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THE STUDY OF DEPOSITION METHOD OF Nb_3Sn FILM ON Cu SUBSTRATE*

Li Xiao†, Xiangyang Lu, Datao Xie, Weiwei Tan, Ziqin Yang, Jifei Zhao, Deyu Yang, Yujia Yang,
Peking University, Beijing, China

Abstract

Our work is mainly focused on the fabrication methods of Nb_3Sn films on Cu substrates and film's properties. There are diffraction peaks of Nb_3Sn in the X-ray diffraction patterns in which without diffraction peaks of copper compounds. Scanning electron microstructures of Nb_3Sn film reflect its nice compactness and binding force between film and substrate.

INTRODUCTION

Niobium is extremely useful in superconducting radiofrequency (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 Nb_3Sn. 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 Nb_3Sn causes the cavity to quench, we choose Oxygen-free cooper 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 Nb_3Sn film on Cu substrate. Programs to produce Nb_3Sn 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 Nb_3Sn films, multilayer sputtering can increase the diffusion efficiency of the atoms in the process of annealing so it is easy to form Nb_3Sn film.

EXPERIMENT

Magnetron sputtering 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 X-ray diffraction (XRD) and high resolution field emission scanning electron microscopy (SEM), and continuously explore the preparation process and conditions of Nb_3Sn film based on copper substrate.

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† email address: 1601110262@pku.edu.cn

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 and abradant. After ultrasonic cleaning for more than three times, we wiped it with anhydrous ethanol and dry it by nitrogen, then installed it on the substrate holder in vacuum chamber of DC Magnetron sputtering device.

DC Magnetron sputtering device like Fig. 1 was used to deposit precursor film which included niobium and tin. The targets of Nb and Sn are detached, they take turns to deposit the film.

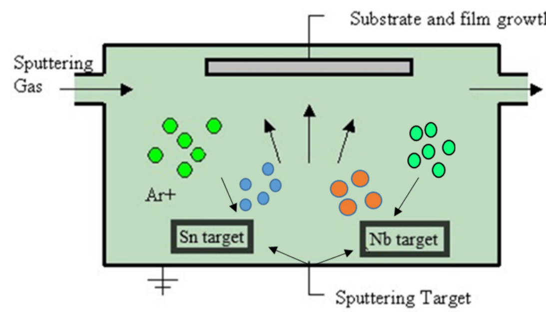

Figure 1: Schematic diagram of the principle of magnetron sputtering.

The base pressure of the chamber is 5×10^{-4} Pa. The working air pressure maintains at 0.5 Pa. 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 6 minutes, Nb and Sn take turn to deposit on the substrate to get multilayer. in the end, we deposit Nb as the outermost shell of the precursor to prevent the loss of Sn during annealing.

Table 1: The Parameters of Coating Procedure

Project		**electric current /A**	**voltage /V**	**Deposit time /min**
Nb isolating layer		1	310	6
multi-layer	Sn	0.11	295	60
	Nb	1	307	60
Nb cover film		1	306	6

Then the precursor was put in the vacuum tube furnace whose air pressure is 1×10^{-4}Pa, The annealing curve is given in Fig. 2. The terraced heating and heat preservation are designed to elevate temperature in the furnace efficiently. The highest temperature is 850℃which lead to the formation of Nb_3Sn crystal. Next, the furnace cooled down naturally.

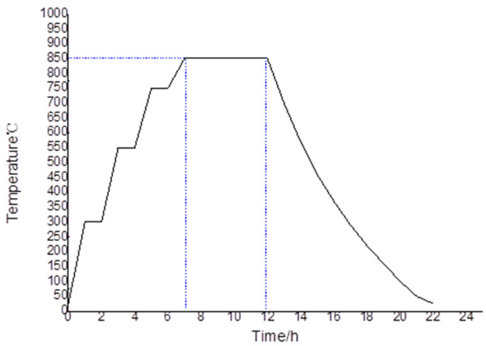

Figure 2: The annealing curve of the experiment.

