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Improved Power Handling Capability of Superconducting Microstrip Lines for Microwave Devices

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Abstract

We examined a microstrip line structure to reduce the current concentration at the outer edge of a microstrip line. We developed three kinds of microstrip line; sliced-microstrip line, layered-film microstrip line, and conventional microstrip line. The first microstrip line is a line divided into the narrow line, and the second one is a line made by a layered thin film. Electromagnetic simulations indicated that the current concentration of the outer edge of the sliced microstrip line and layered film microstrip line was lower than that of a conventional microstrip line. We measured the power handling capability of the filters made by sliced-microstrip lines, layered-film microstrip lines, and conventional microstrip lines. The value of the first and the second filters was better than that of a conventional one. The difference in the characteristics is based on the difference in the current concentration at the outer edge of the microstrip lines.

keywords: Superconducting filter, HTS,YBCO, NbN, layered film

1.Introduction

Superconducting band pass filters have advantages such as high-frequency selection, small insertion loss, and a large out-of-band rejection [1-6]. Consequently, such filters have been put to practical use in receiving systems of base stations for wireless communications in the U.S.A [7] and China [8-9]. Recently, narrow bandpass filters made by HTS resonators were used for a rader of weather in Japan [10].

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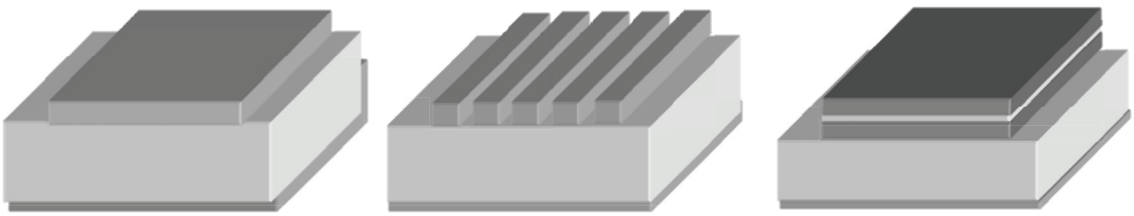
However, the superconducting band path filters have only been used in receiving systems in which small amounts of electric power flow. If the power handling capability of the filter can be improved, it could be used as a transmitting filter, and hence its range of use could be expanded. Some papers are reported to increase a power handling capabilty of the microstripline filters [11-13]. We think that the limit of power handling capability of filters is caused by the current concentration at the outer edge of a microstrip line which the resonators of the filter consists of. [14-15]. Therefore, it is very important to reduce the current concentration on the edge of a microstrip line. We show three different shapes of the microstrip line; sliced-microstrip line, layered-film microstrip line, and conventional microstrip line. We simulated the current concentration at outer edge of the microstrip line and discussed the difference of the concentration current. In addition, we made filters made by the sliced-microstrip lines, layered film microstrip lines, and conventional microstrip lines How the structure of the resonator shape affects the electric power-proof of the filter is discussed.

2. Simulation of current concentration at outer edge of microstrip line

We examined three types of microstrip lines: sliced-microstrip lines, layered-film microstrip lines, and conventional microstrip lines. A schematic drawing of conventional, sliced and layered microstrip lines are shown in Figure 1. A sliced microstrip line (Fig.1 (b)) is a structure thinly divided along its length. The layered microstripline (Fig.1(c)) is a thin film that alternately accumulates the superconducting thin film and the insulating layer. It is reported that the current concentration of the layered superconducting thin film is about half the value of the conventional microstrip line [16]. A schematic drawing of the predicted current concentration at the outer edge of microstrip lines of conventional, as well as the sliced and layered film microstrip line is shown in Figure 2. The current concentration of conventional microstrip line is quite large at the outer edge: however, the current concentration of a sliced microstrip line can be reduced at the outer edge of the same point. The current can flow inside the sliced microstrip line edge. The concentrated current in the conventional microstrip line flows at the bottom of microstrip line as shown in Figure 2 (c). Therefore, we must reduce the concentrated current to increase the power handling capability of microstrip line. To reduce the concentrated current at the bottom of a microstrip line, we propose a layered-film microstrip line. As shown in Fig.2 (d), the concentrated current of a layered-film microstrip line at the bottom can be reduced

