Genesis of topography in buffered chemical polishing of niobium for application to superconducting radiofrequency accelerator cavities

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Abstract

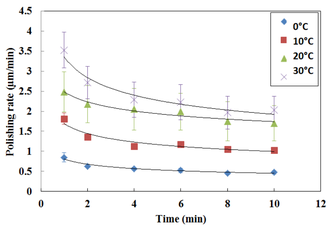
Topography arising from the final etch step in preparing niobium superconducting radiofrequency (SRF) accelerator cavities is understood to significantly impact cavity performance at high field levels. This study investigated the effect of process temperature and time on the etch rate and topography arising from the widely-used buffered chemical polishing (BCP). This study aims to understand more thoroughly the genesis of topography in BCP of polycrystalline niobium. It was found that the etch process is controlled by the surface reaction; and that the etch rate varies with crystallographic orientation. The familiar micron-scale roughening necessarily results. Gas evolution has an impact, but is secondary. The major outcome is that surface smoothness comparable to EP appears to be inherently unachievable for polycrystalline niobium using BCP, setting an upper limit to the gradient for which it is useful.

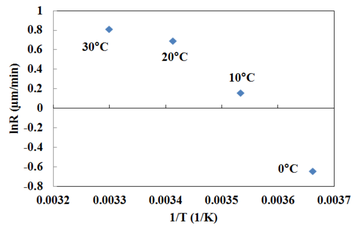
Experiment

Experiments	Temperature	Duration	Orientation
Fine grain	0-30 °C	1-20 min	Face up/down/sideway
Bi-crystal	RT	12 min	Face up
Single crystal	RT	accu. 90min	Face up

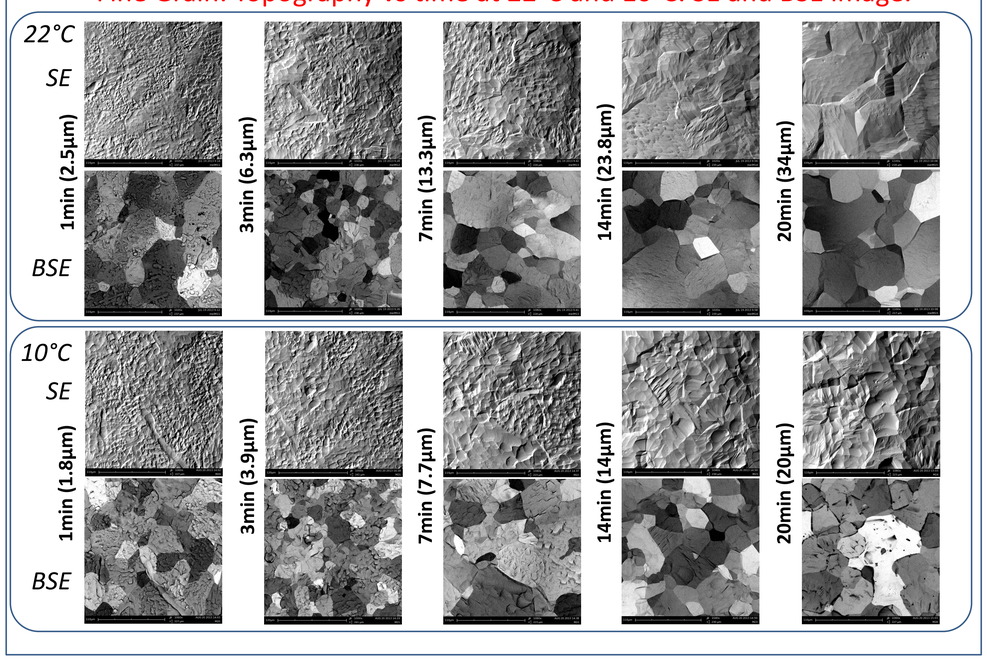
Results

Fine Grain: Static polishing rate vs. time at various temperatures

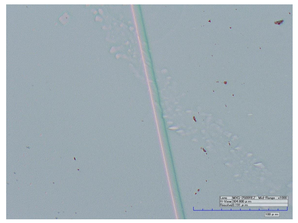


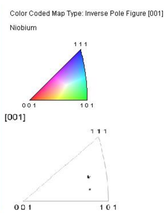


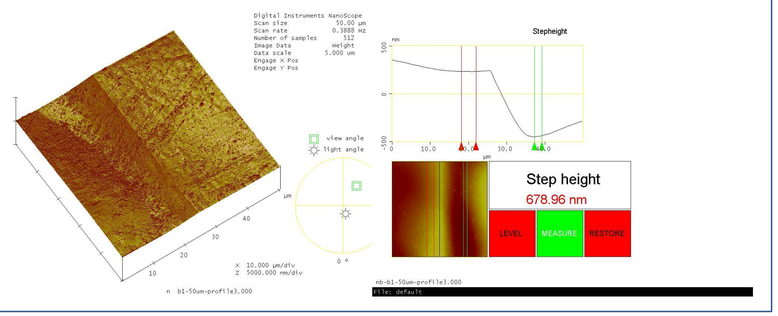
Fine Grain: Topography vs time at 22°C and 10°C. SE and BSE image.



