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Surface Preparation of Metallic Substrates for Quality SRF Thin Films

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Abstract

Surface preparation is an essential prerequisite for thin film depositions. Rough or chemically impure surfaces adversely affect the nature of the thin film. Understanding the properties of the substrate and their influence on the quality of the thin film is necessary to transfer thin film deposition technologies to SRF cavity applications. A substrate that is flat, has sufficient grain size, and is chemically pure is the ideal starting point for thin film depositions. A method for copper substrate preparation is reviewed for niobium thin film deposition that provides epitaxy on large, fine grain and single crystal copper. Preliminary data on niobium substrate preparation will also be included.

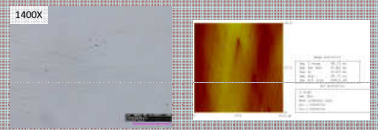
Mechanical Polishing

Substrates are initially mechanically polished to provide a level uniform surface for subsequent processing. The damage from mechanical polishing needs to be removed to provide the best epitaxial substrate. The samples are finished with 3 micron polycrystalline diamond slurry.

Cu Mechanical Polish

Nb Mechanical Polish

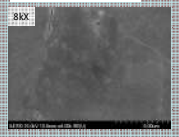
Initial attempts at preparing Nb as substrates demonstrated the differences in Nb and Cu. The Nb was much more difficult to prepare requiring more time at each step. Additionally, Nb is more susceptible to embedded grit. The final polishing cloths used for Cu were not adequate for Nb. More work needs to be invested into developing the procedure for Nb mechanical polishing.

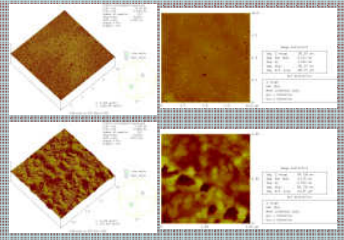


Electropolishing

Mechanical polishing is followed by electropolishing to remove any sub-surface damage, embedded particles, or contamination. Sulfamic acid is used pre-EP to improve uniformity of the Cu oxide and resultant effects on the etching process and post-EP to passivate the Cu surface.

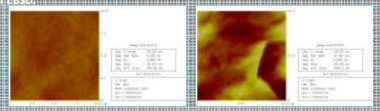
Cu Electropolish





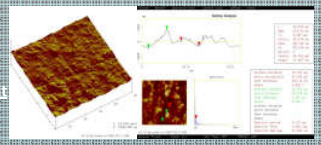
Nb Electropolish

Electropolishing the mechanically polished Nb improved the surface roughness of the polycrystalline Nb substrates prepared. The crystallinity of the Nb substrates post Nb mechanically polished and electropolished were not sufficient to image with EBSD.



Substrate Heat Treating / Recrystallization

Cu Heat Treatment



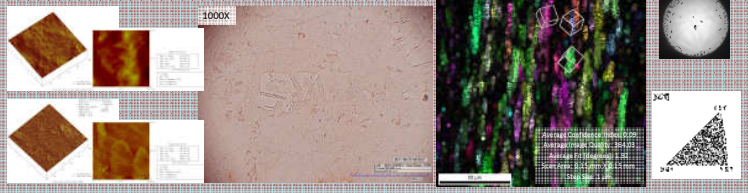
Heat treating Cu in vacuum allows recrystallization of the Cu matrix. This results defect from substrate preparation and inherent to the stock material. The recrystallization process also causes a roughening of the surface due to Ostwald ripening. An equilibrium must be maintained between the bulk volume and the surface. Heat treating increases the bulk volume causing an increase in surface area and roughness to compensate.

Substrate Surface Characterization

Fine Grain Mechanically Polished Cu

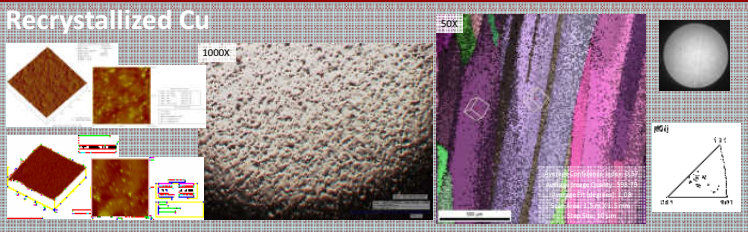
No EBSD Map could be obtained for the mechanically polished substrate. Sub-grain damage from mechanical polishing and fine grain stock have produced a surface with no crystallinity or crystallites smaller than ~50 nm.

