Rapid electropolishing of niobium and 3.9 GHz cavity in non-aqueous solvents

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Content

一、Introduction

BCP and EP of SRF cavities

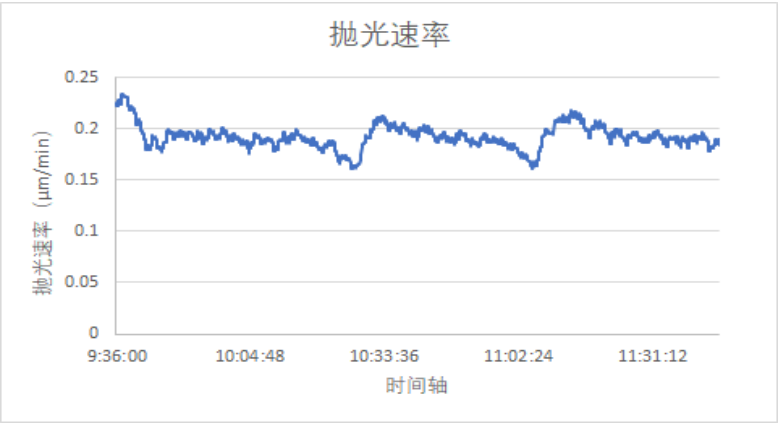
Dangerous!!

EP: HF 、 H_2SO_4

BCP: HF、HNO_3、H_3PO_4

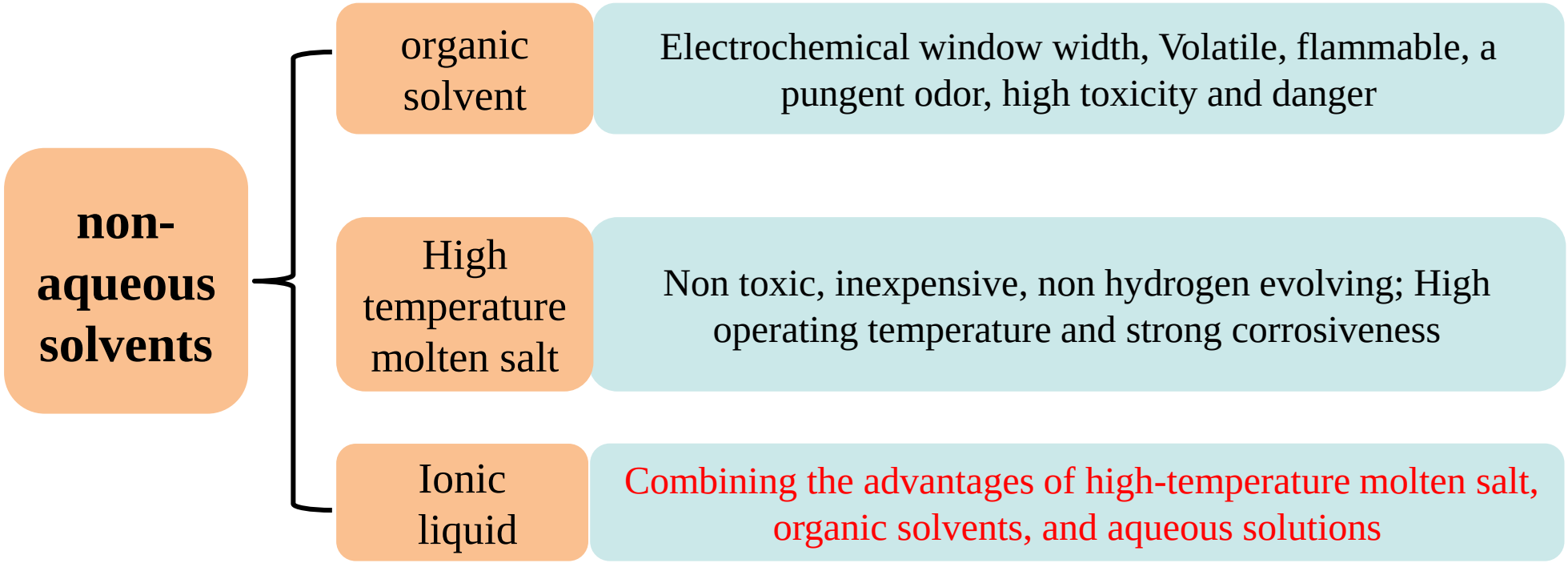
Low polishing rate!!

EP: ~0.2 μm/min BCP: ~1 μm/min



Our goal is to solve these two problems

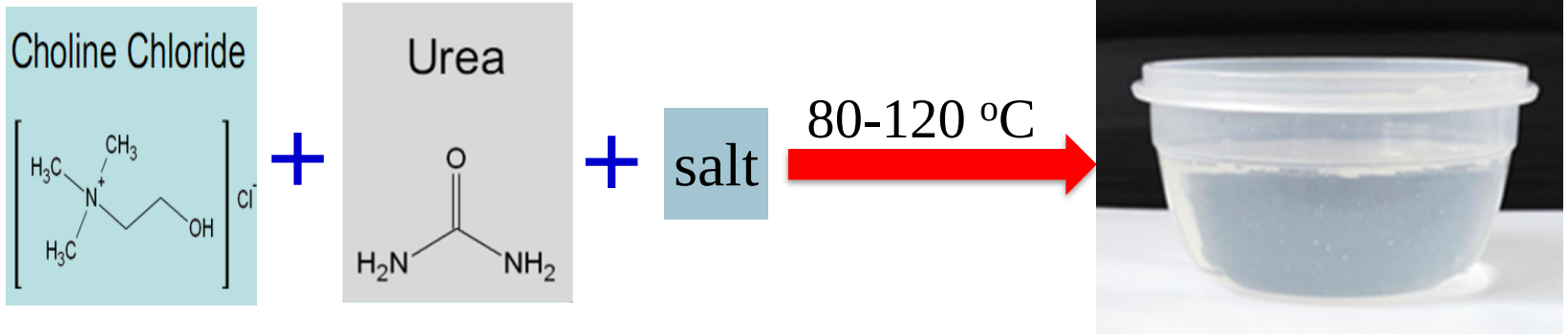
一、Introduction



Room temperature ionic liquids are "21st century solvents" and "green solvents"!

Wide electrochemical window, stable to water and air, affordable, environmentally friendly.

