PANEL DISCUSSION ON RF SUPERCONDUCTIVITY

Panel Moderator : M.G.N. Hine

Panel Members : A. Carne, A. Citron, H. Halama, H. Hahn, M. McAshan, P. Wilson.

Summary of Discussion

Superconducting cavities and rf structures have won great interest as they enable the construction of accelerators and separators with unconventional capabilities. To be suitable for these purposes superconducting resonators are required to have special features, namely, a high quality factor, high field strengths and the ability to maintain these values during long-term operation.

The panel discussion was mainly directed to questions of superconductor material and methods of surface treatment since it has been shown that improvements are especially needed in this field.

On the subject of superconductor material for linear-accelerator applications, since the highest possible electric fields are required and also for fundamental reasons (high T_c, H_c)niobium is clearly favoured. Contradictory views were apparent on the use of lead, as most of the panel members reported that they had not been able in practice to achieve high and stable Q's and high fields in lead-plated cavities with E fields at the surfaces. However, Carne (RHEL) stated that, at present, lead offered somewhat higher deflecting fields than niobium in separator structures and that, for applications within the superconducting capabilities of lead, it had the advantages of easier fabrication techniques and lower cost.

The fabrication of cavity parts made of niobium at HEPL, Stanford, was described. The procedure, which showed good results at X-band, involves UHV heat treatment and chemical polishing, but gave unsatisfactory results for L-band structures to date. Field emission and early breakdown in these structures could be related to a higher level of surface imperfections. A successful process for reducing field emission is to apply high fields to the surfaces in the presence of a helium atmosphere at about 10^{-4}torr. Without changes in Q, the field enhancement factors could be lowered by a factor of 3 to 4, and leakage currents by several orders of magnitude. This was regarded as a way of separating field emission from other breakdown effects.

The discussion on the difficulties of obtaining higher fields in L and S-band structures can be summarized by saying that, at present, treatment techniques are not yet appropriately developed. There are significant differences between small samples and larger structures, which may be related to differences observed in electron-microscope pictures of the surfaces. All laboratories using niobium reported that they tried hard to improve the chemical or electrochemical polishing techniques.

Some advances in chemically polishing niobium samples have recently been achieved at SLAC. A buffered solution at room temperature was used and the liquid was recirculated but at the time of the Conference no results using this method had been obtained on microwave cavities.

A brief summary was given of the experiments made with anodized niobium surfaces at Karlsruhe and Erlangen. Additional measurements had been reported in a paper by Halama given previously in this session. It appeared to be a unanimous opinion that Q values can be increased by anodizing un-heat-treated niobium surfaces. Oxide layers of about 300 to 400 Å were found to be preferable. With respect to obtainable peak fields, the picture was not so clear. X-band measurements showed an increase of breakdown fields by a factor of up to 2 ($B_{max} \leqslant 0.8$ kG). At S-band, the results are comparable to those obtained with heat-treated cavities, while at 80 MHz, where a peak field of 1 kG could be obtained in a helically loaded resonator, no comparable UHV results were available at this time.

Different results were reported about ageing effects in anodized resonators. Halama said that at BNL the Q of an anodized cavity degraded during successive tests. This was not confirmed by measurements at Erlangen and at Karlsruhe. Halama suggested that ageing effects are very probably related to reactions of oxygen at the metal-oxide interface and thus surface-structure changes were unavoidable. But there appeared to be agreement that ageing effects can be tolerated as long as the Q values remain sufficiently high for practical applications, which may be so in some cases.

One notable difference between anodized and pure niobium surfaces could be deduced from measurements at BNL where a niobium cavity was exposed to a proton beam to observe radiation damage. The quality factor, Q, of the pure niobium cavity remained nearly constant whereas the anodized cavity degraded drastically.

Subsequently, the question of whether the methods of surface treatment can be further improved was considered. There is certainly valid evidence that heat treating under UHV conditions increases the breakdown fields from the X-band measurements at HEPL and the improved S-band cavities achieved at BNL. Concerning the influence of heat treatment in changing the resonant frequency of a pretuned resonator, it was found at HEPL that L-band structures did not change frequency by more than $\Delta f/f \approx 10^{-6}$ (a change of 10^{-5} could be compensated by tuning elements).

No explanation was forthcoming on the fact that at low frequencies only poor quality factors could be obtained but considerable peak fields, of the order of 30 MV/m (re-entrant cavity at HEPL, helix at Karlsruhe), were possible. Both structures showed a decrease of quality factors with power by up to one order of magnitude. This effect could not fully be explained but some evidence of joint or welding problems was apparent.