SUPERCONDUCTING TESTS AND BEAM LOAD EXPERIMENTS ON NIOBIUM-COATED COPPER QWR AT PKU*

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Abstract

R&D on superconducting quarter wave resonators (QWRs) for heavy ion linacs were initiated in Peking University of China. A DC bias-voltage sputtering technology was developed for niobium-coated copper QWR. A niobium-sputtered copper QWR was successfully made in October 1999. Low temperature experiments show that accelerating gradient of 5~6 MV/m can be obtained with no beam load at 4.2 K. The QWR was installed after the 2×6 MV tandem to accelerate proton beams and 500 keV energy gain was achieved at the beginning of 2001.

1 INTRODUCTION

Quarter wave resonators (QWRs) are extensively used in heavy ion LINACs. Niobium sputter-coated copper QWRs are developed for many years[1,2]. Niobium-sputtered copper QWRs are selected as the first choice for the accelerating structure of the booster of Beijing Radioactive Nuclear Beam Facility (BRNBF).

A lot of progress has been made in the Institute of Heavy Ion Physics of Peking University on niobium-copper sputtered QWRs. A lot of technologies were developed, such as surface treatment, uniformity of niobium films, morphology and superconducting performance, etc. After the QWR was coated with niobium, liquid helium experiments were processed without beam loading and with proton beam loading.

In this paper the researches on niobium-sputtered copper QWR at Peking University are introduced.

2 DEVELOPMENTS ON QWR AT PKU

2.1 Sputtering devices

In 1997, a DC diode sputtering system was developed [3]. The main component of the system is an ultra-high vacuum chamber with a height of 1.2 m and a diameter of 0.6 m. The base vacuum of the chamber can be pumped down to better than 10^{-7} Pa. This guarantees the performance of niobium films.

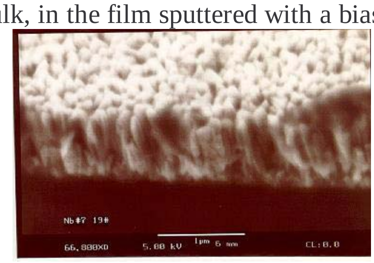
2.2 The uniformity of niobium film

The 144 MHz QWR was first simulated with the code SUPERFISH and then optimized with the code MAFIA with the effects of the beam hole considered[3]. In order to get uniform distribution of niobium film, the niobium target must be properly designed. The distribution of electric field in the resonator is a crucial factor governing the sputtering quality. The target was optimized with code POISSON. Optimized parameters were obtained.

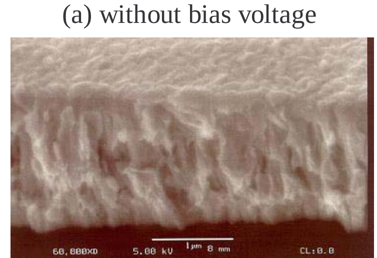
Good film uniformity is difficult to obtain because of the complicated inner geometry of the QWR. A lot of experiments have been done to get high quality films with ideal uniformity. By adjusting the argon pressure, sputtering voltage, sputtering current, bias voltage and sputtering time of different parameters, good results were obtained. The difference of thickness between inner and outer conductor of QWR is within 20%.

2.3 The performance of niobium film

Niobium films were inspected with SEM. Fig. 1 show the structure of niobium films sputtered on silicon substrates. In the photos, both the surface and the cross-section of films are illustrated. Fig. 1 (a) and (b) shows a sputtered film without and with bias voltage, respectively. As can be seen, the film structures are significantly improved with a bias voltage applied. The columnar structure, which is typical for a film without bias voltage, is replaced by a texture, which is more like that of a bulk, in the film sputtered with a bias voltage.



(a) without bias voltage



(b) with bias voltage

Fig. 1 Microstructure of Nb films with SEM

The critical temperature and the residual resistance ratio (RRR) of the films were also measured, figure 2 is

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the results. The result shows that the niobium films can be used in Nb-Cu QWRs.

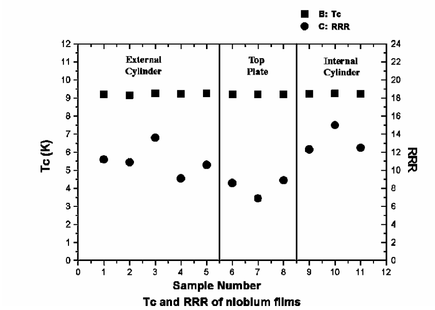


Fig. 2 Tc and RRR of niobium film samples

2.4 Niobium Coating of the OFHC QWR

Based on the above critical technologies for niobium-sputtered superconducting cavities, the QWR could be coated with niobium films. Before coating, the OFHC QWR was treated with electropolishing, high-pressure water rinsing, ethanol dehydrating, and Ar ion cleaning in vacuum[4]. Due to these pre-treatments, the niobium film adhered to the surface of QWR tightly.

With all these preparations mentioned above, we have successfully finished the sputtering of the first niobium-copper QWR in October 1999. This is the first Nb-Cu QWR in China. Fig. 3 showed the QWR after electropolishing and after niobium coating.