一、Introduction



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Full Length Article

Electropolishing behavior of niobium in choline chloride-based deep eutectic solvents

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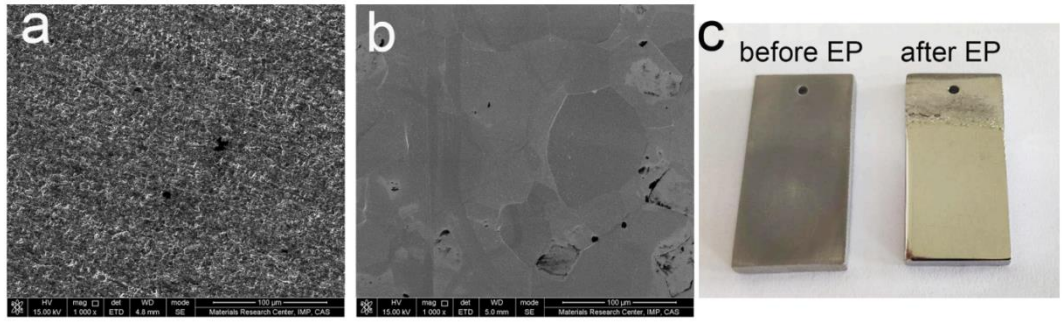
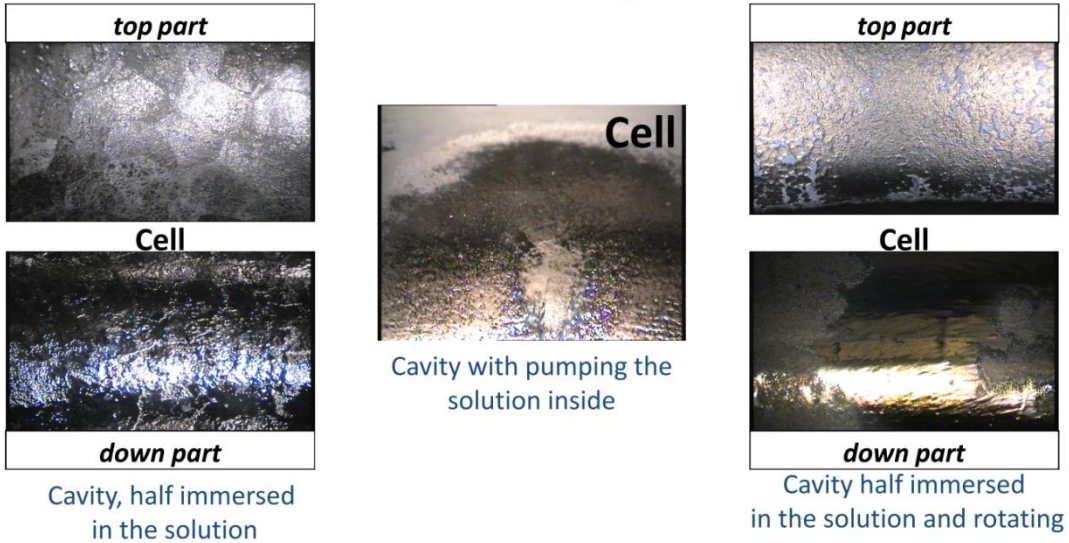




V. Pastushenko LNL-INFN, 16th International Conference on RF Superconductivity, SRF 2013

High viscosity, poor effect, obvious advantages and disadvantages

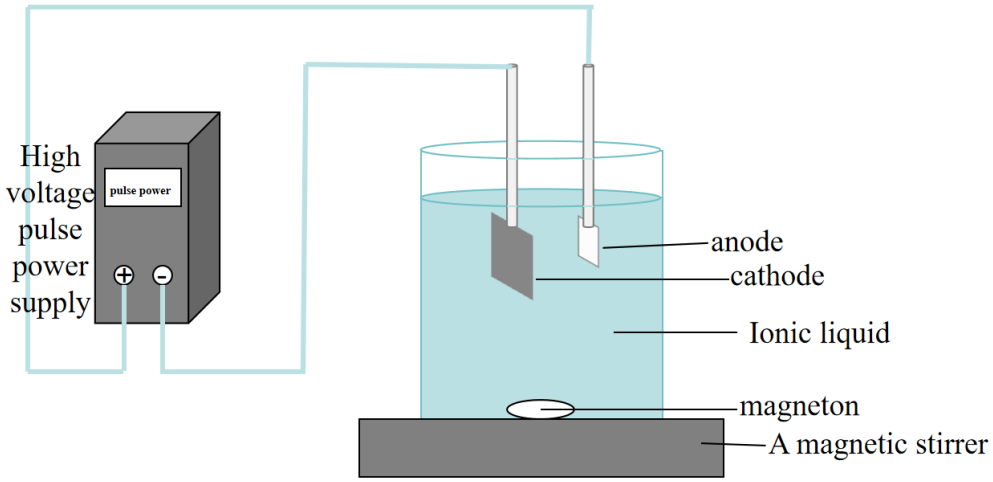
Is there no possibility of application for ionic liquids?

1 Introduction

Ethylene glycol —fluoride salt solution

more stable than aqueous solution, acceptable viscosity, acid free, safe

+ High voltage



Electropolishing device:

a dual pulse power supply, a two-electrode cell,

a stirring system, temperature control system.

direct voltage:

70-110 V

pulse voltage:

100-250 V

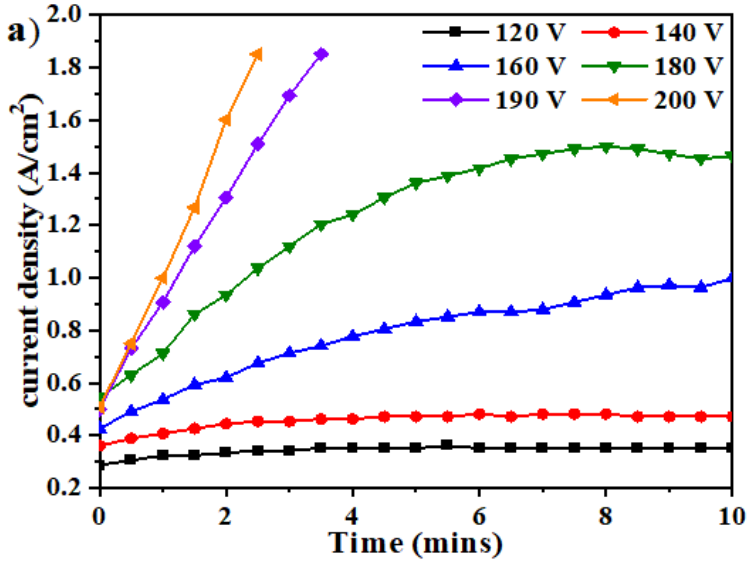
Surprise!!

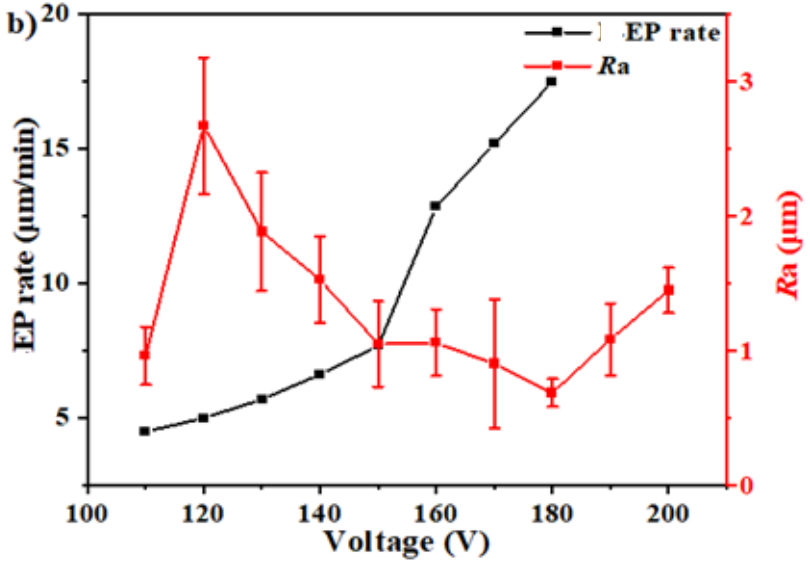
the polishing rate and electrolyte safety are both very good

