EXPERIMENTAL STUDY OF THE SURFACE RESISTANCE OF THE 141 MHZ QUARTER-WAVE RESONATOR AT TRIUMF

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Abstract

The upgrade (Phase II) of the ISAC-II superconducting linac was completed in the spring of 2010 and subsequently commissioned during August 2010. Two spare 141 MHz Quarter-Wave Resonators made of bulk Niobium are available at TRIUMF to enable more specific systematic studies on surface resistance. This opportunity has also been taken to optimize the surface treatment to improve the accelerating field gradient at the operating power level (7W). The aim of the study presented here is to link together several surface treatments (etching depth, 120C baking) and test conditions (Q-disease, 4.2 K and 2K tests) and sequence them in an appropriate order to understand more deeply their dependencies.

INTRODUCTION

The ISAC-II, Phase-II installation[1] will extend the existing linac by 20 more cavities to 40 in total. These quarter-wave resonators (See table 1) are made of bulk Niobium operating at 141 MHz with two spare cavities now available for further studies. These two cavities have been repaired after first etching as they both revealed a leak at the welding joint between the inner conductor and the drift tube (donut). The unique difference between a repaired and non-repaired cavity is that the inner conductor is cut out of the upper flange, repaired and then welded back into place As these cavities may be used later for ISAC-II operations, the study presented here has to comply with ISAC-II requirements (frequency and mechanical stiffness) constraining the etching possibilities.

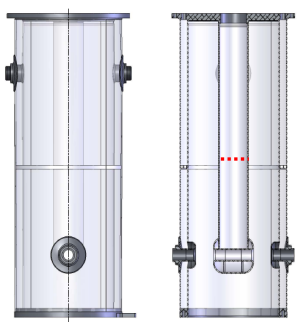

Figure 1: The 141.44MHz rf cavity for Phase II.

As this study aims also at improving the surface treatment of operating cavities, the surface conditioning and cleaning procedures for this study are exactly the same as for ISAC-II cavities. All the steps of this study will be presented further in this paper as well as preliminary results obtained so far.

Table 1: Parameters of the Isac II Phase-II cavities

frequency	MHz	141.44
beta		0.11
U/E_a^2	$J/(MV/m)^2$	0.067
R_SQ_0	Ω	26
E_P/E_a		4.9
B_P/E_a	mT/(MV/m)	10
R/Q	Ω	544

STUDY PRESENTATION

This study commenced towards the end of May 2010 when the two spare cavities were received from PAVAC [2], a local company based in Richmond, BC. Only one cavity has been tested to date as the second could be used later to refine or complete the study depending on the results of the first one.

This study process forms a loop where surface or temperature treatments are sequenced in an appropriate way and characterised each time by a Q-curve measurement at 4.2K so that only one parameter is changed (see Figure 2). No 2K test is evaluated during the early stages of etching as the residual resistance is at least three times larger than the BCS resistance. The Q improvement is thus not very well resolved between 4.2K and 2K.

The main point in this study is to achieve very reproducible steps. This requires that all treatments be performed in the same conditions. The loop can be repeated several times (in our case three times, limited by the material wall thickness and total surface etched).

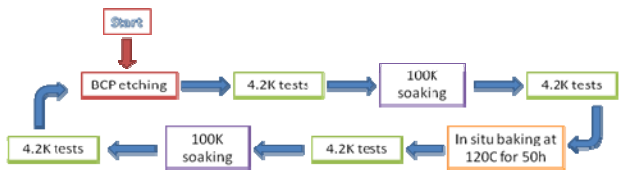

Figure 2: One loop study layout.

By comparing each 4.2K test versus the total etching depth or the Q-disease strength before and after 120C baking, it will be possible with this study to highlight any dependencies between the etching depth, the baking and Q-disease.

Etching and HPR

The first step is a standard BCP etching. Custom etching is employed such that the cavity will reach the correct operating frequency after three etching steps. Since both repaired cavities are higher in frequency than the goal operating frequency custom etching involves

etching more from the `root' end (high magnetic field) than from the beam tube end (high electric field). The cavity helium jacket is filled with cold circulating water and placed with `root' end down and ports plugged. It is first filled half way to etch ~60micron. A slow agitation is provided during the process and the acid refreshed every 10 minutes. The temperature of the acid bath is monitored and kept around 12C. The cavity is then drained and rinsed with deionized water. The second step is an overall etching of about 20 μm with circulating chilled acid. Upon completion the cavity is rinsed with deionized water, then pure alcohol (ethanol) and the cavity is dried in the fume hood.

