Impact of medium temperature heat treatment on flux trapping sensitivity in SRF cavities

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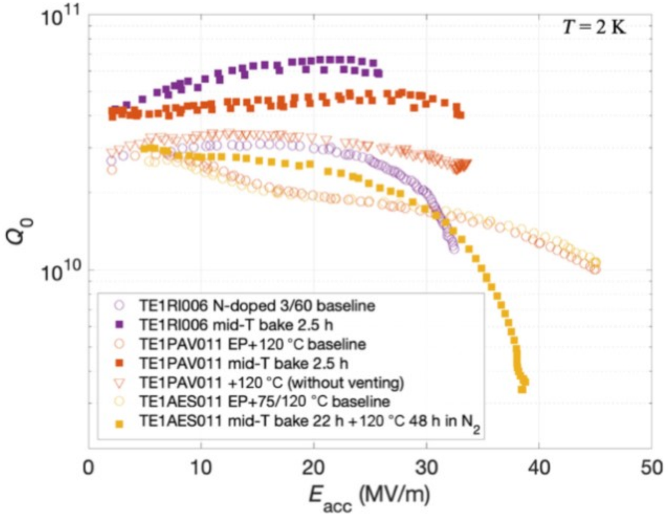
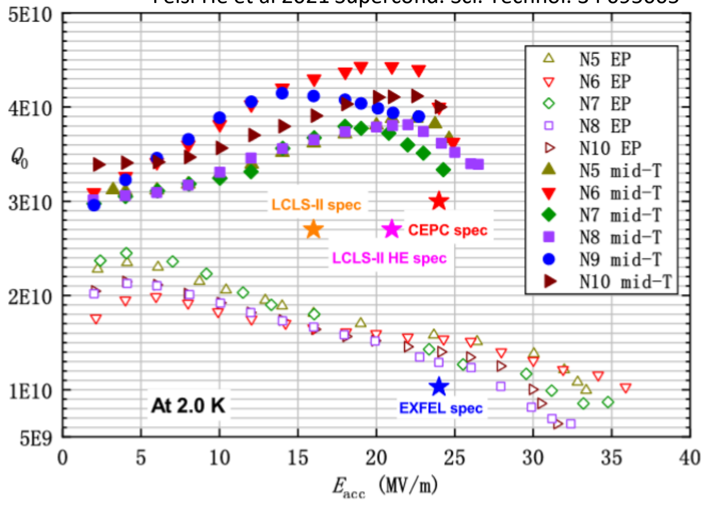
Background

- Over the last decade, SRF technology progressed towards achieving high Q_0, with material “doping”, “Infusion”, “alloying”….
- Although active area of research, high Q_0 is understood due to the reduction in BCS surface resistance due to the presence of impurities and Q-rise arise from the change in quasi-particle density of states.
- Recent processing technique was focused on medium temperature baking (200- 400 °C) due to its simple process.
- Due to the presence of impurities, the additional rf loss in introduced due to residual flux trapping.

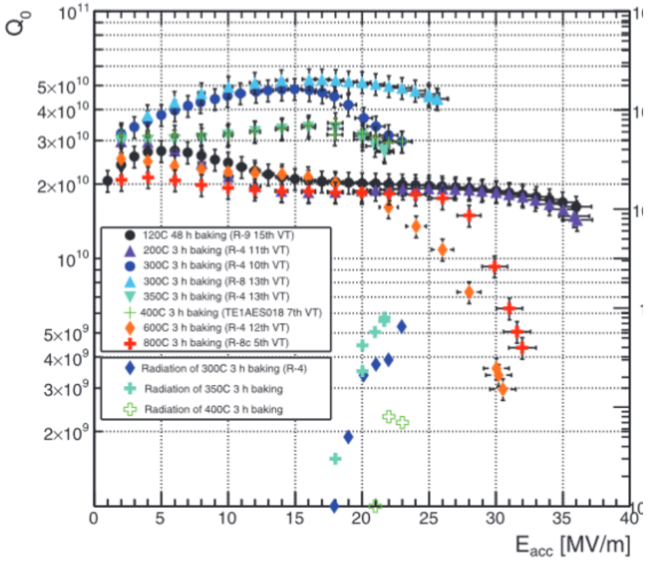
Posen et al., PHYS. REV. APPLIED 13, 014024 (2020)



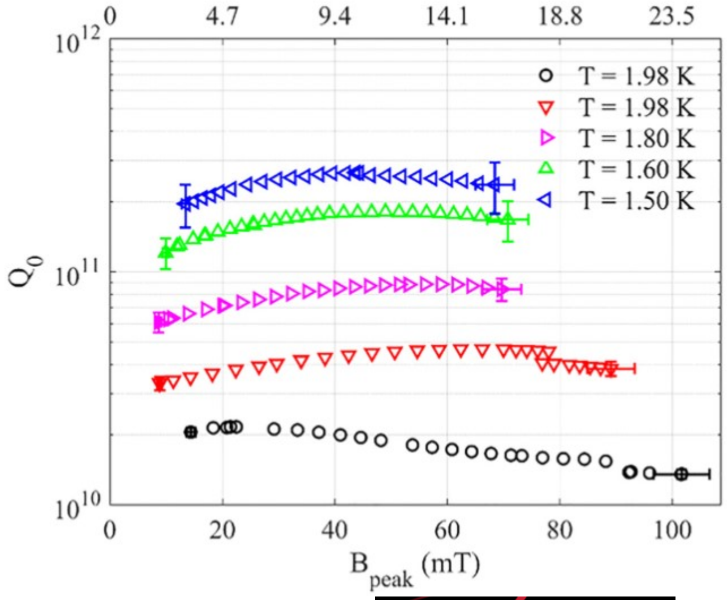
Feisi He et al 2021 Supercond. Sci. Technol. 34 095005



Ito et al., Prog. Theor. Exp. Phys. 2021, 071G0



Lechner et al., Appl. Phys. Lett. 119, 082601 (2021)



Current Study

- Two 1.3 GHz TESLA shaped single cell cavities, namely TE1-05 and TE1-06 were used for this current study. The cavities were previously heat treated at higher temperature (1000 ^oC) followed by 25 μm electropolishing to ensure that the cavity provides good flux expulsion.

