R&D ON THE NIOBIUM-COPPER SUPERCONDUCTING CAVITY AT PEKING UNIVERSITY*

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Abstract

R&D on low-β quarter wave resonators (QWRs) for heavy ion LINACs were initiated in China several years ago. The sputtering technology with a DC bias-voltage, which has been successfully developed at LNL, Italy, was adopted to make niobium-copper sputtered QWRs. Extensive researches and experiments have been conducted on a niobium-sputtered QWR at Peking University since 1996. Niobium films with good properties have been obtained. The first sputtered QWR was successfully finished in October 1999. In addition, a new type of cryostat has been manufactured and its low temperature performance has been checked as well. We expect to perform low temperature experiments of the niobium-copper QWR in November this year.

1 INTRODUCTION

Quarter wave resonators (QWRs) are extensively used in heavy ion LINACs. These resonators enjoy the advantage of good performance yet lower manufacturing cost. For this reason, niobium-sputtered copper QWRs are selected as the first choice for the accelerating structure of the booster of Beijing Radioactive Nuclear Beam Facility (BRNBF).

Since 1996, a lot of progress has been made in the Institute of Heavy Ion Physics of Peking University, regarding the research and experiment on niobium-copper sputtered QWRs. Based on experience at LNL, Italy [1] [4], we have developed a sputtering system. A series of experiments were conducted to optimize the sputtering parameters.

In 1999, a QWR machined out of OFHC was manufactured. In the mean time, a cleaning method for OFHC surfaces was developed. By using this cleaning method, robust niobium coatings were obtained. The surface morphology and superconducting performance of niobium-copper coatings were examined. Now we have finished the sputtering of the first niobium-copper QWR. It will be tested in our new cryostat in the near future.

In addition to that, we are also planning to develop superconducting accelerator technology for accelerating high current electron beams. A united superconducting RF center is to be built up with collaboration between Peking University and the Institute of High Energy Physics of China. We believe that this joint effort will speed up the development of RF superconducting technology in China. Strong support to the center will come from the National Laboratory for High Energy Physics of Japan.

2 RESEARCHES AND EXPERIMENTS ON NIOBIUM-COPPER QWRS

2.1 Sputtering devices

In 1997, a DC diode sputtering system was developed. 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. A mass flow controller and a mass spectrometer are installed for controlling the argon gas flow and analyzing the elements in residual gases. Fig. 1 shows the QWR being installed on the supporting frame of the sputtering system. Between the QWR and the supporting frame, an additional cylindrical tube is added in order to eliminate the fringe field effect near the end of the outer wall of the QWR. This extension section turned out to be essential to guarantee good film uniformity. A RRR 250 niobium cylindrical target is used. Three heaters are located out of the QWR.

2.2 Optimization of the QWR and target

The frequency of the QWR has been selected to be 150MHz. The geometry of the QWR was first simulated with the code SUPERFISH and then optimized with the code MAFIA with the effects of the beam hole considered [2]. In order to get ideal sputtering performance, the niobium target has to be properly designed. Among others, the distribution of electric field in the resonator is a crucial factor governing the sputtering quality. This was optimized with the aid of the code POISSON. Optimized parameters were obtained by adjusting the distance between the inner conductor and the auxiliary cathode, the radii of the target, etc. An

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OFHC QWR, shown in Fig. 2, was made available from China Institute of Atomic Energy.

Figure 1: The QWR installed on the supporting frame.

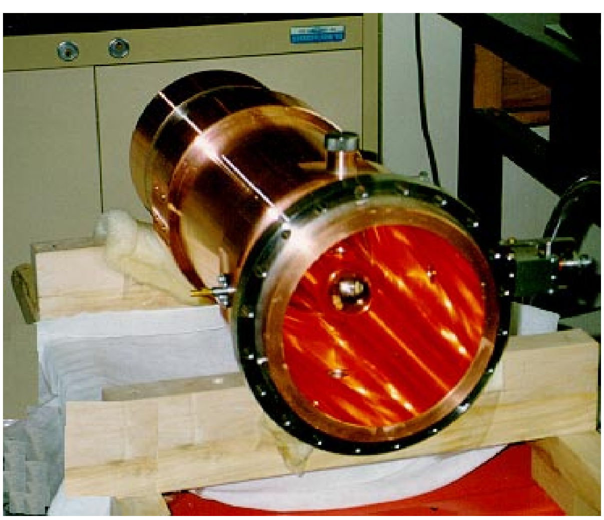
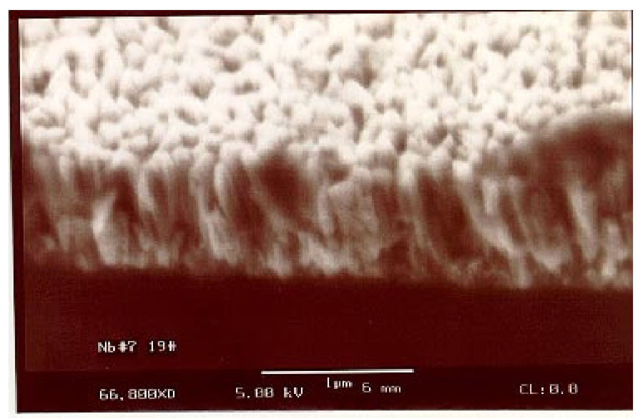


Figure 2: The copper quarter wave resonator.

