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Frequency fine adjusting of LTCC microwave resonators based on BZN ceramics

Yang Xiaojing[a], Liu Xiaobing[a], Ding Shihua[b,*], Yu Yu[c], Yao Xi[d]

[a]School of Energy and Environment, Xihua University, Chengdu 610039, China
[b]School of Materials Science and Engineering, Xihua University, Chengdu 610039, China
[c]School of Mechanical Engineering and Automation, Xihua University, Chengdu 610039, China
[d]Functional Materials Research Laboratory, Tongji University, Shanghai 200092, China

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Abstract

BZN-based ceramics with low sintering temperature were prepared using a conventional route. Green sheets of ceramics were formed using tape casting technique. The laminated tapes were pressed together for forming multilayer microwave resonators. The green chips were sintered at about 950 °C. In order to adjust the resonant frequency of resonator, the width of the ground terminal electrode of the stripline can be changed. When the width of the ground terminal electrode varied from 1.0 to 2.4 mm, the resonant frequency of resonator changed from 0.971 GHz to 0.986 GHz. As the width of the ground terminal electrode increased, the resonant frequency of resonator varied slowly and then saturated. The maximum adjusting value of the resonant frequency of resonator is about 1.5%.

Keywords: A. Tape casting; BZN ceramics; Microwave resonator

1. Introduction

Microwave resonators and filters are an important component in wireless system. With the development of mobile communication, compact size is an essential requirement in many microwave applications. Low temperature co-fired ceramics (LTCC) are extremely advantageous to reduce the size of microwave devices. A multilayer LC chip filter using low sintering temperature ceramics was first introduced [1]. In addition, high dielectric constant (> 80), such as BZN-based pyorochlore ceramics, could effectively reduce the size of microwave devices [2,3]. Telecommunication technology industry requires microwave components with excellent electrical performance, high reliability, miniaturization and surface mounting techniques. Dielectric resonators and filters are traditionally based on the microwave ceramics sintered at high temperature. Although they are high-quality, low-cost and small in size [4–6], they are not suitable for planar circuit technology. Microwave devices with multilayer structure based on the LTCC technology have been developed [4]. Multilayer resonator [7], semilumped circuit LC filter [7] and planar filter have been used for portable telephone applications using LTCC technology [8].

Adjusting of the resonant frequency of microwave multilayer resonators and filter with stripline structure using LTCC techniques is very difficult. In this work, a simple structure of microwave multilayer resonators, gap-coupling capacitors used to couple the input and output terminals electromagnetically with external circuitry, was fabricated. The resonant frequency of microwave multilayer resonators can be adjusted by changing the width of grounded end of stripline. It is convenient for fine adjusting the resonant frequency of microwave multilayer resonators.

2. Experimental procedure

BZN-based ceramic powders were prepared using a conventional solid state processing. Oxides in an appropriate proportion were milled for 24 h in distilled water with zirconia media. Powders were calcined at 800 °C for 2 h and then remilled again under the same condition as

*Corresponding author. Tel.: +86 28 87720869; fax: +86 28 87720514.
E-mail address: dshihua@263.net (D. Shihua).

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mentioned above. Finally ceramic powders with average particle size of 0.5 μm were obtained. The ceramic powders were mixed with the binder, the solvent, the dispersant and the plasiticizer for about 24 h. The green sheets of ceramics (about 80 μm in thickness) were formed using tape casting technique. The pattern of inner electrode was screen printed on the sheets using gold paste (Dupont 5715 and ESL400). The laminated tapes of screen-printing were pressed together with static press and then diced into chips. The green chips were fired to eliminate binder and then sintered at about 950 °C for 1 h. The terminal electrodes were coated on the terminations of the sintered chips using silver paste. The dielectric constant and Q value of the sintered ceramics were measured by Hakki–Coleman method [9]. The characteristics of devices were measured by HP8753E network analyzer. The microstructure observation of the sintered ceramics was performed by SEM (JOEL, 5510LV).

