DESIGN AND COMMISSIONING STATUS OF NEW CYLINDRICAL HIPIMS Nb COATING SYSTEM FOR SRF CAVITIES

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Abstract

For the past 19 years Jefferson Lab has sustained a program studying niobium films deposited on small samples in order to develop an understanding of the correlation between deposition parameters, film micro-structure, and RF performance. A new cavity deposition system employing a cylindrical cathode using the HiPIMS technique has been developed to apply this work to cylindrical cavities. The status of this system will be presented.

INTRODUCTION

The cavity deposition system described here follows several years of small sample studies at JLab involving niobium films produced using energetic condensation techniques [1]. High Peak Power magnetron sputtering (HiPPMS) was chosen as the niobium source for this system because the technique is well developed, and it is easily adapted to coat the inside of a cavity. HiPPMS is a form of ion beam assisted deposition (IBAD), and although much of the literature in this field is generally useful, it will be necessary to characterize the niobium flux in terms of ion energy spectrum and ion to neutral atom ratio. It will also be necessary to benchmark the film structure obtained with HiPIMS with respect to that obtained using other energetic condensation deposition parameters with well established results [2]. To enable this direct comparison, a provision for depositing niobium films on small coupons has been included in this system.

An additional feature is included which will allow the coated cavity to be cryogenically tested directly without intervening exposure to air. It is well known that the final RF surface of a niobium cavity is to a large degree what is left over from the inevitable exposure to air and wet chemistry. Advances, such as low temperature baking have helped by modifying what is there by default rather than intention. Alternatively, there are many options available for use in thin film cavities to create, *in situ*, a well-engineered, highly repeatable RF surface which is chemically inert before removal from the system. One of many potential advantages of thin film cavities is that of bringing cavity performance within the realm of standard engineering practice and repeatability.

SYSTEM DESCRIPTION

The magnetron and cavity are supported at opposite ends of the system, as shown in Figures (1 and 2).

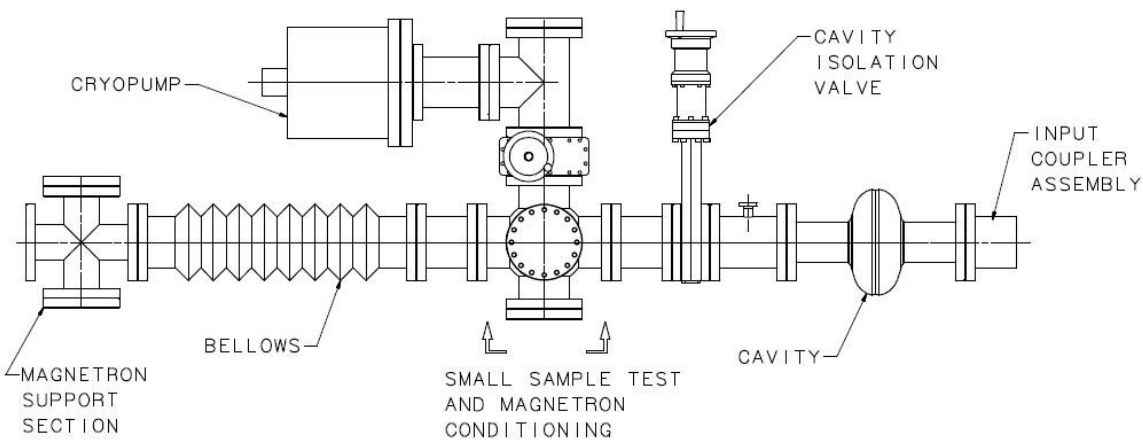

Figure 1: Schematic of the cylindrical HiPIMS cavity deposition system.

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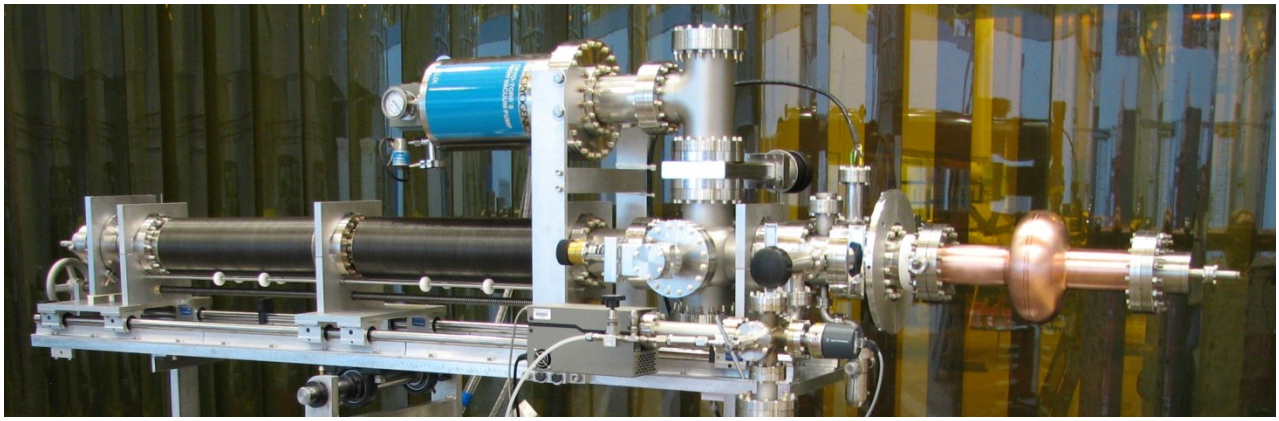

Figure 2: Actual cylindrical HiPIMS cavity deposition system.

