Operations of Copper Cavities at Cryogenic Temperatures

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This work is focused on the anomalous skin effect in copper and how it affects the efficiency of copper-cavities in the temperature range 40-50 K. The quality factor Q of three coaxial cavities was measured over the temperature range from 10 K to room temperature in the experiment. The three coaxial cavities have the same structure, but different lengths, which correspond to resonant frequencies: around 100 MHz, 220 MHz and 340 MHz. Furthermore, the effects of copper-plating and additional baking in the vacuum oven on the quality factor Q are studied in the experiment. The motivation is to check the feasibility of an efficient, pulsed, ion linac, operated at cryogenic temperatures.

Test Cavity Geometry

Figure 1: Structure of the shortest λ/4 coaxial cavity.

Table 1: Design parameters of the cavities

f (Design, MHz)	Length(mm)	Gap(mm)
100	735	54
220	324	54
340	201	54

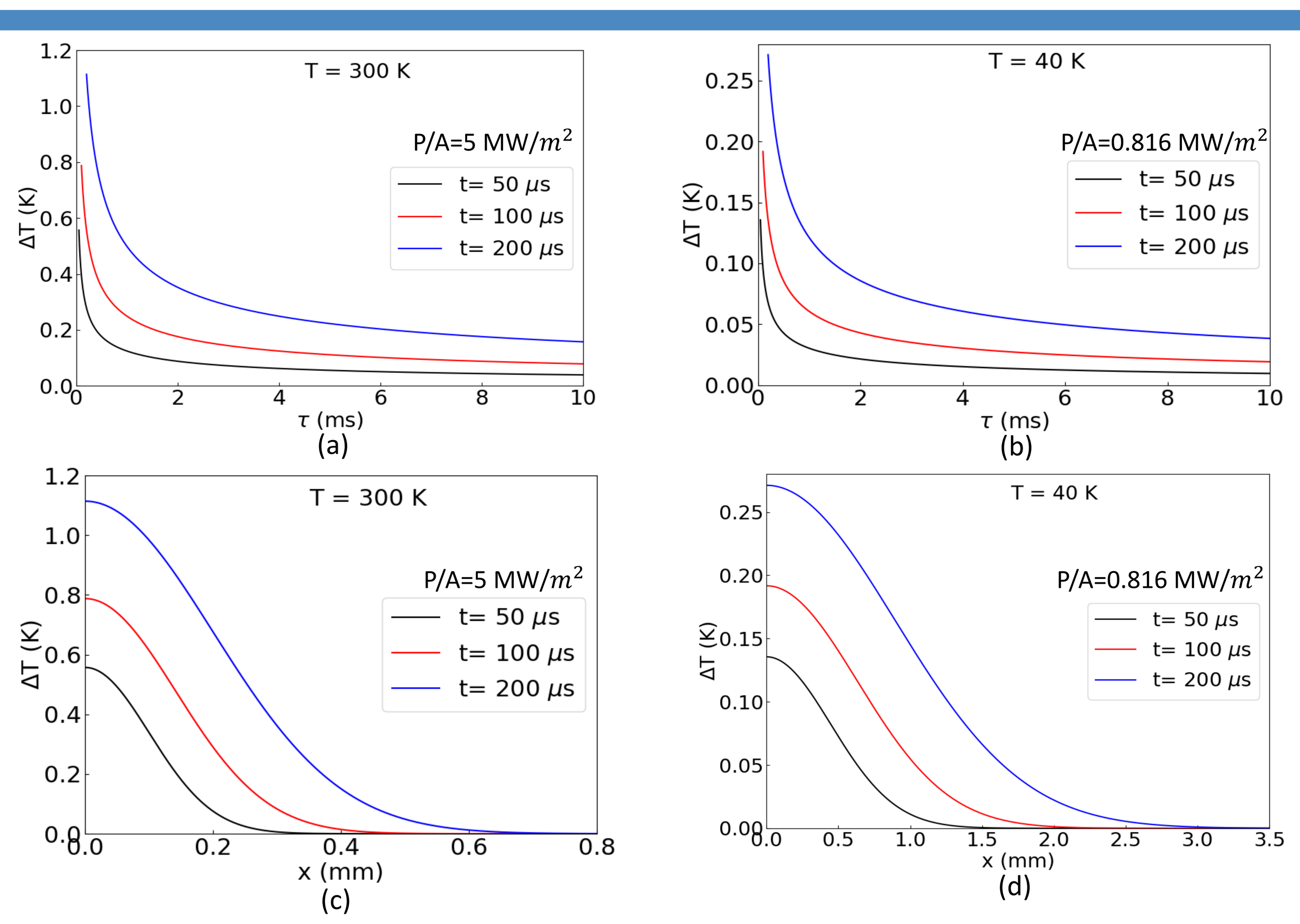

Figure 4: Temperature response of the energy pulse at surface with time (a and b). Temperature profile at the pulse end (c and d).

All the results are calculated for copper parameters as reached after the copper plating and the vacuum annealing. Power loss P/A = 5 MW/m^2 at T = 300 K, P/A = 0.816 MW/m^2 at T = 40 K.

