ELSEVIER

Ceramics International 30 (2004) 1191–1193

CERAMICS INTERNATIONAL

www.elsevier.com/locate/ceramint

Multilayer microwave resonators with Bi-based dielectric ceramics

Ding Shihua*, Yao Xi, Lu Xudong, Yang Yong

Functional Material Research Laboratory, Tongji University, Shanghai 200092, China

Received 4 December 2003; received in revised form 18 December 2003; accepted 22 December 2003

Available online 27 April 2004

Abstract

Multilayer microwave resonators were fabricated using low temperature (~950 °C) sintered Bi-Based dielectric ceramics with high permittivity (>80). A simple structure with input/output terminals was designed with stripline to couple the resonators to external circuit. In this structure, gap-coupling capacitors were used to couple the input/output terminals to external circuit. Effect of coupling gap, the length of input/output pads and other sizes of the resonators on the resonant frequency and *Q*-value of the resonators was studied. The *Q*-value of one-port resonator is higher than 200 at 1.887 GHz and that of two-port resonators is higher than 80 at 960 MHz.

Keywords: Microwave resonators; Dielectric ceramics; *Q*-value

1. Introduction

Telecommunication technology industry requires microwave components with excellent electrical performance, high reliability, miniaturization and surface mounting techniques. To realize this, multilayer microwave devices were proposed. Low temperature co-fired ceramics (LTCC) are extremely advantageous to reduce the size of microwave devices. Dielectric resonators and filters are traditionally based on microwave ceramics sintered at high temperature. Although they are high-quality, low-cost and small in size [1,2], they are not suitable for planar circuit technology. Microwave devices with multilayer structure based on the LTCC technology have been developed [3]. Multilayer resonator [4], semilumped circuit LC filter [5] and planar filter for portable telephone applications [6] using LTCC technology were reported.

In this paper, we present a new structure of multilayer stripline resonators with gap-coupling capacitor input/output which was printed on the same layer of the stripline. The influence of coupling gap, the length of input/output pads and other sizes of the resonators on the resonant frequency and *Q*-value of the resonators was studied.

2. Experimental procedure

Ceramic powder was prepared using a conventional route. Oxides in an appropriate proportion were ball milled for 24 h in a nylon jar using ZrO_2 media. Powders were calcined at 800 °C for 2 h and then ball milled again under the same condition as mentioned above. Final ceramic powder with average particle size about 0.5 μm thus obtained. The ceramic powders were mixed with binder for about 24 h in a nylon jar using ZrO_2 media. The viscosity of the ceramic slurry was adjusted with solvents. Green sheets of ceramics (about 80 μm thick) were formed using tape casting technique. Gold paste pattern was screen printed on the sheets. The laminated tapes were pressed together and then diced into chips. The green chips were fired to eliminate binder and then sintered at about 950 °C. The dielectric constant and *Q*-value of the sintered ceramic were measured by Hakki–Coleman [7] method. Terminations were formed on sintered chips. Device characteristics were measured by HP8753E network analyzer.

3. Structure of multilayer resonators

Fig. 1 is the structure of a one-port resonator. This is a λ/4 balanced strip line resonator with a conductive strip at the center of the LTCC module as shown in Fig. 1 (bottom elec-

* Corresponding author. Tel.: +86-21-65980544; fax: +86-21-65985179.
E-mail address: dingshihua@fmrl.ac.cn (Ding Shihua).

0272-8842/$30.00
doi:10.1016/j.ceramint.2003.12.032

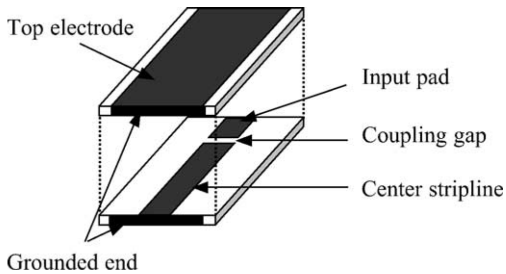

Fig. 1. Structure of multilayer one-port resonator.

trode not showed). The input pad, coupled to the stripline, is in the same layer with the center conductive strip. This resonator is end short circuited. This new structure is very convenient for manufacturing in comparison with the conventional structure [4]. In this work, the width of center conductive strip is equal to the width of input pad and is 1 mm. The length of center conductive strip is 4.2 mm. The distance between top electrode and bottom electrode is 1 mm. The top electrode and bottom electrode are connected together and short circuited with the terminal of the center stripline.