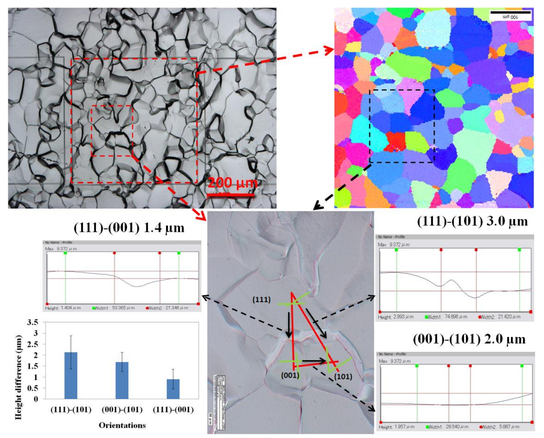
Bi-crystal: Topography, EBSD, AFM. 20°C, 12min, 30µm removal





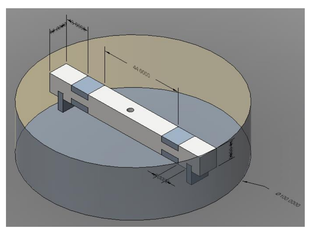


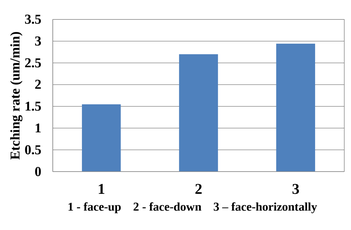
FG: Topography, EBSD. Nano-polished, RT, 6min, 15µm removal



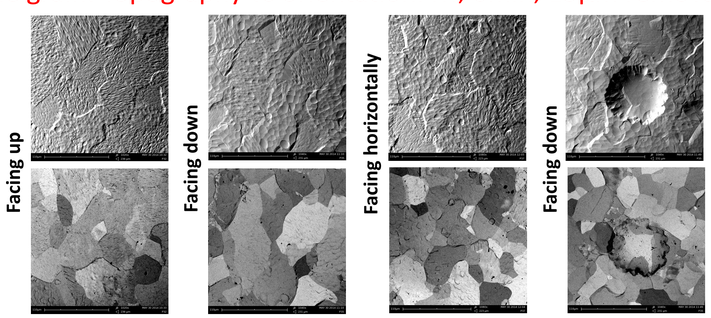
- From highest to lowest: blue, red, green
- Height difference between blue and green: 1.5-3 µm

Fine grain: Polishing rate vs orientation, 20°C



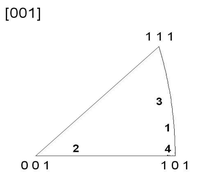


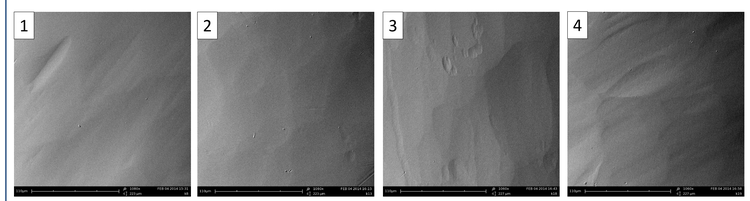
Fine grain: Topography vs orientation. RT, 6min, 15µm removal



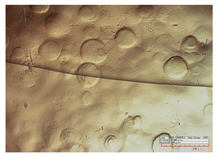
Single crystal: Topography 22°C, 90min, 225µm removal

No significant difference in removal rate among 4 samples, 1.8±0.2 µm/min.

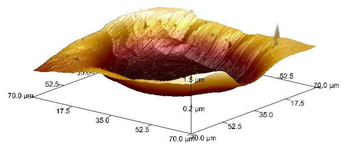




Bi-crystal topography: Bubble print. Facing-up, RT, 80 µm removal



Bubble dimension: diameter 50 µm, depth 1 µm



Conclusion

- Under static conditions, the topography of BCP'd fine grain niobium is primarily determined by grain orientation dependent differential etching. Step size at grain boundaries depends on the crystal orientation of the two grains. Bubble print from gas evolution is a secondary contributor.
- Polishing rate is temperature and sample orientation dependent.
- Topography is decided by total removal, which is a combined result of time, temperature and orientation.

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