RESEARCHES AND EXPERIMENTS ON NIOBIUM-SPUTTERED SUPERCONDUCTING QWR IN PEKING UNIVERSITY*

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Abstract

R&D on SC quarter wave resonators (QWRs) for heavy ion linacs were initiated in China several years ago. A DC bias-voltage sputtering technology was developed in Peking University for niobium-coated copper QWR. A niobium-sputtered copper QWR with good niobium films was successfully made in October 1999. Low temperature experiments was done from November 1999 to September 2000. The accelerating gradient of 5~6 MV/m can be obtained with no beam load at 4.2 K. The QWR is installed after the 2×6 MV tandem and is used to accelerate proton beams. The accelerating gradient of 3 MV/m was obtained with proton beam load.

Key words: accelerator, superconductivity, sputter

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, including the surface cleaning, uniformity of niobium films, morphology and superconducting performance, etc. After the QWR was coated with niobium, low temperature experiments were processed without beam loading and with proton beam loading.

2 R&D ON NB-CU QWR IN 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.

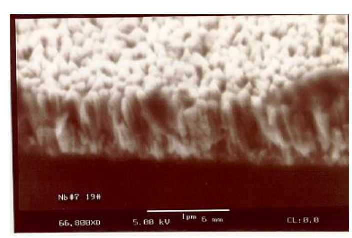
2.2 The uniformity of niobium film

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 has to be properly designed and 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.

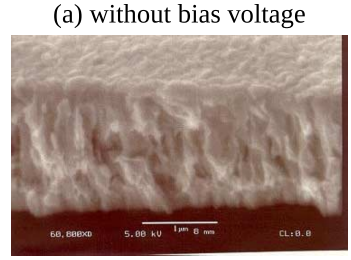
Good film uniformity is difficult to obtain because of the complicated inner geometry of the QWR. A lot of experiments were done to get high quality films with ideal uniformity. By adjusting the argon pressure, sputtering voltage, sputtering current, bias voltage and sputtering time of different parameters, 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 t

Niobium films were inspected with a SEM. Fig. 1 show the photos 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

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The critical temperature and the residual resistance ratio (RRR) of the films were measured, see Fig. 2.

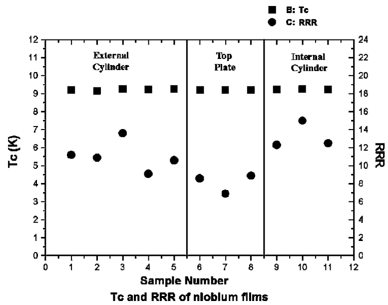


Fig. 2 T_c and RRR of niobium film samples

2.4 Niobium Coating of the OFHC QWR

With the critical technologies for niobium-sputtered superconducting cavities, the QWR was 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 electro-polishing and after niobium coating.

(a) (b)

Fig. 3 QWR after electro-polishing (a) and after niobium coating (b)

3 SUPERCONDUCTING PERFORMANCE OF NIOBIUM-COPPER QWR

Liquid helium experiments have been done to test the performance of the niobium-sputtered superconducting QWR. A new type of cryostat has been designed and installed. The base vacuum in the cryostat can be maintained better than 10^{-6} Pa in room temperature. The cryostat has been tested with liquid nitrogen. A set of microwave system, a 150 W RF power source and low power amplifiers are set up for measuring.

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.

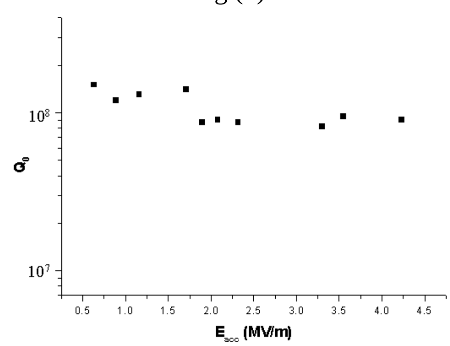
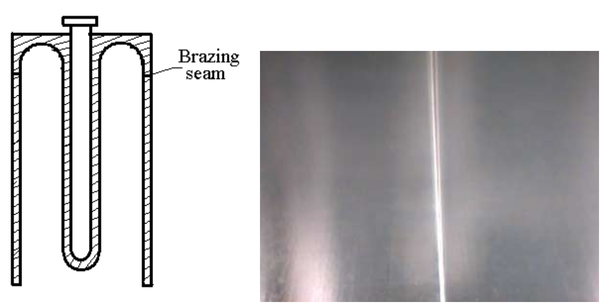


Fig. 4 Q vs. E_{acc} of QWR



(a) (b)

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

4 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 Eacc are obtained by magnetic filed scanning, see Fig. 7. In CW mode, the Eacc on the beam line with proton beam loading can get to 3 MV/m when the input RF power is 6 W.

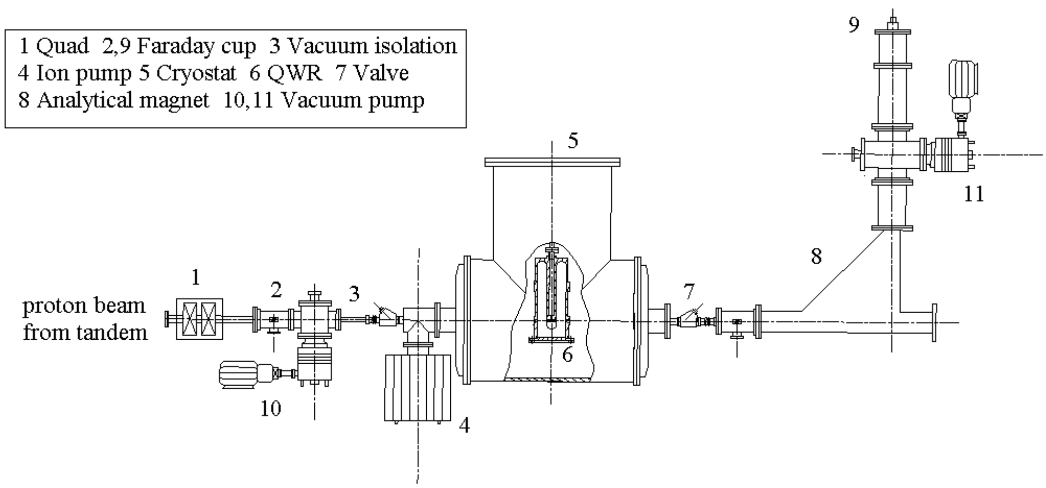


Fig. 6 Layout of proton beam accelerating structure

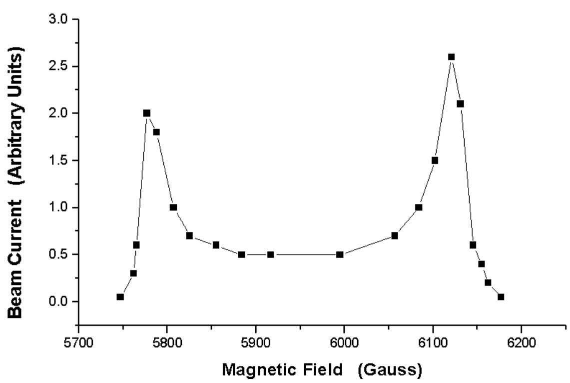


Fig. 7 Energy spectrum by magnet filed scanning

5 SUMMARY

Researches and experiments have been done on niobium-sputter coated copper QWR in Peking University. Crucial techniques are developed on making good niobium films. High quality niobium films are coated on OFHC QWR. Accelerating gradient of 6 MV/m with on 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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