Towards More Uniform Etching of Superconducting RF-Cavities

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Introduction

Impurities of different sorts, possibly stemming from rolling, deep drawing, grinding, eb-welding, or titanification of Nb sheet material tend to lodge in a thin layer just beneath the sheet surface. It is therefore standard practice to remove 100 µm or more from the RF surface by etching, electropolishing, grinding(tumbling) or a combination of these. While the former two methods lead to enhanced material removal (30 - 100 %) at iris with respect to equator[1,2], tumbling can be employed to enhance material removal at equator but tends to embed abrasive particles into the RF surface[3] which need then to be removed by etching. With tumbling and electro polishing not yet available at DESY, it would be desireable to have available a method that provides more uniform etching rate. Such a method is described below.

Apparatus and principle of operation

The method used at DESY for etching the RF surface of cavities is closed loop circulation of acid mixture through the cavity at a flow rate of 10 ··· 25 l/min [4]. The velocity of acid flow at the RF-surface is naturally larger at iris than at the equator. This fact is deemed the reason for the observed variation in etching rate between iris and equator.

To remedy this situation it is proposed to apply to the cavity oscillatory rotational motion about the cavity axis with frequency f and amplitude α_0

which the acid mass will practically not paticipate in. The relative tangential velocity at radius r is then

$$v_{\tan} = \frac{d\alpha}{dt} \cdot r$$

Tangential velocity of acid relative to RF surface is seen to depend linearily on r and can be expected to lead to enhanced etching rate at equator with respect to iris.

More quantitative discussion

Forced rotary harmonic motion of cavity about its axis is easily achieved and will provide jerk-free motion:

(1) $$\alpha(t) = \alpha_0 \sin \omega t, \qquad \omega = 2\pi f$$

(2) $$\frac{d\alpha}{dt} = \alpha_0 \omega \cos \omega t.$$

One may expect the etching rate to be strongly correlated to the *mean* tangential velocity

$$\bar{v}_{\tan} = r\overline{\left(\frac{d\alpha}{dt}\right)} = \frac{2r\alpha_0\omega^2}{\pi} \int_0^{\pi/2\omega} \cos \omega t dt,$$

with integration over 1/4 period. The result is

(3) $$\bar{v}_{\tan} = \frac{2\alpha_0 \omega r}{\pi} = 4 f \alpha_0 r.$$

It is seen, then, that one can adjust average velocity at a particular radius with choice of amplitude and frequency of the rotary oscillation.

Numerical example

with the above mentioned flow rate and the iris diameter being 0.07m, the axial velocity at iris ranges from 0.04 ··· 0.1 m/s. The axial velocity at equator will be much lower. If it is conservatorily taken to be 0 , one obtains as condition for *equal* velocity at iris and equator(at iris axial and tangential velocities need to be added vectorially):

(4) $$\sqrt{v^2_{ax,iris} + \bar{v}^2_{\tan,iris}} = \bar{v}_{\tan,eq}.$$

With

$$v_{ax,iris} = 0.1 m/s.$$
$$r_{iris} = 0.035 m,$$
$$r_{eq} = 0.103 m,$$
$$\alpha_0 = 0.2 radian$$

one obtains using (3) and(4):

$$f = 1.25\ s^{-1},$$

a frequency easily achieved in practice. Considerably higher velocity of acid flow at equator relative to iris is possible by inreasing frequency, amplitude or both.

Conclusion

The proposed scheme for uniform etching rate appears to be capable of realization, with ample range for varying ratio between flow velocities at equator and iris; even enhanced etching at equator appears to be possible.

It should be tried, and if sucessful, be applied to routine cavity etching. Transport from out off the cells of gas evolved during etching might be aided by the oscillatory motion.

References

1 G. R. Kreps, private communication

2 K. Saito, private communication

3 V. Palmieri, private communication

4 D. Reschke, private communication