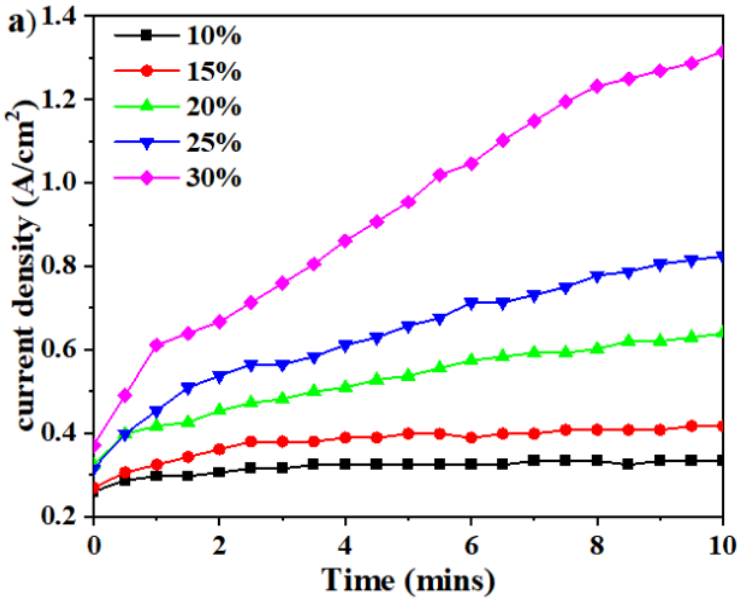
2.1 Parameter influence

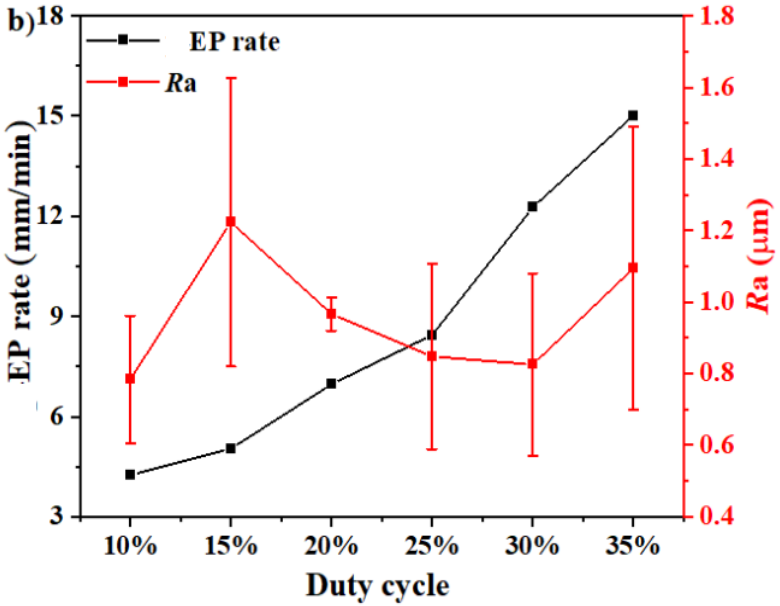
The optimal range of EP conditions for Nb is 160 V-180 V, 20-30%

The EP rate exceeds 10 μm/min, and the roughness can be as low as 0.5 μm.

