

HIGH-GRADIENT SRF CAVITY R&D AT CORNELL UNIVERSITY*

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Abstract

Achieving high accelerating field is a critical R&D topic for superconducting RF cavities for future accelerators including the International Linear collider (ILC). The ILC requires an average accelerating field of 35MV/m with a Q_0 of at least 8.9×10^9 at 2K. In this paper, we report the latest results from high-gradient research at Cornell, which focusses on 75°C vacuum baking to improve maximum (quench) fields. We demonstrate that such low temperature bakes can significantly improve quench fields in certain cases. We further report on high-pulsed power results of these cavities before and after baking.

INTRODUCTION

High-gradient SRF cavities R&D is critical for future superconducting accelerators. The proposed International Linear Collider (ILC) for future High-Energy Physics research ought to generate a beam energy of up to 250 GeV [1]. Hence the SRF cavities, the key component of this accelerator, are required to provide an operating accelerating gradient of 35MV/m with the quality factor above 8.9×10^9 at 2K.

The 75°C baking effect [2] had been firstly discovered after a furnace malfunction during a standard 120°C baking; the cavity after the non-standard bake reached nearly 50MV/m. Hence, it is warranted to carry out dedicated low-temperature baking studies aiming at benefiting SRF cavity performance for future accelerator projects.

CAVITY PREPERATION

We used two 1.3 GHz ILC-type single-cell SRF cavities (LTE1-14 and LTE1-15) and a 2.6 GHz ILC-shape SRF cavity (STE1-1) for this work. As the baseline treatment of the 1.3GHz cavities, the cavities were treated by the ILC baseline recipe [3], i.e. 100 μ m surface removal by electro polishing (EP), and 900°C baking for 3 hours, and then 120°C baking for 48 hours. After the baseline treatment, both cavities have been vertically tested on the Cornell waveguide insert allowing regular CW and high-power pulse measurement in same cryogenic cycle. After that, the cavity LET1-14 was baked at 800°C for 3 hours then baked at 120°C under ~ 40 mTorr N_2 for 48 hours. LET1-14 has been tested after the infusion. Finally, the cavity was 75°C baked for 6 hours on the insert and tested again.

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

STE1-1 was baked in a 40mTorr N_2 atmosphere at 160°C for 48 hours before the cavity was vertically performance tested. After the test, the cavity was HF rinsed to regrow the oxide layer on the surface and then it was loaded into a furnace for a 6 hours 75°C vacuum bake.

The set-up for the 75°C baking on the wave-guide insert is shown in Fig. 1. 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 $75 \pm 3^\circ\text{C}$.

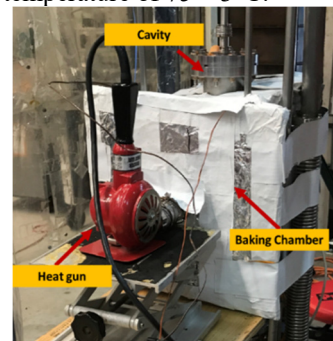


Figure 1: Set-up of 75°C baking on the waveguide insert.

TEST RESULTS AND ANALYSIS

The Q_0 versus E_{acc} results from cavity LTE1-14 are summarized in Fig. 2. The baseline test showed that the cavity quenched around 23MV/m with an average 2K Q_0 of $\sim 1.4 \times 10^{10}$. After the 120°C infusion, the quench field was increased to 26 MV/m with average $Q_0 \sim 2 \times 10^{10}$ in CW measurement. The cavity achieved 40MV/m in high-power pulse (HPP) tests in which 300kW, 250 μ s high-power pulses were applied to the cavity, as is shown in Fig. 3. The 75°C baking decreased the cavity Q_0 to 1.2×10^{10} , but the maximum CW field was improved to 30 MV/m. In the three tests, there no medium-field Q-slope was observed. The maximum gradients in CW and HPP operation are summarized in Table 1.

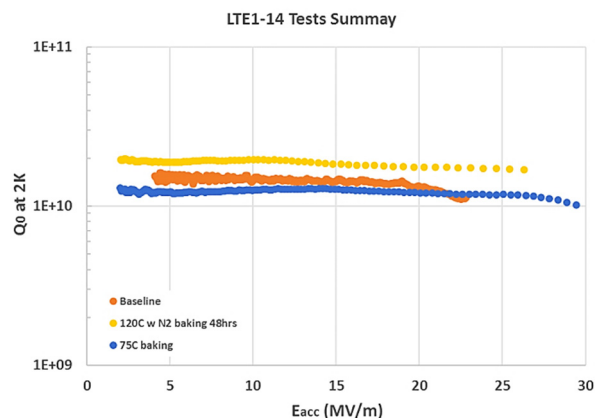


Figure 2: LTE1-14 Q_0 vs. E_{acc} curves at 2K.