- Before mid-T heat treatment, the cavities were high pressure rinsed with de-ionized water, dried in a class 10 clean room, installed clean Nb foils in the beam-tube opening, and transported to the furnace.

- The furnace temperature was increased at a rate of $\sim 2 - 5$ ^oC / min until it reached the target temperature. The furnace was held at the desired temperature for 3 hours and cooled to room temperature.

- The RF measurements consist of $Q_0\ (T)$ at low peak rf field $B_p \sim 15\ mT$ at $Q_0\ (Bp\ )$ at 2.0 K was measured with two different condition of flux trapping (< 1 mG and ~ 20 mG)

- Flux trapping sensitivity was calculated using:

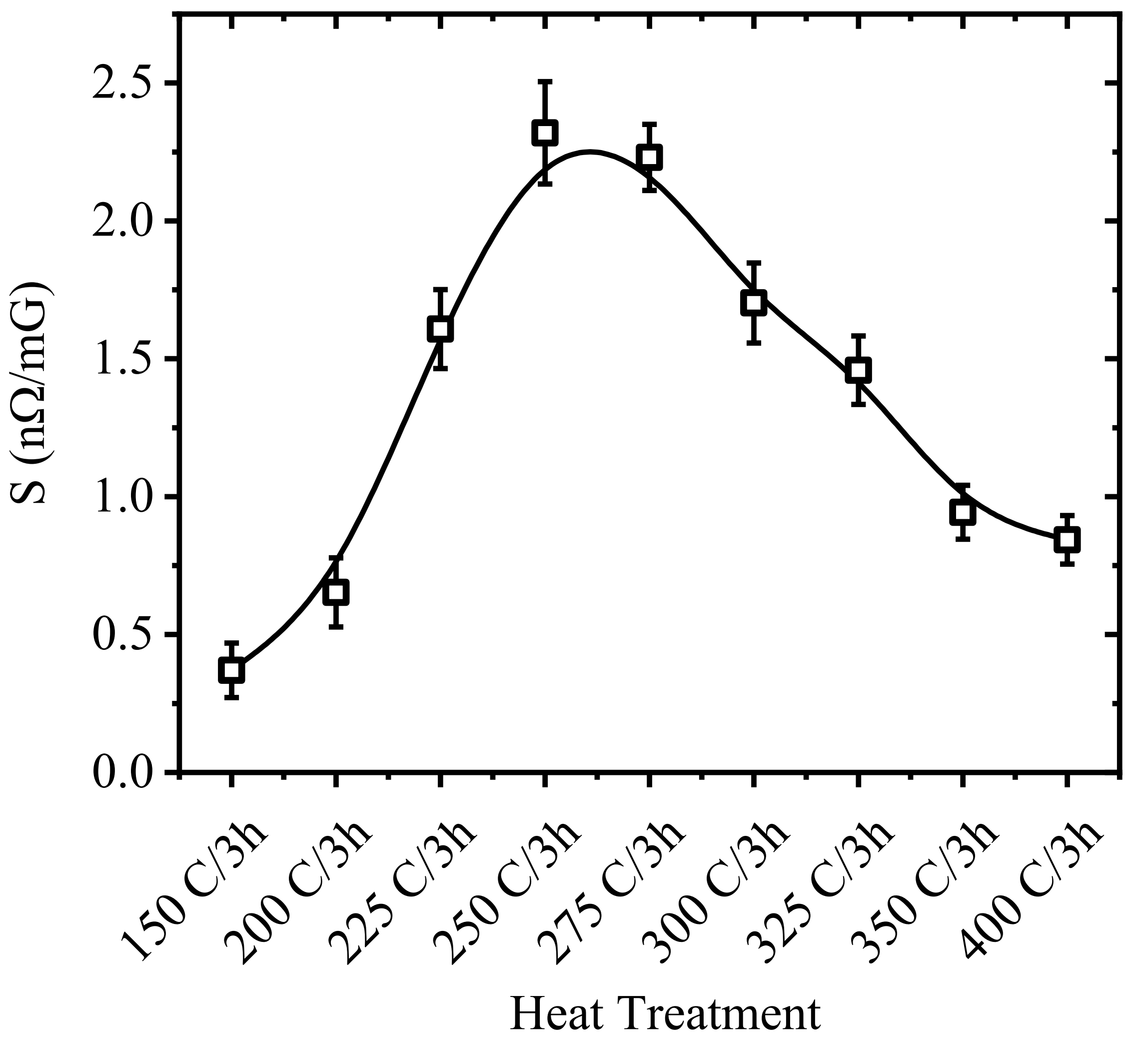
$$S = \frac{R_{i,B_2} - R_{i,B_1}}{B_2 - B_1}$$