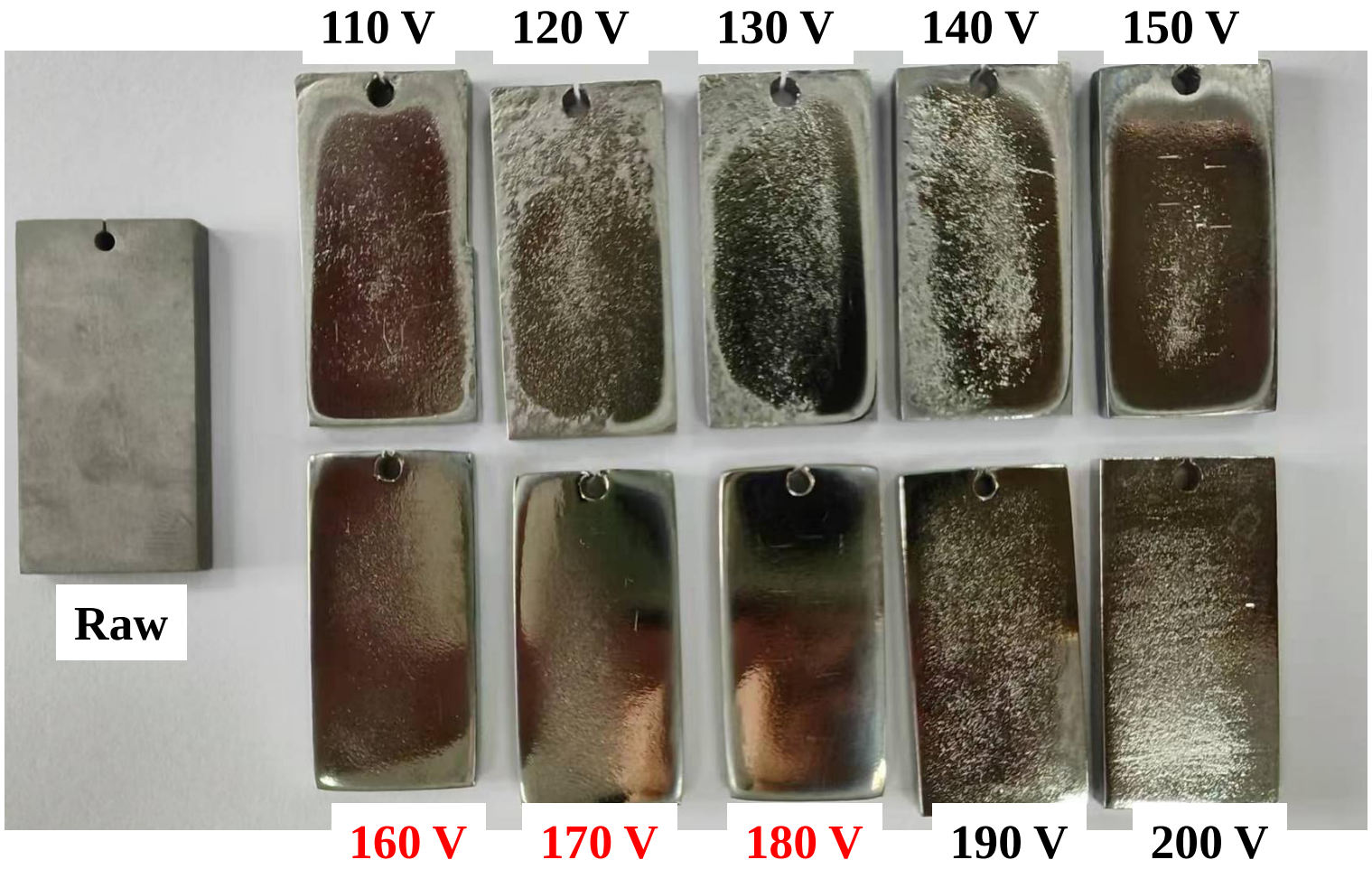


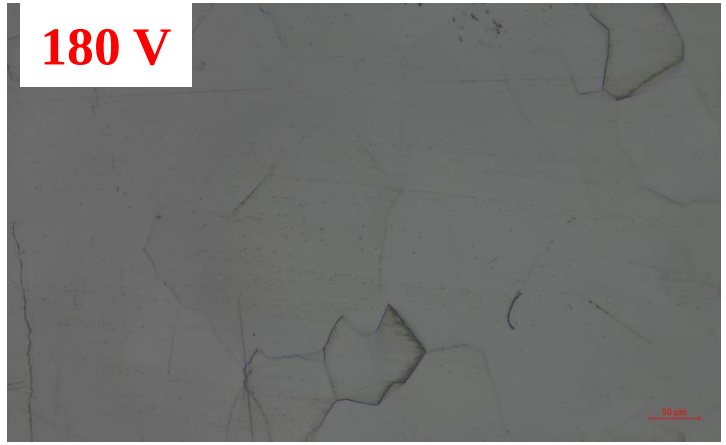


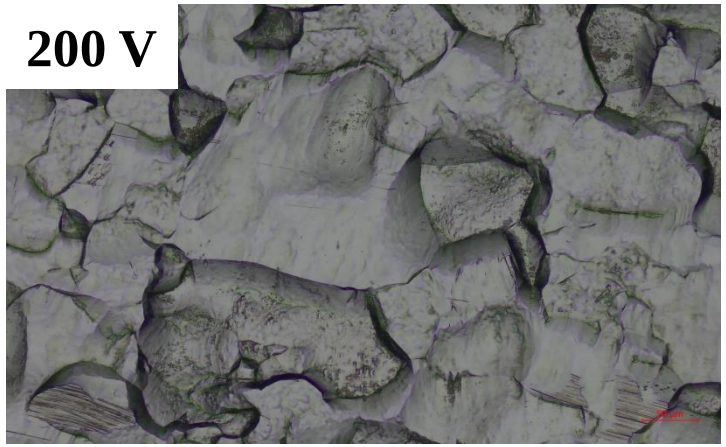




2.1 Parameter influence







The Nb samples were electropolished at 30%, 10 minutes.
The positive voltage ranges from 110 V to 200 V.

