Plasma Processing
of
Niobium SRF Cavities

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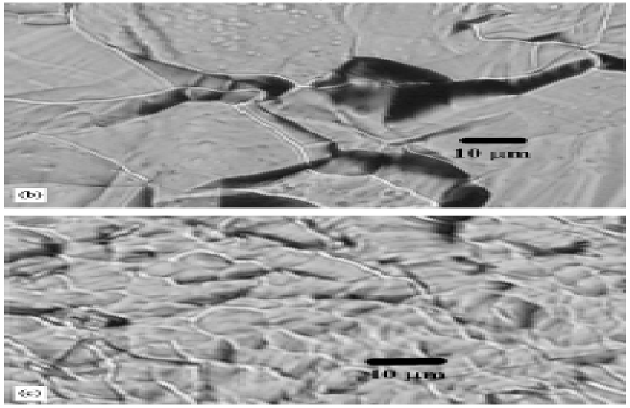
Outline

- Motivation
  - Low Cost
  - No wet chemistry
  - Environment and People friendly (compare to wet etching process)

Comparison of surface micrographs taken with KH-3000 digital microscope with magnification 10×350



BCP Process

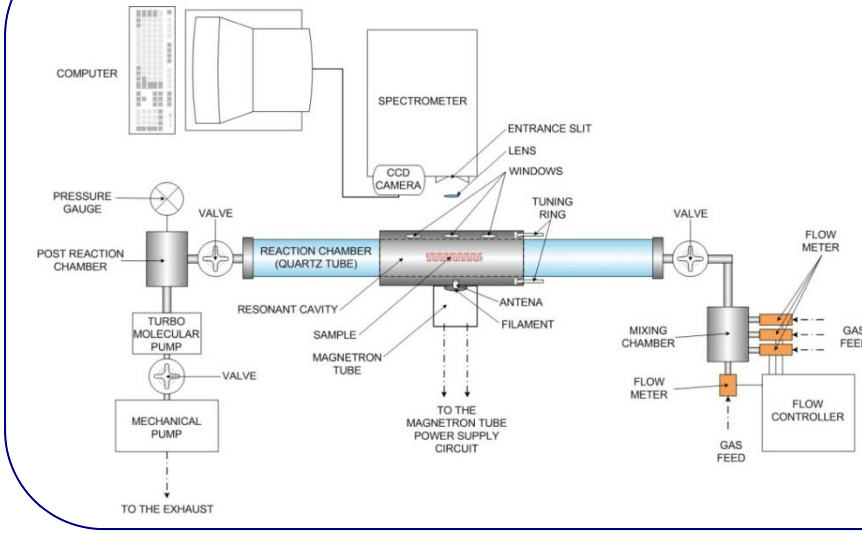
Dry Process

M. Rašković, L. Vušković, S. Popović, L. Phillips, A. M. Valente-Feliciano, S. B. Radovanov, and L. Godet, Nucl. Instrum. Methods Phys. Res. A **569**, 663 (2006

  - Full control on the final surface (A variety of surfaces can be intentionally created through plasma processing, such as pure niobium pentoxide, or superconducting niobium nitride…)
- Flat Samples (Summary)
- Single Cell Cavity Setup (Present Status)
- Work Plan