The stripline with short circuited end is equivalent to a *R*, *L* and *C* parallel-resonance circuit in Fig. 2. According to the transmission line theory [6], when attenuation constant is small,

$$R = \frac{Z_0}{\alpha l}; \quad C = \frac{\pi}{4\omega_0 Z_0}; \quad L = \frac{1}{\omega_0^2 C};$$

$$Q = \omega_0 RC = \frac{\beta}{2\alpha} \tag{1}$$

where α is attenuation constant, l the length of transmission line, ω_0 the resonance regular frequency, β the propagation constant, and Q the unloaded quality factor.

It can be seen from Eq. (1) that the small attenuation constant is a key factor for high *Q*-value. The attenuation constant, α, consists of dielectric loss and metal loss. At microwave frequency, low dielectric loss and high metal conductivity are important for high *Q*-value. Because of high dielectric constant, the length of resonator can be reduced. But the characteristic impedance of stripline in the above structure (about 8 Ω) is too small to match the external circuit (50 Ω). If it is directly connected to external circuit, the loaded *Q*-value will be much degraded. A coupling capacitor was used between the stripline resonator and the external circuit for impedance matching. Fig. 2 shows the equivalent circuit. C_0 and Q_0 in Fig. 2 is the coupling capacitor and

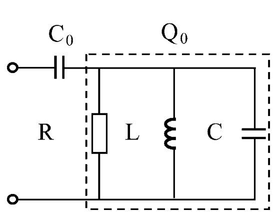

Fig. 2. Equivalent circuit of one-port resonator.

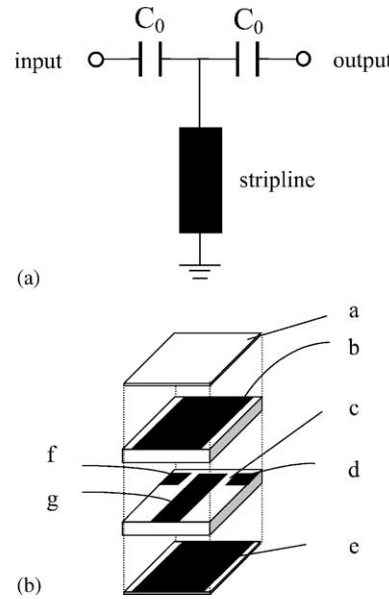

Fig. 3. (a) Equivalent circuit of two-port resonator. (b) Structure of multilayer two-port resonator.

unloaded *Q*-value, respectively. The λ/4 stripline with one short circiuted end in the resonating state can be expressed as a lumped-element parallel-resonance circuit consisting of *R*, *L* and *C*.

Fig. 3 shows the structure of a two-port resonator. Fig. 3a is an equivalent circuit of λ/4 stripline resonator. The C_0 in Fig. 3a is input or output gap-coupling capacitor between the resonator and the external circuit. One end of the stripline is grounded. Fig. 3b shows the structure of the resonator. It consists of four layers. The g in Fig. 3b denotes stripline, f and d are input/output pads, c is coupling gap between g and f or d, b and e are shielding layers, and a is a top cover layer. The center conductive stripline of resonator and the input/output pad are in the same layer. The width of center stripline and the input/output pad was 1 mm.

4. Results and discussions

The permittivity of the Bi-based dielectric ceramics for fabricating resonators is high (>80). The resonant frequency of one-port resonator was design to be 1.8 GHz. The length of input pad and coupling gap can be adjusted. The *Q*-value and resonant frequency of resonators were measured by reflection coefficient S_{11} with an HP8753E network analyzer. Results are given in Tables 1 and 2. The resonant frequency and loaded *Q*-value of the resonator depend on the coupling gap and the length of input pad. The *Q*-value reaches a maximum when the coupling gap is 0.2 mm and the length of input pad is 0.5 mm. When the coupling gap is 0.2 mm, both the center frequency and loaded *Q* of resonator decrease with the length of input pad increasing. The gap-coupling capacitance is depending on the coupling gap. The line in-

Table 1
The resonant frequency and loaded *Q* of resonator at different coupling gaps

Coupling gap (mm)	Resonant frequency (GHz)	*Q*-value
0.1	1.777	140
0.2	1.887	225
0.4	1.720	95
0.8	1.614	104

Length of input pad: 0.5 mm.