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Figure 4 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 high-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 a 2nd 75°C baking of the cavity, but the performance did not change in the following test. The quench fields of LTE1-15 in CW and HPP measurements are summarized in Table 2.

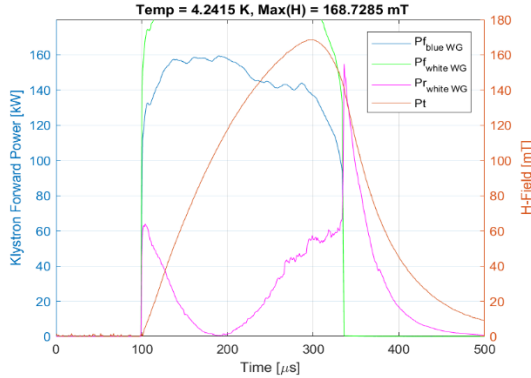


Figure 3: HPP test results after 120°C infusion showing the maximum B-field achieved was 169 mT, i.e. $E_{acc} \sim 40$ MV/m.

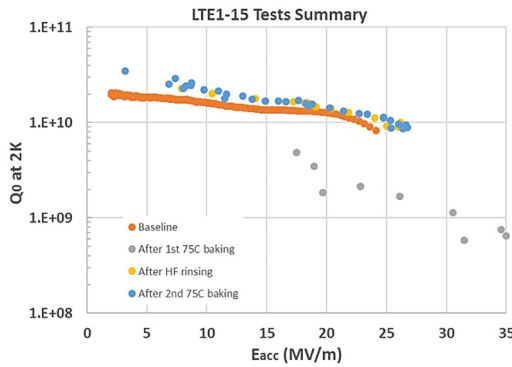


Figure 4: LTE1-15 Q_0 vs. E_{acc} curves.

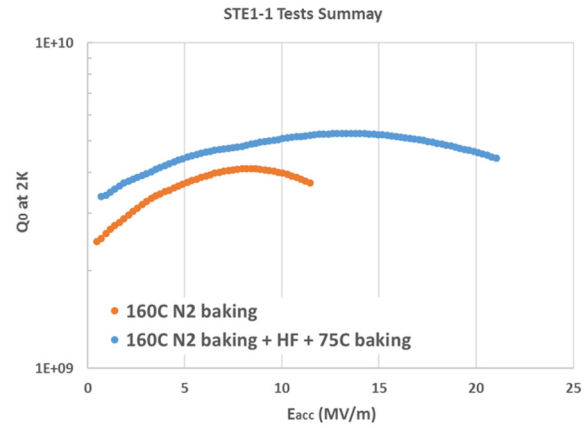


Figure 5: LTE1-15 Q_0 vs. E_{acc} curves.

The comparison of the Q vs. E_{acc} curves of STE1-1 before and after 75°C baking is showed in Fig. 5. In this case, we performed a HF rinsing to reduce R_0 . The maximum accelerating field was dramatically improved after the baking.

The LTE1-14 and LTE1-15 surface resistance results are summarized in Fig. 6 and Fig. 7 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 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
1 st 75°C baking	36	NA
HF rinsing	26	NA
2 nd 75°C baking	26	NA

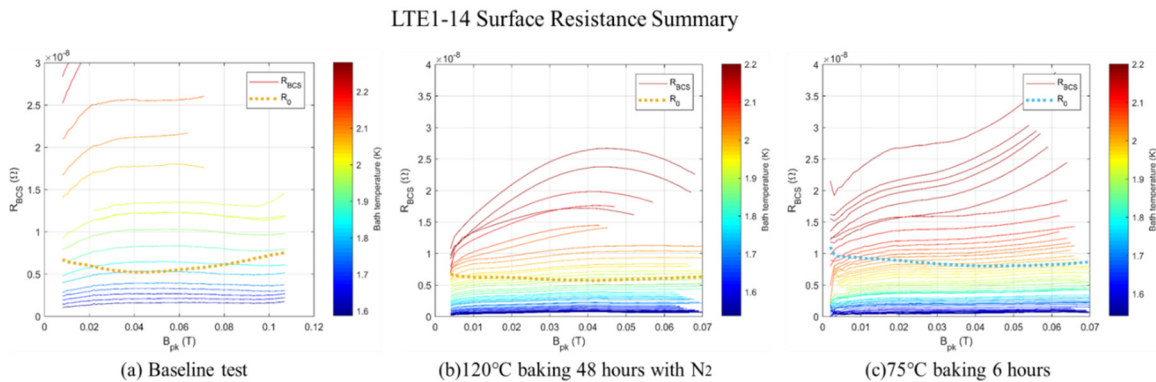


Figure 6: LTE1-14 surface resistance summary.