Flat Samples

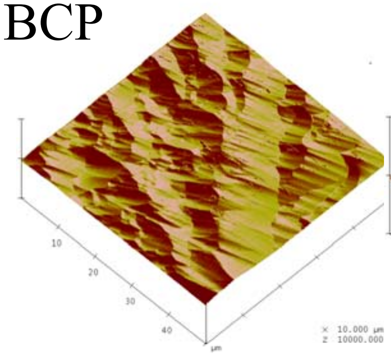
Microwave Glow Discharge System

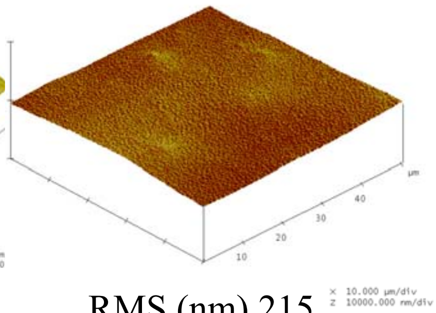


Surface Roughness

BCP

BCP + PE



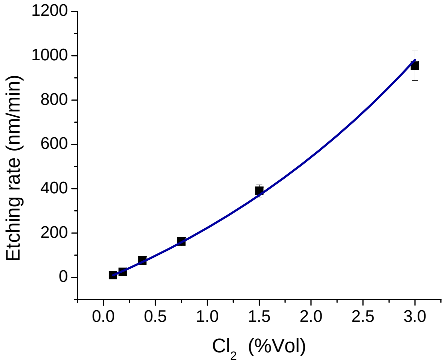


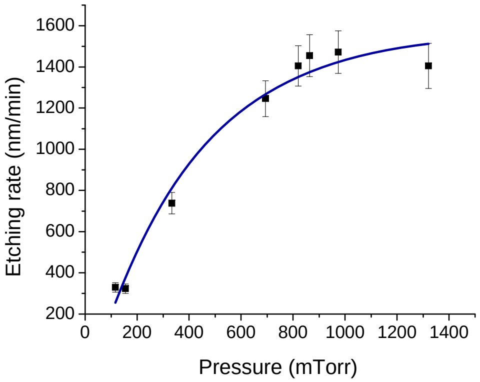
RMS (nm) 286

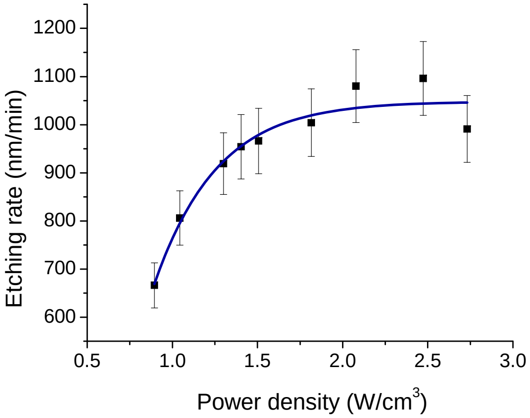
RMS (nm) 215

AFM scan (50 µm × 50 µm)

Etching Rate Dependence on Discharge Parameters



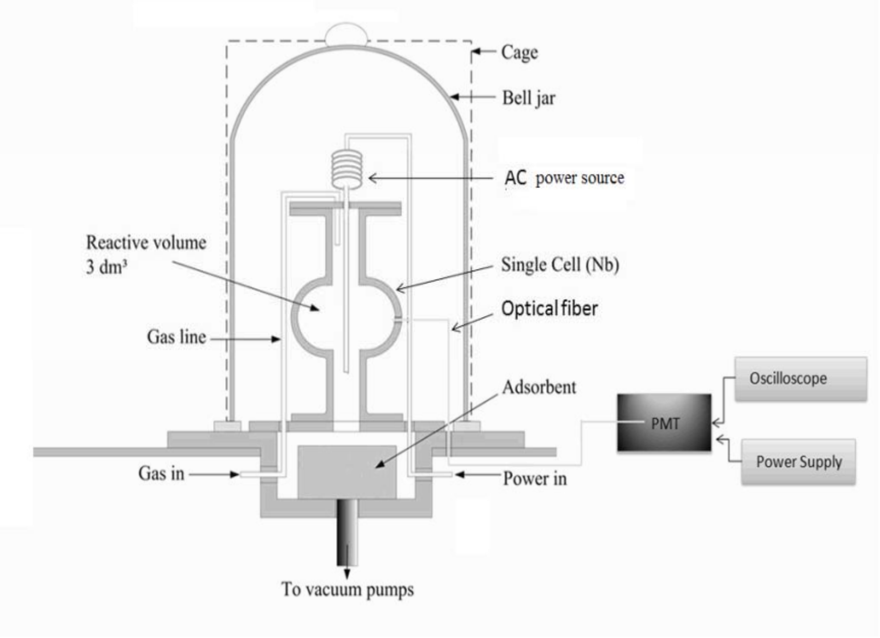




M. Rašković, S. Popović, J. Upadhyay, and L. Vušković, L. Phillips, A. M. Valente-Feliciano, "High etching rates of bulk Nb in Ar/Cl2 microwave discharge," J. Vac. Sci. Technol. A.27(2),301(2009).