Fine Grain Electropolished Cu



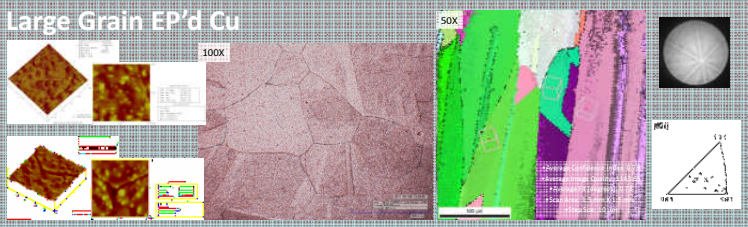
Poor EBSD maps were obtained on the electropolished copper surface. Patterns could be found but the fine grain nature of the substrate combined with any mechanical polishing damage prevented high quality EBSD maps.

Recrystallized Cu



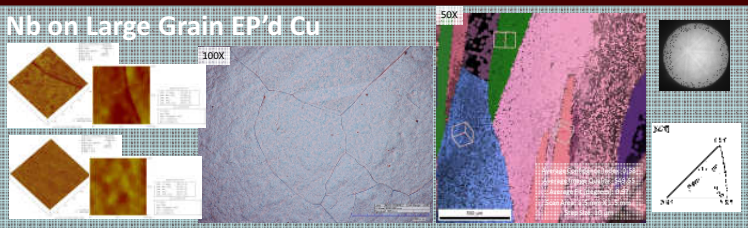
Heat treating the Cu substrates under high vacuum caused the fine grains to recrystallize and repaired the damaged surface layer. The Cu grains roughen and expand at different rates based on orientation.

Large Grain EP'd Cu



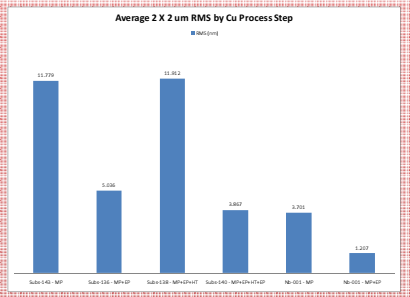
Final electropolishing smoothes the surface and removes any contamination. The crystallinity of the exposed surface is sufficient to support epitaxy of Nb ECR depositions.

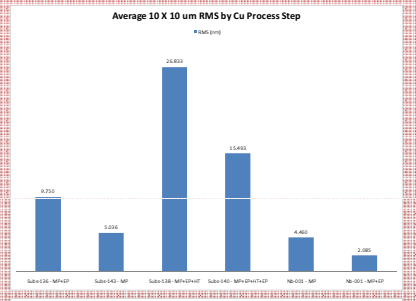
Nb on Large Grain EP'd Cu

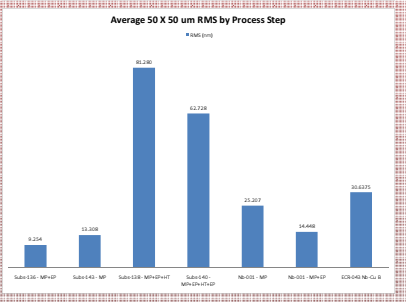


In order for Nb epitaxy to proceed on Cu, the native oxide must be removed prior to the ECR deposition. Thermal, plasma, or a combination of both can be used in-situ to remove the native oxide.

Average RMS by Process Step







Conclusions

- Method for low RMS copper with a highly ordered crystalline surface is reported.
- Initial results for Nb mechanical and electropolishing are compared to Cu.
- Demonstrated the suitability of Cu substrates prepared by reported method to support Nb epitaxy in ECR deposition.

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