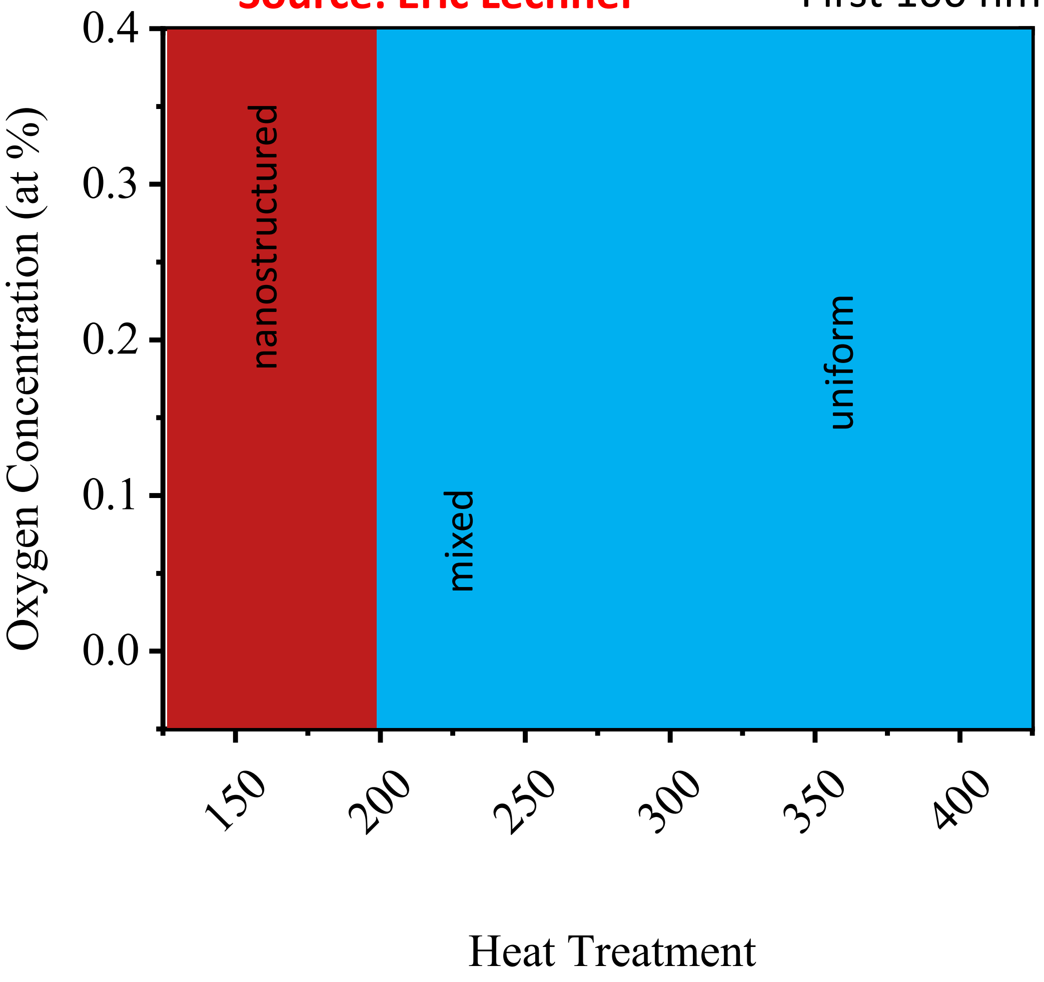
R_i = Residual resistance

$$S = \frac{R_{s,B_2} - R_{s,B_1}}{B_2 - B_1}$$

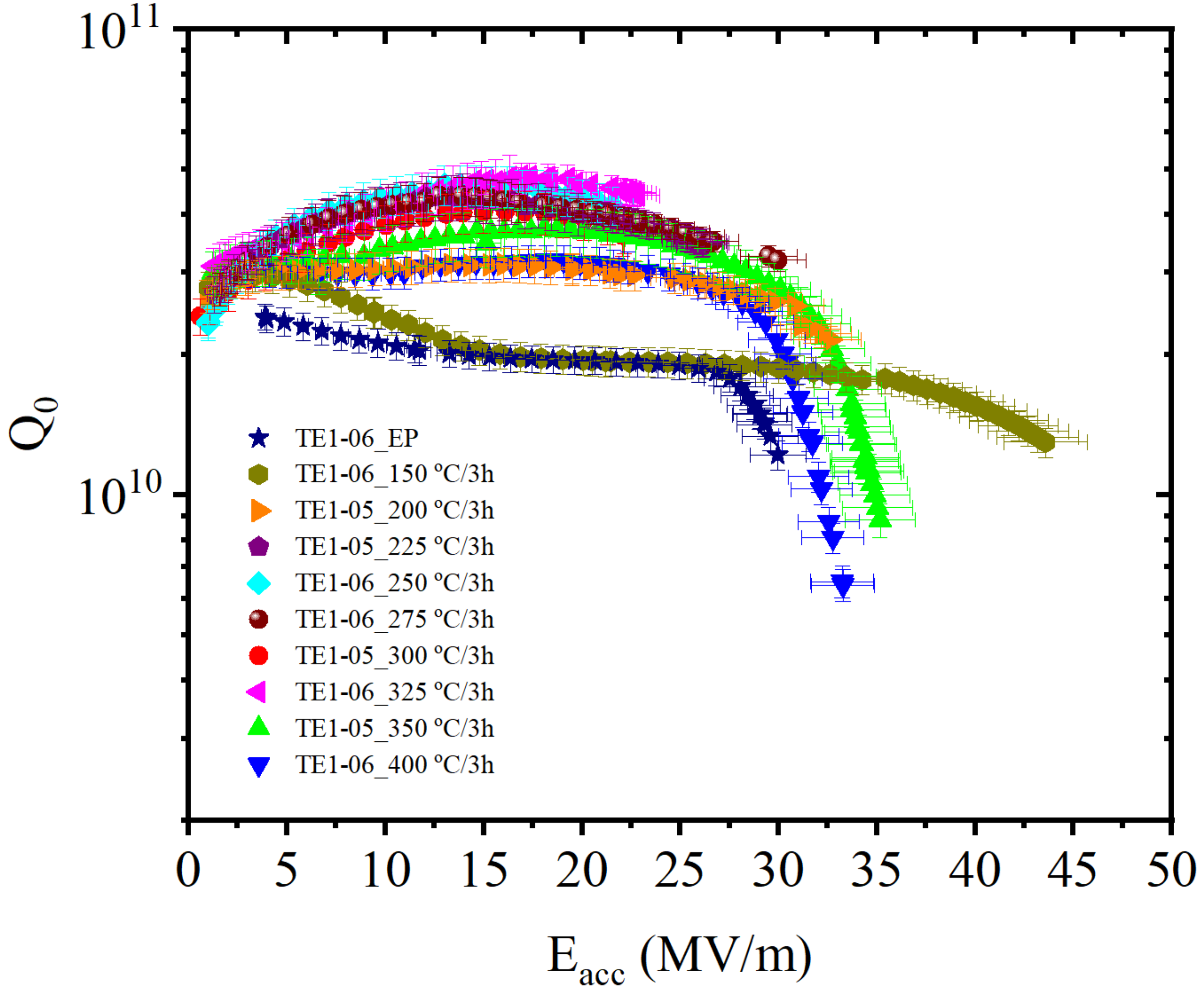