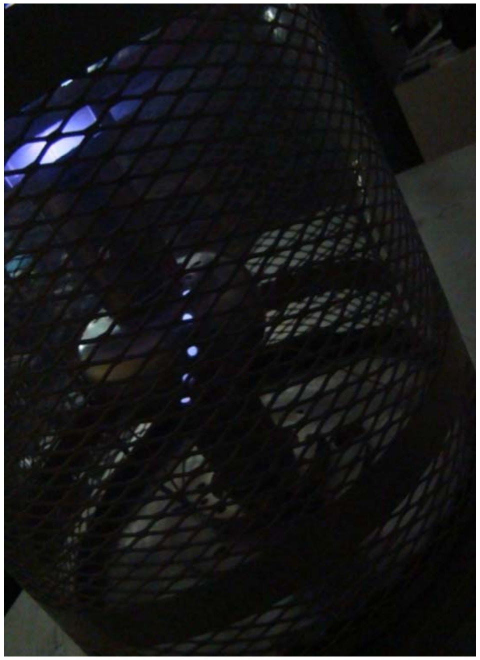
Single Cell Cavity Process

Schematic Diagram

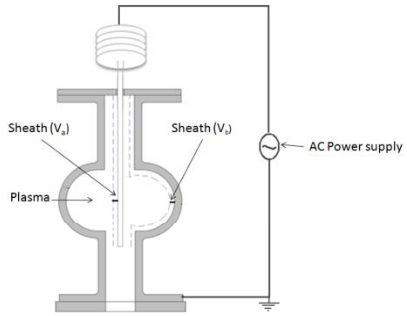


Bell-Jar System

Plasma in The Cavity



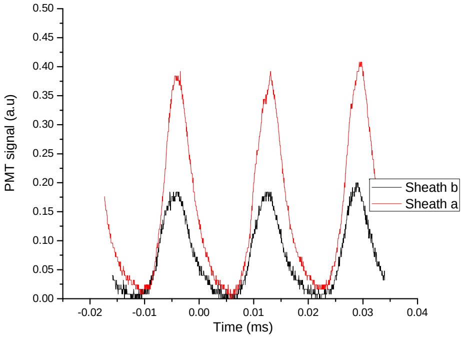
Asymmetric Discharge



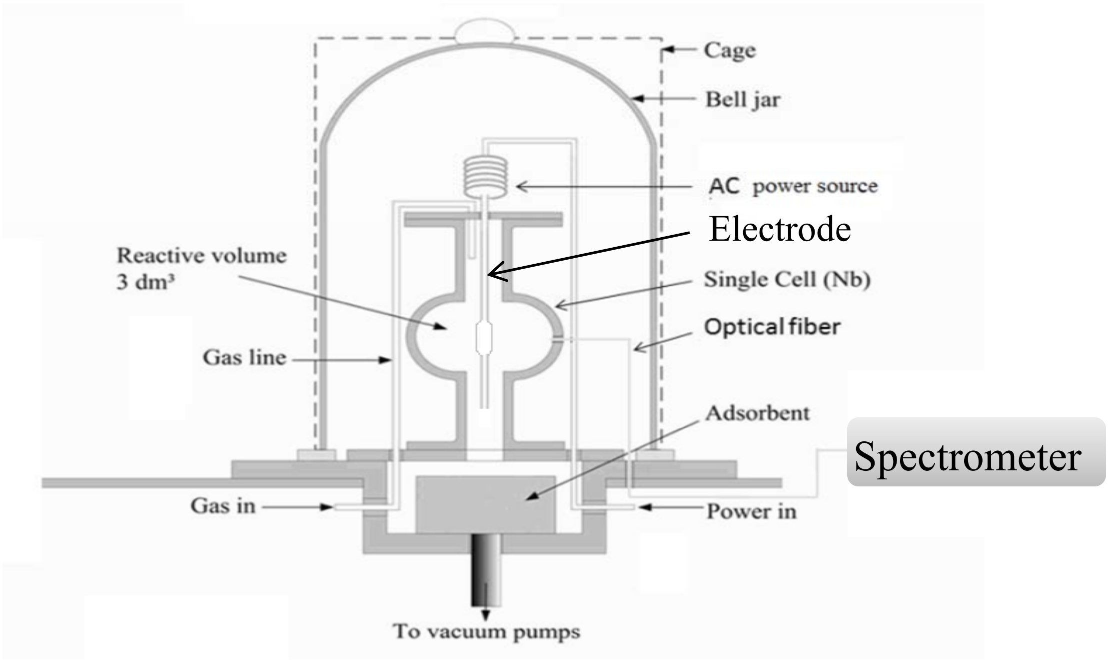
The scaling of the voltage drop in the plasma sheath with the surface area of the electrode :