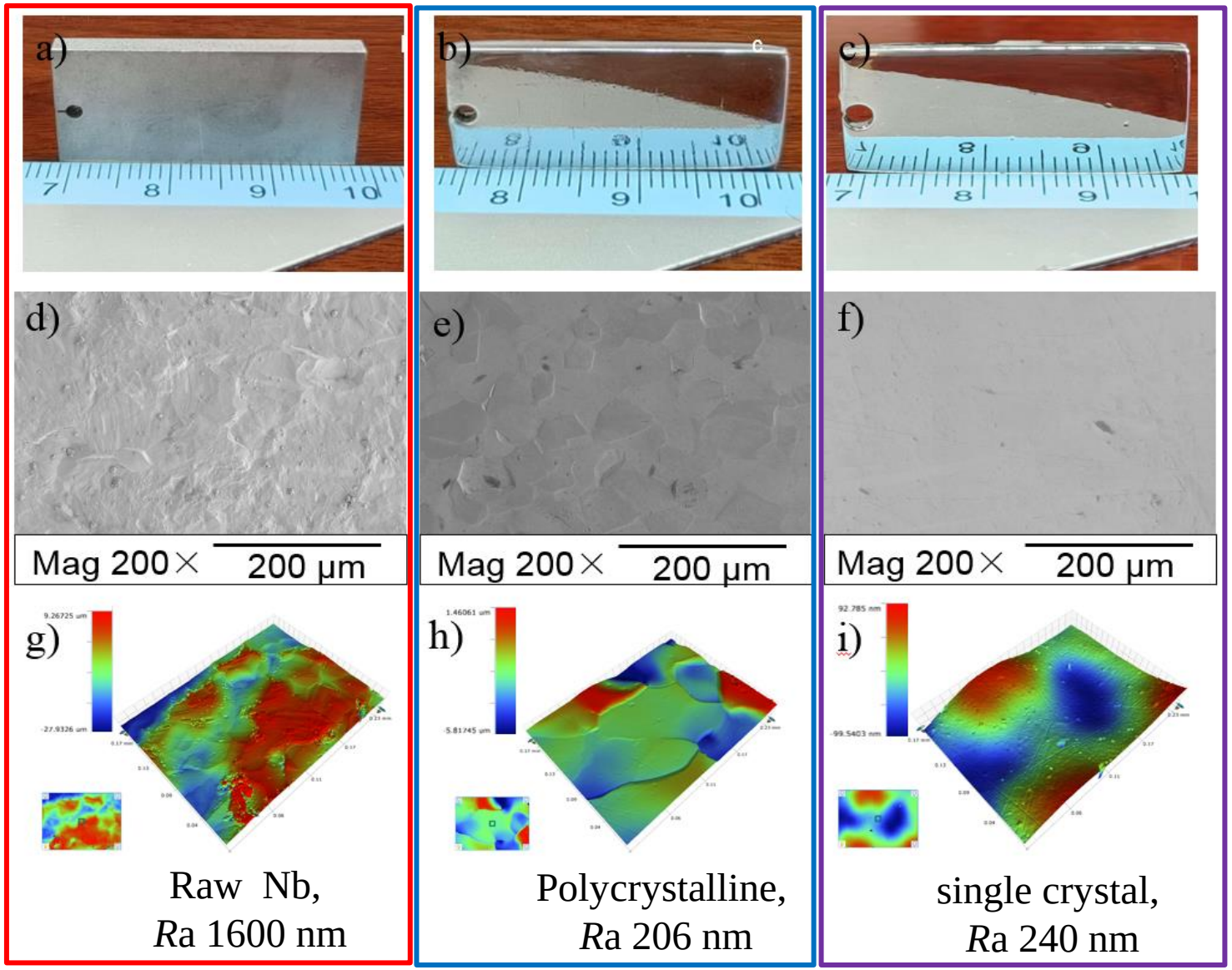
2.1 Parameter influence

duty cycle: 30%

positive voltage: 170 V,

frequency:700 Hz,

removal amount:140 μm



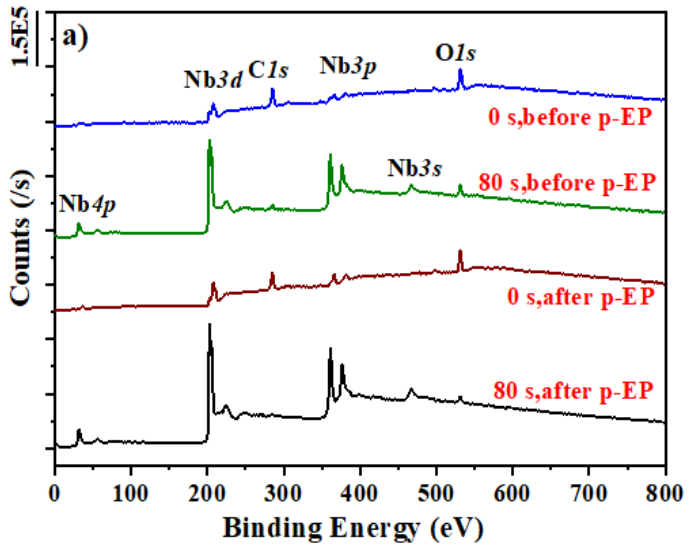
Raw Nb, *R*a 1600 nm

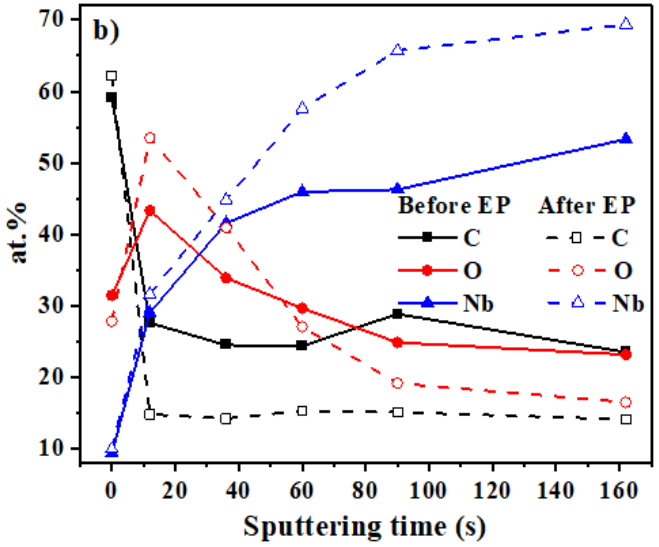
Polycrystalline, *R*a 206 nm

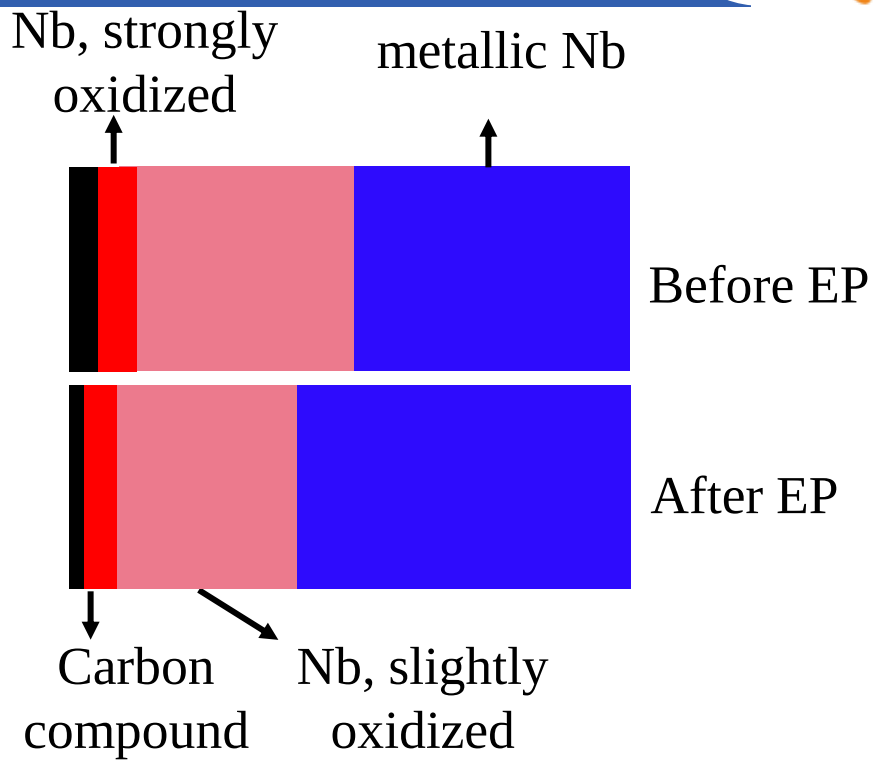
single crystal, *R*a 240 nm

A uniform and mirror-like Nb surface can be obtained

2.1 Parameter influence







As the Ar+ sputtering time increases, C content decreases, O content first increased and then decreased, and the Nb content increased, eventually stabilizing.

The oxide layer on the surface of the niobium after EP treatment became thinner

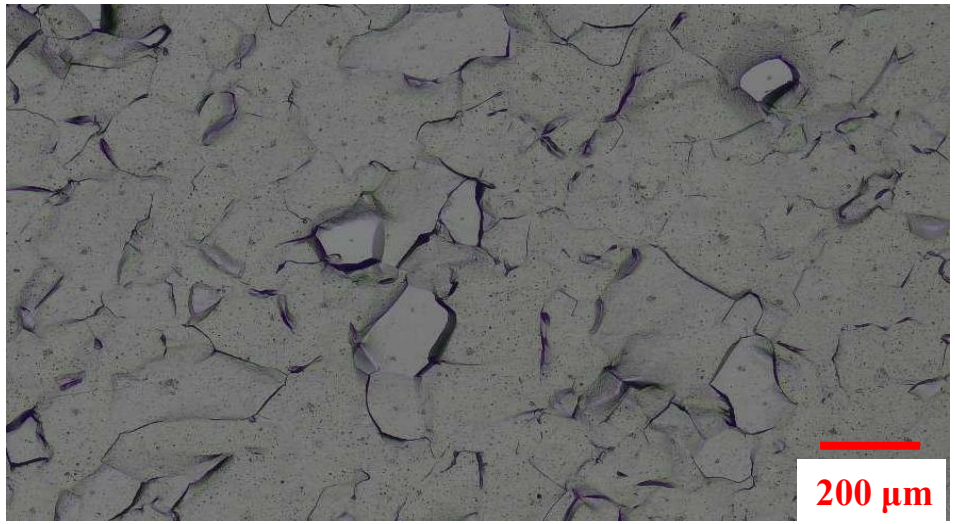
2.2 Large-sized niobium

Raw Nb

3*55*85 mm

3*55*85 mm

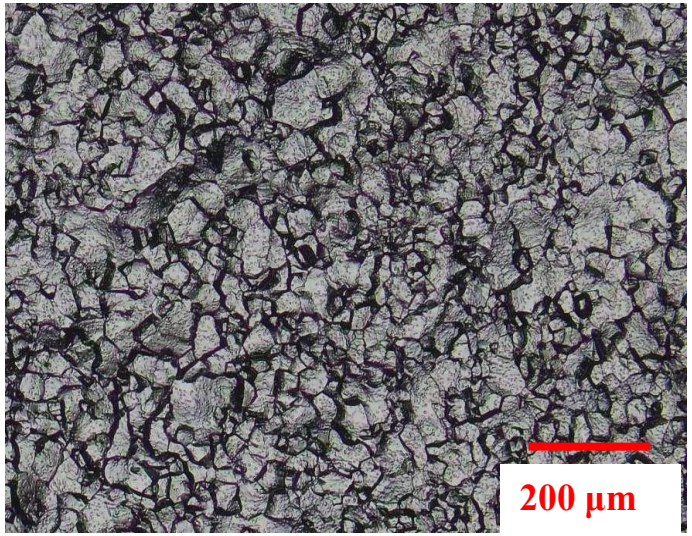
S(cathode)>S(Nb)



