HTS microstrip disk resonator with an upper dielectric layer for 4GHz

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Abstract. We propose HTS microstrip disk resonator with an upper dielectric layer as a candidate resonator structure of HTS compact power filter for 4GHz band. The electromagnetic simulations on the upper dielectric layer examined the current distributions of the HTS resonators that had TM\(_{11}\) mode resonance of about 4 GHz. By the simulations, it is evaluated that of the maximum current density near the end portion of the disk-shape pattern of the resonator with the thick upper-layered structure decreases by roughly 30-50 percent, as compared with that of the resonator without it. Then, we designed and fabricated the resonator samples with and without the upper dielectrics. The RF power measurement results indicated that the upper dielectric layer leads to an increase in handling power.

1. Introduction
This study was conducted on high-Tc superconducting (HTS) power filters for possible use in future base stations of the fourth-generation [1] mobile communication systems, with a possible frequency of 3-5 GHz. In order to clarify the more HTS compact power filter [3-6] conditions for excellent power handling and low intermodulation, we have been carrying out R&D of HTS resonators [6], which fulfill the conditions. We propose HTS microstrip disk resonator with an upper dielectric layer as a candidate of the resonator structure. In this paper, we report on the examinations by electromagnetic (EM) simulations and test resonator sample according to the above proposal of the microstrip disk resonator with the upper dielectric layer for the handling power improvement.

2. Structure of the Resonator with the Upper dielectric layer
As a candidate of resonator structure for the compact HTS power filter for 4 GHz band, we have studied HTS microstrip disk resonator with TM\(_{11}\) mode for 4GHz [6]. It is well known that the same type of this HTS disk microstrip resonator with TM\(_{11}\) mode can have a superior power handling to HTS microstrip line one. In order to improve more power handling capability of the HTS microstrip disk resonator, we propose HTS microstrip disk resonator with an upper dielectric layer as shown in Fig. 1. In this example, the (b) structure is obtained by layering a dielectric plate on the (a) structure. Here, each disk diameter has the value of 14 mm. In this condition, the (a) resonator can shows a resonance frequency of TM\(_{11}\) mode around 4.0 GHz. The upper dielectric layer is characterized by dielectric constant \(\varepsilon_{\text{UD}}\) and its thickness \(t_{\text{UD}}\) for the EM simulation mentioned bellow.

By providing the upper dielectric layer, it is expected that the external coupling Q (Qe) of the resonator decreases because the electromagnetic coupling between the disk-shaped pattern & the feeder increases by capacitive effect of the upper dielectric layer. Also, it is done that the electric field...
E around the end portion of the YBCO pattern decreases by increasing the effective dielectric constant $\varepsilon_{rUD}^{(eff)}$.

![Microstrip disk resonator structure models](image)

(a) (b)

Fig. 1 Microstrip disk resonator structure models for TM$_{11}$ mode for 4GHz band. Graph (a) shows the structure without the upper dielectrics [6]. On the other hand, graph (b) shows the structure with the upper dielectric layer.

3. EM simulations on the handling power ratios

The EM simulations in the cases of the different upper dielectric layers of MgO and LaAlO$_3$ (LAO) examined the current distributions of the HTS resonators that had TM$_{11}$ mode resonance of about 4 GHz, respectively. The simulations were carried out using the Moment method. We can evaluate the maximum current density by each simulation in the cases of the different $\varepsilon_{rUD}$.

![Current distribution maps](image)

(a) (b) (c)

Fig. 2 Current distribution maps as the results of the EM simulations. Warmer color shows higher current density. The (a) map graphs no upper dielectric layer case. The (b) map graphs the case of MgO crystal plate of which $\varepsilon_{rUD} = 9.7$ and $t_{UD} = 0.5$ mm were adopted as parameters for the simulations. The (c) do the case of LAO crystal plate of which $\varepsilon_{rUD} = 23.8$ and $t_{UD} = 0.5$ mm were done as the same.

Table 1 summarizes the evaluation results on the maximum current-density $J_{\text{max}}$ ratio and maximum handling-power $P_{\text{max}}$ ratio. In Table 1, higher $\varepsilon_{rUD}$ corresponding to the MgO and LaO, result in lower $J_{\text{max}}$ and higher $P_{\text{max}}$.

| Upper dielectric layer | Current density $J_{\text{max}}$ ratio | Handling power $P_{\text{max}}$ ratio [dB] |
|------------------------|----------------------------------------|------------------------------------------|
| No upper layer (reference value) | 1                                      | 0                                       |
| MgO                    | 0.64                                   | 3.87                                    |
| LAO                    | 0.50                                   | 6.57                                    |
As the main result of the examination using the simulations, it is evaluated that of the maximum current density near the end portion of the disk-shape pattern of the resonator with the thick upper-layered structure decreases by roughly 30-50 percent, as compared with that of the resonator without it.

4. Resonator samples and Handling Power Measurement

Then, we designed and fabricated the resonator samples actually. The test samples with and without the upper dielectric layer using MgO crystal plate with 0.5 mm thickness have as shown in Fig. 1 (a) and (b), respectively. Fabrication method of the resonator sample, that is for the comparison reference, with no upper dielectric layer was reported our previous paper [6]. It was prepared with the epitaxial YBCO films on the both sides of the MgO (100) substrate.

The sample with the upper dielectric layer was fabricated using process of laminating the MgO plate on the sample without the upper dielectric layer. This process means that a series of the examinations were carried out using the same YBCO films because of exact estimation on the power handling with no influence of the YBCO films, which quality difference leads to the different RF handling power [6]. The upper dielectric layer was mounted on a cryo-package with metal enclosure and two coaxial-connectors for I/O. The RF handling power values were measured at resonance frequency at cryogenic temperatures up to input power about 10 W that was limited due to the experiment system [6]. The input-output characteristics of the power measurements were performed between I/O connectors of outside of the metal enclosure.

5. Measurement Result

Figs. 3, 4 and 5 show the input-output power properties of the resonator samples at 80, 77.3 and 70 K, respectively. As the temperature increases from 70 to 80 K, the resonator sample with no upper dielectric layer shows the lower power breakdown. The measurement results indicated that the upper dielectric layer leads to an increase in handling power using the same conditions, such as measurement temperature and cryo-package. Therefore, it is suggested that the RF power characteristics improvements are mainly obtained from decreases in the maximum current density as well as in the Qe value between the disk and the feeder.

Fig. 3 The input-output properties at 80 K. Fig. 4 The input-output properties at 77.3 K.
6. Conclusion

In order to develop high power HTS filter for the future 4G base stations for mobile communications, Microstrip disk resonators with YBCO films for 4 GHz band were examined on the basis of our proposal. The proposed structure of the microstrip disk resonator is with an upper dielectrics and TM₁₁ mode. As the results of the EM simulation analysis, it is predicted that the handling power increases by adding the upper dielectrics. In addition, the resonator sample was fabricated actually, and carried out the power transmission examination. Accordingly, the measurement result accorded in the EM simulation results qualitatively. As a factor of the handling power improvement of a resonator sample by a dielectric layering, it is suggested that reduction of $J_{\text{max}}$ of the disk pattern edge under the same condition except difference of the upper dielectric layer.

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