



Response of Microstrip Ring Resonator due to $\text{Ba}_{1-x}\text{Sr}_x\text{TiO}_3$: $0 \leq x \leq 1$ Dielectric Overlay

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Abstract: Effect of $\text{Ba}_{1-x}\text{Sr}_x\text{TiO}_3$: $0 \leq x \leq 1$ pellet, in touch overlay on the Ku band resonance characteristics of the Ag thick film microstrip ring resonator is studied. The overlay decreases the resonance frequency, increases the peak transmission and broadens of the resonance curve. The shift in resonance frequency has been used to predict the effective dielectric constant of the multilayer structure. Ceramic composition dependent shift in resonance frequency, broadening of the transmission curve, and increase in peak transmission are observed.

Keywords: $\text{Ba}_{1-x}\text{Sr}_x\text{TiO}_3$, effective dielectric constant, overlay, ring resonator

I. Introduction

The propagation of electromagnetic waves in dielectrics is accompanied by absorption of energy and variation in the phase of the waves, which depend on permittivity of the medium. The permittivity intern depends other physical properties of the medium such as its moisture content, density and composition. It also varies with frequency and temperature [1]. Recent airborne and deep space applications require the broadband and real time dielectric characterization of the materials at microwave frequencies apart from need of planerisation.

Ferroelectrics are being studied as candidates for frequency and phase agile tunable microwave components, such as tunable filters, tunable oscillators, and phase shifters For optimum performance of these devices it is important to synthesis a material with high dielectric tunability, low dielectric losses, and a low temperature dependence of the dielectric constants in the device's operational frequency and temperature ranges. Many studies have attempted to optimize ferroelectric materials and produce proof-of concepts for ferroelectric microwave components. Among the numerous ferroelectric materials, barium strontium titanate ($\text{Ba}_{1-x}\text{Sr}_x\text{TiO}_3$ ~BST) has been regarded as a promising candidate for applications in electrically controllable microwave devices. [2-3]

In the last few years, BST have been intensively researched due to their structural and dielectric features. It is a well-known perovskite-structured material with a cubic paraelectric phase above 105 K and a bulk dielectric constant of about 300 for sintered ceramics [4, 5].

In microwave frequency region, transmission line method, cavity resonator methods are mostly used [6]. To determine dielectric constant an essential part of instrumentation required for such measurements is an appropriate sensor. At present there is no commercially available equipment capable of measuring directly the relative dielectric constant (ϵ') and dielectric loss tangent (ϵ'') of materials at microwave frequencies. The usual method of examining the microwave properties of sheet materials is by patterning a simple device such as planar capacitor, co-planar wave guide, microstrips etc and examining their microwave response and evaluating its microwave properties. [7-10] But these methods are destructive, as metal has to be permanently coated on the material.

The use of microwave distributed coplanar sensors by in touch overlay technique is proposed in view of their advantages over other techniques. Desecrate sensors provide measurements in one location, whereas distributed sensors respond to the average values along the sensor, and can be kept in touch with one surface of the test material. This is important is practical application such as moisture content measurement, coplanar sensors can be placed conveniently in contact with one side of the test materials and therefore provide non-destructive measurement of the test dielectric [11-13]

The microstrip ring resonator is a simple microwave integrated circuit as shown in figure 1. The Q value and resonance frequency of such a circuit is affected by the perturbation. The perturbation can be brought about by use of overlay. The dielectric constant of the overlay changes the strength of the perturbation, which translates into changes in resonance frequency and peak amplitude of the resonator. The studies in our lab [11–13] on rejection filter, band pass filter, and ring resonator have shown that component characteristics are very sensitive to the type of the overlay. This paper reports the effect of the composition of $\text{Ba}_{1-x}\text{Sr}_x\text{TiO}_3$: $0 \leq x \leq 1$ on Ag thick film microstrip ring resonator in the X and Ku band. The changes in resonance frequency have been related to the effective dielectric constant of the overlay BST material.