R_s = Surface resistance at 2 K

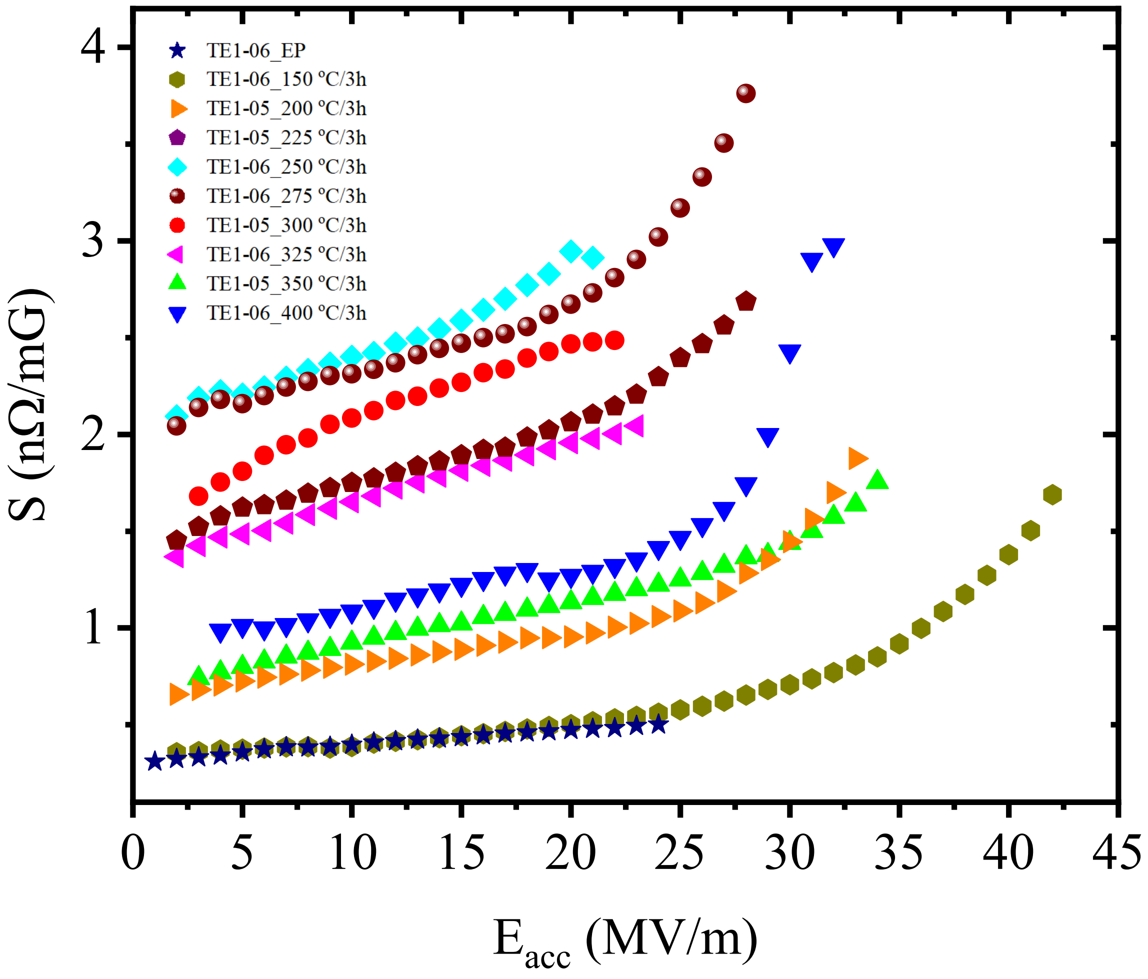
Flux trapping sensitivity from residual resistance