The magnetron is connected to the system by a bellows, allowing it to be moved from the interior of the cavity to a small sample deposition chamber which also serves as a cathode conditioning and storage chamber. When in the small sample chamber, the cavity isolation valve can be closed and removed with the cavity evacuated. The input and transmitted power probes are present in the cavity during deposition. The removed gate valve/cavity unit is sealed with a second flange and the intervening space evacuated with an all metal valve and the cavity is then cryogenically RF tested. The goal of this feature is to develop techniques to tailor properties, such as electron mean free path, within the superconducting penetration depth to give optimum performance for a given application, followed by a cap treatment to provide immunity to subsequent exposure.

The magnetron consists of a niobium cathode surrounded by an open grid-like anode, made of niobium in order to avoid contamination by secondary anode sputtering (Figure 3). The cathode and internal rare earth magnets are cooled by water. The field from these magnets extends the entire length of the cathode which extends entire length of the cavity. The field penetrates the cathode surface every 1.7 cm producing a peak B field of 0.2 T at a 4 mm distance from the cathode surface with the same longitudinal periodicity.

NIOBIUM DEPOSITION PROCEDURE

Copper cavity substrates will be used initially. Cavities will be first prepared by centrifugal barrel polishing (CBP) to a mirror like finish [3,4]. The cavity interior is then electropolished to remove CBP artifacts to a minimum depth of 5 to 10 microns to insure the absence of lattice damage. After evacuation on the system the cavity is baked to 360 °C. This temperature was found to produce good results in earlier small sample studies at JLAB [5].

The magnetron is conditioned in the small sample test chamber by pre-sputtering before moving it into the cavity. Some sputtering gas must be present since niobium cannot self-sputter. Krypton will be used due to its lower rate of inclusion in the growing film. A lower gas density in the growing film is also expected, since the HIPPMS process can operate at lower gas pressures than standard DC magnetron sputtering. Also, since the film is deposited in pulses with a very high flux rate during the pulse, the Krypton burial rate will be significantly lower at the same pressure than it would in the DC case. Gas inclusion is only relevant if it becomes a significant source of electron scattering and for reasons mentioned, this is not likely.

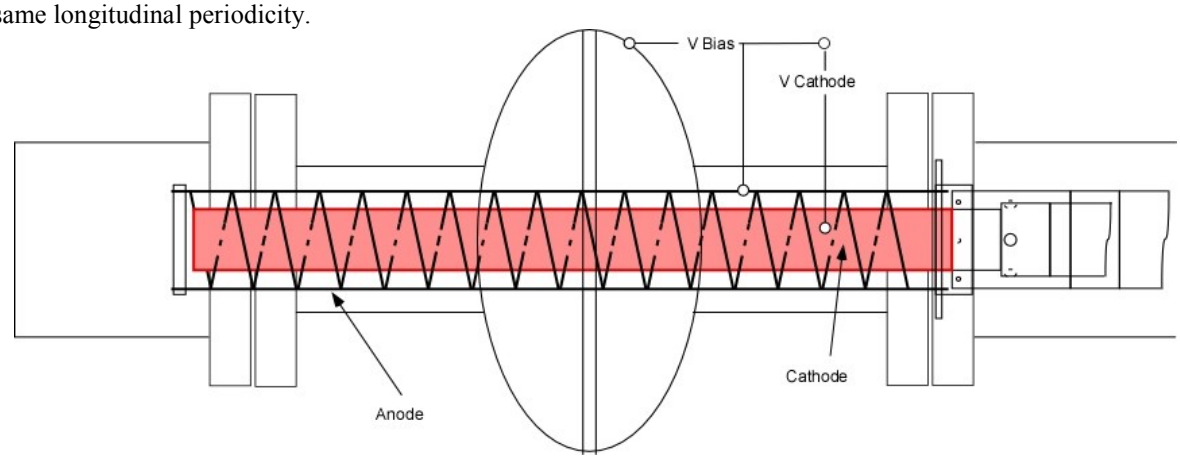

Figure 3: Schematic of the cylindrical magnetron.

INITIAL MEASUREMENTS

The first task is to characterize the flux obtained from the magnetron under various applied pulse conditions from the generator. Of great importance is the energy spectrum of the ion flux. Equally important is the ratio of niobium ions to neutral atoms. This last item will depend on the design of the anode structure, and the anode structure will also affect the niobium ion energy spectrum. One anode is complete and a second design is nearing completion.

The second task is to establish film properties (initially T_c and *RRR*) as a function of deposition parameters using small coupons. A good starting point will be to adjust the cavity bias potential such that the normalized energy to the growing film in eV/atom is equal to the same value for monoenergetic ions which have produced a good known result. This information will soon be available from extensive film studies involving the deposition of niobium ions from an ECR source [6,7].

After a suitable range of deposition conditions has been established, these parameters can be used to coat single cell cavities in this system under the same conditions with which the coupons were produced.

SUMMARY

A cavity system for the deposition of niobium on copper cavities has been completed and is in the process of being commissioned. Films will be deposited energetically using HIPPMS techniques. Post surface processing after deposition will also be studied by maintaining hermeticity through cryogenic testing before exposing the surface to air. Deposition process parameter selection will be guided by small sample studies.

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