$$\frac{V_a}{V_b} = \left(\frac{A_b}{A_a}\right)^{5/2}$$

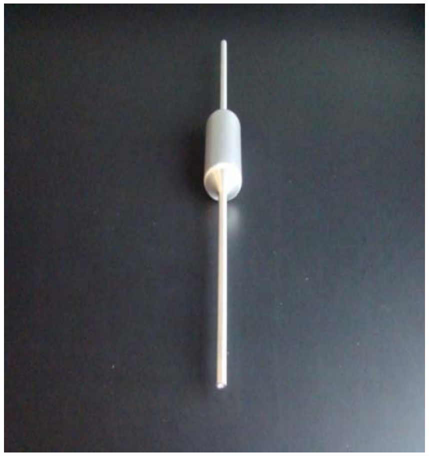
Optical Intensity

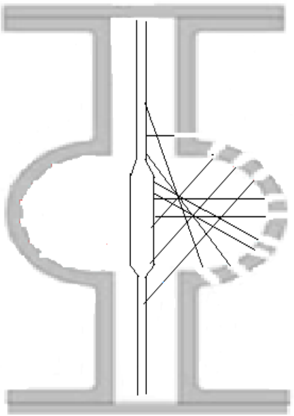


Single Cell Cavity



New Electrode

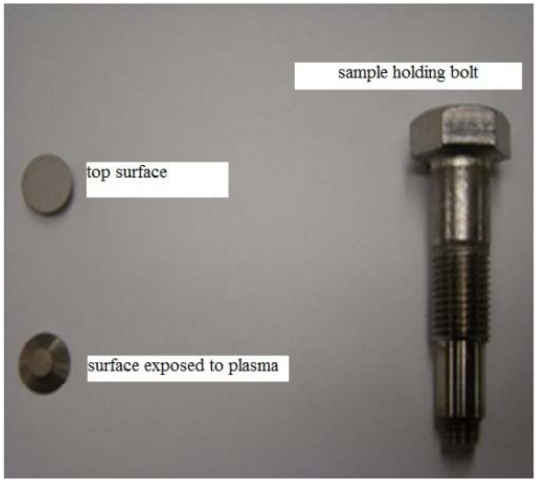




- Movable multiple optical fiber system attached with spectrometer would be used for tomographic study of plasma inside the cavity.

Single Cell Cavity for Sample Etching

Sample and the Bolt for Holding Sample



Work Plan

- Choose an optimal power supply frequency between RF (50-200 MHz) and MW (2.45 GHz).

- See the plasma etching behavior on samples placed on actual geometry of the single cell cavity.

- Do the plasma etching of a single cell cavities and test the RF performance of the cavity.

Conclusion

- The RF performance is the single feature that remains to be compared to the "wet" process, since all other characteristics of the "dry" technology, such as etching rates, surface roughness, low cost, and non-HF feature, have been demonstrated as superior or comparable to the currently used technologies.

- surface modifications can be done in the same process cycle with the plasma etching process.

- The geometry of the inner surfaces of cavity implies that the plasma discharge has to be asymmetric.