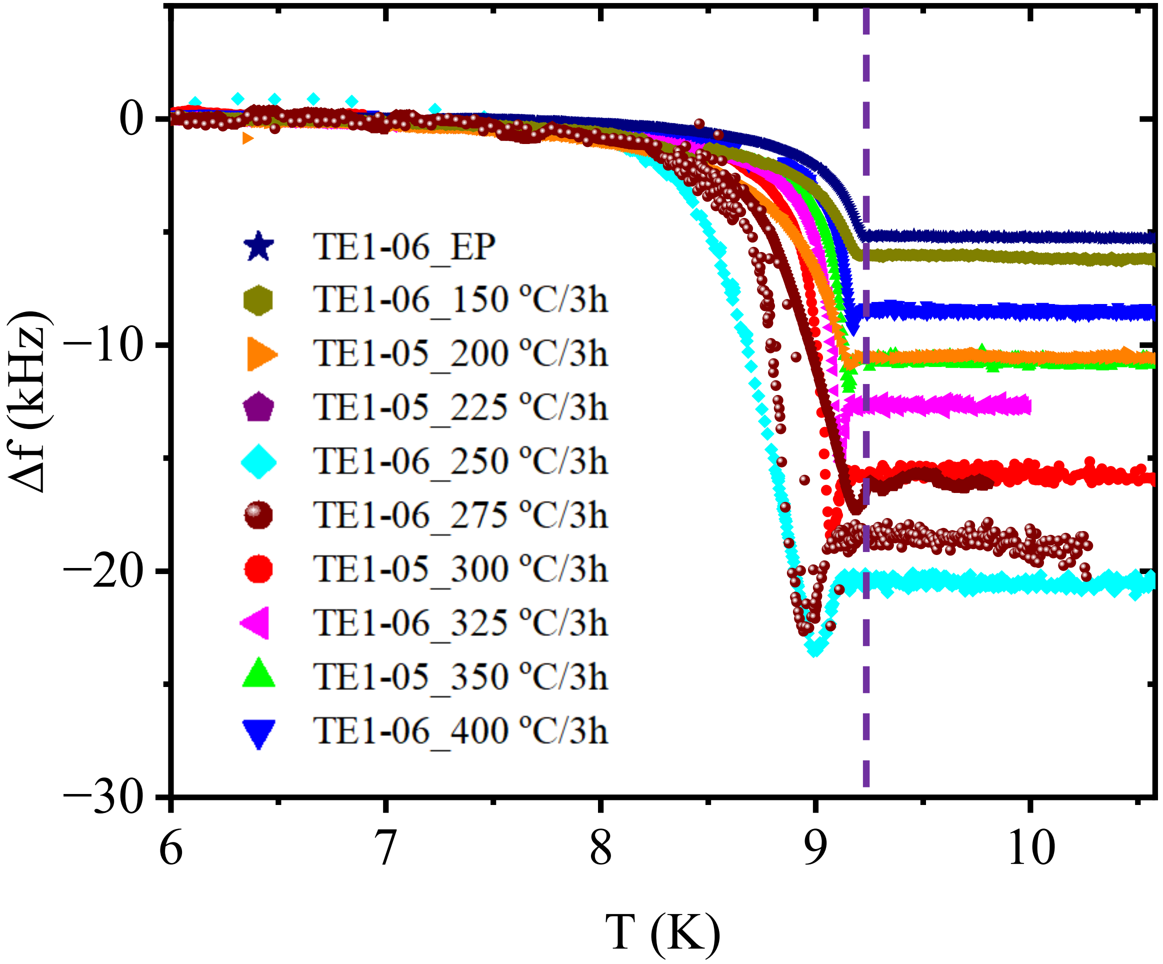
$Q_0(E_{acc})$ and 2.0 K and field dependence of S

