10×10mm^2 MgB_2 FILM FABRICATED BY HPCVD AS A CANDIDATE MATERIAL FOR SRF CAVITY *

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Abstract

Magnesium diboride (MgB_2) is a candidate material for superconducting radio frequency cavities because of its features: high transition temperature of ~39K and absence of weak links between grains which prevents other high-Tc superconducting materials to be used for SRF cavity, such as YBCO. Most of MgB_2 films fabricated on metal substrates by HPVD are about 5 × 5 mm^2. In this work, we successfully grew 10 × 10 mm^2 MgB_2 film on Mo substrate with polycrystalline structure by using HPCVD method. SEM images indicate the good surface morphology and uniformity of this film. *Tc* at different parts of the film are from 38 K to 39 K, with transition width *ΔT* less than 0.5 K.

INTRODUCTION

Because of its simple components, high transition temperature (~39 K) and none weak – link behavior at grains boundaries [1], MgB_2 becomes a promising candidate material for SRF thin film cavity [2][3], which is expected to increase the accelerator operation temperature [4] and provide a higher accelerating gradient. Therefore it is necessary to study the RF characteristics of MgB_2 film except DC superconducting properties. Different from the DC study which can be done with small size MgB_2 films, larger MgB_2 film is required for RF characteristics study because the MgB_2 film should be a sufficient part of the inside surface of test cavity. Successful large scale MgB_2 films on sapphire substrate were reported by Moeckly and Ruby [2], Wang [3] and Teng Tan [5] respectively. Recently a surface resistance of 9 ± 2 μ Ω was observed for an MgB_2 film on Al_2O_3 (0001) substrate at 2.2 K and 7.4 GHz with a surface impedance characterization system (SIC) in Jefferson Lab [6]. However, considering the mechanical and thermal characteristics of SRF cavity, it is necessary to fabricate MgB_2 film on metal substrates. Different kinds of metal such as Cu, Nb, Mo and stainless steel have be studied as substrates [7][8][9]. But most of MgB_2 films fabricated on metal substrates by HPCVD method are about 5 × 5 mm^2. Recently, we explore a technique to deposit larger MgB_2 films on Mo substrate, and the surface morphology and uniformity of the film are analysed.

EXPERIMENT

The schematic of the HPCVD equipment is shown in Fig. 1 (a). A new reactor chamber made of stainless steel is designed with better vacuum and larger space. An inductive heater under Mo susceptor is used to heat the Mg bulk pieces and the substrate. It is found that if we made the temperature of substrate a little lower than the susceptor, a better uniformity of MgB_2 film could be obtained. Therefore, a thermal insulation layer is introduced to decrease the substrate temperature only, seeing Fig. 1 (b). We used a 10 × 10 mm^2 MgO slice with 0.3 mm thick as the interlayer, which has a much lower thermal conductivity (~ 20 W/mK) than Mo susceptor(~ 139 W/mK).

Before deposition, 6 – 8 ingots of bulk Mg are put around the Mo substrate for generating sufficient Mg vapor, and they are heated to 720 ° C in an ultrahigh-purity hydrogen atmosphere with a pressure of 75 torr. During the MgB_2 film growth, a mixed gas flow with 75% diborane and 25% ultrahigh-purity hydrogen is delivered into the chamber at a flow rate of 6 standard-state cubic centimeter per minute (sccm).

Only XRD analysis was carried out with the whole film. For investigation of other properties, we divided the film into 3 pieces to characterize the uniformity of the 10 × 10 mm^2 film. Each of them is about 3.3 mm × 10 mm in size, and the properties are measured respectively. The XRD analysis was performed using a Philip’ X’ pert-MRD diffractometer. The surface morphology was studied

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by using a QUANTA 200 PEG SEM. The *R-T* curves were measured by the standard 4-probe method. The thicknesses of the three pieces from one film were measured by Dektek stylus profiler and are all around 250 nm.

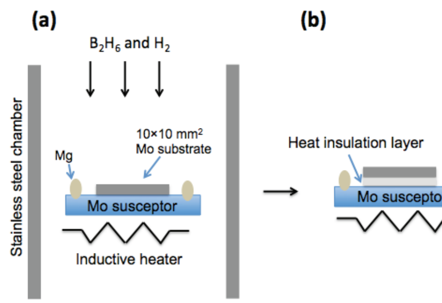

Figure 1: Schematics of (a) HPCVD equipment and (b) heat insulation layer.