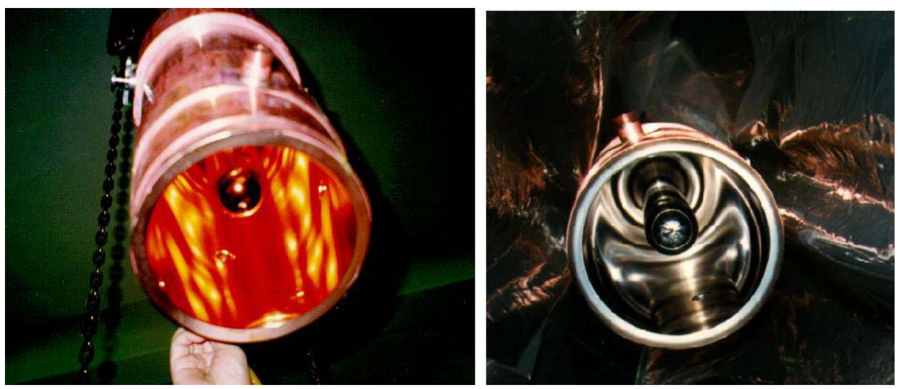


Fig. 3 QWR after electropolishing (a) and after niobium coating (b)

2.5 Low temperature experiments on QWR

Liquid helium experiments have been done to test the performance of the niobium-sputtered superconducting QWR. Before low temperature tests, high power processing is used to overcome multipacting effects. Low temperature experiments were done from November 1999 to September 2000. Fig. 4 showed the Q value versus accelerating gradient. The E_{acc} obtained is more than 5 MV/m.

The Q value is under 10^9, this is because the brazing seam on the outer conductor of the QWR. The QWR is brazed with two parts, see Fig. 5(a). The film near the seam is not so good, see Fig. 5(b). The brazing seam must be modified to improve the performance of niobium film on QWR.

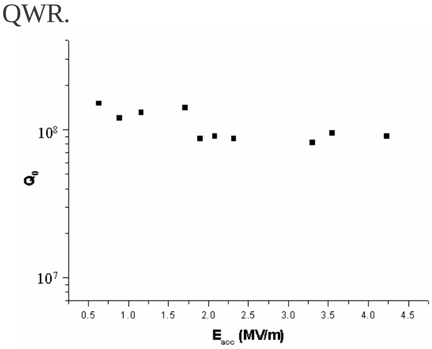
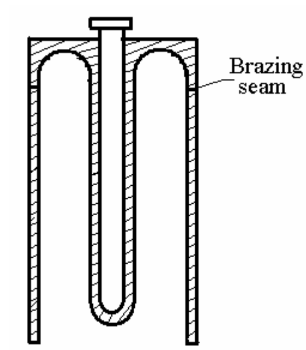


Fig. 4 Q vs. E_{acc} of QWR



(a)

(b)

Fig. 5 Brazing seam on QWR (a) and niobium film near the seam (b)

3 PROTON BEAM ACCELERATING WITH NB-CU QWR

After the low temperature experiments, we installed the QWR to the terminal of the 2×6 MV tandem at the Institute of Heavy Ion Physics to do some beam test with proton beams to verify its performance. Fig. 6 is the layout of the accelerator beam line. The proton beam energy gain curves at different E_{acc} are obtained by magnetic filed scanning, see Fig. 7. In CW mode, when the input RF power is 6 W, the energy gain of proton beam is 500 keV, the E_{acc} on the beam line with proton beam loading can get to 3 MV/m.

Fig. 6 Layout of proton beam accelerating structure

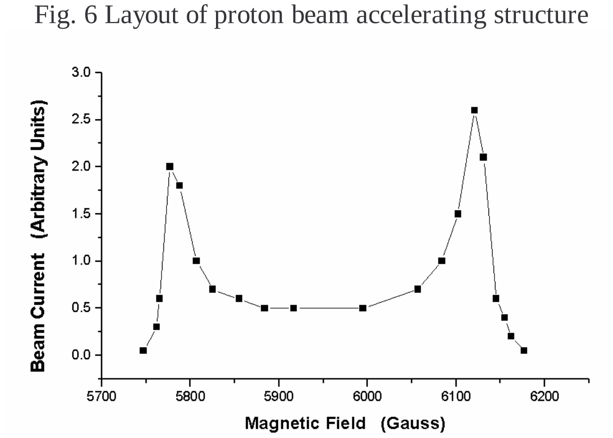


Fig. 7 Energy spectrum by magnet filed scanning

4 IMPROVEMENT OF NIOBIUM FILMS

To improve the properties of the niobium films, researches on new type of niobium films were done. The prepared niobium film samples were sent to Cornell University to test the performances. The measured results showed that the Tc of the new niobium film got to 9.7 K. Fig. 8 showed the Tc figure measured in Cornell University.

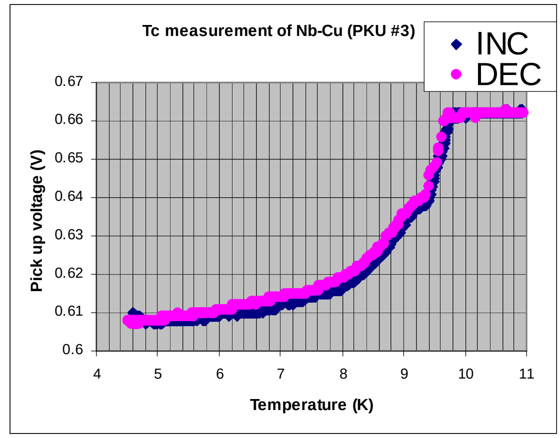


Fig. 8 Tc measurement of new niobium film (at Cornell University)

5 SUMMARY

Researches and experiments have been done on niobium-sputter coated copper QWR in Peking University. Sputtering techniques are developed on making good niobium films. OFHC QWR was coated with high quality niobium films. Accelerating gradient of 5 MV/m with no beam and 3 MV/m with proton beam can be obtained. The improvements of niobium films are in processing at the present.

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