Fine CBP provides a very reproducible smooth surface as compared with other treatments. After 100 minutes EP (~30±3μm removal), fine CBP Nb surface achieves the best surface finishing.

Surface Topography III –Power Spectral Density



The fine grain Nb is rougher than single crystal after EP suggests a chemical etching occurs in parallel with the desired EP brightening process at the regulated 30˚C

Conclusion:

In this study, the topographical transformation of 24 different starting processing conditions Nb surface has been systematically characterized by optical microscopy, AFM, SP and analyzed by PSD before and after a well-controlled EP. The statistical results show the fine CBP may provide a reproducible starting surface, and could to be transformed to a nano-smooth surface finishing by only a ~ 30 micron removal. These studies provide an useful data for the optimization EP of niobium cavities, and the knowledge is expected to convey to engineering application to single and multi-cell cavities.

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