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LOW-TEMPERATURE BAKING AND INFUSION STUDIES FOR HIGH-GRADIENT ILC SRF CAVITIES*

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Abstract

Low-temperature infusion has become a hot-topic in SRF researches recently. Past results show that low-temperature infusion can produce high quality factor at medium accelerating fields. Also, 75ºC baking recently has been shown to improve accelerating gradients of SRF cavities. Hence these treatments are very promising for reducing cost of the ILC. In this work, we present latest results of low temperature infusion and baking, showing that these treatments can improve SRF cavities performance.

INTRODUCTION

The proposed International Linear Collider (ILC) is a proposed 200-500GeV linear electron-positron collider, based on 1.3GHz superconducting radio-frequency (SRF) technology [1]. The total cost of the ILC is an important constraint, determining whether the project is feasible or not. As the main part of the linear collider consist of SRF cryomodules, the performances, e.g. quality factor Q_0 and accelerating gradients (E_{acc}), of the SRF cavities are critical to control the cost of the ILC; because high-Q_0 cavities can reduce cryogenic loads, and high-gradient cavities will decrease the total length of the ILC.

The baseline technology of ILC to produce SRF cavities is electropolishing and 120°C baking which can produce a cavity with E_{acc} ~35 MV/m with $Q_0 \sim 8\times10^9$. However, recently new discoveries in SRF field, e.g. low-temperature infusion [2, 3] and 75°C baking [4], could have large potentials to improve quality factor and gradient, and thereby to reduce cost.

CAVITY PREPERATION

We use two 1.3 GHz ILC-type single-cell SRF cavity (LTE1-14 and LTE1-15) for this work. As the baseline treatment, the two cavities had been treated by the ILC baseline recipe [5], i.e. 100 um surface removal by electropolishing (EP), and 900ºC baking for 3 hours, and then 120ºC baking for 48 hours. After the baseline treatment, both cavities have been vertically tested on the Cornell wave-guide insert allowing regular CW and high-power pulse measurement in same cryogenic cycle, as is shown in Fig. 1 [6]. After that, the cavity LET1-14 was baked at 800 ºC for 3 hours then baked at 120ºC under ~40mTorr N_2 for 48 hours. During the baseline treatment and 120ºC infusion, witness samples were baked with the cavities. SIMS data of the samples showed the 120ºC infusion increases the level of nitrogen and carbon, as is shown in Fig. 2. LET1-14 has been tested after the infusion; then the cavity was 75°C baked for 6 hours on the insert and tested again.

LTE1-15 received the 1st 75°C baking for 6 hours on the insert after the baseline test; then the cavity was tested again. After that we did HF rinsing of the cavity, followed by another test. At last, the 2nd 75°C baking was carried out for the cavity on the insert and followed by a final vertical test.

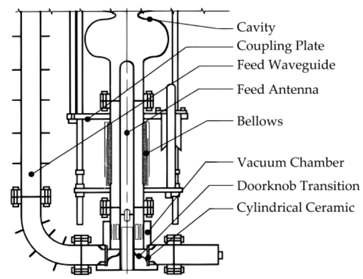
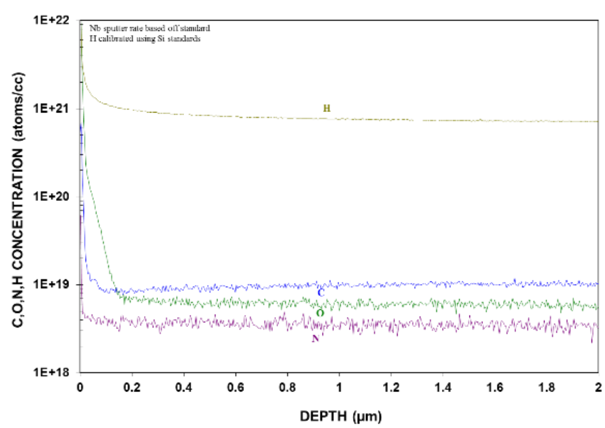
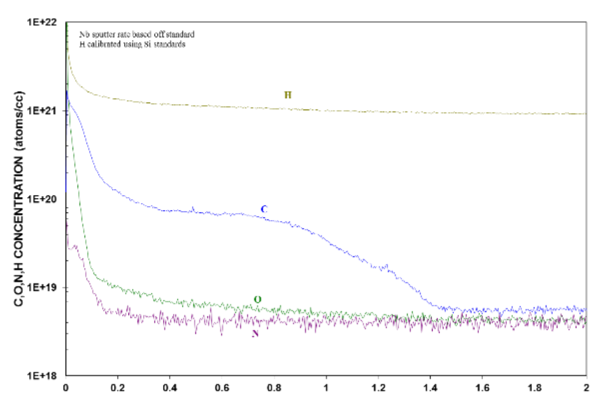