The cavity is then assembled with stainless steel top flange and damper assembly, then High Pressure Rinsed, and alcohol rinsed and left to dry overnight in a clean room. The cavity is then mounted on the vertical test assembly, inserted in the test cryostat and placed under vacuum. A 24h in-situ drying is performed, consisting in warming up the cavity to around 60C.

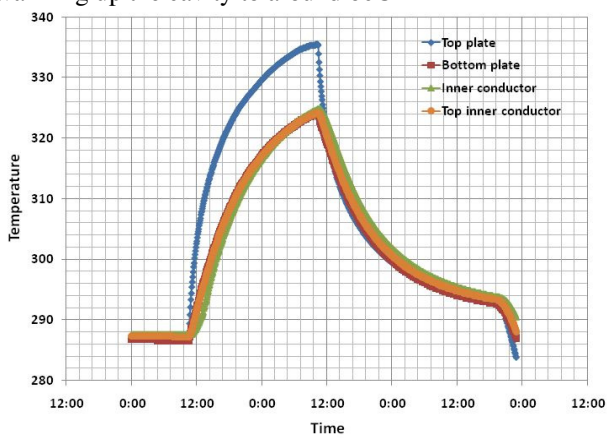

Figure 3: Temperature monitoring during an in-situ drying before test.

4.2 K test and RF set up

TRIUMF is equipped with a vertical cryostat with passive magnetic shielding and a radiation interceptive shield cooled with nitrogen. Liquid helium is supplied directly from refrigerator through isolated transfer lines. Helium exhaust can be pumped down to operate at 2K. During cooling down, a 141 MHz QWR spends less than 1 hour between 200K and 50K limiting the effect of Q-disease (see figure 4).

The RF system is composed of a self-excited loop driven by a 1kW solid state amplifier, that is typically operated to 100W max due to limitations in the RF feedthrough. Measurements are controlled by a Labview program using a frequency meter, oscilloscope and 3 power meter sensors, two connected on a directional coupler measuring the forward and reverse power and one last on the pick-up cable measuring the transmitted power through the cavity pick-up probe. The coupler antenna is mounted on a movable frame allowing adjustments of the coupling during measurement.

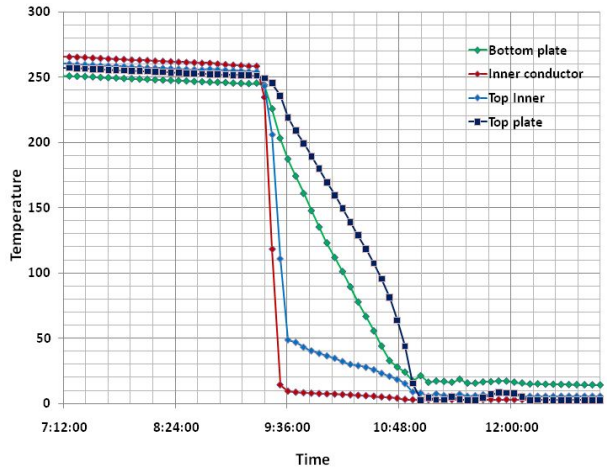

Figure 4: Temperature monitoring during a cooling down from 300K to 4.2K.

Before increasing the field in the cavity, a calibration point is taken to evaluate the calibration factor linking the pick-up power to the energy stored in the cavity. Each measurement is done in critical coupling to minimize error bars.

100K soaking

The aim of the 100K soaking in this study is to evaluate after each additional etching and 120C baking, the strength of the Q-disease and therefore to probe the concentration of Hydrogen close to the surface. This could help to determine whether the improvement after a 120C baking is caused by redistribution of the hydrogen concentration or not.

Thus, to be conclusive, the 100K soaking has to be carried out each time in identical conditions. Two heaters installed on the top and bottom flanges warm the cavity to around 100K after 5h. The cavity is then cooled down below 50K to freeze hydride precipitation.

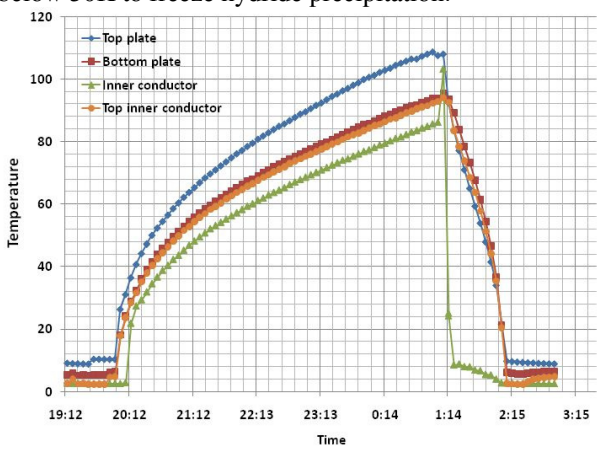

Figure 5: Temperature monitoring during 100K soaking. The cavity reaches 90K after 5h.