210 V, 30%, 750 Hz

2.2 Large-sized niobium

D=90 mm



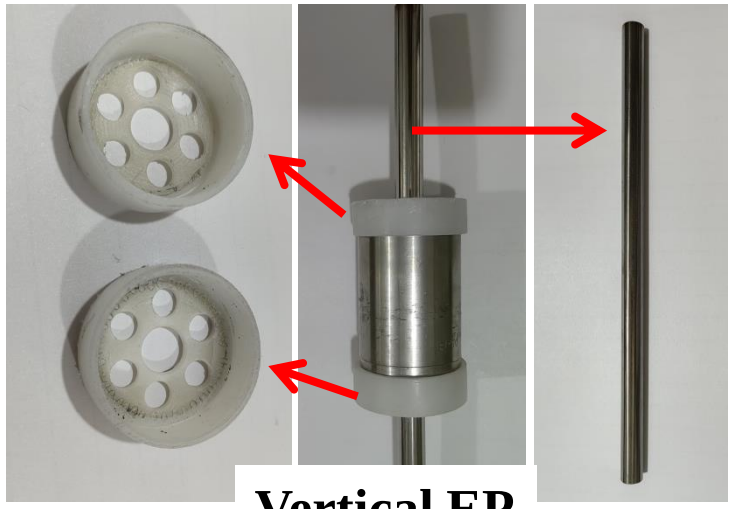
S(cathode)<S(Nb)

A small cathode and a large anode

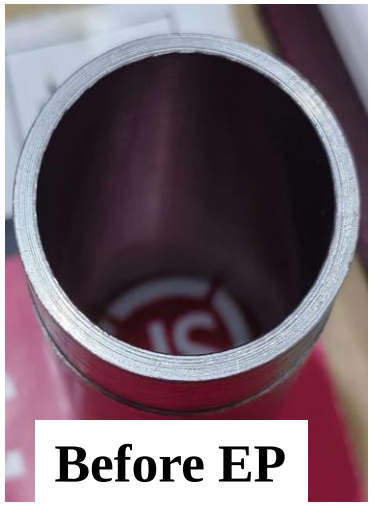
The current density could not increase

The electropolishing effect was not ideal

2.3 3.9 GHz cavity

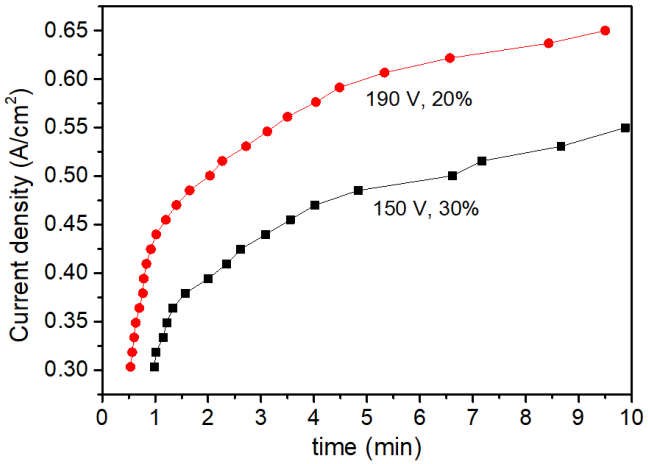


Vertical EP



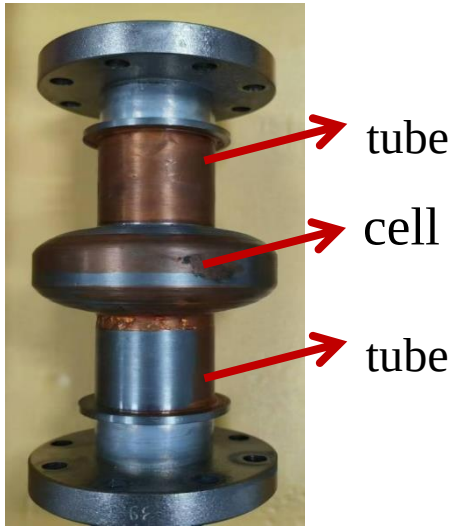
Before EP

After EP



S=64 cm² ~ 25°C→~ 80°C

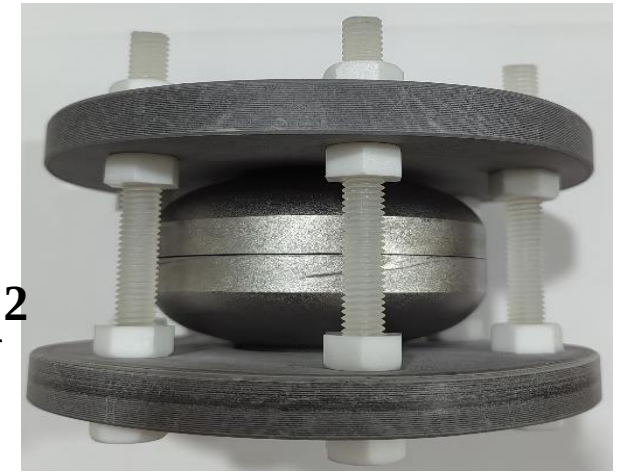
3.9 GHz cavity

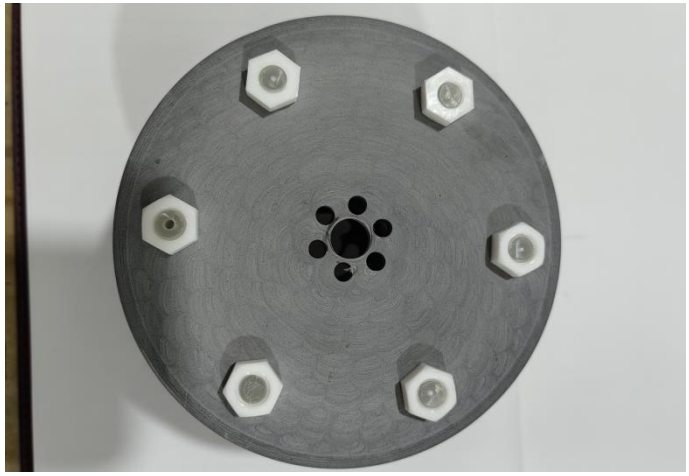


Potential (V)	Duty cycle (%)	stirring rate (r/min)	Polishing rate (μm/min)
150	30	700	5.9
150	30	750	7.4
190	20	700	4.4
190	20	750	4.4