Table 2
The resonant frequency and loaded *Q* of resonator at different length of input pad

Length of input pad (mm)	Resonant frequency (GHz)	*Q*-value
0.5	1.887	225
2.0	1.395	88
4.0	1.322	96

Coupling gap: 0.2 mm.

Table 3
The resonant frequency and *Q* of resonator at different thickness

Thickness (mm)	Resonant frequency (MHz)	*Q*-value
0.6	962	77
1.0	960	83
1.6	987	52

Coupling gap: 0.5 mm.

Table 4
The resonant frequency and *Q* of resonator at different gap

Coupling gap (mm)	Resonant frequency (MHz)	*Q*-value
0.2	971	81
0.5	960	83

Coupling gap thickness: 1 mm.

ductance of input pad will change as the length of input pad is varied, so the *Q*-value and the resonant frequency will vary with the coupling gap and the length of input pad.

The resonant frequency of two-port resonator was designed to be 1 GHz. The width of input and output pad is 1 mm and the length of center conductive stripline is 7 mm. It can be seen from Tables 3 and 4 that the resonant frequency and the *Q*-value of resonators depend on the thickness between the top and bottom shield layer and the coupling gap. The *Q*-value of resonators reaches a maximum when the thickness between the top and bottom shield layer is 1 mm when the coupling gap is 0.5 mm. The *Q*-value decreases dramatically with the increase of the thickness in the structure described above. This means the thickness between the top and bottom electrode of stripline can adjust the resonant frequency and *Q*-value of resonators. The size of resonator in this work is suitable for surface mounting technology (SMT).

5. Conclusions

Multilayer resonators with a simple structure were fabricated. In this structure, gap-coupling capacitors were used as input/output terminals fabricated on the same layer with the stripline. The resonant and *Q*-value were dependent on the coupling gap, the length of input/output pads and the thickness between the top and bottom shield layer. The *Q*-value of the one-port resonator is higher than 200 at 1.887 GHz and that of the two-port resonators is higher than 80 at 960 MHz.

Acknowledgements

This work were supported by the Ministry of Science and Technology of China through 863-project under grant 2001AA325110, 973-project under grant 2002CB613302 and the University key studies project of Shanghai.

References

[1] H. Miyake, S. Kitazawa, T. Ishizaki, T. Yamada, Y. Nagatomi, A miniaturized dual band filter using ceramic lamination technique for dual mode portable telephones, IEEE MTT-S Int. Microwave Symp. Dig. (1997) 789–792.
[2] H. Kagata, T. Inoue, I. Kameyama, et al., Low-fire dielectric ceramics for multilayer microwave devices, Natl. Tech. Rep. 40 (1) (1994) 17–21.
[3] T. Nishikawa, RF front end circuit components miniaturized using dielectric resonators for cellular portable telephones, Trans. Inst. Electron. Inf. Commun. Eng. E 74 (6) (1991) 1556–1562.
[4] T. Ishizaki, T. Yamada, H. Miyake, A first practical model of very small and low insertion loss laminated duplexer using LTCC suitable for W-CDMA portable telephones, IEEE MTT-S Int. Microwave Symp. Dig. 2 (2000) 87–190.
[5] B.W. Hakki, P.D. Coleman, A dielectric resonator method of measuring inductive capacitance in the millimeter range, IRE Trans. Microwave Theory Tech. MTT 8 (4) (1960) 402–410.
[6] L. Chengen, Microwave Technology, XD University Press, Xian, 2002.
[7] T. Ishizaki, M. Fujita, H. Kagata, T. Uwano, H. Miyake, A very small dielectric planar filter for portable telephones, IEEE MTT 42 (11) (1994) 2017–2022.