DEVELOPMENTS ON SUPERCONDUCTING ACCELERATOR STRUCTURES AT DORNIER

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Abstract: In the last years at Dornier an R&D program has been performed concentrating on niobium coated copper cavities. For preparing the copper surfaces chemical and electrochemical treatments have been experienced. Via a magnetron sputter device experiments on sputter coated 500 and 350 MHz monocell cavities have been performed. Measurements on samples showed T_c values of (9.43 ± .03) K and RRR's of 19 ± 2. A niobium coated 500MHz cavity equipped with a new cooling system containing only 4 l of LHe was tested at DESY. At low fields a Q of $2 \cdot 10^9$ and an accelerating field of 3 MV/m at reduced Q have been reached. The cooling system was sufficient to lead away 50 to 60 W under normal refrigerator conditions.

Introduction

The convincing results of niobium coated copper cavities at CERN [1] encouraged Dornier to start a R&D program in this field. Advantages of these cavities are as pointed out by CERN:

- no field limitation by quenching;
- no reduction of the Q values due to external magnetic fields in the Gauß range, and therefore possibly no need of magnetic shielding;
- higher Q values due to low RRR values of about 20 compared to the one of very pure niobium with an RRR of 300 [2];
- reduced costs of cavity material.

With the high thermal conductivity, it further seems possible to reduce the LHe tank to a minimum. Especially with increasing length of s. c. accelerator structures the large amount of LHe in the cryogenic system is a potential source of danger [3]. Therefore various systems to diminish the content of LHe have been developed: cavity shaped tanks [4], cylindrical tanks with displacement bodies [5] and pipe cooling [3].

Design of a cavity with integrated helium tank

Basic considerations for the development of an helium tank integrated to the cavity have been:

- considerable reduction of the LHe;
- the number of the inlets and outlets for the helium should be as small as possible;
- no increased pressure for the forced flow of the helium to avoid firstly an increase of the temperature and connected with this a reduction of the Q value and secondly the need of heat exchangers.

The model developed under these considerations is shown in Fig. 1. Fig 2. shows the cross section of the cavity in the testing position. The resonator geometry is taken from the DESY 4 cell cavity design [5]. The inner shells are formed by spinning from 3 mm copper sheet, the outer shells are deep drawn using copper sheets of 1 mm thickness. The 4 steps of the outer shell form the circular cooling channels which are connected by two radial channels lying opposite to each other. The outer shells are connected to the cavity cell by eb welding. The cut off tubes are cooled by pipes fixed near the irises. The volume of the system is about 4 l. Two models of the cavity type have been built: one has been

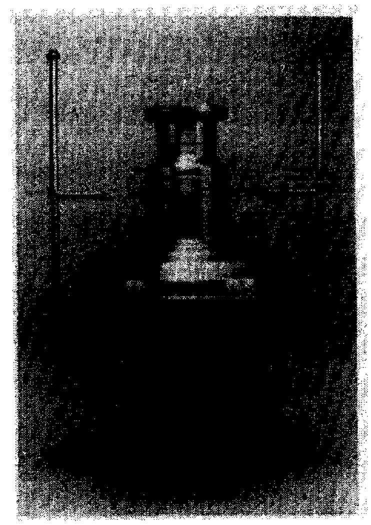

Fig. 1: Single cell 500 MHz copper cavity with integrated helium tank.

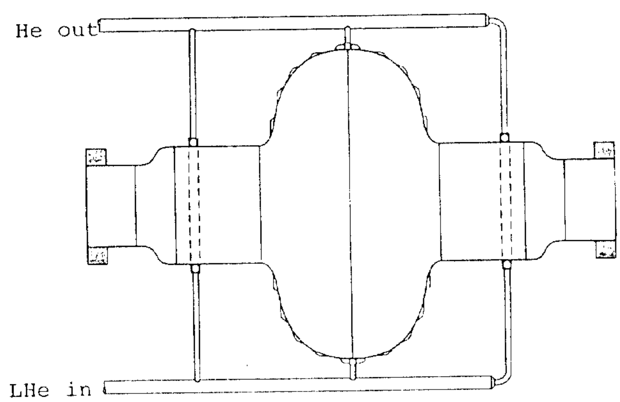

Fig. 2 Cross section of a single cell 500 MHz copper cavity with integrated helium tank.

sputter coated with niobium by CERN in a CERN / DESY cooperation, the other was sputter coated at Dornier. Both cavities have been measured. The results are given below.

