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THE TECHNICAL STUDY OF NB_3SN FILM DEPOSITION ON COPPER BY HiPIMS

Li Xiao †, Xiangyang Lu, Datao Xie, Weiwei Tan, Yujia Yang, Liang Zhu
Peking University, Beijing, China

Abstract

Our work is mainly focused on the deposition methods of Nb3Sn films on Cu substrates and film's properties. The superconducting transition temperature (Tc) of Nb3Sn film is 12K. There are diffraction peaks of Nb3Sn in the X-ray diffraction patterns in which without diffraction peaks of copper compounds. Scanning electron microstructures of Nb3Sn film reflect its nice compactness and binding force between film and substrate.

INTRODUCTION

Niobium is extremely useful in superconducting radio frequency (SRF) cavities because of its properties, so that it is by far the material of choice for modern SRF accelerators, but now cavities are being produced that reach close to the fundamental limits of this material. To continue to increase the reach of particle accelerators for frontier scientific research and to open new industrial applications, for accelerators, researchers are examining the potential of alternatives to niobium with superior SRF properties [1]. An overview of the different materials being considered for SRF applications is given in [2], but one especially promising material is Nb3Sn. It offers both a large critical temperature (Tc as high as 18 K) and large predicted H_{sh}, both of which are approximately twice those of niobium[3,4] And to avoid that the poor thermal conductivity of Nb3Sn causes the cavity to quench, we choose Oxygen free copper substrate which has higher thermal conductivity. At the same time, the cost of copper is lower. So it is significant in the SRF accelerator filed to deposit Nb3Sn film on Cu substrate. Programs to produce Nb3Sn coatings by methods have made continuing progress throughout the current decade, such as multilayer sputtering, vapor diffusion, chemical vapor deposition, liquid tin dipping, mechanical plating, electron beam co-evaporation, bronze processing, and electrodeposition [5– 15]. Compared with all the other deposition methods of Nb3Sn films, multilayer sputtering can increase the diffusion efficiency of the atoms in the process of annealing so it is easy to form Nb3Sn film.

EXPERIMENT

High Power Impulse Magnetron sputtering (HiPIMS) method and vacuum annealing technology were used to deposit the Nb-Sn multi-layer on copper substrate in this paper. After that, we analyze the thin films by such as Magnetic Property Measurement System (MPMS) , X-ray diffraction (XRD) and high resolution field emission scanning electron microscopy (SEM), and continuously explore the preparation process and conditions of Nb3Sn film based on copper substrate.

Films Preparation and Heat Treatment

At first, we deal with the copper substrate to get Smooth and clean surface. We polish copper substrate with 1200#, 2000#, 3000# sandpaper. After Electrochemical Polishing, we use ultrasonic to clean it for more than 10 mins, and dry it by nitrogen, then installed it on the substrate holder in vacuum chamber of HiPIMS device. HiPIMS device like Fig. 1 was used to deposit precursor film which included niobium and tin. The targets of Nb and Sn are detached, they deposit the film at the same time.

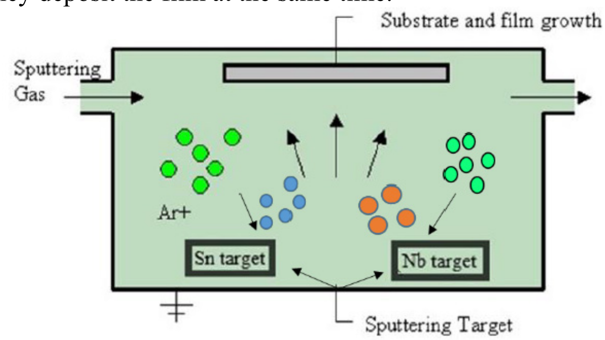

Figure 1: Schematic diagram of the principle of magnetron sputtering.