II. Experimental

Sol-gel auto combustion method for synthesis of nanopowders of $\text{Ba}_{1-x}\text{Sr}_x\text{TiO}_3$: $0 \leq x \leq 1$ the Nanopowders were sintered at 600°C . formation of nanostructuredThe sintered powders were uniaxially pressed into disks 13 mm in and again sintered at 500°C .

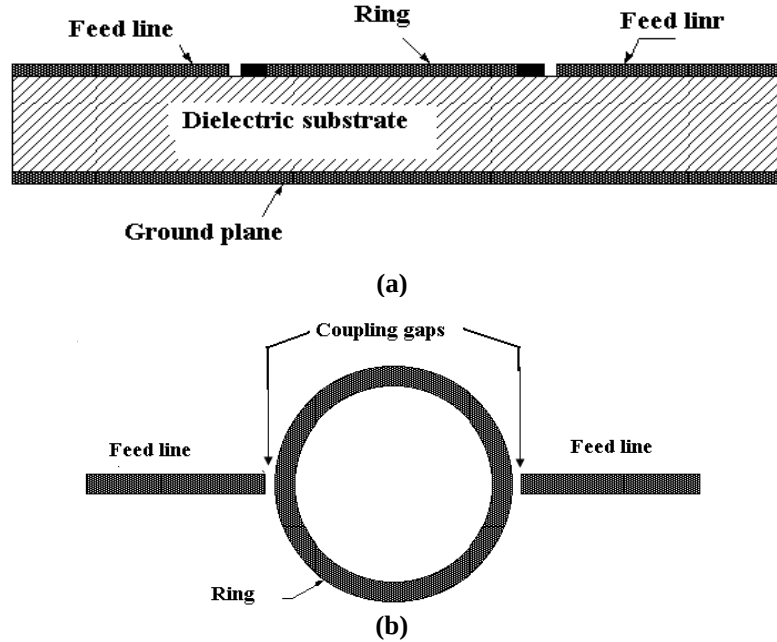


Figure 1. Microstrip ring resonator: a. Cross sectional view b. Planer view

The microstrip ring resonators delineated by screen-printing the silver paste on 96% alumina substrate. The thick film circuit was fired at 700°C . by conventional thick film firing cycle. The dimensions were calculated using the relation (1).

When an integral multiple of wavelength equals the mean circumference of the ring structure, resonance (maximum transmission of the signal) occurs. The dimensions were calculated using by using Owen's formula [14]

$$2\pi R = n\lambda_g \quad \text{or} \quad 2\pi R = \frac{nC}{f_r}; \quad \text{for } n=1, 2, 3 \text{ etc or } ; \quad \text{for } n=1, 2, 3 \text{ etc.} \quad (1)$$

Where R was mean radius of the ring, n was number of wavelengths on the ring (in our case $n=1$), and the resonance frequency, coupling gap was 0.2 mm.

For performance evaluation the resonator was mounted in a resilient MIC (microwave integrated circuit) test fixture. The transmission (S_{21}) measurements were made using vector network analyzers (N5230A). For overlay studies the pellets of $\text{Ba}_{1-x}\text{Sr}_x\text{TiO}_3$ was kept as in touch overlay with the resonator and the transmittance (S_{21}) measurements were made.

The effective dielectric constant of the multilayer structure was calculated by considering the resonance frequency of the resonator with and without overlay using formula [15]

$$\frac{\epsilon_{eff1}}{\epsilon_{eff2}} = \frac{F_2^2}{F_1^2} \quad (2)$$

Where ϵ_{eff1} and F_1 are the effective dielectric constant and resonance frequencies without overlay and ϵ_{eff2} and F_2 are the corresponding parameters with the overlay.

The effective dielectric constant of the microstrip component is calculated by using owens formula [16]

$$\epsilon_{eff1} = \frac{\epsilon_r + 1}{2} \left[\left(1 + \frac{29.98}{Z_0} \left(\frac{2}{\epsilon_r + 1} \right)^{0.5} * \left(\frac{\epsilon_r - 1}{\epsilon_r + 1} \right) \left(\ln \left(\frac{\pi}{2} \right) + \frac{1}{\epsilon_r} \ln \left(\frac{4}{\pi} \right) \right) \right)^2 \right] \quad (3)$$

Where $\epsilon_r = 9.6$, the dielectric constant of the substrate.