The sample is like Figure. 3 finally.

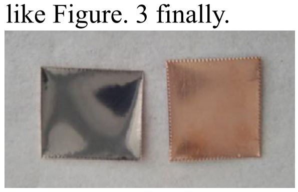

Figure 3: The pros and cons of the sample after annealing.

RESULTS AND DISCUSSION

The SEM images of Nb_3Sn are given in Fig. 4. This Nb_3Sn sample was annealing at 850 °C for 5h. The SEM images show that there are some broken area in the film, which means that Nb_3Sn may be a little friable.

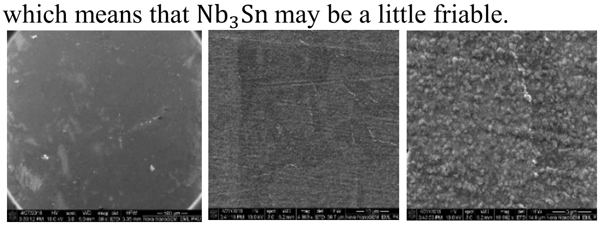

Figure 4: SEM images of Nb_3Sn film annealing at 850° C for 5h.

During the exploring the fabrication of Nb_3Sn film, we work out the problem of the loss of tin. Make thicker and more layers film to avoid Sn running away from the film. At the same time, every layer was deposited thinner to contribute to the diffusion of Nb and Sn during the period of annealing. sequentially, Sn was ensured to stay in the film. The EDX image of Nb_3Sn film is given in Fig. 5. It confirmed the existence of the tin.

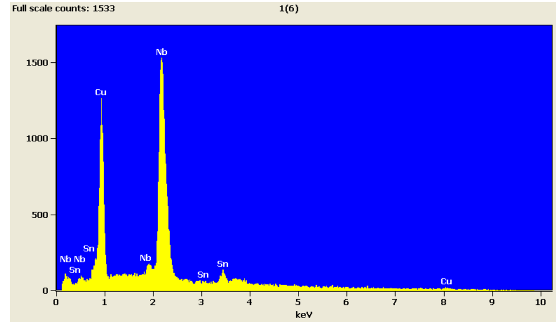

Figure 5: EDX image of Nb_3Sn film annealing at 850° C for 5h.

Last but not least, the X-ray diffraction patterns of the film is given in Fig. 6. There are diffraction peaks of Nb_3Sn in the X-ray diffraction patterns in which without diffraction peaks of copper compounds. The image shows that Nb_3Sn crystal has been generated. There are some Nb but no Sn in the image, it means that Nb is superfluous.

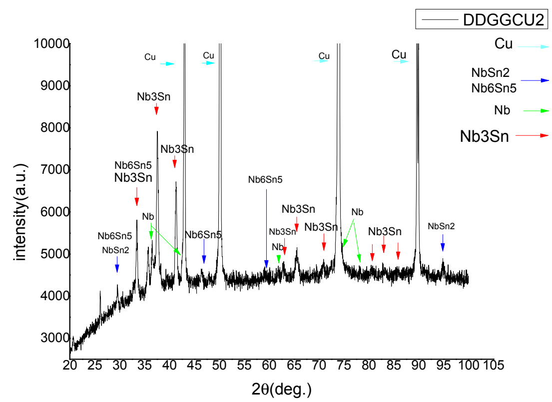

Figure 6: XRD image of Nb_3Sn film annealing at 850° C for 5h.

CONCLUSION

We adopted DC Magnetron sputtering device to prepare the multilayer precursor film including niobium and tin whose substrate is copper. After annealing, there are diffraction peaks of Nb_3Sn in the X-ray diffraction patterns, and it means that Nb_3Sn crystal has been generated. So the experiment demonstrates the feasibility that Nb_3Sn can be deposited on the copper by DC Magnetron sputtering device. By further improving the content and cleanliness of Nb_3Sn films on copper substrate is in progress.

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