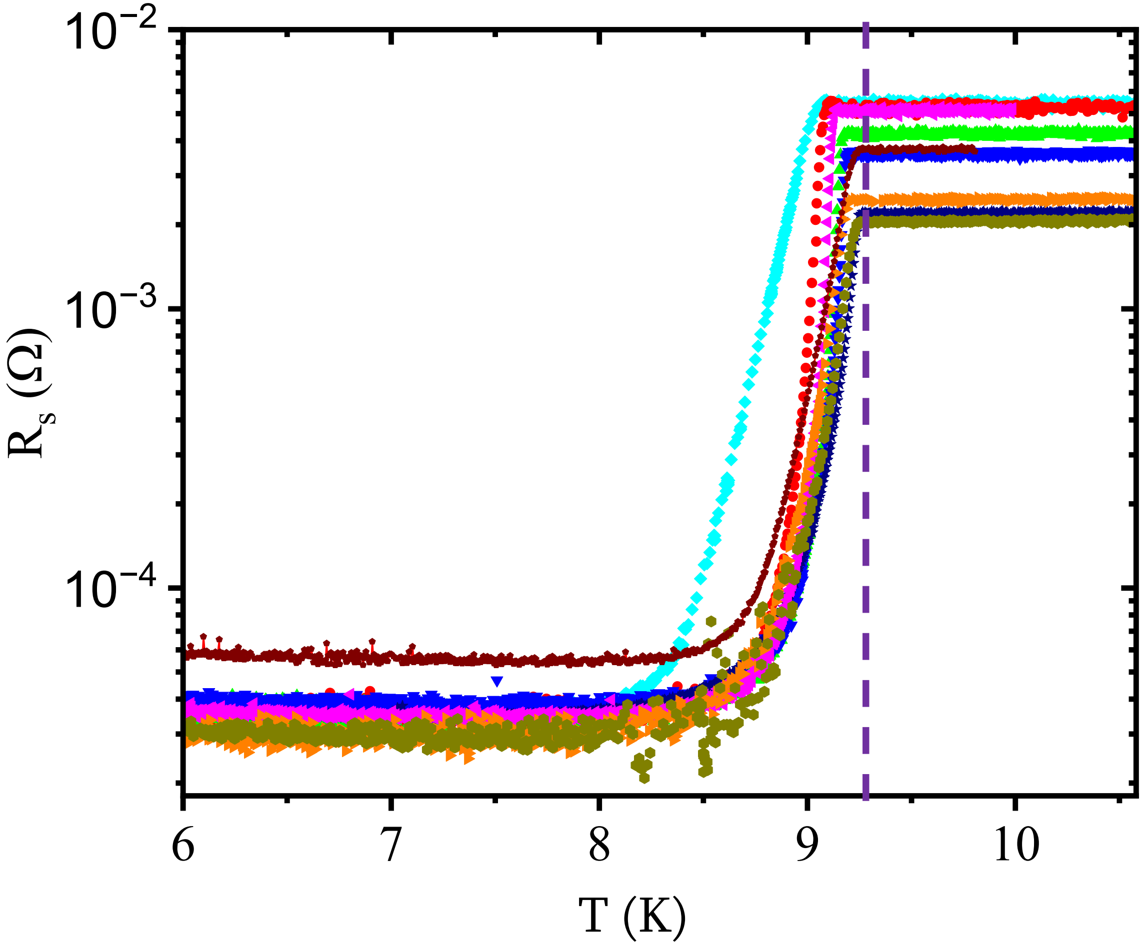




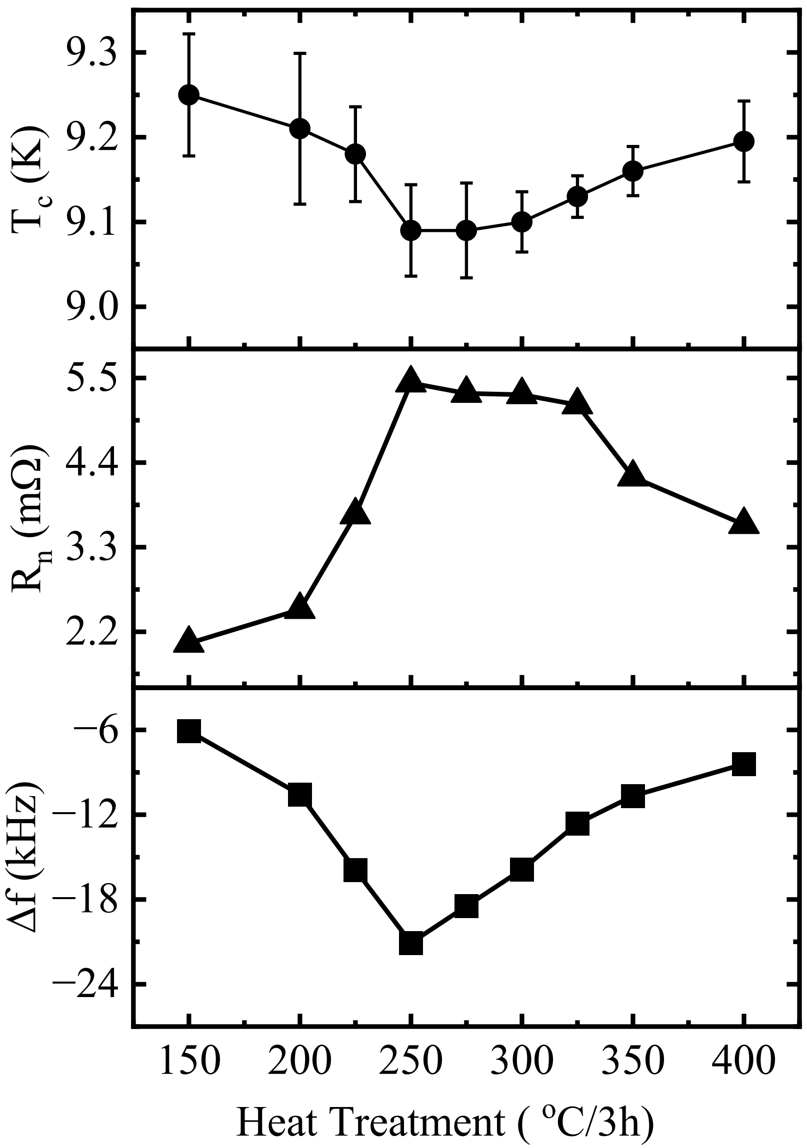
Similar observation by Ito et al

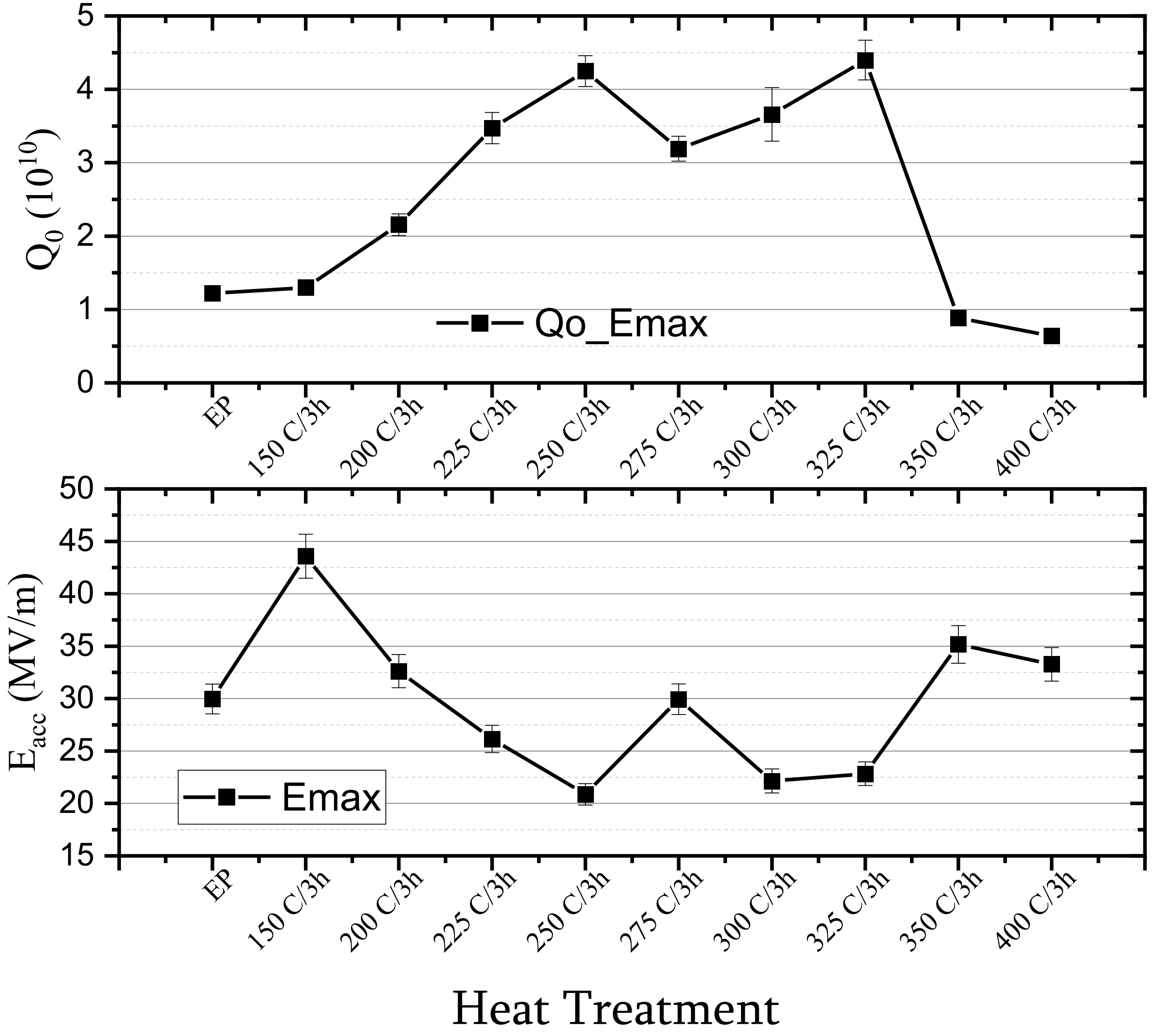
Frequency and Q_0 during warm up



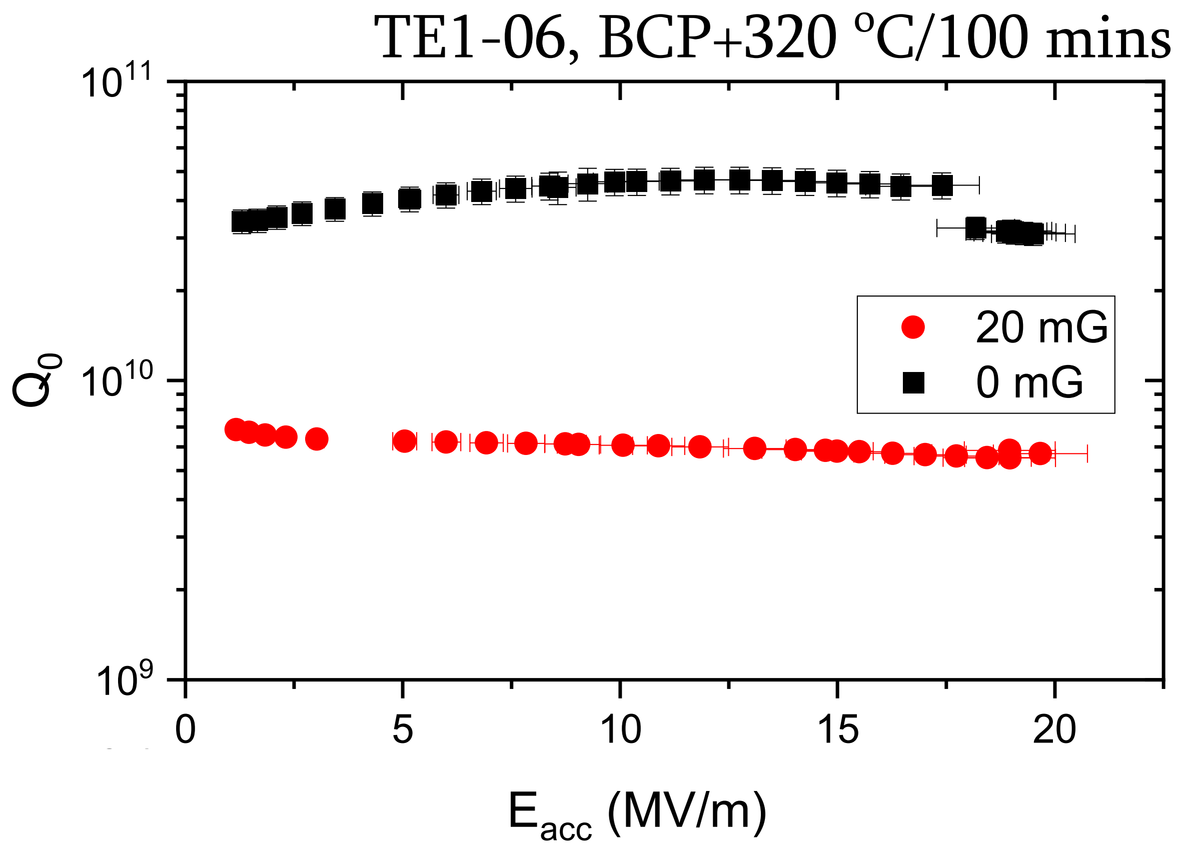


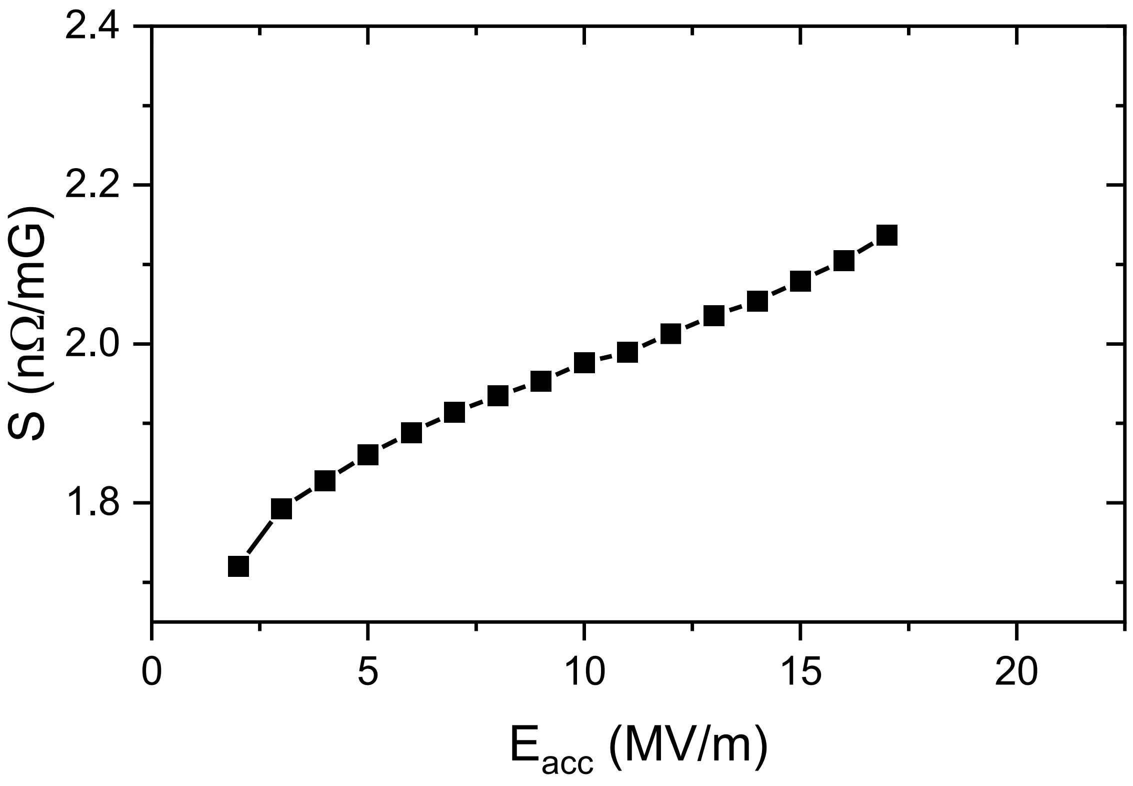
RF Results Summary





Mid T on BCP treated cavity





Mid-T works on BCP treated cavities as well

Summary

- The enhancement of the quality factor through Q-rise is evident following heat treatments within the temperature range of 200 to 400 ^{o}C over a duration of 3 hours
- Cavities treated within the temperature range of 250 to 325 ^{o}C/3h exhibit a tendency to quench at lower gradients (20 - 25 MV/m) compared to cavities treated outside of this temperature range.
- Several instances of strong multipacting were observed at this gradient range in contrast to the baseline EP'ed cavities, suggesting a possible surface modification due to heat treatment, which causes a change in secondary electron emission yield.
- The sensitivity to flux trapping increases with rising heat treatment temperatures within the range of (200 - 325 ^{o}C/3h) and the sensitivity to flux trapping gradually diminishes with increasing heat treatment temperatures.
- The feature on frequency near Tc and change in Tc shows the redistribution of the oxide on the Nb surface due to heat treatment.
- The reappearance of high field Q-slope when heat treatment temperature higher than 350 ^{o}C, still need further investigation.