2.3 3.9 GHz cavity

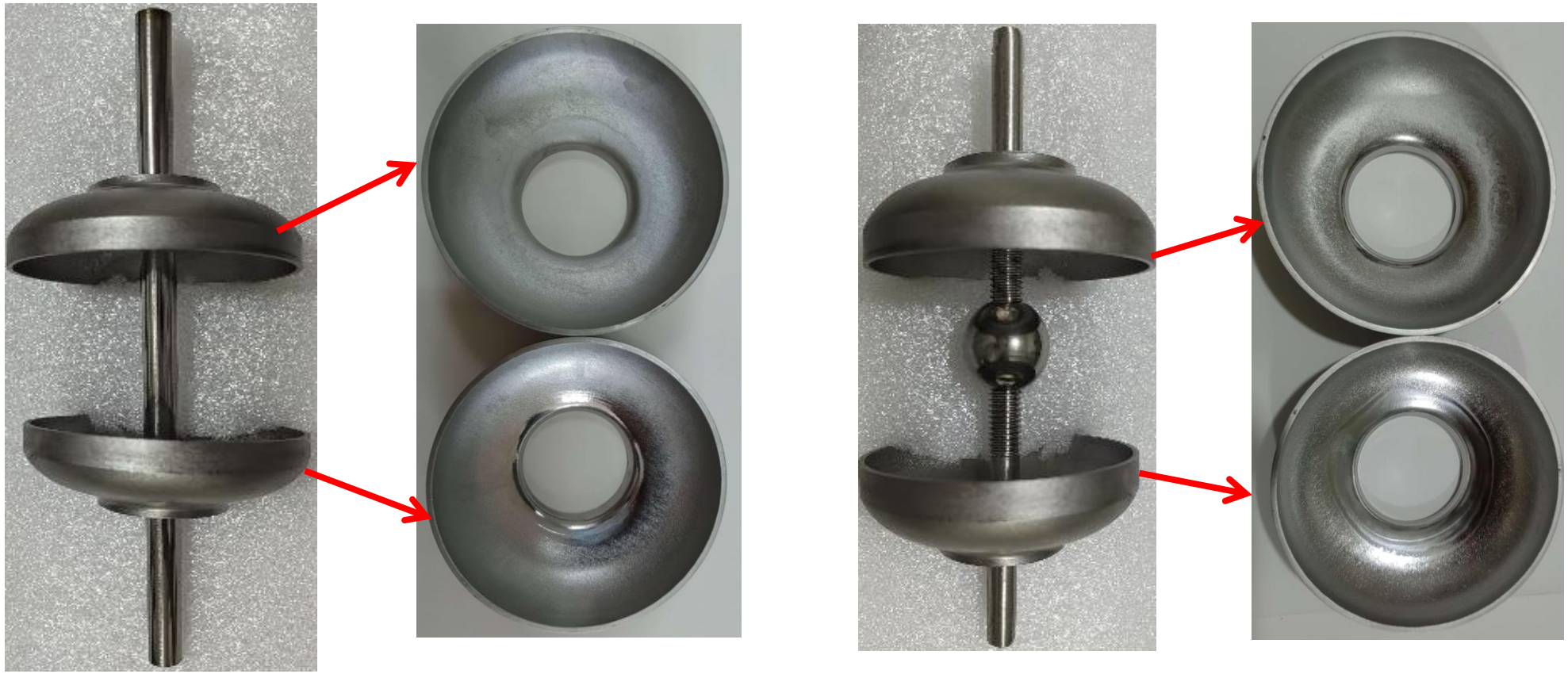
S=103 cm^2





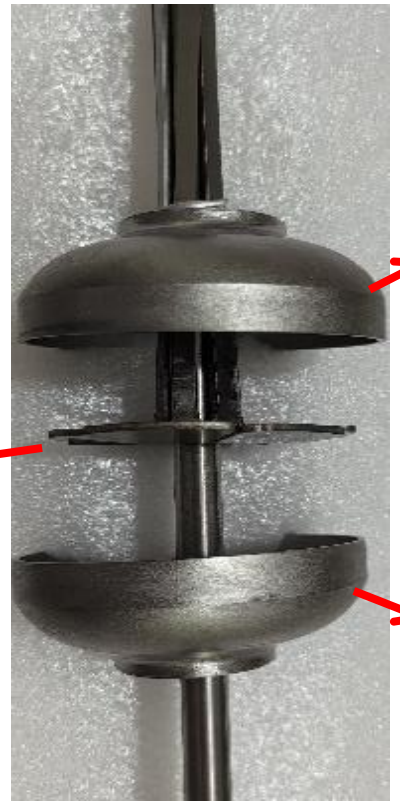
the tooling for the cell section

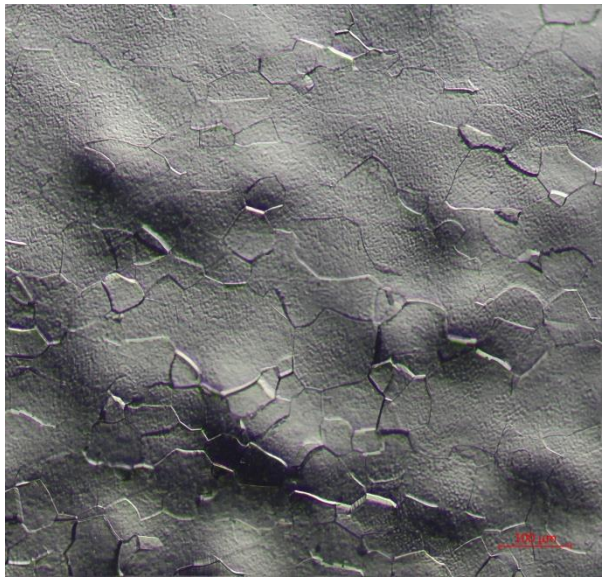
2.3 3.9 GHz cavity



The influence of cathode electrodes with different structures on the up and down parts of the cell

