Electric Properties of Superconductors for Electric Power Transmission

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Abstract - SiO_2 film coated as a passivation layer for YBCO based electronic devices is investigated by measuring the micro wave properties of micro strip line resonators. The SiO_2 film coated resonators are compared with coated resonators for two degradation conditions, a 200 ℃ annealing in air and an exposure to air at 85 ℃ 85% relative humidity. The SiO_2 film reduces the YBCO thin film degradation caused by oxygen stoichiometry change and reaction with water.

Keywords: YBCO, degradation

1. Introduction

The recent worldwide success in applying high temperature superconductors to electric power components, such as motors, cables, and current limiters, has renewed the interest for this technology. These achievements have only been possible due to the rapid worldwide progress in developing high Tc superconductor wire and tape with acceptable performance for these prototype demonstrations.

This talk will briefly highlight the performance of high Tc superconductor wire and tape related to the current and long-range objectives of these power system related applications.

The major problems facing this technology will be discussed, as well as the prospects for commercialization and integration into the utility sector. The eventual widespread utility acceptance for superconducting power equipment will ultimately be based on several key factors; the system performance must be improved over conventional technology; the efficiency, reliability and maintenance must be comparable to conventional power equipment; the life cycle costs must be lower; and the installation costs must be highly competitive and justifiable to the utilities. The latter is impacted by the current tremendous cost of high Tc superconductors, which must be lowered to costs identical to conventional Nb-Ti wire.

This cost factor is coupled with the requirement for improved transport performance in magnetic fields of a few teslas of high Tc superconductor power components. The overall focus on efficiency improvement, which is critical for the motor application, is not the key factor for most of the other applications.

The performance, life cycle costs and reliability within the electric systems emerge as the major factors governing the consideration and purchase of a superconductor electric power component.

For future high Tc superconducting micro wave device application, we require YBCO thin film with stable and inert properties in various fabrication processes and operating environments. This is because the YBCO thin film degrades by oxygen stoichiometry change during high temperature fabrication processes. Furthermore, the material is susceptible to reacting with water in the various environments[1].

Therefore, we intend to study its passivation effect[2] using SiO_2 film by measurements of the microwave loss. For application of coated film to passivation for microwave devices, it is important to select the coating material with low dielectric constant and low loss tangent.

The SiO_2 film material has relatively low dielectric constant and low loss tangent. We have characterized the effect of the coated SiO_2 film on the YBCO resonator against annealing in the air and high temperature humidity exposure.

2. Experimental

The c-axis oriented YBCO thin films with 300nm thickness were prepared at 200 mTorr of O_2 gas pressure and at 750℃ of the substrate temperature. Microstrip line resonators using the YBCO thin film as a conductor were prepared.

The line patterns were made by conventional photolithography and Ar ion milling. The length of the center line between the gaps is 5.02mm and the resonant frequency is approximately 10.7GHz.

The SiO_2 films with 0.35um thickness were deposited to cover the lines except for the gold electrodes using the RF magnetron sputtering method at the O_2 partial pressure of 1.5 mTorr and the Ar partial pressure of 3.5 mTorr.

The substrate temperature was room temperature. To

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characterize the c effects as a passivation layer, two degradation conditions were performed. First, the resonators coated and uncoated SiO_2 films were annealed at 200℃ in air using an electric furnace.

The annealing time was up to 15 hours. Second, the resonators coated and uncoated SiO_2 films were exposed to air at 85℃ and 85% relative humidity for 30 min. These are the standard conditions used for accelerated humidity testing.

The transmission characteristic was measured by a scalar network analyzer in the temperature range of 20 to 90 K and in the microwave power range between -27 to 16 dBm to obtain the unloaded Q factors (Qo). The measurements were made before and after the two degradation conditions.

3. Experimental Results and Discussion

The results of the annealing testing are demonstrated using Qo at 14 dBm and 25K of both SiO_2 film coated and uncoated resonators against annealing time in Fig. 1. Qo was normalized to the value obtained prior to the annealing. Here, concerning the SiO_2 coated resonator, almost no decrease of Qo was observed against the annealing time up to 8 hours. On the other hand, the SiO_2 uncoated showed the degradation with increasing annealing time. Qo value strongly reflects the surface degradation, because the majority of microwave current flow occurs at the film surface including the line edge. In this case, the oxygen stoichiometry change is thought to occur by the annealing at 200℃. That is to say, for the SiO_2 uncoated resonator, the oxygen diffusion from YBCO thin film caused the deterioration of Qo. In conclusion, the SiO_2 film passivated the YBCO thin film with regard to the oxygen deficiency damage as a result of the annealing.