Figure 1: Schematic of wave-guide insert allowing regular CW and high-power pulse measurement in same cryogenic cycle.



(a) SIMS data of samples baked at 120°C under vacuum.



(b) SIMS data of samples baked at 120°C under N_2.

Figure 2: SIMS data comparison between 120°C baking under vacuum and under N_2.

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The set-up used during the 75°C baking on the wave-guide insert is shown in Fig. 3. The reason for baking on the insert is to minimize chances of contamination from cavity disassembly. During the baking, a heat gun blows hot air to keep cavity at the temperature of 75 ± 3°C.

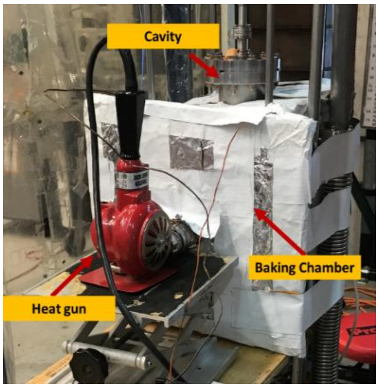

Figure 3: Set-up of 75C baking on the wave-guide insert.

TEST RESULTS AND ANALYSIS

The Q_0 versus E_{acc} results from cavity LTE1-14 are summarized in Fig. 4. The baseline test showed that the cavity quenched around 23MV/m, the average Q_0 is ~1.4×10^{10}. After the 120°C infusion, the quench field was increased to 26 MV/m with average Q_0 ~ 2×10^{10} in CW measurement. The cavity achieved 40MV/m in high-power pulse (HPP) tests in which 300kW 250 us high-power pulses were applied to the cavity, as is shown in Fig. 5. The 75°C baking decreased the cavity Q_0 to 1.2×10^{10}, but the max field was improved to 30 MV/m. In the three test, there is no medium-field Q-slope. The maximum gradients in CW and HPP operation are summarized in Table 1.

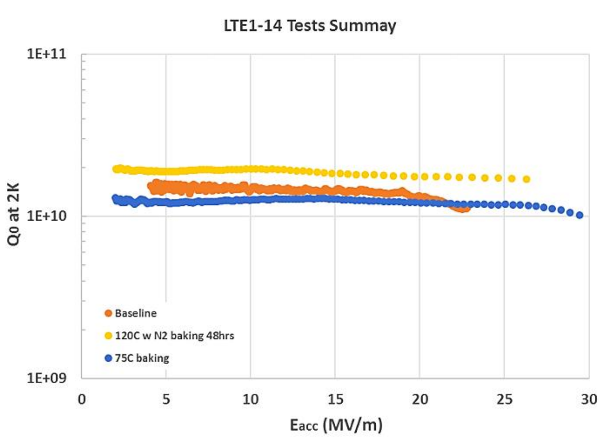

Figure 4: LTE1-14 Q_0 vs. E_{acc} curves.

