MICROWAVE SURFACE RESISTANCE OF YBaCuO SUPERCONDUCTING FILMS LASER-ABLATED ON COPPER SUBSTRATES

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Abstract
In order to apply high-$T_c$ material to a real accelerator cavity, it may be indispensable that the material is deposited on metal substrate. It is now possible to align the $c$ axis of YBa$_2$Cu$_3$O$_y$ (YBCO) film perpendicular to a metal surface. Furthermore, the constituent crystals can be in-plane aligned with a laser ablation technique following the formation of yttria-stabilized-zirconia (YSZ) buffer layer of controlled grain orientation. Using a demountable copper cavity operated at 13 GHz in the $TE_{111}$ mode, the microwave surface resistance was measured over a temperature range from 11 K to 300 K.

I. INTRODUCTION

Since the discovery of a high-$T_c$ superconductivity, the possibility to use a high-$T_c$ material to an accelerator cavity has been discussed. For high-power accelerator cavities, not only must high-$T_c$ films be deposited onto large-area substrates of complex shape, but the use of metallic substrates of high thermal conductivity is also essential. As the thermal conductivity of high-$T_c$ materials is rather low[1], heat must be released to keep the film in a superconducting state even under a high field.

In KEK we have been involved[2] in developing thick high-$T_c$ films of YBCO or Bi$_2$Sr$_2$CaCu$_2$O$_y$. The YBCO films were prepared through a low-pressure plasma-spraying technique and melt-reaction process either on silver substrate or nickel-plated copper substrate. The Bi$_2$Sr$_2$CaCu$_2$O$_y$ films were prepared either by a screen-printing or spraying method either on silver substrate or silver-plated copper substrate. The microwave surface resistances were measured using a demountable cylindrical cavity made of copper at 3 GHz in the $TE_{111}$ mode. The surface resistance of YBCO film on a silver end plate was 0.2 m$\Omega$ at 20 K. However, the preparation of well-controlled surface of this size (the diameter and length is 150mm and 84mm, respectively) is expensive, time-consuming and not necessarily successful.

Therefore we made another demountable cavity operated at 13 GHz of the same mode. It was cooled by a compact refrigerator and temperature-controlled from 11 K up to the room temperature. The high-$T_c$ films were formed by a laser-ablation method on well-controlled YSZ layer. The surface resistances of the samples were found from the measured quality factors following the same procedure as before[2]. However, as the reflection at 13 GHz was more severe and temperature-dependent than that at 3 GHz, we were required to be more cautious in measuring the rf parameters.

II. FABRICATION OF FILMS

An YSZ/Cr film was used as buffer layer for the deposition of YBCO on copper substrates. The Cr underlayer was found to be essential to protect copper against oxidation, resulting in good adhesion of the YSZ layer on copper. Copper substrates, 36-mm dia. disk with a thickness of 3 mm, were polished to a mirror finish. They were then ion-plated with the Cr layer of about 0.5 $\mu$m, subsequently sputter-deposited with the YSZ buffer layer of as thick as 0.8 $\mu$m.

The grain orientation of YSZ layer was controlled using a modified bias sputtering technique. The technological fundamentals of this method were reported elsewhere [3], [4], [5].

![Figure 1. The configuration of electrodes.](image_url)

Figure 1 shows a pair of specially devised electrodes installed in the sputtering system. Using this equipment, we made an attempt to obtain YSZ films with in-plane texturing over the whole surface of the sample. In brief, the films grown without the biased electrodes showed a poor crystallinity and random orientation. In contrast, when a negative d.c. bias of 200 V was applied both to the substrate holder and auxiliary electrodes, an apparent in-plane texture occurred in the films. However, the degree of in-plane texturing varied depending upon the sample position; films grown on the part of of the substrate located directly above the center between the two auxiliary electrode plates, showed comparatively poor texture. This is because glancing angle ion bombardment during deposition is one of the requirements for the achievement of in-plane texturing. However, at this area, Ar$^+$ ions impinge on a film not obliquely but at almost right angles. In order to avoid the growth of this poorly-oriented film, masks made of zirconium tape were placed at these positions, as illustrated in Fig.1. In addition, we incorporated a movable substrate holder electrode which enabled us to slide the substrate.
Figure 2. Pole @gure for (a) in-plane aligned YBCO,(b) in-plane non-aligned YBCO @lms.

Figure 3. Resistance $R$ vs $T$ of YBCO @lms grown on (a) in-plane textured, (b) untextured, YSZ buffer layers and (c) (100)MgO.
**IV. EXPERIMENTAL RESULTS AND DISCUSSION**

Fig. 5 shows the surface resistance of the copper $R_s(T)$ composing the host cavity. The value below 32.7 K falls less than 10 mΩ and remains almost constant. The value measured for the 3 GHz cavity is also shown.

As the input power to the cavity is small, the rf losses observed in high-$T_c$ materials are explained by a model of Josephson coupling between the superconducting grains. The thick solid line in Fig. 6 shows the surface resistance of the in-plane aligned YBCO film and the thick dotted line shows that of the copper. The surface resistance of the sample below 71.5 K is lower than that of copper and around 1 mΩ below 45 K. As the surface resistance of the material decreases below that of the copper, the relative error increases as described in Ref. 2. Thus with a copper host cavity, the absolute measurement of a low surface resistance is substantially inappropriate. Meanwhile it has an advantage in measuring a surface resistance with the same order of copper and for a wide temperature range. Note that the situation can be improved to some extent, if we change the geometrical factors.

Before long the properties of the samples would be clarified through the analysis of the data and will be reported elsewhere. We can also obtain the complex impedance through the data analysis.

**References**