2.3 3.9 GHz cavity





170 V 700 Hz 30% 2 min

23 ℃→80 ℃ 0.5 A/cm^2→0.7 A/cm^2

11 μm/min

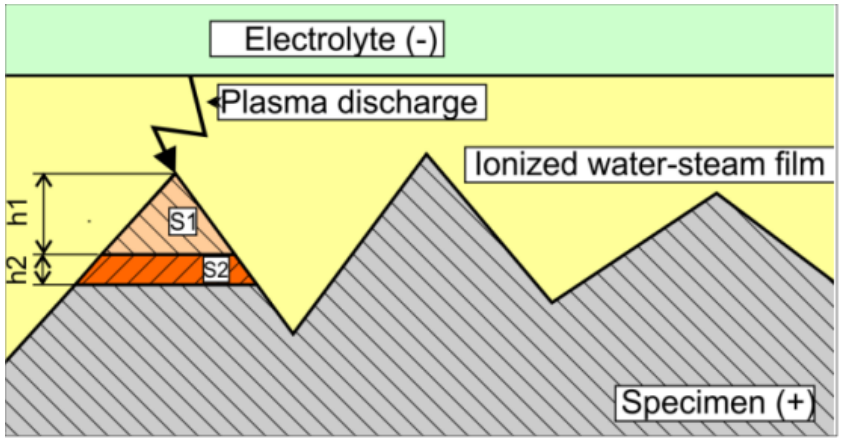
150 V 700 Hz 30% 6 min

19 ℃→90 ℃ 0.4 A/cm^2→0.6 A/cm^2

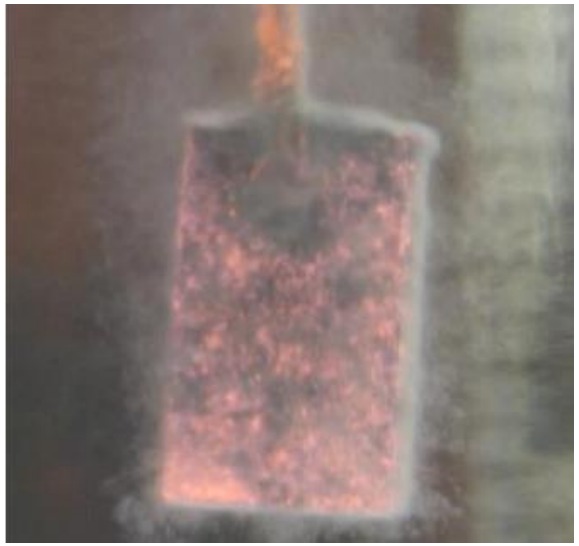
8 μm/min

2.4 EP mechanism

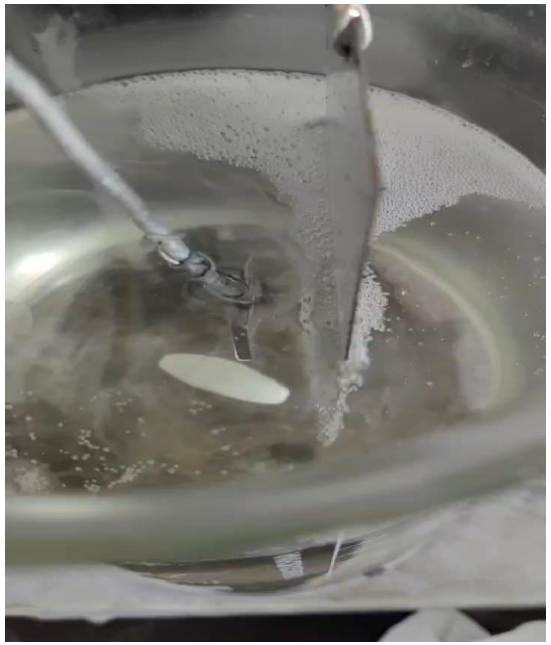
Plasma Electrolytic Polishing (PEP)



Vana, D et. al, Int. J. Mod. Eng. Res. 2013



Process / parameters	EP (1:9)	**PEP**
Solution composition	$HF:H_2SO_4$	**Diluted salts**
Voltage	18 V	**300 V**
Current density	0.025 A/cm^2	**0.15-0.6 A/cm^2**
Power density	0.45 W/cm^2	**~90 W/cm^2**
Removing rate	0.3 μm/min (30℃)	**3.5 μm/min (78℃)**



Similar to PEP processing. Is the polishing mechanism the same??

No, our treatment does not generate plasma.

Two different methods for treating niobium and SRF cavities

2.4 EP mechanism

➢ **Electrochemical mechanism**:

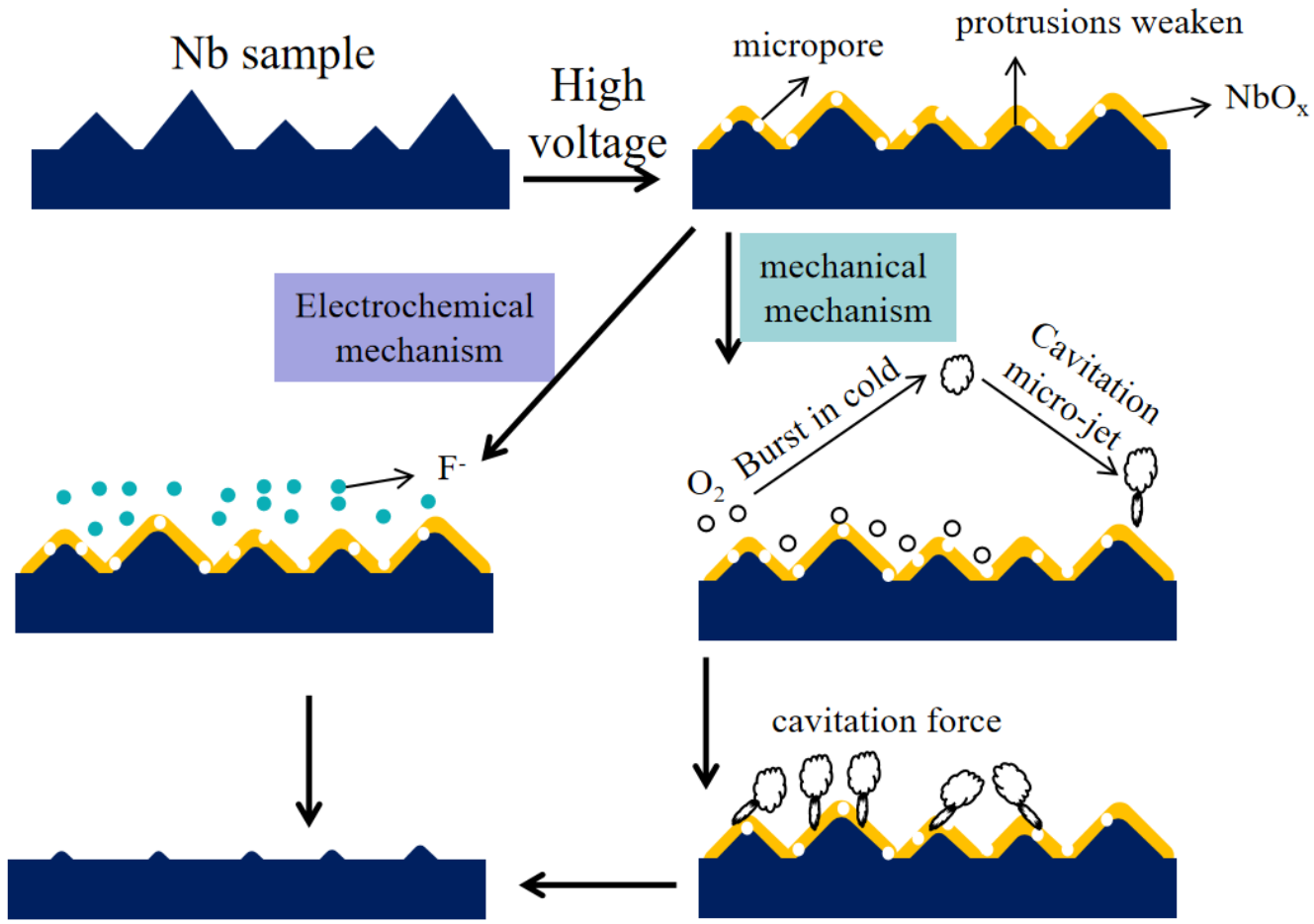
$Nb \rightarrow ne^- + Nb^{n+}$

$Nb^{n+} + nF^- \rightarrow NbF_n$

➢ **Mechanical mechanism**:

$OH^- \rightarrow O_2$, forming a nanojet during the migration process towards the Nb surface when bubbles collapse

- The combination of the two achieves the effect of high polishing rate



3. Summary

- This is the first time to combine ionic liquids and high-voltage pulse polishing for niobium, breaking through the traditional limitations of BCP and EP that must use HF, while significantly improving polishing efficiency.
- For Nb sample, the electropolishing rate can exceed 10 μm/min, and the roughness can be as low as 0.5 μm. A uniform and mirror-like Nb surface can be obtained.
- For 3.9 GHz cavity, EP the tube is relatively easy and the effect is good. The EP effect at the cell is closely related to the cathode electrode, and we will further optimize it in the future.

Thank you !

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