A disadvantage of this cooling system in the experimental stage seems to be that temperature mapping and therefore propper analysis of defects is not possible.

Sputter depositon of niobium

After first experiments on coating 1.5 GHz monocell cavities [6] with niobium in the last year experiments on sputter coating cavities with frequencies of 500 and 350 MHz have been performed at Dornier. Based on the previous experiments, deposition has been performed via the magnetron sputter deposition. Two different methods of preparing the copper surface before sputtering have been experienced.

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Surface treatments

To avoid insufficient adhesion of the niobium film on the copper, the preparation of the copper surface is essential. Two types of surface treatments have been experienced: electrochemical and chemical polishing.

Electrochemical polishing: For 350 MHz cavities an electropolishing system was developed. The electrode, adapted to the cavity shape is shown in Fig. 3.

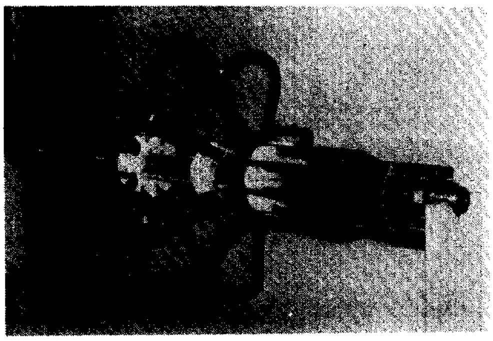

Fig. 3 Electrode for electrochemical polishing

As electrolyte a mixture of H_3PO_4, water, and alcohol was used. With a potential of about 10 V and a current of about 10 A/dm² mirror like surfaces were achieved. The polishing rate is about 50 µm/h.

Chemical polishing: As a polishing electrode has to be adapted to size and shape of a cavity, the electrode shown above can not be used for 500 MHz cavities. Therefore in a first experiment the cavity shown above was treated by a chemical method, the agents of which are commercially available [7]. With a procedure not optimized only very rough surfaces were obtained. Fig. 4 shows the surface roughness and a REM photograph of the same sample. For comparison the same features of an electropolished sample are given. Nevertheless this cavity was sputter coated and measured by DESY.

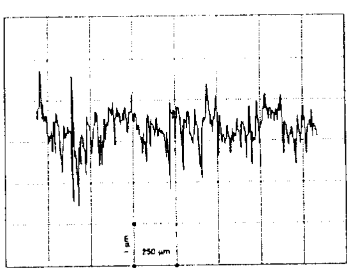

Fig. 4 Surface roughness and structure after not optimized chemical treatment of copper

Sputter experiments

Experimental set up: For sputter coating the copper cavities with a niobium film a magnetron system is used (Fig. 5). The system is very similar to the one developed at CERN [1]. In the cavity, used as the vacuum vessel, a niobium tube is mounted. A permanent magnet, which can be moved in the niobium tube, localizes the plasma discharge. During coating the cut off tubes, the magnet is permanently moved, but it is centered in the equator plane of the cavity during coating the cell. Water cooling of the niobium tube is sufficient to remove the produced heat. The cavity is pumped with a 1500 l turbomolecular pump. With adapters the system is used to coat single cell cavities of 350 MHz CERN shape, and 500 MHz DESY shape. Prior to the sputter deposition a sputter cleaning of the copper surface is performed. Typical sputter parameters are: a basic pressure of few 10^{-9} mbar, a pressure of argon used for sputtering in the range of 10^{-4} mbar, a voltage of about 300 to 400 V - depending on the cavity to be sputtered - and a discharge power of about 5 an 6.5 kW respectively.

