Progress on RF superconductivity at Saclay

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Abstract

We report substantial progress in R&D on superconducting accelerating cavities at Saclay.

I. INTRODUCTION

The Saclay program of R&D on RF superconductivity has been actively pursued, aiming at applications in the frame of the TESLA and "European Electron Accelerator for Nuclear Physics" projects. The most important issues of this research are the quest for high accelerating gradients and reduced RF dissipation.

II. HIGH GRADIENTS

The gradients available in superconducting cavities are now limited mainly by field emission. This phenomenon has been studied on samples, in both DC and RF regimes, with specific facilities. We have confirmed that the electron emission in cavities is mainly due to micron sized dust particles. Selective contamination experiments showed that metallic particles behave as especially strong emitters. Greater care in cavity cleaning and mounting have in fact resulted in an improvement in cavity performance : accelerating gradients as high as 18 — 20 MV/m can now be reliably achieved in 1.5 GHz single cell cavities (Fig.1).

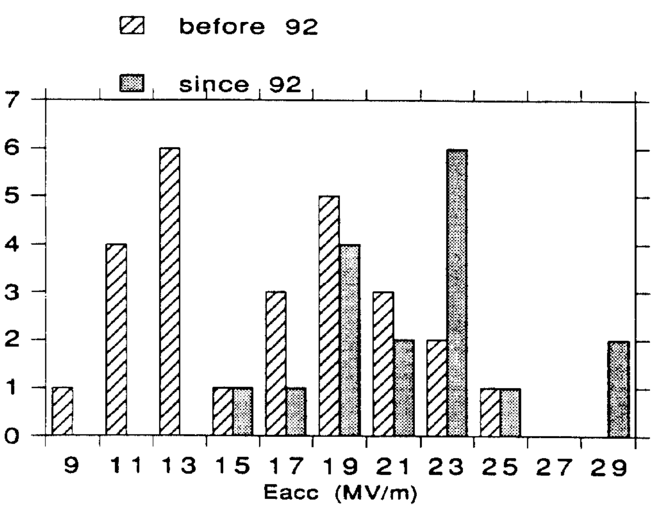

Figure 1 A large number of single cell Nb cavities at 1.5 GHz has now been tested at Saclay by the "Groupe d'Etudes des Cavités Supraconductrices". The corresponding systematics are summarized in Fig.1. It can be seen that the latest tests correspond to results significantly better than the older ones. The improvement is thought to be due to improved cleanliness during cavity treatment and mounting.

One cavity of this type, tested in the same laboratory, has reached an accelerating gradient of 28 MV/m (Fig.2) after a particularly careful surface treatment involving firing and titanification at 1300° C during 16 hours in a vacuum furnace, followed by chemical polishing, rinsing and drying in a recently developed automated facility [1].

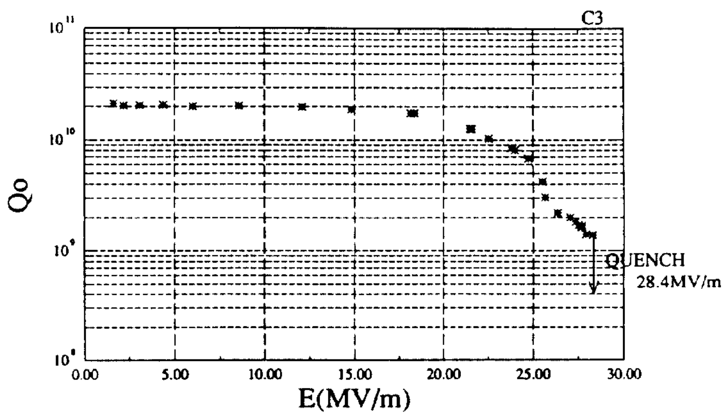

Figure 2 Q value vs accelerating gradient for the "high gradient" cavity

III. LOW DISSIPATION

The residual surface resistance routinely obtained in our Nb cavities is 15 nΩ at 1.5 GHz. The origin of the associated dissipation is now understood as the sum of the contribution due to trapping of the residual magnetic flux during cooldown, plus a new one due to the polycrystalline nature of the niobium used for making the cavities. Both contributions have been studied theoretically and experimentally [2]. This work opens the perspective of improved Q values for superconducting cavities.

