FABRICATION OF HIGH Q SUPERCONDUCTING NIOBIUM CAVITIES

I. Weissman
Central Research Laboratories
Varian Associates, Palo Alto, California

X-band superconducting cavities were fabricated by two methods: chemical vapor deposition of niobium onto copper and niobium substrates, and machining from bulk, electron-beam-melted (EBM) solid niobium followed by chemical polishing.[1] The latter method yielded cavities with residual Q's as high as 3.8×10^{10} in the TE_{011} mode at 11.2 GHz and 2.1×10^{10} in the TM_{010} mode at 8.4 GHz. Both the TM and TE mode solid cavities were limited in power by a critical magnetic field (H_c^{ac}) of about 450 G, which is only one-fourth the dc value of H_{c1} for pure niobium. Subject to high fields the TM_{010} mode cavity tested exhibited some Q degradation from its initial high value but it was found that after a sufficient operating period at high fields stable values of $Q = 1.16 \times 10^9$ measured at low power, and 1.06×10^9 measured at high power could be maintained. While these stable values of Q are sufficiently high to make cavities fabricated in this manner from EBM niobium attractive in accelerator and particle separator applications, the cost of fabrication is relatively high and it would be desirable if comparable results could be obtained with plated Nb on some suitable, less costly substrate.

TE_{011} mode cavities fabricated by chemical vapor deposition of Nb layers varying in thickness from 5 to 25 μ onto Cu substrates have been evaluated. The deposition is done in a tube furnace at 950 to 1000°C and the Cu substrates experience considerable grain growth during the predeposition heating. The Nb layers deposit initially as a multitude of large single crystal platelets whose size, orientation and growth are uniquely related to the substrate crystal structure. The surface of the Nb film gets rougher with increasing thickness and at a thickness varying between 10 μ and 25 μ, there is a tendency for renucleation at the surface. After renucleation, growth of a dense deposit may be continued, but the as-deposited surface is small grained, duller in appearance and considerably rougher than the surface prior to renucleation. Measurements on as-deposited Nb on Cu TE_{011} mode cavities have yielded residual Q's from 3.3×10^6 to 6.3×10^7 with the value of Q <u>decreasing</u> monotonically as a function of increasing deposit thickness. Polishing of the deposited surface increases the residual Q by between one and two orders of magnitude (in a particular case from 3.3×10^6 to 1.6×10^8). The residual Q thus appears to be critically dependent on surface roughness and the quality of the surface finish. A further increase in residual Q was achieved with cavities consisting of chemically vapor deposited Nb surfaces on Nb rather than Cu substrates. As an example, the as-deposited residual Q would typically be of the order of 2×10^8, increasing to about 5×10^8 with abrasive polishing of the deposited surface. This further improvement is attributed primarily to the elimination of differential thermal expansion between deposit and substrate. However, other factors, such as elimination of dissolved Cu from the substrate, in the Nb surface layer, may also be important.

1. J.P. Turneaure and I. Weissman, J. Appl. Phys. 39, 4417 (1968).

Results to date on cavities fabricated of chemically vapor deposited Nb layers indicate that with additional effort residual Q's comparable to those achieved with solid Nb structures can be realized. The major problem is to find a more compatible substrate-deposit combination. To this end, Elkonite, a copper-impregnated tungsten matrix material, is suggested as a substrate member. With the proper Cu-W ratio (approximately 70% W, 30% Cu) its macroscopic expansion coefficient closely matches that of Nb. Also the thermal conductivity of Elkonite is almost as high as that of Cu, thus making it an ideal substrate material insofar as heat transfer through the cavity walls to the helium bath is concerned.