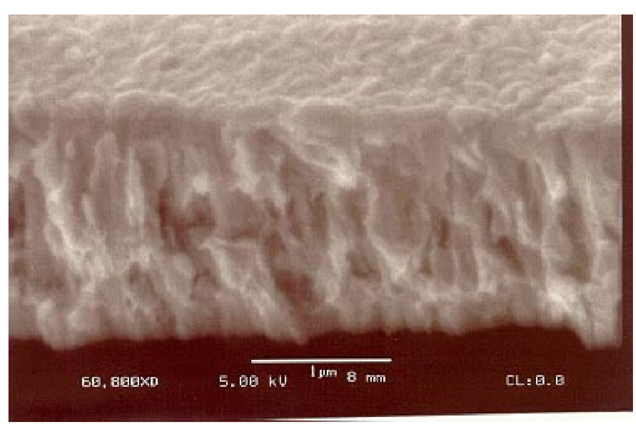
2.3 *The coating uniformity*

The uniformity of the niobium films is an important aspect of the film quality. However good film uniformity is difficult to obtain because of the complicated inner geometry of the QWR. A lot of experiments were dedicated to strive for high quality films with ideal uniformity. By doing experiments with a model QWR, the diameter of the niobium target was determined. Besides the electric field distribution in the QWR, another governing parameter is the argon gas pressure in the main chamber during sputtering. By adjusting the argon pressure, sputtering voltage, sputtering current and bias voltage, good results were obtained.

We have also inspected the microstructures of the film with an SEM. Fig. 3 show the photos of niobium films coated on silicon substrates. In the photos, both the surface and the cross-section of films are illustrated. Fig. 3 (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

Figure 3: The microstructure of niobium films

The main parameters are:

- Argon pressure: 8 – 14 Pa,
- Sputtering voltage: 1 - 1.7 kV,
- Sputtering current: 2 – 3 A,
- Bias voltage: 100 – 150 V.

We measured the thickness and the residual resistance ratio (RRR) of the films. The films have good uniformity. The thickness ratio of the niobium films in outer wall and inner conductor is about 1:1.4. Fig. 4 depicts the critical temperature and RRR of the sample films.

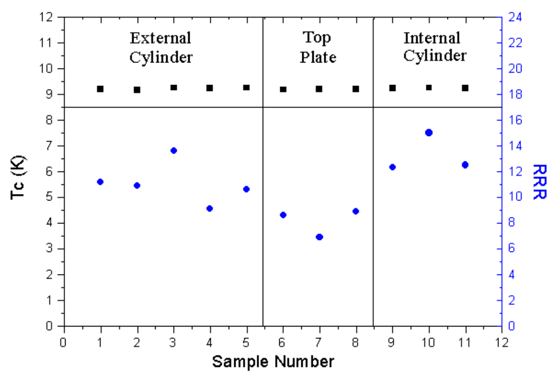


Figure 4: Critical temperature and RRR versus the sample position. Square: critical temperature Tc(K); Circle: RRR.

2.4 Cleaning of the OFHC

The cleaning of the OFHC surface is an important process [3]. It determines the adhesion of the niobium films to the copper substrate. At the beginning, we cleaned the surface with a procedure as follows:

- Electro-polishing,
- Chemical polishing,
- High-pressure water rinsing,
- Ethanol dehydrating.

However the niobium films sputtered on a substrate being cleaned following this procedure would easily fall off. So we have to deal with this problem. We finally came up with a simple procedure to clean the OFHC surface. Now we use a procedure as follows:

- Electro-polishing,
- High-pressure water rinsing,
- Ethanol dehydrating,
- Clean the surface in vacuum chamber with argon ions.

After the cleaning with argon ions, the bounding between the niobium film and the copper substrate is greatly improved.

With all these preparations mentioned above, we have successfully finished the sputtering of the first niobium-copper QWR.

3 FUTURE EXPERIMENTS AND PLAN

We will do experiments at liquid helium temperature to test the performance of the niobium-sputtered superconducting QWR. A new type of cryostat has been designed and installed (see Fig. 5). The base vacuum in the cryostat can be maintained better than 10^{-6} Pa. Since the clearance from the top of the cryostat to the roof of the laboratory is critically constrained, it is difficult to insert the QWR directly into the cryostat. This problem will be solved by assembling the liquid tank with the QWR part by part. The cryostat has been tested with liquid nitrogen. A set of microwave system, a 150 W power source and low power amplifiers are all available by now. The low temperature experiment will be carried out in November.

Figure 5: The cryostat with the QWR

After the low temperature experiments, we will try to install 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 and verify its performance.

4 ACKNOWLEDGMENT

We give our thanks to Dr. Palmieri of LNL, Italy, for his help and useful discussions with us. We thank Dr. Proch of DESY, Germany, for his support to our superconducting project. China Institute of Atomic Energy is appreciated for lots of support to our researches.

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