- In order for the asymmetric discharge to be effective, the lower sheath voltage at the treated surface (large area, undriven electrode) has to be at least equal or higher to the plasma floating potential at every point of the surface.

Acknowledgement

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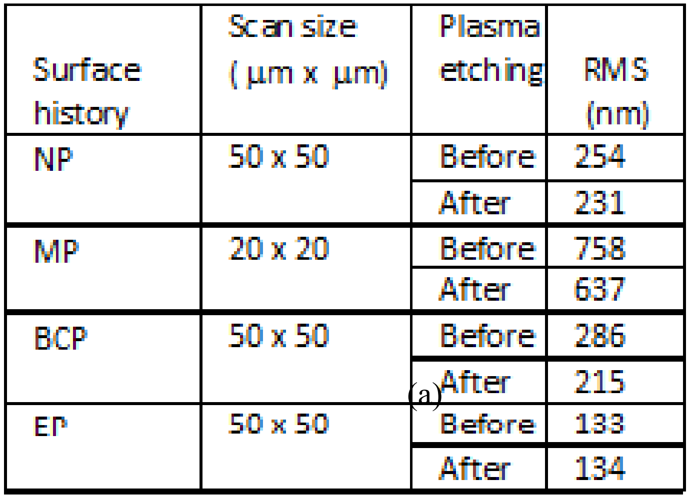
- Work done in collaboration with

  Dr. Leposava Vuskovic and Dr. Svetozar Popovic , Old Dominion University, Norfolk ,Virginia

  Dr. Larry Phillips and Anne –Marie Valente -Feliciano, Jefferson Lab, Newport News , Virginia

Surface Roughness



Surface history	Scan size (µm x µm)	Plasma etching	RMS (nm)
NP	50 x 50	Before	254
		After	231
MP	20 x 20	Before	758
		After	637
BCP	50 x 50	Before	286
		After	215
EP	50 x 50	Before	133
		After	134

(a)

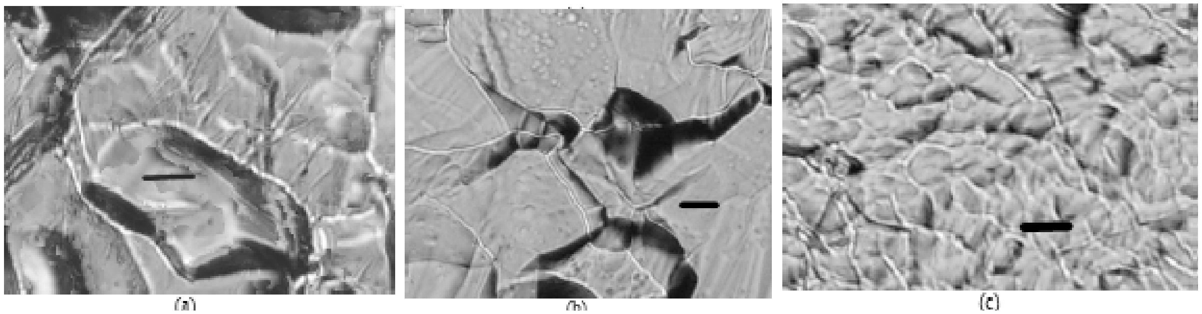
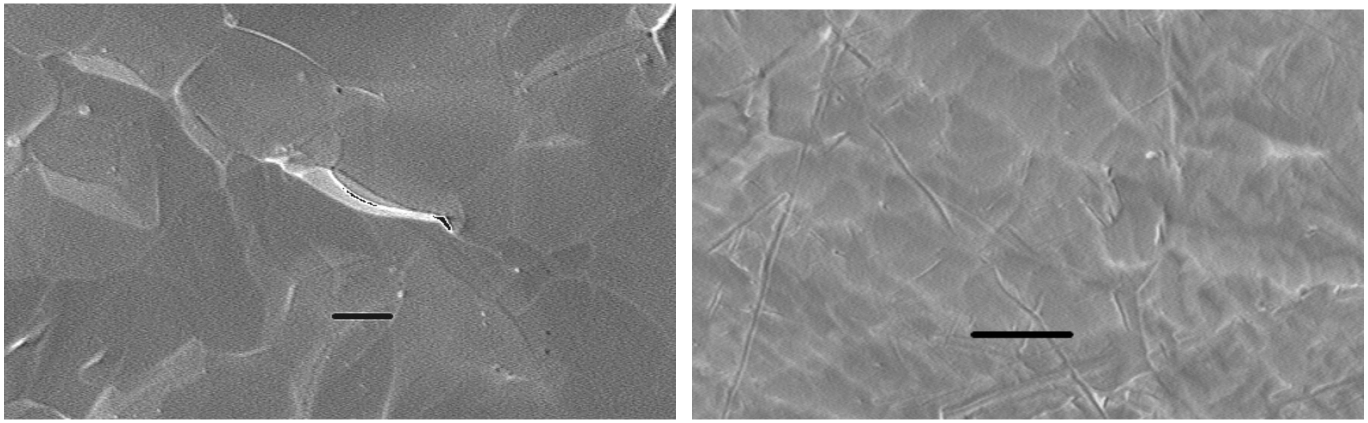