The configration of the three-pole filter is shown in Figure 3. We designed an optimal configuration of the filter using three-type shape resonator by an electromagnetic simulator, Sonnet EM. Table 1 shows the maximum current concentration at the outer edge of the conventional, sliced and layered microstrip line filter. The maximum current concentration of conventional and sliced microstrip lines was calculated by an electromagnetic simulator, Sonnet EM. The value of the layered-film was predicted from the descrived in reference 16. The maximum current concentration of a sliced microstrip line was about 25% smaller than that of conventional microstrip line, and the layered one was about 50% smaller. Therefore, we will obtain a high power handling capability of the filter by using a sliced and a layered microstrip line.



(a) (b) (c)

Fig.1. Schematic drawing of a three kinds of microstrip lines: (a) conventional, (b) sliced and (c) layered-film microstrip lines.

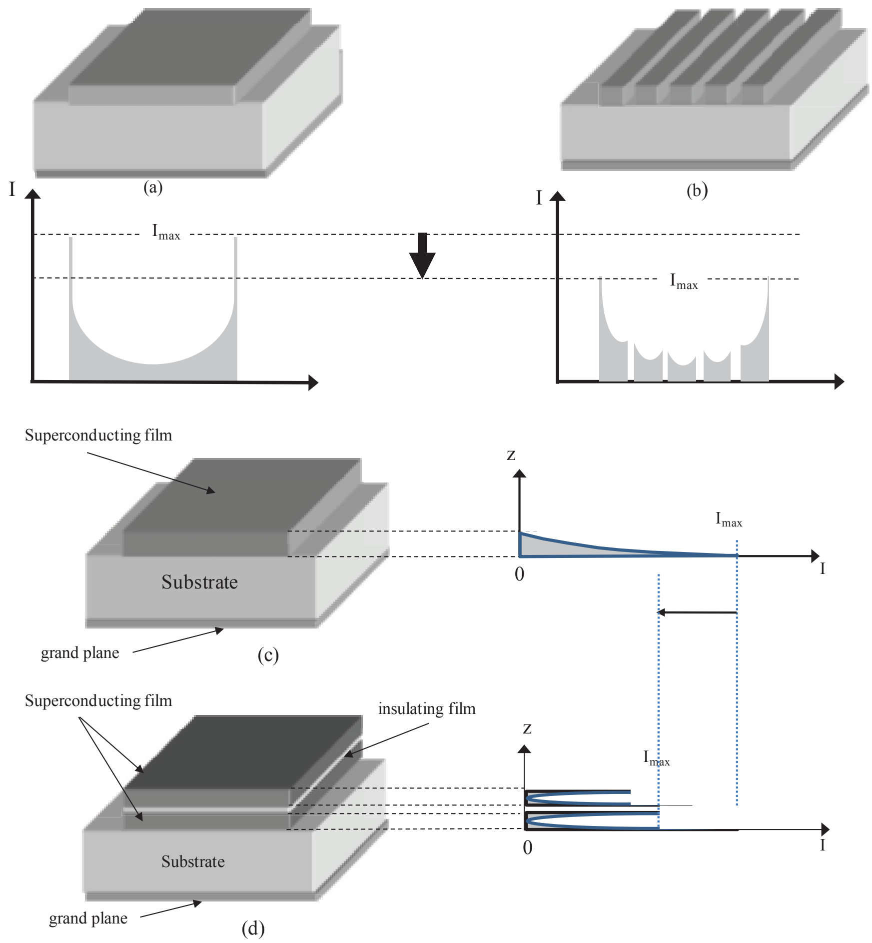


Fig.2. Schematic drawing of current concentration at outer edge, surface, and bottom of microstrip lines (a) current concentration of a conventional microstrip line at outer edge of microstrip line (b) current concentration of sliced-microstrip line at its outer edge (c) current concentration of conventional microstrip line at its bottom (d) current concentration of layered-film microstrip line at bottom. The I_{max} means the maximum current concentration at the outer edge or the surface of the microstrip lines in the figure.