The base pressure of the chamber is 1×10^{-6}Pa. The working air pressure maintains at 0.5Pa. Pulse Width is 200μs, frequency of operation is 60Hz.The parameters of coating procedure are listed in Table 1.In order to avoid the reaction between copper and tin, and importing unnecessary impurities, we decide to deposit Nb on the copper substrate at first as the isolating layer [16]. After that, Nb and Sn deposit on the substrate.

Table 1: The Parameters of Coating Procedure

Project	Electric current /A	Voltage /V	Frequency /Hz
Nb	120	590	60
Sn	10	590	20

Then the precursor was put in the vacuum tube furnace whose air pressure is 1×10^{-4} Pa, The highest temperature is 650 ℃, which lead to the formation of Nb3Sn crystal. Next, the furnace cooled down naturally.

RESULTS AND DISCUSSION

The Tc of Nb3Sn film is around 12 K which measured by MPMS, image is given in Fig.2. This proves that thin films have superconducting properties, but it can be further improved by optimizing preparation process.

† [illegible]@pku.edu.cn

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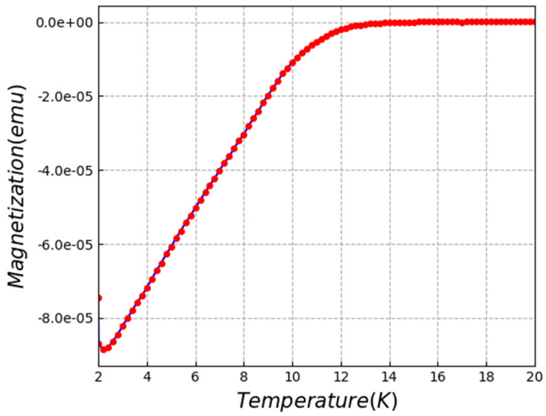

Figure 2: MPMS image of Nb3Sn film.

The SEM images of Nb3Sn are presented in Fig.3. The SEM images show that there are some tin islands in the film, which means that tin is uneven in the film, and the formation of the islands is not relate to the base temperature. At the same time, after annealing, tin islands will not disappear.

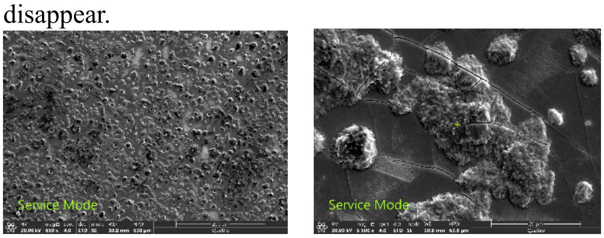

Figure 3: SEM images of Nb3Sn film.

Finally yet importantly, the X-ray diffraction (XRD) patterns of the film are given in Fig.4. There are diffraction peaks of Nb3Sn in the XRD patterns in which without diffraction peaks of copper compounds. The figure on the left is the image of annealed film, and the figure on the right is the image of film annealed under 650°C.The images shows that Nb3Sn crystal has been generated, and diffraction peaks of Nb3Sn have enhanced after annealing.

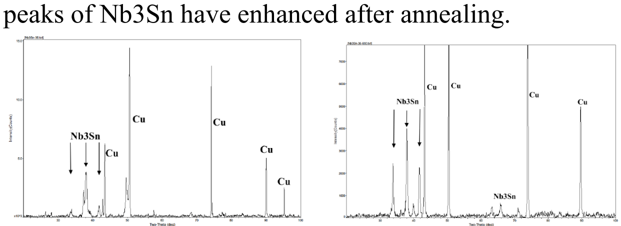

Figure 4: XRD image of Nb3Sn film before and after annealing.

CONCLUSION

We adopted HiPIMS device to prepare the Nb3Sn film whose substrate is copper. After annealing, Tc of Nb3Sn film achieved 12 K, and there are enhanced diffraction peaks of Nb3Sn in the X-ray diffraction patterns .It means that Nb3Sn crystal has been generated . So the experiment demonstrates the feasibility that Nb3Sn can be deposited on the copper by HiPIMS device. By further improving the content and cleanliness of Nb3Sn films on copper substrate is in progress.

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