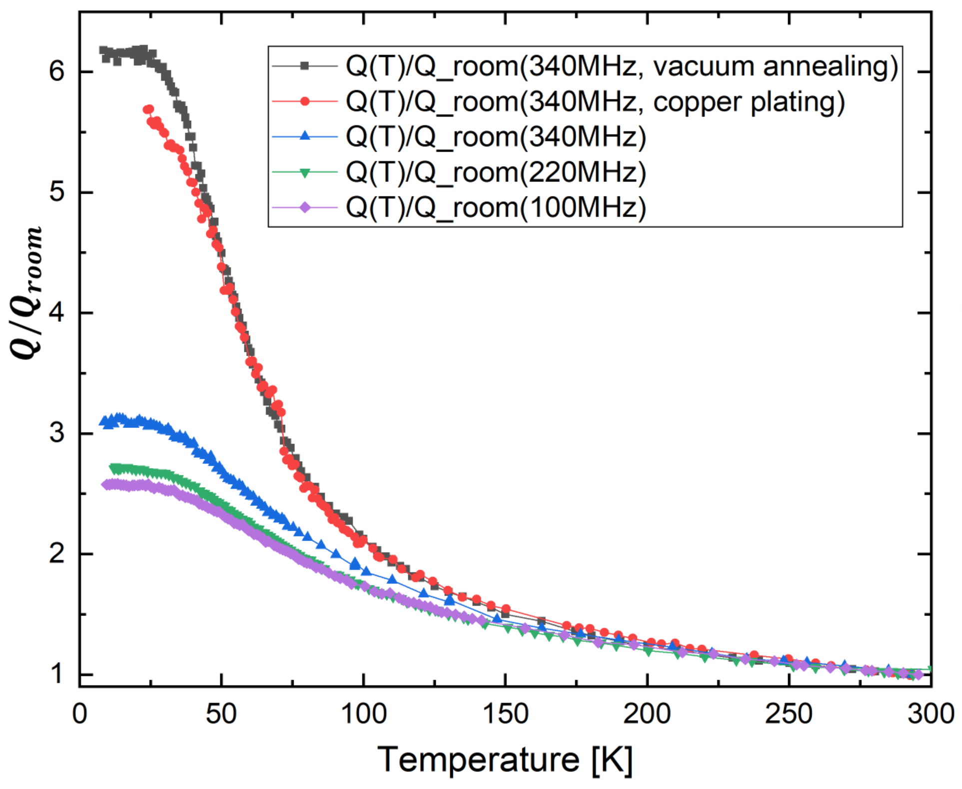

Figure 2: Measurements of the Q factor over the temperature range from about 10 K to room temperature.

The RRR values for the three original cavities are too small, therefore the anomalous skin effect does not occur by them. After the copper plating and the vacuum annealing, the RRR of the 340 MHz cavity is improved significantly.

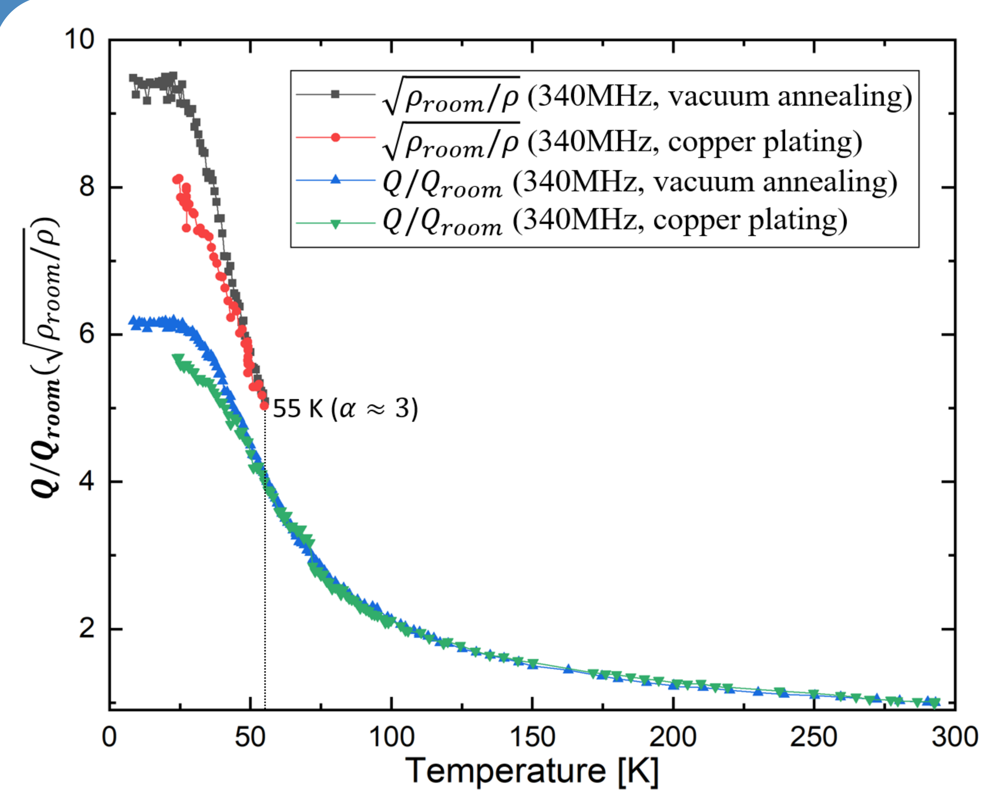

Figure 3: Calculated ratios of the electrical resistivity compared with the ratios of the quality factor. [R. G. Chambers, *The anomalous skin effect*, 1952.]

The calculated $\sqrt{\rho_n/\rho}$ at 10 K is 9.48 after the vacuum annealing, while the Q factor ratio Q/Q_n is only 6.18 at 10 K due to the anomalous skin effect. Nevertheless, the ratio of the quality factor at 40 K is still 5.37 and at 50 K is 4.5. Accelerators operated around these temperatures still have a lot of potential: the RF power losses are reduced by these factors.

Conclusion

This work shows us that the RRR of copper can be greatly improved by the copper plating and the vacuum annealing, thereby improving the efficiency of the accelerators. Although the quality factor has declined due to the anomalous skin effect at the cryogenic temperatures, there is still quite a potential of the pulsed ion linac, operated at cryogenic temperatures between 40-50 K.

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