In situ 120C baking

The capability to bake a cavity at 120C in-situ under vacuum at TRIUMF is very recent and inspired from IPN Orsay. This is achieved by blowing heated air at about

150C into the helium circuit while the cavity remains in the vertical cryostat. A home-made heater inserted into a cane funnels the hot air directly to the cavity. Two heaters on both the top and bottom flanges are also set. The baking duration is about 48h so that the cavity wall temperature far from the air flow is above 110C for 41h. During the baking process the cavity vacuum is maintained and actively pumped on.

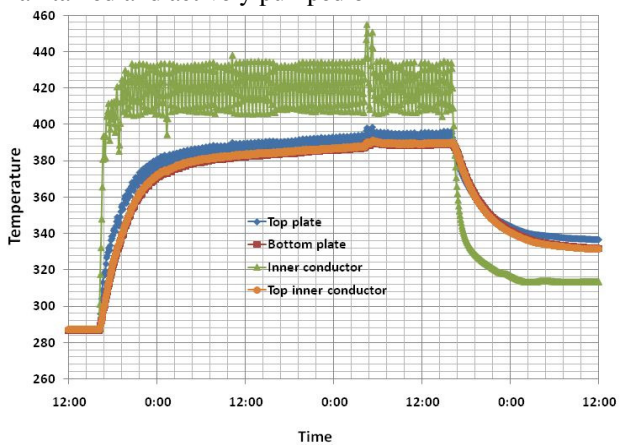

Figure 6: Temperature monitoring during 120C baking. The cavity is above 110C for 41h.

PRELIMINARY RESULTS

At present only one entire loop has been completed. Unfortunately, some technical issues have delayed significantly this study. However, some interesting observations can still be observed (see Figure 7).

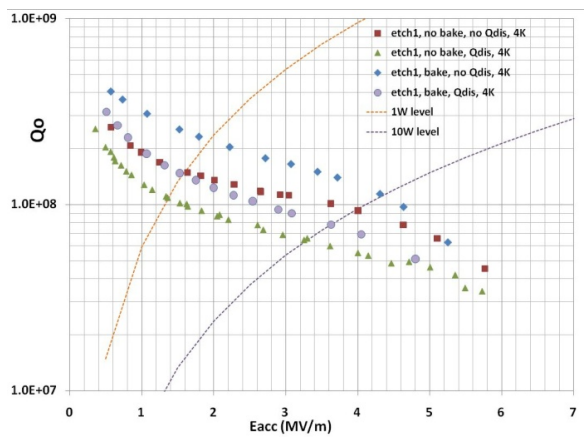

Figure 7: Q curves from the first loop. Square curve is no baking and no Q-disease. Triangle curve is no baking after 100K soaking. Diamond curve is after 120C baking. Circle curve is after 120C baking and 100K soaking.

All four curves here show a Q-disease behaviour whereas only two have been measured after a 100K soaking. As the cavity had been slightly etched (73 µm on magnetic region and 18 µm elsewhere), a part of the damaged layer remains. The latter can contain a non negligible amount of hydrogen that can precipitate enough even during a fast cooling down. We expect, for the next loops, this Q-disease pattern to vanish with an increasing etching depth. Indeed, the Q-factor at low field for a good cavity that meets ISAC-II specifications is supposed to be >1E9 with no slope in the low field region [3].

After a 40h baking at 120C under vacuum, the Q-factor at low field has been improved from 2E8 to 3E8. We can also notice that the Q drop due to the 100K soaking before and after baking shows a similar trend.

In the high field region (>5MV/m), the Q-factor tends to be the same as dissipations from field emission start dominating.

CONCLUSION AND PERSPECTIVES

Due to technical issues, this study has been delayed with only one loop completed. Since the aim of the study is to compare the results at each stage to the results of other loops, no conclusion can be made at this time. This first loop will be used as a reference point. All next etching steps, 100K soaking and 120C baking will be carried out in identical conditions.

The main interest of this study will be to help understanding the 120C baking effect and its link with hydrogen by performing a 100K soaking before and after baking for different etching steps. This will also give us the opportunity to define the minimal etching depth required to meet ISAC-II specification. This 3-loops study should be completed at the end of this year.

ACKNOWLEDGEMENTS

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REFERENCES

[1] R.E. Laxdal, et al, “Operating Experience of the 20MV Upgrade Linac”, these proceedings.
[2] R. E Laxdal, et al, “ISAC-II : Status of the 20MV Upgrade”, SRF2009, Berlin, September 2009.
[3] http://www.pavac.com/