Preparation of Tl-2212 and 1223 superconductor thin films and their microwave properties

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Abstract

$Tl_2Ba_2CaCu_2O_y$ (Tl-2212) and $Tl(Ba,Sr)_2Ca_2Cu_3O_y$ (Tl-1223) superconductor thin films have been prepared on CeO_2 buffered sapphire substrate by an *ex situ* process namely, Amorphous Phase Epitaxy (APE) method. In the case of Tl-1223, an amorphous layer of $TlSr_2CaCu_2O_y$ (TlSr-1212) was deposited on top of CeO_2 layer to avoid chemical reaction between Tl-1223, containing Ba, and CeO_2 layers. All films are epitaxial with smooth surface and excellent crystallinity. Superconducting transition temperatures (T_c) of Tl-2212 and 1223 are around 95 and 104 K, respectively. Critical current density (J_c) at 77 K measured on 5×5 mm films by inductive technique is as high as 2 MA/cm^2. Surface resistance R_s of Tl-2212 films measured by a dielectric resonator technique at 38 GHz is comparable to the best YBCO films.

Key words: Superconducting films; Tl-2212 and Tl-1223 films; Dielectric resonator; Surface resistance

1. Introduction

It is well known that high-T_c superconductor (HTS) films have very low surface resistance compared to the normal conducting films at microwave frequencies. Therefore, these films have potential applications in passive microwave devices. It has been established that $YBa_2Cu_3O_y$ (YBCO) films have surface resistance as low as 0.4 mΩ at 10 GHz and 77 K. Since the critical temperature of such YBCO films is about 90 K it is difficult to operate any microwave device such as filters and antennas at 77 K. Therefore, we require HTS films with $T_c \geq 100$ K so that at 77 K the R_s does not vary significantly with temperature. Thallium based superconductor films such as Tl-2212, Tl-2223 and Tl-1223 with T_c=110K, 125 K and 130 K, respectively, are suitable for microwave applications at 77 K. However, the toxicity of thallium and its high vapor pressure are serious drawback to fabricate such films on large area with good crystallographic and superconducting properties. On the other hand, owing to the low melting of Tl_2O and its vapor phase reaction an appropriate partial pressure of oxygen and thallium environment leads to minimize the preparation time drastically. Preparation of Tl-2212 film is relatively easy and Tl-1223 exhibits low anisotropy and therefore it is expected to have high J_c and low R_s compared to Tl-2212 and Tl-2223 systems. Although there are reports of surface resistance measurements on Tl-2212 films the preparation method for thallium films with reproducibility at the microstructure level is a difficult task.[1] Keeping this in mind, we have investigated the preparation and microwave surface resistance of Tl-2212 and Tl-1223 systems and the results are presented herein.

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2. Experiments

About 6000 Å of Tl-2212 and Tl-1223 films were prepared on CeO_2 buffered sapphire substrate (5×5 and 10×10 mm^2 area) by APE method as described elsewhere.[2] However, for Tl-2212 films a slightly different method for annealing the amorphous films was adapted. In this method, the amorphous film of composiotion Tl-2223 was kept in silver capsule along with known amount of Ag_2O and prereacted Tl-2212 powder, sealed and annealed at 840°C. Phase purity and crystallographic orientation of films were characterized by x-ray diffraction. Surface morphology was investigated by Scanning Electron Mircoscopy (SEM) and Atomic Force Microscopy (AFM). Cationic composition was examined by Energy Dispersive x-ray Analysis (EDAX). The T_c of the films was measured by ac susceptibility and J_c was estimated from the measurement of ac field amplitude dependence of out-of-phase susceptibility. Temperature dependence of surface resistance was measured on 10×10 films by a dielectric resonator technique at 38 GHz.[3]

3. Results and Discussion

The details of preparation, characterization and superconducting properties of Tl-1223 films have already been reported.[2] Therefore, only the results on surface resistance measurements of Tl-1223 films will be discussed here. θ - 2θ scan of Tl-2212 films confirmed that these films are c-axis oriented with excellent crystallinity. ϕ scan of (1 0 17) reflection of Tl-2212 film, as shown in Fig. 1, suggests that these films are grown epitaxially. SEM analysis showed that the grains were uniform with a size of about 1μm. AFM analysis showed a smooth surface with no particles. The surface roughness was in the range 50 - 200 Å. It should be mentioned that these films are reproducible with same microstructure. EDAX anaysis of Tl-2212 films showed that the composition is similar to that of the amorphous film *ie* $Tl_2Ba_2Ca_2Cu_3O_y$. The diamagnetic onset temperature of Tl-2212 is about 95 K. J_c was estimated to be as high as 2 MA/cm^2.

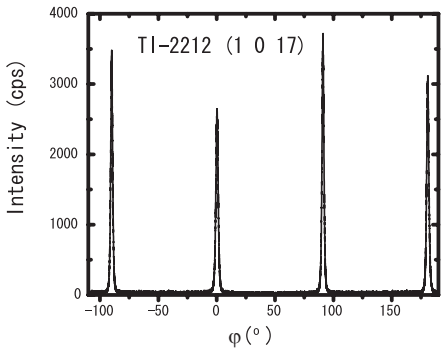

Fig. 1. ϕ scan of (1 0 17) reflection of Tl-2212 film showing a good in-plane alignment.

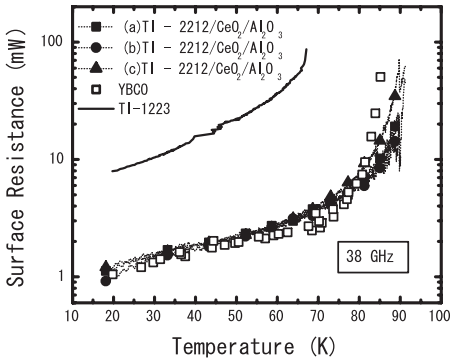

Fig. 2. Temperature dependence of surface resistance of Tl-2212, Tl-1223 and YBCO films measured at 38 GHz.

Temperature dependence of surface resistance of both Tl-2212 and Tl-1223 films along with YBCO film is shown in Fig. 2. It can be seen that R_s of Tl-2212 films is comparable to the best YBCO films with higher T_c. The films denoted as a, b, and c are annealed at various amount of Tl-source. It seems that the surface resistance is not influenced by a small change in the amount of Tl-source. Our preliminary results on Tl-1223 show a high value of R_s which may result from inhomogeneity or poor quality film. Attempts are underway to enhance T_c of Tl-2212 film and follow the new method of annealing for the preparation of Tl-1223 films.

4. Conclusion

A reproducible method of preparation of Tl-2212 superconductor thin films at the microstructure level has been established. T_c of these films is close to 95 K and J_c can be as high as 1 MA/cm^2. Temperature dependence of surface resistance is comparable to the best YBCO film.

References

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