In order to demonstrate the result of the accelerated humidity testing, the temperature dependences of Qo are shown in Fig. 2 (a) and (b), the SiO_2 uncoated resonator in Fig. 2 (a) and SiO_2 coated resonator in Fig. 2 (b). Fig. 2 (a) indicates a drastic decrease in Qo values by exposure to the high temperature humidity for 30 min. Also, Tc deterioration from 84 to 72 K can be seen.

The degradation is suggested to penetrate into not only the surface but also the bulk of the YBCO thin film. On the contrary, in Fig. 2 (b), the SiO_2 coated resonator revealed almost the same Qo values and no Tc deterioration between before and after the exposure despite such severe degradation conditions shown in Fig. 2 (a).

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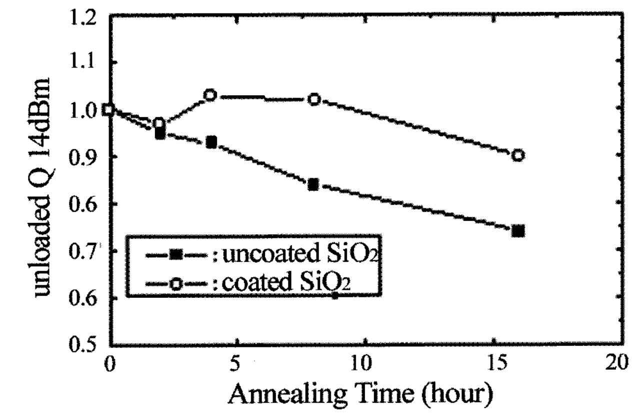
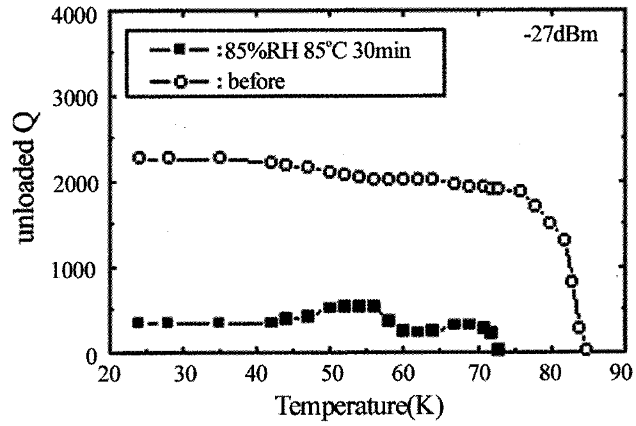
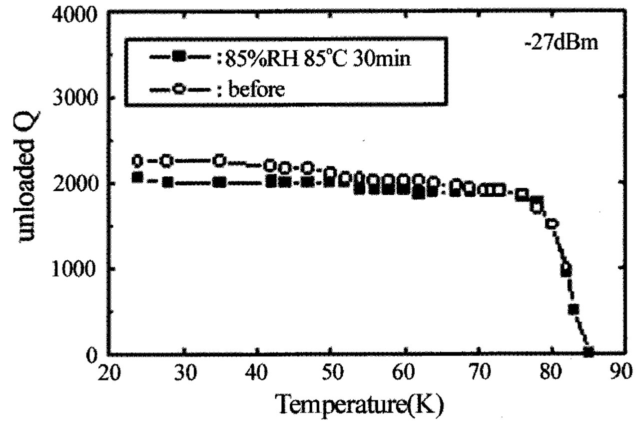


Fig. 1 The normalized unloaded Q at 14dBm and 25 k against the annealing time.



(a) uncoated SiO_2



(b) coated SiO_2

Fig. 2 The temperature dependence of unload Q

4. Conclusion

The SiO_2 film proved to be a superior passivation layer for the YBCO resonators. The two severe degradation conditions, 200℃ annealing in air and an exposure to air at 85℃ 85% relative humidity, were tried to estimate SiO_2 passivation film caused by the oxygen diffusion and reaction with water. We propose the SiO_2 film as a passivation layer for high Tc superconducting microwave devices.

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