RESULTS AND DISCUSSTION

Figure 2 shows the XRD pattern of the whole 10 × 10 mm^2 MgB_2 film. (101) and (111) peaks of MgB_2 indicate its poly-crystalline MgB_2 crystal structure. There are not any impurity peaks in the spectrum, which means that the environment inside the stainless steel chamber is clean enough.

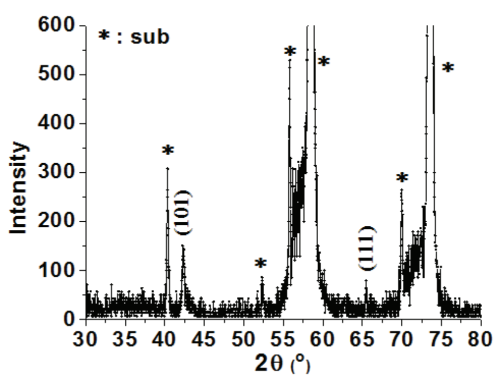

Figure 2: X – ray diffraction patterns of 10 × 10 mm^2 MgB_2 film.

Figure 3 shows the scanning electron microscopy (SEM) images in the centre areas of three slices from one 10 × 10 mm^2 MgB_2 film. The similar surface morphology is observed for these three slices and all of them are composed of hexagonal crystallites with a size of ~ 500 nm. It shows the good uniformity of the film. The grains pattern growing in different directions consists with the polycrystalline structure indicated by XRD.

The curve of resistivity versus temperature is shown in Fig. 4 (a). The transition temperature *Tc* (onset) is about 39 K, which is similar to that of small – size film [9]. The superconducting transition is sharp, with a width less than 0.5 K, which indicates the good connectivity of the film. . The *R – T* curves of the other two films are plotted in Fig. 4 (b). The *Tc* of three pieces ranges from 38 to 39K and the ⊿*T* are all less than 0.5 K, which also demonstrates that the 10 × 10 mm^2 MgB_2 film on Mo can have good uniformity. We also evaluated the residual resistivity of MgB_2 film with large scale by average the values of three pieces. It is about 1.1 μΩ• cm, which reflect a relatively high purity of the film. The resistivity of Mo (~ 5.2 μΩ• cm) substrate was subtracted.

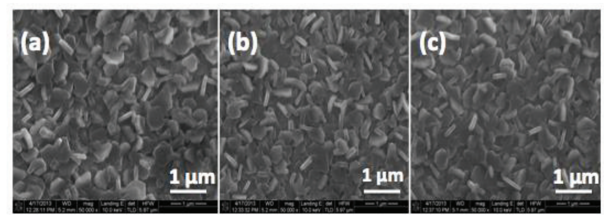

Figure 3: SEM images of three pieces from one MgB_2 film. (a) Left one, (b) middle one and (c) right one.

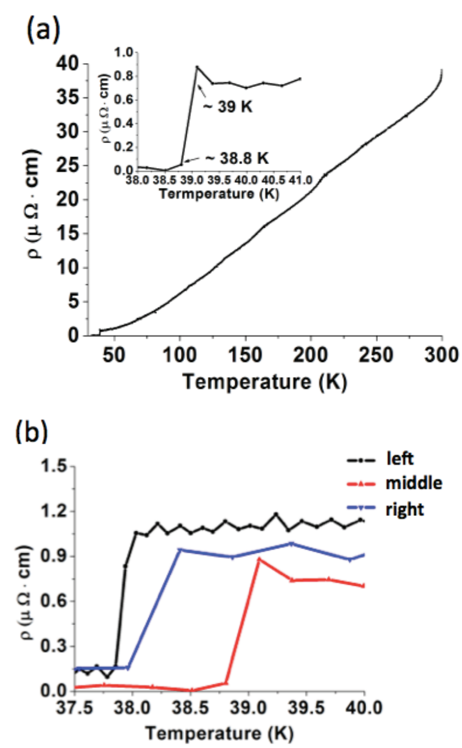

Figure 4: (a) Resistivity versus temperature curve for the middle one of three pieces, (b) Resistivity versus. temperature curves nearby the transition region of three pieces.

CONCLUSION

We successfully fabricated 10 × 10 mm^2 MgB_2 film on molybdenum substrate by HPCVD. XRD indicates its polycrystalline structure. The *Tc* at different parts ranges between 38 and 39 K, with all transition width less than 0.5 K. The average thickness and residual resistivity of film is about 250 nm and 1.1 μ Ω• cm receptively. The SEM images show its good uniformity.

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