$Z_0 = 50 \text{ ohm}$.

III. Results

The XRD patterns of the samples $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ were shown in the figures 1. The XRD patterns conforms the formation of typical Nano crystalline powder. All the peaks are ascribed to a tetragonal perovskite structure.

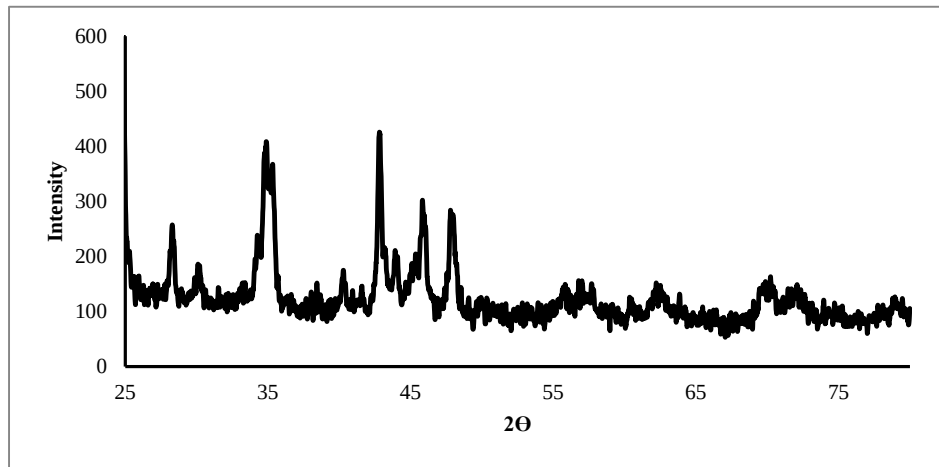


Figure 1: XRD patterns of $\text{Ba}_{1-x}\text{Sr}_x\text{TiO}_3$

The variation in the transmittance (S_{21}) and reflectance with frequency of the designed microstrip ring resonator is shown in figure 2. The resonance (Maximum S_{21}) is at 15.14 GHz. The response of the resonator due to the $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ overlay is shown in figure 3. From the figures it is seen that, due to the overlay the resonance frequency shifts towards lower frequency side with substantial increase in the peak transmittance. The resonator shows broadband characteristics due to thick film overlay.

The effective dielectric constant of the multilayer structure was calculated using formula (1). The obtained effective dielectric constant of the $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ is shown in figure. From the figure it is seen that dielectric properties are composition dependent

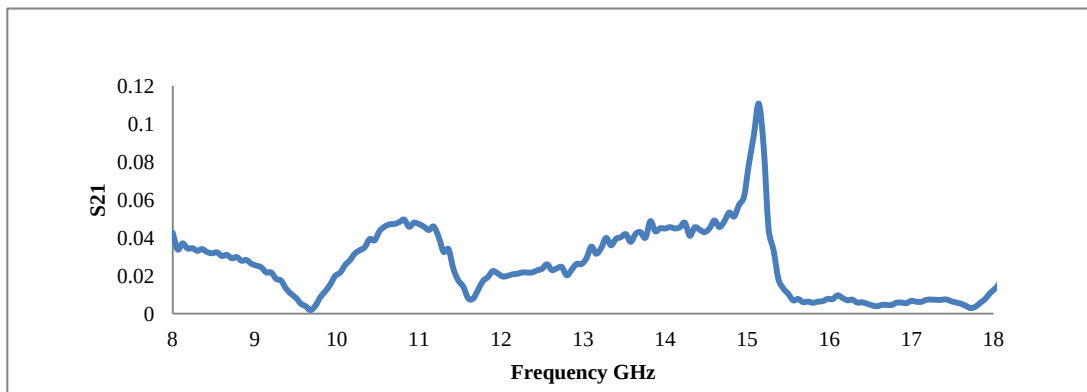


Figure 2: Variation of transmission coefficient (S_{21}) of microstrip Ring resonator as a function of frequency, without overlay