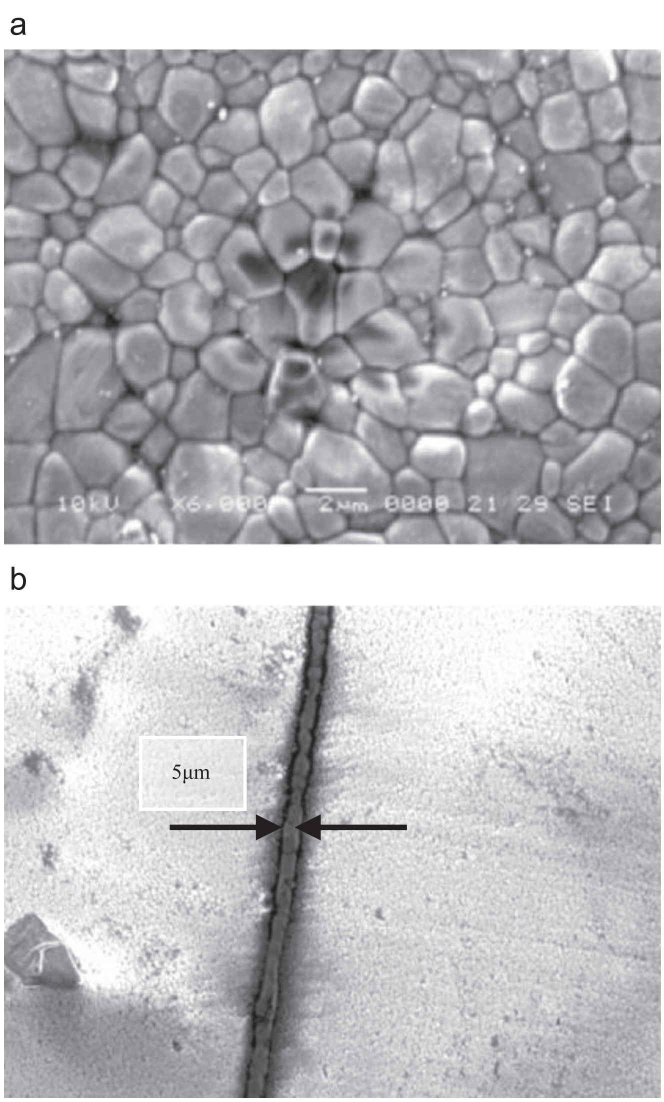

Fig. 1. (a) The SEM photographs of the BZN-based ceramics at the sintering temperature of 950 °C for 1 h, and (b) the section of the sintered chip.

The SEM photographs were shown in Fig. 1. It can be seen from Fig. 1(a) that the BZN-based ceramics is dense and the grain size is about 2 μm at the sintering temperature of 950 °C for 1 h. The section of the sintered chip was illustrated in Fig. 1(b). The thickness of gold electrode is 5 μm that will be appropriate for microwave devices.

The dielectric constant and the quality value Q of the sintered ceramics were measured using the Hakki–Coleman dielectric resonator methods at approximately 5 GHz [9]. The $TE_{01\delta}$ mode was examined using a vector network analyzer (HP8753E). The dielectric constant and Q value of the BZN-based ceramics used in this work were 81 and 1000, respectively.

3. Results and discussion

3.1. Structure of multilayer resonators

The geometry of a two-port prototype microwave resonator which is constructed by a stripline structure, a planar-type of transmission line, is shown in Fig. 2. The input and output pads, coupled electromagnetically with the stripline, were in the same layer with the center conductive strip. This structure is very convenient for manufacturing in comparison with the conventional structure [6]. Fig. 2(a) shows the structure of the multilayer

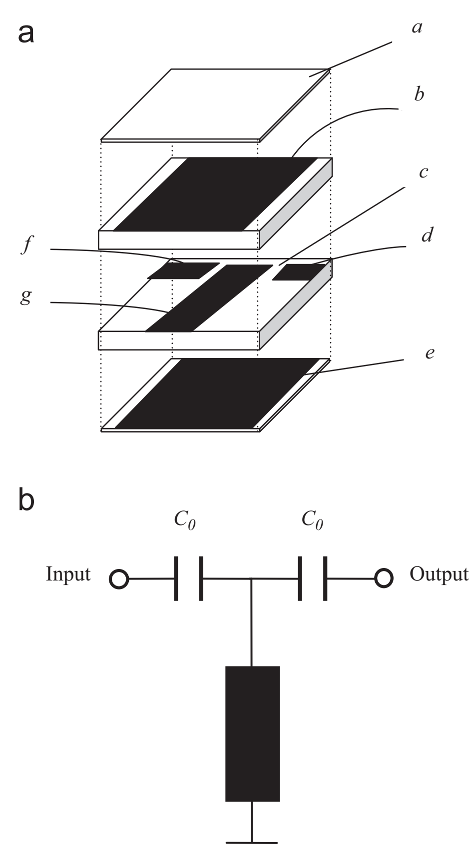

Fig. 2. (a) The geometry of multilayer two-port resonator and (b) equivalent circuit of two-port resonator.

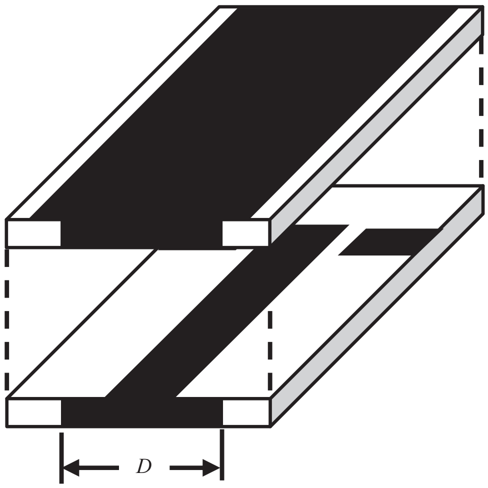

Fig. 3. The width of ground terminal electrode (D).