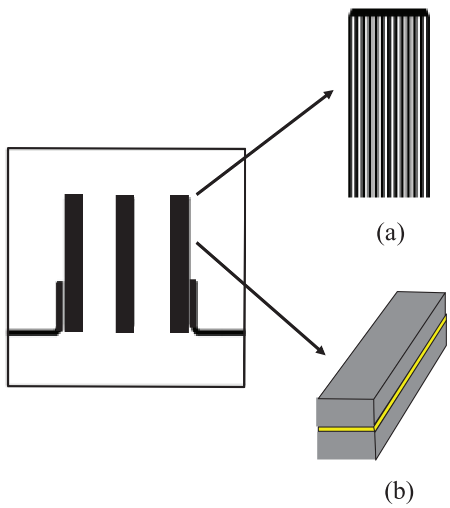


Fig.3. Configuration of sliced microstrip line filter and layered film microstrip line filter: (a) sliced microstrip line resonator and (b) layered-film microstrip line resonator.

Table I. Current concentration at outer edge of microstrip line; The value of conventional and sliced-microstrip lines was obtained by electromagnetic simulation, and that of layered-film was obtained by prediction from reference 16.

Type of microstrip line	Current concentration at outer edge of microstrip line
Conventional	2.4×10^5 A/cm^2
Sliced	1.8×10^5 A/cm^2
Layered	1.2×10^5A/cm^2 (*)

3. Power handling capability of a conventional, a sliced and a layered microstrip lines filters

The power dependence of the output power in the filter with conventional and sliced microstrip line filters is shown in Figure 4. The both filters were made by a NbN thin film on an MgO substrate. The thickness of the NbN thin film was about 200nm. To reduce the heat generation at the feed point, we used a NbN thin film. The horizontal axis shows the effective input power.i.e., input power minus reflected power. The vertical axis shows the difference between the input and the output power. When the input power is smaller than 23 dBm the difference between the input power and the output power is nearly zero, that is the loss of the filter is zero. However, when input power becomes larger than 25 dBm, the output power is smaller than input power. We are defining the power proof of the filter as that where the output electric power minus the input electric power is minus 0.5dBm (dashed line in the figure). As shown in Fig.4, the electric power proof of the sliced-microstrip line filter and the conventional microstrip line filter was 27.8 and 26.0 dBm, respectively. Therefore we found that the electric power proof of the sliced-microstrip line filter increased by about 1.8dBm compared with that of the conventional microstrip line filter. The power dependence of the output power in the filter with conventional and layered microstrip line filters is shown in Figure 5. The both filters were made by a NbN and NbN/AlN/NbN thin film on the MgO substrate. We prepared NbN and AlN thin films by a reactive magnetron sputtering. As the high quality layered YBCO

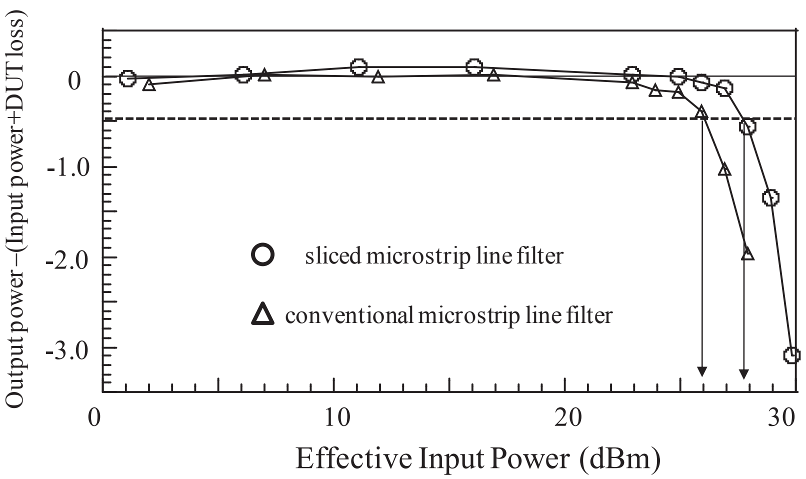


Fig.4. Power dependence of output power in filter with conventional and sliced microstrip line filters. The shape of the sliced microstrip line is shown in Fig.3 (a). The electric power-proof value of the filter is shown by the arrow in the figure.