Figure 6 shows the Q_0 versus E_{acc} measurements for cavity LTE1-15. The baseline test showed a quench around 24 MV/m. After the 1st 75°C baking, the cavity gradient increased to 35 MV/m, but the cavity showed heavy field emission (FE) and low low-field Q_0. The cavity was disassembled for HF rinsing and re-HPR to reduce residual resistance and eliminate the FE. Afterwards, Q_0 had improved, but the quench field decreased to 26 MV/m. Likely, the HF rinsing removed the 75°C baking effect. We then carried out the 2nd 75°C baking of the cavity, but the performance had not charged in the following test. The quench fields of LTE1-15 in CW and HPP measurements are summarized in Table 2.

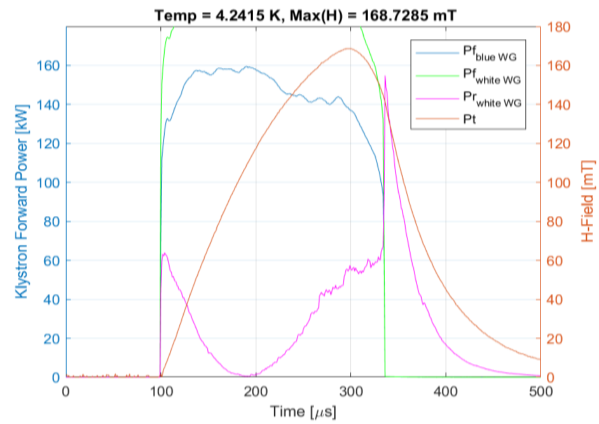

Figure 5: HPP test results after 120°C infusion showing the maximum B-field achieved was 169 mT, i.e. E_{acc} ~ 40 MV/m.

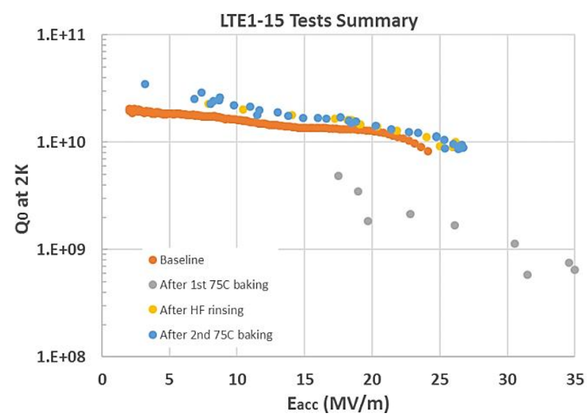

Figure 6: LTE1-15 Q_0 vs. E_{acc} curves.

Table 1: LTE1-14 Quench Field Summary

Treatment	CW (MV/m)	HPP (MV/m)
Baseline	23	NA
120°C baking with N2	26	40.2
75°C baking	30	NA

Table 2: LTE1-15 Quench Field Summary

Treatment	CW (MV/m)	HPP (MV/m)
Baseline	24	34.3
1st 75°C baking	36	NA
HF rinsing	26	NA
2nd 75°C baking	26	NA

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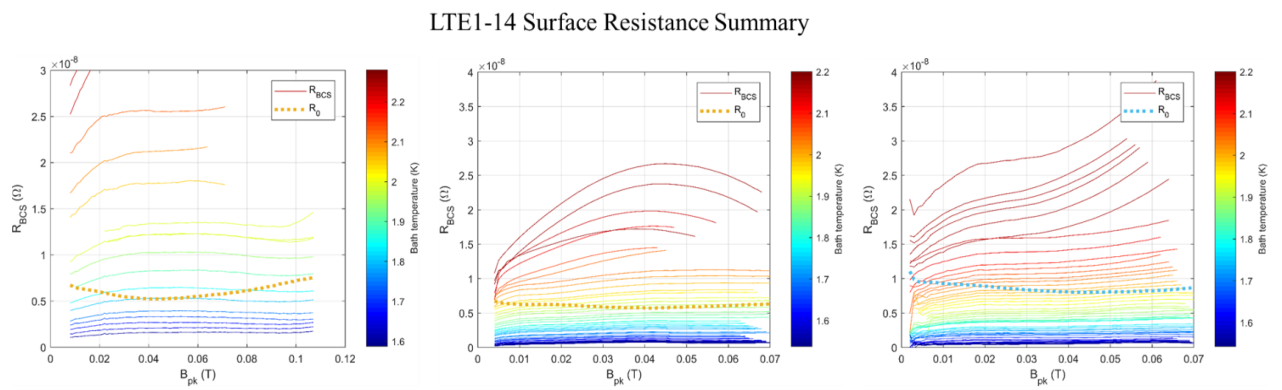