Fig. 5 Set up for magnetron sputtering with the niobium cathode on the left side

Results and discussion

Results on samples: Before coating cavities, various experiments on samples, mounted inside the resonators of the two sizes, have been performed. To determine the layer thickness, homogeneity , and structure of the niobium film, electropolished copper samples have been used. Residual resistance ratios (RRR) and critical temperature T_c have been measured on Nb layers deposited on silicon wafers.

Measurements of the layer thickness resulted in a deposition rate of (20 ± 3) nm /min in the 350 MHz cell with a strong increase to (37 ± 3) nm/min very near to the iris. We assume that this increase is due to the overlapping sputter procedures in the cell and the cut off tubes.

Fig. 6 shows the cross section of a very ductile niobium layer, strongly deformed to measure the layer thickness taken by REM.

Fig. 6 Surface structure of sputter deposited Nb layer

Measurements of RRR and T_c showed critical temperatures of (9.43 ± .03) K and RRR values of 19 ± 2. These values have been measured on layers deposited as well in the cell as in the cut off tubes (Fig. 7).

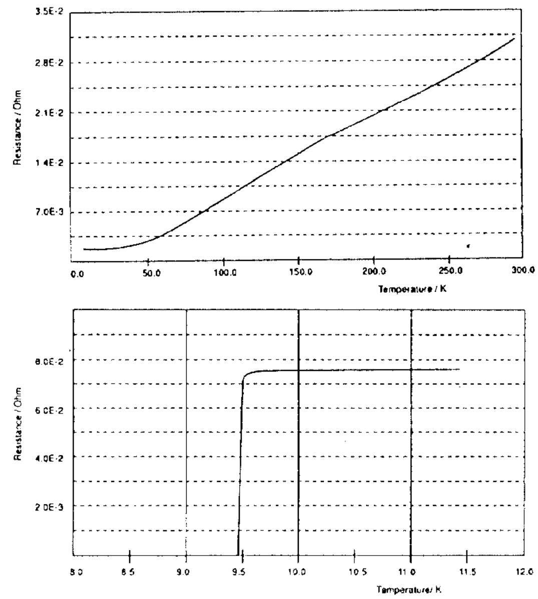

Fig. 7 RRR and Tc of sputter deposited niobium

Measurements on cavities

Two cavities of the type shown in Fig. 1 have been built. The measurements are performed in a specially constructed Dornier cryostat installed at DESY and operated by the DESY MHF group. Fig. 8 shows the measured Q(E) curve. The low field Q of 2.0 10^9 and a

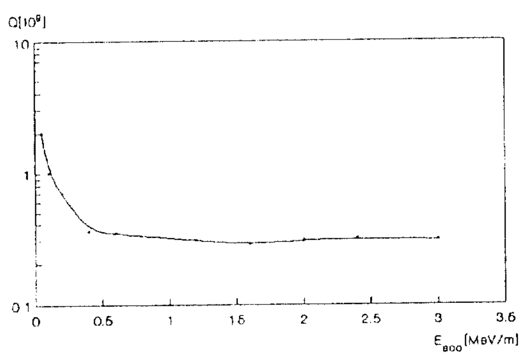

Fig. 8 Q(E) measurements of the sputter coated Nb/Cu cavity with integrated helium tank

fast decreaseof Q with increasing fields is observed. As no hysteresis during the Q(E) measurements have been observed [8], the degradation may not be related to blisters but to the very rough surface [9].The field is power limited at 3 MV/m . The losses of 50 to 60 W could be removed with normal refrigerator operation [8]. Even if Q and E_{acc} are not yet sufficient probably due to the poor quality of the surface, the tests give positive results by demonstrating the effectivity of the newly developed cooling system.

Acknowledgements

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