thin films are very difficult to obtain in our group, we used a NbN/AlN/NbN layered film for filter. The Tc of NbN was about 15 K and the thickness of the NbN film was 200 nm. We are defining the input electric power value as that where the output electric power minus the input electric power is minus 0.5dBm (dashed line in the figure) as the electric power-proof of the filter. As shown in Figure 5, we found that the power proof of the layered microstrip filter increased about 1.9 dBm compared with that of the conventional microstrip line filter.

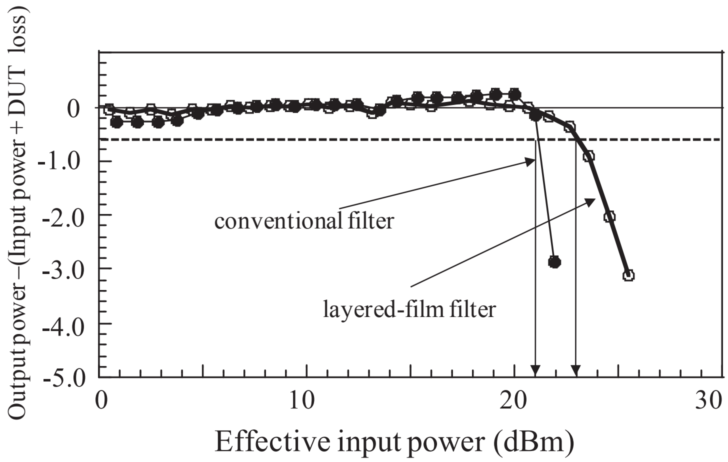


Fig.5. Power dependence of output power in filter with conventional and layered-film microstrip line filters. The shape of the layered-film microstrip line filter is shown in Fig.3 (b). The electric power-proof value is shown by the arrow in the figure.

4. Discussion

To increase power proof of the filter, we propose the use of two kinds of resonator, sliced-microstrip line resonator and a layered-film microstrip line resonator. From the simulation of the current concentration of the microstrip lines, we can estimate the increase of power proof. The concentrated current was about $2.4 \mathrm{x} 10^5$ A/cm^2 in the conventional microstrip line and $1.8 \mathrm{~x}~ 10^5$ A/cm^2 in the sliced microstrip line as shown in Table 1. If this difference directly accounts for the improvement in the power handling capability of the filter, we can estimate the difference in proof between the conventional and sliced microstrip line filters from the following equation.

$$P(dB) = 10\log\left(\frac{2.4\mathrm{x}10^5}{1.8\mathrm{x}10^5}\right)^2 = 2.5(dB) \qquad (1)$$

This estimate agrees with the experimental results. When similarly calculating from the expression (1) we can obtain the difference in proof between the layered-film filter and a conventional-microstrip line one. The difference was about 6 dB, which does not agree with the experimental results. To increase the power proof of the layered-film filter, we must examine optimal thickness of the superconducting and insulating films [16]. However, in this experiment we could not use the optimal thickness. We think that the reason for the lack of agreement between the simulation and the experimental result is the thickness of the NbN and AlN films.

5. Conclusion

To increase the power handling capability of superconducting bandpass filter, we proposed new resonator configurations, a sliced and a layered-film microstrip line. The following results were obtained.

(1) Current flowing along the outer edge of the sliced-microstrip line was less concentrated than in the conventional-microstrip line.

(2) Current flowing at the bottom of the microstrip line of a layered-film was less concentrated than in the conventional-microstrip one.

(3) The electric power proof of the sliced-microstrip line filter and the layered-film microstrip line filter was larger than that of the conventional filter.

(4) The electric power proof of the filter can be estimated from the concentrated current along the outer edge of the microstrip line.

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