(a) Baseline test (b)120°C baking 48 hours with N2 (c)75°C baking 6 hours

Figure 7: LTE1-14 surface resistance summary.

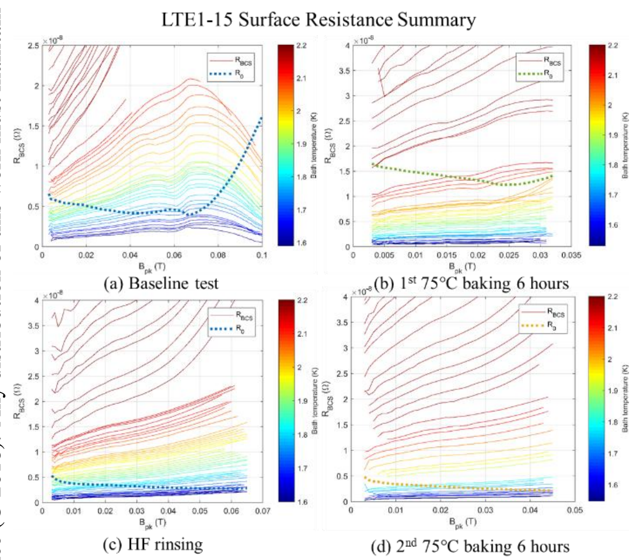

Figure 8: LTE1-15 surface resistance summary.

The LTE1-14 and LTE1-15 surface resistance results are summarized in Fig. 7 and Fig. 8 respectively. Frequency versus temperature data was taken during cavity warm-up. The mean-free-path of each treatment was extract from these, and are listed in Table 3 and Table 4 for LTE1-14 and LTE1-15 respectively.

Table 3: LTE1-14 Mean-free-path Summary

Treatment	**Mean free path** (nm)
Baseline	~260
120C baking with N2	2.4
75C baking	47

Table 4: LTE1-15 Mean-free-path Summary

Treatment	**Mean free path** (nm)
Baseline	~260
1st 75°C baking	83
HF rinsing	71
2nd 75°C baking	62

CONCLUSION

A series of surface preparation recipes have been studied via two 1.3 GHz ILC-type SRF cavities (LTE1-14 and LTE1-15). SIMS data showed that the 120ºC N2-infusion increases the level of nitrogen and carbon in the RF penetration layer. The test results after the infusion showed that the residual resistance was at the same level as during the baseline test, but the BCS resistance had been reduced to below 10 nΩ. Hence the Q_0 has improved to ~2×10^{10}. We applied 75ºC baking after 120ºC baking. The 75ºC baking increased residual resistance in both tests. But it did not dramatically change the BCS resistance.

The cavities achieved much higher E_{acc} in the HPP tests in which ~300kW 250 us high-power pulses were applied to the cavities. We observed that the max field of cavities E_{acc} had been significantly improved after 75ºC baking. HF rinsing can remove the extra residual resistance added by 75ºC baking, but it also removed the gradient improvements from the 75ºC baking.

Frequency versus temperature fitting shows that the mean free path became extreme short ~2.4nm after 120ºC infusion; but the mean-free path level was 47-83 nm after 75ºC baking.

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