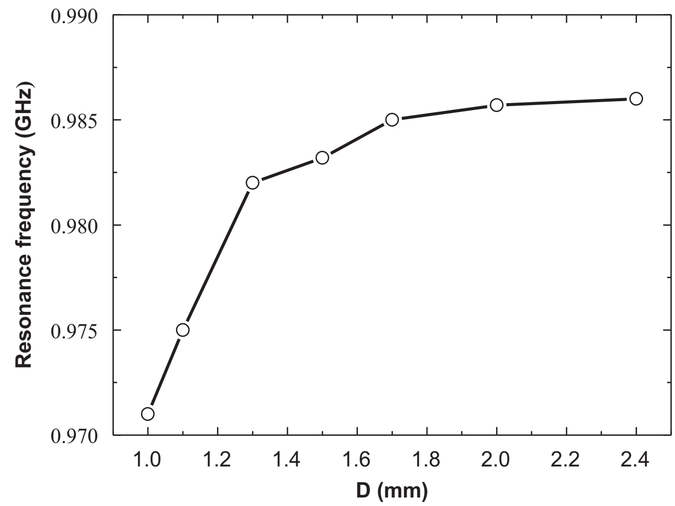

Fig. 4. The dependence of the resonant frequency of resonator on the width of ground terminal electrode.

resonator. It consists of four layers. The g represents center conductive strip, f and d are input/output pads, c is coupling gap between g and f or d, b and e are the ground planes, and a is a top cover layer. BZN ceramics with high dielectric constant, as dielectric, were filled between the ground planes (b and e) used as the top and bottom shield layers. Since stripline has two conductors and a homogenous dielectric, it can support a TEM wave and reduce radiation loss [10]. Fig. 2(b) is an equivalent circuit of $\lambda/4$ short-circuited stripline resonator. The C_0 in Fig. 2(b) is input or output gap-coupling capacitance between the stripline and the external circuitry. The gap-coupling capacitance is used for impedance matching between an external circuitry and the stripline. One end of the stripline is grounded by the ground terminal electrode which will be discussed next. The center conductive strip of resonator and the input/output pads are in the same layer. In this work, the width of center conductive stripline and the input/output pad was 1 mm.

The resonant frequency of two-port resonator was designed to be 1 GHz. The width of center conductive stripline and the input/output pads was 1 mm, the length of center conductive stripline is 7 mm. It was known that the resonant frequency and the Q value of resonators depend on the thickness between the ground planes and the coupling gap used as gap-coupling capacitors, the C_0 shown in Fig. 2 [6]. The resonant frequency and the Q value of resonators, measured by reflection coefficient S_{11} with HP8753E network analyzer, are 0.971 GHz and 81, respectively, when the thickness between the ground planes is 1 mm, the coupling gap is 0.2 mm and the width of the ground terminal electrode (D, see Fig. 3) is 1 mm.

3.2. The adjusting of resonant frequency of resonator

The thickness between the top and bottom shield layers and the coupling gap could not be changed when the multilayer resonator chip with stripline structure using LTCC techniques was sintered. It is not possible to adjust the resonant frequency of the multilayer resonator. But the outer electrode including ground terminal electrode were coated with Ag paste after the sintering. The width of ground terminal electrode can be controlled by laser trimming after terminal firing. In our work, the ground terminal electrode of the sintered multilayer resonator chips was coated at various widths and then fired.

The width of the ground terminal electrode D given in Fig. 3. The dependence of the resonant frequency of the resonator on the width of ground terminal electrode D is given in Fig. 4. It can be seen the resonant frequency increased as D become wider. The resonant frequency increased from 0.971 to 0.985 GHz as D from 1 mm, the same as the width of center conductive stripline, to 1.7 mm. When D increased further to 2.4 mm, the resonant frequency varied slowly and then saturated. The maximum adjusting value of the resonant frequency of resonator is about 1.5%.

In the $\lambda/4$ short-circuited stripline resonator given in Fig. 3, there exits the capacitance in the open terminal and the inductance in the ground terminal electrode, equivalent to LC series circuit. The capacitance in the open terminal is fixed, and the inductance will decrease with increasing the width of the ground terminal electrode (D). The resonant frequency of resonator increases as D increases. The stripline resonator with dielectrics of high dielectric constant supports the TEM mode and electromagnetic energy mainly concentrates in the vicinity of the center conductive strip. So when D is more than 1.7 mm, the inductance varied slightly, the resonant frequency varied slowly and then saturated finally. It is convenient for fine adjusting the frequency of multilayer resonator.

4. Conclusions

A prototype microwave multilayer resonators with stripline structure were fabricated. It is not possible to adjust the resonant frequency of the sintered multilayer resonator using LTCC techniques. But the ground terminal electrode could be coated after the sintering. The resonant frequency of resonator increased as the width of ground terminal electrode increased. The resonant frequency increased from 0.971 to 0.985 GHz as the width of ground terminal electrode increased from 1 mm to 1.7 mm. When the width of ground terminal electrode increases further to 2.4 mm, the resonant frequency varied slowly and then saturated. These resulted from the inductance decreasing in the ground terminal electrode and the electromagnetic energy of TEM mode concentrating in the vicinity of the center conductive strip in the stripline structure. The maximum adjusting value of the resonant frequency of the multilayer resonator is about 1.5%.

Acknowledgments

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