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CYLINDRICAL MAGNETRON DEVELOPMENT FOR Nb_3Sn DEPOSITION VIA MAGNETRON SPUTTERING*

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Abstract

Due to its better superconducting properties (critical temperature T_c~ 18.3 K, superheating field H_{sh}~ 400 mT), Nb_3Sn is considered as a potential alternative to niobium (T_c~ 9.25 K, H_{sh}~ 200 mT) for superconducting radiofrequency (SRF) cavities for particle acceleration. Magnetron sputtering is an effective method to produce superconducting Nb_3Sn films. We deposited superconducting Nb_3Sn films on samples with magnetron sputtering using co-sputtering, sequential sputtering, and sputtering from a stoichiometric target. Nb_3Sn films produced by magnetron sputtering in our previous experiments achieved DC superconducting critical temperature up to 17.93 K and RF superconducting transition at 17.2 K. A magnetron sputtering system with two identical cylindrical cathodes that can be used to sputter Nb_3Sn films on cavities has been designed and is under construction now. We report on the design and the current progress on the development of the system.

INTRODUCTION

Nb superconducting radiofrequency (SRF) cavities used in modern particle accelerators are reaching close to the theoretical limit for the quality factor and accelerating gradient due to the limited superconducting critical temperature T_c of 9.25 K and the superheating field H_{sh} of 200 mT [1,2]. Nb_3Sn promises a better performance than niobium due to the high T_c (18.3K) and H_{sh} (400 mT) [2]. Since Nb_3Sn is a brittle material, thin films of Nb_3Sn inside a Nb or Cu cavity are considered. The most widely used technique to coat Nb_3Sn inside the cavity is Sn vapor diffusion method [2-4]. Also, magnetron sputtering has been used to fabricate Nb_3Sn films on small substrates [5-12].

We have fabricated Nb_3Sn films on small Nb substrates by magnetron sputtering [7-12]. We are commissioning a cylindrical sputtering system to fabricate Nb_3Sn films inside a 2.6 GHz SRF cavity. Here, we report our initial progress on the cylindrical sputtering system fabrication.

NB_3SN GROWTH BY MAGNETRON SPUTTERING

We deposited superconducting Nb_3Sn films with magnetron sputtering in three ways: multilayer sputtering of Nb and Sn films followed by annealing, sputtering from a stoichiometric Nb_3Sn target, and co-sputtering of Nb and Sn followed by annealing. An AJA ATC Orion 5 Magnetron sputter coater was used for the fabrication. For the multilayered samples, we have deposited multiple layers of Nb and Sn films with a thickness of 20 and 10 nm respectively. The multilayers were annealed at 950 °C for 3 h. Figure 1 shows the transmission electron microscopic (TEM) images and EDS mapping of the cross-section of as-deposited multilayers and annealed Nb_3Sn film. The multilayers are easily distinguishable from the EDS mapping of the as-deposited films. The TEM-EDS mapping of the annealed film showed that Sn (green color in the mapping image) is uniformly diffused.

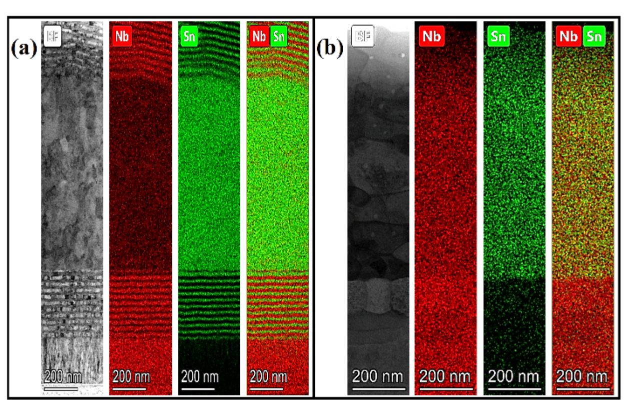

Figure 1: TEM image and EDS mapping of (a) as-deposited Nb-Sn multilayers, and (b) annealed Nb_3Sn film.

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Table 1: The Superconducting Properties of Nb_3Sn Films Fabricated by Three Different Magnetron Sputtering Processes

Fabrication method	T_c	ΔT_c	*RRR*
Multilayer sputtering	17.93	0.02	5.1
Stoichiometric target	17.83	0.03	5.41
Co-sputtering	17.6	0.22	3.63

For the samples fabricated from a stoichiometric target, sputtering was performed at a 3 mTorr Ar pressure with a constant DC current of 150 mA on a substrate heated up to 800 °C. For co-sputtering, the powers of both targets were optimized to maintain the film stoichiometry and the co-sputtered samples were further annealed. The resistance vs temperature graph of the film co-sputtered at room temperature and further annealed at 950 °C for 3 h is shown in Fig. 2. The superconducting properties of the films are shown in Table 1.

The RF superconducting properties of the films were also measured using the surface impedance characterization (SIC) system at Jefferson lab. For the Nb_3Sn film fabricated by multilayer sputtering, a superconducting transition of 17.2 K was observed [12]. For the films sputtered from a stoichiometric target, the highest RF superconducting transition was observed at 17.44 K [11].

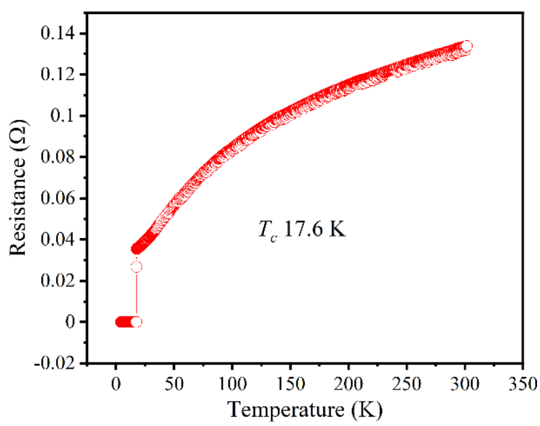

Figure 2: Resistance as a function of temperature of the Nb_3Sn film fabricated by co-sputtering.