A Q value of 5.10^{10}, corresponding to a residual surface resistance of 4 nΩ, has actually been reached recently with a 1–cell niobium accelerating cavity at 1.5 GHz (Figs 3,4). This is probably the best value ever obtained on an accelerating cavity in the GHz frequency range. The main reasons for this success are improved magnetic shielding and reduced RF losses at the ends of the cutoff tubes. The use of high purity niobium (RRR 320) may also have played a favourable role. We will now try to demonstrate the reproducibility of this result, and its validity in a real accelerator environment.

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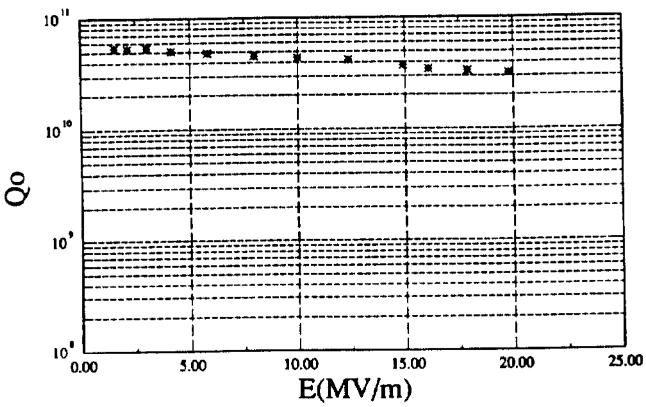

Figure 3 Q value vs accelerating gradient for the "low dissipation" cavity

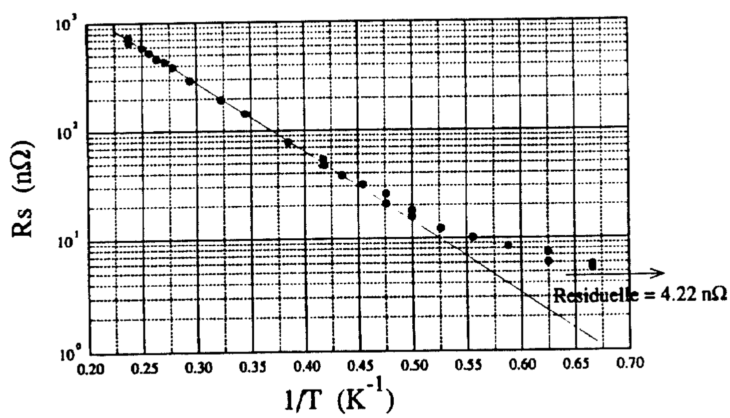

Figure 4 Surface resistance vs inverse temperature for the "low dissipation" cavity

IV. THIN SUPERCONDUCTING FILMS

Efforts have also been continued to develop the thin film coating technology at Saclay [3]. A sample of NbTiN film, deposited on copper substrate by magnetron sputtering, reached a RF field level of 35 mT and exhibited a low residual surface resistance (40 nΩ at 4 GHz), with a very small BCS resistance and an unusually small dependence of Rs vs RF field. If this result can be reproduced in a full scale accelerating cavity, the "thin film way" will certainly regain some credibility for the construction of superconducting structures.

V. PROGRESS ON THE ACCELERATOR MACSE

A continuous electron beam of 100 μA was accelerated in the MACSE prototype [4], with excellent stability, emittance and energy resolution (ΔE = 7 keV at E = 26 MeV). A distributed RF power scheme (one klystron for 4 cavities) was applied successfully, without energy spread degradation. Pulsed RF processing at moderate power (5 kW) suppressed e^- loading due to field emission in the MACSE cavities. The accelerating gradient was then limited by quench at an average value of 12 MV/m. A gradient as high as 18 MV/m was reached in one cavity. This is the first time that such a gradient is obtained with a superconducting cavity in an electron accelerator.

VI. CONCLUSION

These encouraging results confirm that superconducting cavities are still far from their limits and that the associated technology can make important progress, toward the construction of future large accelerators.

VII. REFERENCES

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