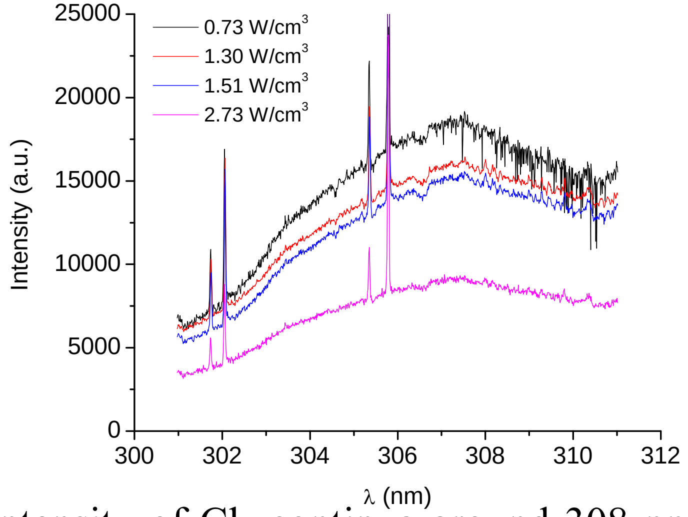
Figure 13. Comparison of surface micrographs taken with KH-3000 digital microscope with magnification 10×350: (a) an untreated sample; (b) BCP sample; (c) plasma-etched



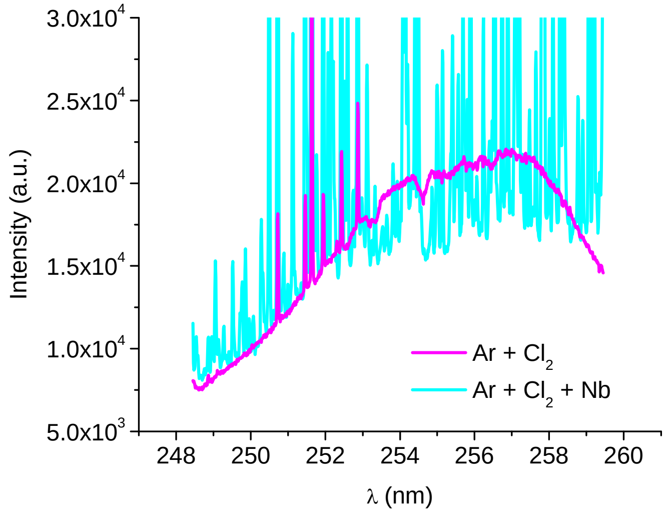
(a) (b)

Figure 15. Surface micrographs obtained with scanning electron microscope: (a) sample treated with BCP technique – magnification 500x, (b) plasma treated sample – magnification 1500x. Black lines indicate distance of 10 µm.

Optical Emission Spectroscopy



Intensity of Cl_2 continua around 308 nm as function of input power density in Ar/Cl_2 discharge.



Intensity of Cl_2 continua around 257 nm .