CYLINDRICAL SPUTTERING SYSTEM

Design

A cylindrical magnetron sputtering system for deposition of a multilayer Nb and Sn layers, with its associated computer control unit has been designed and fabricated by PLASMIONIQUE Inc. The design of the sputtering system to fabricate Nb_3Sn films inside the SRF cavities is shown in Fig. 3. The goal of our current research is to establish a multilayer sputtering system to deposit Nb_3Sn films inside a single cell RF cavity. The system will be optimized further to apply co-sputtering and sputtering from a stoichiometric target. The system consists of two identical cylindrical magnetrons (Fig. 3(b)) facing to each other in a vacuum chamber. The movement of the magnetrons are controlled by bellows and the cathode temperature is facilitated by water cooling.

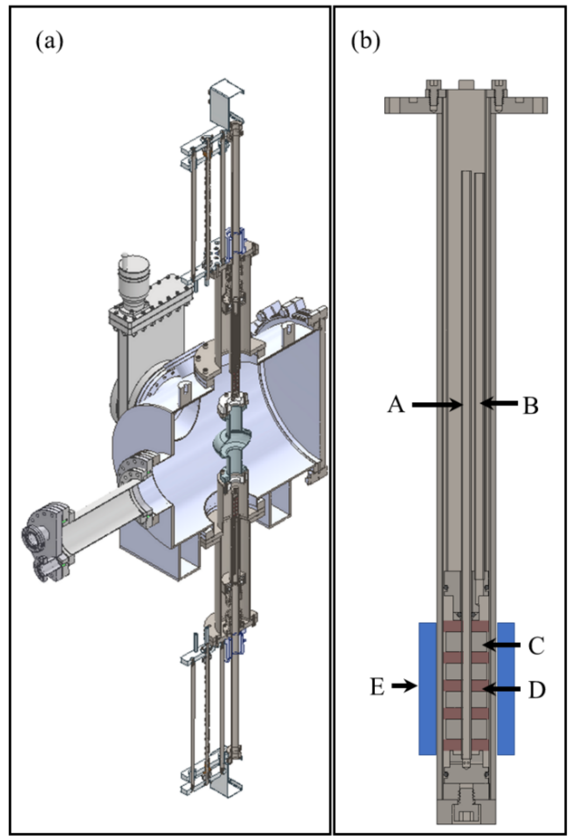

Figure 3: Design of the sputter system: (a) the whole cylindrical sputtering system, (b) cross-section of the individual magnetron: A. cooling water inlet, B. water outlet, C. magnets, D. magnet spacers, E. target.

Plasma Discharge

Due to the complex shape of the cavity of the 2.6 GHz cavity, in order to obtain a uniform deposition, it was decided to limit the size of the magnetron length to 2". A large number of finite element simulations were performed to obtain an ideal magnet configuration. The plasma discharge for one configuration and the magnetic field strength of similar design are shown in Fig. 4.

The vacuum chamber for the system was designed by Kurt J. Lesker. The vacuum chamber and all required vacuum system components are ready for installation. The magnetrons based on the results are near completion.

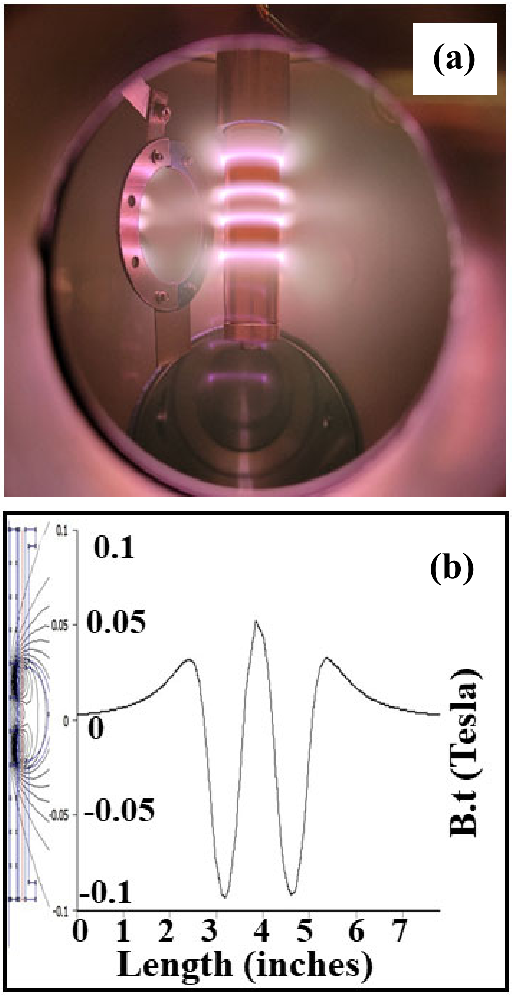

Figure 4: (a) Plasma discharge with 40 W at 10 mTorr;, (b) the magnetic field strength plots of similar design.

CONCLUSION

A cylindrical magnetron sputtering system has been designed to fabricate Nb_3Sn films inside a 2.6 GHz cavity. The simulation and experimental results validated the design for SRF cavity coating. The fabrication procedure of the sputtering system has been initiated to commission the system for 2.6 GHz SRF cavity coating.

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