R&D OF NIOBIUM-SPUTTERED COPPER QWR FOR HEAVY ION LINAC IN PEKING UNIVERSITY

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Abstract

With the advance in the research on the RF Superconductivity, a lot of experiments on niobium-sputtered copper quarter wave resonator (QWR) have been done in Peking University. A DC sputtering system with other auxiliary devices is set up completely. Sputtering parameters are under control. Superconducting properties of the cavity and the properties of the niobium film are measured. Experiments in low temperature and with beam load will be carried out by the end of 1998. Niobium-sputtered QWR can be used for heavy ion linac such as Beijing Radioactive Nuclear Beam Facility.

1 INTRODUCTION

Superconducting linear accelerators are used widely throughout the world. Resonators are the most important elements of linear accelerators. There are several types of resonators such as helix, spiral, interdigital, split loop and QWR. Quarter wave resonators (QWR) have many advantages compared with other heavy ion accelerating structures. The QWR's are used in most superconducting heavy ion accelerators as accelerating structure since 80's.

Sputtering technology has been developed in recent years. LNL of Italy and CERN have used this technology in accelerators.

The Institute of Heavy Ion Physics of Peking University manufactured the first superconducting niobium cavity in China in 1994 and accumulated many experiences. We have a set of microwave and cryogenic system. We have collaboration with some foreign laboratories, such as KEK, TJNAF, BNL, DESY, LBL, etc. Based on this, we did a lot of researches and experiments on niobium-sputtered copper cavity and made great progresses. The result is pleasing. With more work done, we can provide superconducting QWR's for any accelerators. For example, Chinese Institute of Atom Energy (CIAE) has started to build Beijing Radioactive Nuclear Beam Facility (BRNBF) based on HI-13 tandem accelerator, Nb-Cu QWR's will be used in the heavy ion linac which is the post booster of BRNBF.

2 THE NIOBIUM-SPUTTERED COPPER QWR

As is well known, a quarter wave resonator has the following advantages [1]:

(1) A broad curve of the transit time factor.
(2) A structure which is simple to manufacture.
(3) High frequency of the lowest mechanical mode.
(4) Low peak surface field.
(5) Convenient to cool because of the empty inner conductor.
(6) Elimination of the end plates (compared to split loop and spiral resonators).

The parameters of QWR are easy to optimize.

We make superconducting niobium-sputtered copper QWR's because of the advantages of both niobium and copper. Niobium has good superconducting performance, but its thermal conductivity is very low. Low thermal conductivity will induce thermal instability of the resonator. The temperature of part of the inner surface will increase and induce quench. To improve the thermal instability, we need to increase the thermal conductivity of the cavity material. One effective method is to sputter a layer of high pure niobium about several microns thick on the surface of the OFHC copper cavity. The OFHC copper has good thermal conductivity, 7×10^3W/(m·K), which is one order larger than niobium in low temperature. A small amount of liquid helium can gain refrigeration effect because of the excellent thermal conductivity of copper. Another advantage is that the copper is cheaper than niobium. The RF superconducting performance of niobium-sputtered copper QWR can attain the same level as the pure niobium cavity.

3 SPUTTERING STRUCTURE AND EXPERIMENTS

3.1 Design and Structure

We use the program MAFIA to design the sputtering chamber according to our need. The whole sputtering system consists of sputtering chamber, vacuum system, gas control system and analysis system.

The cathode target is in the middle of the inner conductor and the outer wall. We use an auxiliary cathode to make the film near the beam hole and the end of the resonator uniform. We also use an additional outer wall to support the resonator so that the field distribution is more uniform at the end of the outer wall. The additional section has a declining angle. Fig. 1 is the sputtering configuration.

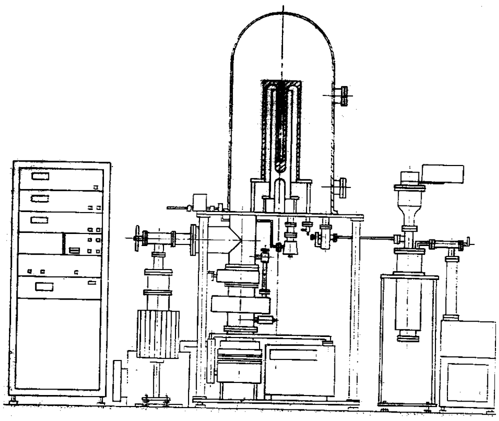

Fig. 1 Sputtering configuration.