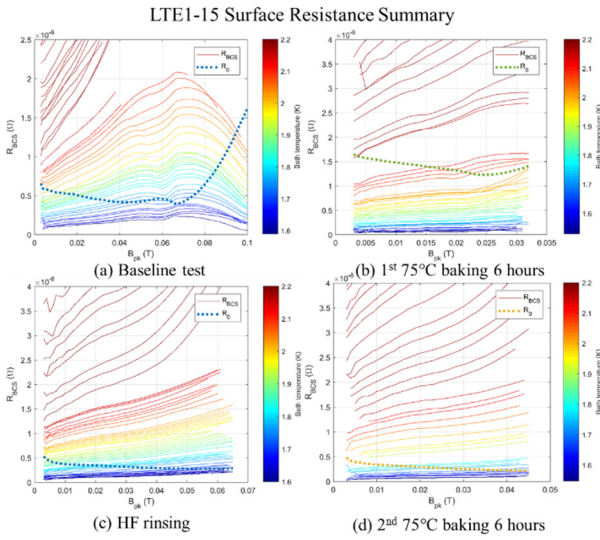


Figure 7: LTE1-15 surface resistance summary.

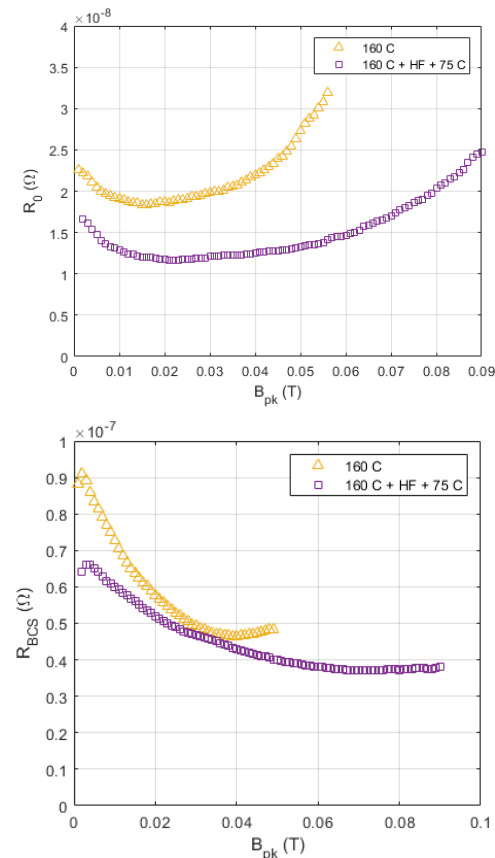


Figure 8: STE1-1 surface resistance summary. The top-plot summarizes R_0 and bottom-plot is the comparison of R_{BCS} .

The comparison of the surface resistance, shown in Fig. 8, shows that the residual surface resistance had been dramatically reduced by the HF rinsing and 75°C baking. The minimum R_0 after the HF rinsing is closed to 10 nΩ, almost 50% less than the value before the treatment. The R_{BCS} before and after the treatment is very close in the medium-field region.

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

Treatment	Mean free path (nm)
Baseline	~260
120°C baking with N ₂	2.4
75°C baking	47

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

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

CONCLUSION

A series of surface preparation recipes has been studied via two 1.3GHz ILC-type SRF cavities (LTE1-14 and LTE1-15) and one 2.6 GHz ILC-shape SRF cavity (STE1-1). The 1.3 GHz cavity results after the infusion showed that the residual resistance was at the same level as for the baseline test, but the BCS resistance had been reduced to below 10 nΩ. Hence the Q_0 had been improved to $\sim 2 \times 10^{10}$. We applied 75°C baking after 120°C baking. The 75°C baking increased residual resistance in both tests, but it did not dramatically change the BCS resistance. In the 2.6 GHz cavity case, the both residual and BCS resistances were reduced after the HF rinsing plus 75°C baking.

The cavities achieved much higher E_{acc} in the HPP tests in which ~ 300 kW 250 μs high-power pulse was applied to the cavities. We observed that the maximum field of the cavities had improved after 75°C baking in both 1.3 GHz and 2.6 GHz cavity cases. Frequency versus temperature fitting shows that the mean-free-path (MFP) became extreme short ~ 2.4 nm after 120°C infusion; but the MFP level was 47-83 nm after 75°C baking.

REFERENCES

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