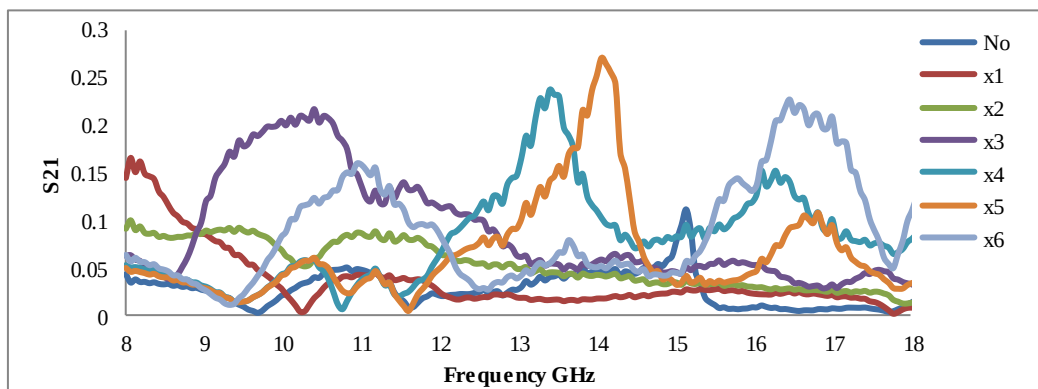


Figure 3: Variation of transmission coefficient (S_{21}) of microstrip Ring resonator as a function of frequency, with overlay of $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$

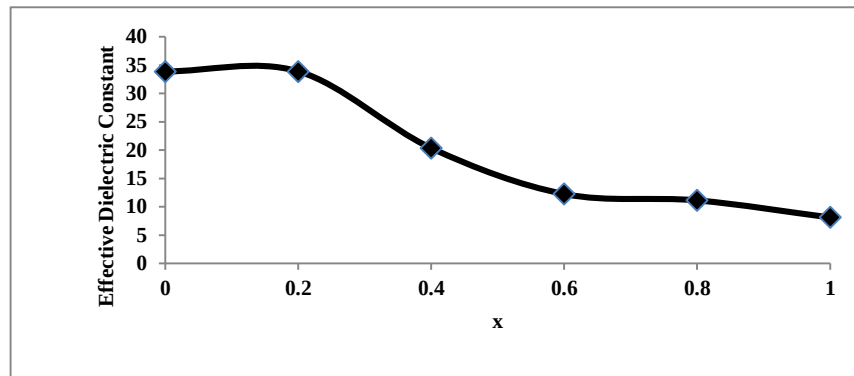


Figure.4: Variation of effective dielectric constant with composition of $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$, of overlay.

IV. Discussion

When the microstrip component is covered by a dielectric material as superstrate or overlay. The overlay will also change the odd and even mode characteristics impedance. The Q value and resonance frequency of such a circuit is affected by perturbation [17, 18]. The perturbation can be brought about by use of overlay. The dielectric constant of the overlay changes the strength of the perturbation which translates into changes in resonance frequency and peak amplitude of the resonator. This cause changes in transmission (S_{21}) the fringing field of the microstrip components interacts with the dielectric, which results in the increased effective dielectric constant of the system, which in turn results in the changes in the characteristics of microstrip component. The coupled circuit has odd and even mode propagation. The splitting of resonance curve is due to even and odd modes of coupling. The peak shifting toward lower frequency side is due to even mode of coupling and the peak shifting towards higher frequency side is due to odd mode coupling. The loss value of the odd mode is larger than the even mode. In the coupling sector, the odd mode fields are concentrated and this contributes to the conductor loss. The even mode contributes more to the frequency dependence of ϵ_{eff} than the odd mode [206]. The broadening of resonance curve is due to lossy nature of the overlaid material.

V. Conclusions

The Ag thick film microstrip ring resonator can be used to predict the properties of dielectric constant of the $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$. The composition dependent dielectric constant is observed. The overlay of $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_3$ increases the peak transmission of the microstrip component.

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