The electric field distribution in the cavity is very important to the properties of the film. Due to the particular shape of the QWR, it is difficult to make the field distribution uniform in the cavity. To avoid the sparking in the sputtering procedure and improve the properties of the niobium, we use the program POISSON to optimize the distribution of the electric field in the resonator, especial the round corner and the end of the inner conductor. We changed the distance between the inner conductor and the auxiliary cathode, the radii of the cathode target and the declining angle of the addition outer wall many times. Finally we got appropriate parameters. Fig. 2 is the distribution of the field optimized by POISSON.

Fig. 2 Distribution of the electric field in the resonator.

The sputtering chamber is sealed with metal. We use mechanical pump, turbomolecular pump to get the required vacuum. The background vacuum can attain 10^{-7} Pa after baking. An ion pump is used to maintain the vacuum.

We adopt the DC sputtering system. Although post-magnetron sputtering system is widely used in many devices for its high deposition rates, low discharge potential and low argon pressure, the disadvantages are exist compared to DC sputtering[2]. The shape of the QWR makes it difficult to be sputtered with post-magnetron sputtering system. The cooling system is more complicated than in DC sputtering system. The ion density in magnetic sputtering changes from place to place, which greatly influences the superconducting properties of niobium films. While in DC sputtering system, these problems are not so obvious. In DC sputtering system, the configuration is simple, but the film properties are easily influenced by the shape of the target and the parameters of sputtering. The three main parameters are the sputtering gas pressure P, voltage U and current I. After many experiments, now we can make uniform films on a large area.

We take argon as the sputtering gas. The operation current is very important to the properties of the niobium films. The current must be constant. This is controlled by a mass flow controller. The residual gases influence the properties of the film, so we must make analysis on the residual gases. In order to improve the quality of the niobium film, we use quadrupole mass spectrometer to analyze the elements of the residual gases. The temperature is another factor in the sputtering process. We use a Pt thermometer to measure the changes of the temperature.

3.2 Experiments

At the beginning, we manufactured a prototype resonator. We did sputtering experiments with the prototype resonator to find out the problems and the relationship of the film property and the sputtering parameters. By doing this, we gained valuable experience.

The next step is to make the niobium-sputtered QWR. To save material and to get the correct shape of the cathode target, we first manufactured an aluminum resonator and a copper target. The size of the aluminum resonator is the same with the required copper resonator. The frequency is 150MHz and β=0.1. Because aluminum cavity cannot stand high temperature, we manufactured a stainless steel resonator.

Before the sputtering, the surface of the resonator must be cleaned. The procedure consists of the mechanical polishing, electric polishing and high pressure water rinsing.

Before the process of sputtering, we put glass samples in different places of the outer wall and the inner conductor. When sputtering, the films on the samples are the same with the film in the surface of the resonator. After sputtering, we measure the thickness of the films on the samples to get the thickness distribution of the film on the resonator surface. The thickness is the most important parameter of the film. It is difficult to make the films on the inner conductor and the outer conductor uniform. We changed the radii of the target and the sputtering parameters to make it possible. After a lot of experiments, the film thickness of the inner and outer conductor is approximately the same. The homogeneity of the film is well. The thickness difference of the film between the upper and the bottom part of the resonator is less than 10%.

3.3 What to do next

Based on the above work, we manufacture the copper QWR and the niobium target. At the same time, we will use niobium samples to measure the properties of the superconducting QWR. Firstly, we will measure the residual resistance ratio (RRR) of the niobium samples in liquid helium temperature. We have designed and made a new helium cryostat. When all the properties of the QWR are in good condition, we will begin to make niobium-sputtered copper QWR's for the usage in the field of accelerator.

We also begin to prepare low temperature experiments and beam load experiments with the niobium-sputtered copper QWR on the 2×6MV tandem. We can test the performance of the cavity with the increase and decrease of the continuous beam.

We have been doing researches and experiments on a laser driven high-brightness electron beam source since 1996[3]. A photo-cathode is used to generate electron beam. We will use niobium-sputtered copper cavity to accelerate the electron beam.

4 CONCLUSION

Great progresses have been made on niobium-sputtered copper quarter wave resonators. The properties of the film on the surface of the resonators are measured. The film thickness is uniform and the homogeneity is good. The measure of RRR, experiments in low temperature and experiments with beam load will be carried out. High-quality QWR's can be provided for linear accelerators.

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6 REFERENCE

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