A microwave dielectric material for microstrip patch antenna substrate

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High quality factor and near-zero temperature coefficient of resonant frequency (τ_f) are the two key issues for a certain microwave dielectric material system used in microstrip patch antennas. $ZnTiO_3$-based ceramics is a promising candidate for microstrip patch antennas. On inhibiting the decomposition of $ZnTiO_3$ by adding sufficient amount of MgO, high quality factor microwave dielectric material $(Zn_{0.7}Mg_{0.3})TiO_3$ was obtained. The deviations between theoretical and observed dielectric polarizabilites, the packing fraction, and bond valence were calculated to analyze correlation between structure and properties of $(Zn_{0.7}Mg_{0.3})TiO_3$. TiO_2 was added to adjust τ_f of $(Zn_{0.7}Mg_{0.3})TiO_3$, and $0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$ with an ε_r of 28.5, a *Qf* of 125,050 GHz, and a near-zero τ_f which satisfied the requirement as a substrate material for microstrip patch antenna was obtained at 1100 °C. In addition, a dielectric microstrip antenna was designed and fabricated using the proposed dielectric materials. The microstrip patch antenna exhibited a −34.96 dB return loss and a 1.05 voltage standing wave ratio at 2.5 GHz.

I. INTRODUCTION

Dielectric microstrip antennas, due to their small size, high radiation efficiency, and ease of excitation, have received much attention in recent microwave telecommunications.[1,2] The important characteristics required for a dielectric material used in microstrip antennas are: (i) high quality factor to achieve high radiation efficiency since the quality factor is representative of the antenna losses. Typically, there are radiation, conduction, dielectric, and surface wave losses. Since the dielectric microstrip antenna has a very low dielectric loss and has no metallic loss, it offers very high radiation efficiency; (ii) high dielectric constant (ε_r) to reduce the size of the antenna because the wavelength (λ) in a dielectric is inversely proportional to $\sqrt{\varepsilon_r}$ of the wavelength (λ_0) in vacuum ($\lambda = \lambda_0/\sqrt{\varepsilon_r}$); and (iii) near-zero temperature coefficient of resonant frequency (τ_f) for high temperature stability.[3–5]

$ZnTiO_3$-based ceramics was one of materials suitable for the applications at microwave frequencies because of its high *Qf* value and low sintering temperature (1100 °C).[6,7] But as reported by Kim et al.,[6,7] $ZnTiO_3$ would decompose to TiO_2 and cubic Zn_2TiO_4 at above 945 °C which has a rather low quality factor. According to their report, single-phase $ZnTiO_3$ can be successfully synthesized by applying a sol–gel process and a semichemical route combined with vigorous milling using zirconia beads. Adding glass–sol or B_2O_3 is useful to enhance sinterability of it. The microwave dielectric properties of the specimens sintered at 875 °C with B_2O_3 (0.5 wt%) additions were: ε = 29–31, *Qf* = 56,000–69,000 GHz, and τ_f = −10 to +10 ppm/°C.[8] Moreover, their further research indicated that adding sufficient amount of MgO is one of the effective methods to inhibit the decomposition of $ZnTiO_3$ without the use of sintering aids, and the *Qf* value reached 70,000 GHz.[9] Because of its good properties and fine sinterability, (Zn, Mg)TiO_3 microwave dielectric ceramics were widely studied.[10,11] But the correlations between crystal structure and microwave dielectric properties were not discussed.

In this work, MgO was added to inhibit the decomposition of $ZnTiO_3$. To understand the correlation between crystal structure and microwave dielectric properties of $(Zn_{0.7}Mg_{0.3})TiO_3$ ceramic, the Rietveld refinement was used to analyze the structure of $(Zn_{0.7}Mg_{0.3})TiO_3$. The deviations between theoretical and observed dielectric polarizabilites, the packing fraction, and bond valence were calculated. TiO_2 was added to adjust τ_f of the $(Zn_{0.7}Mg_{0.3})TiO_3$ ceramic. Furthermore, investigations on the $0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$ ceramics for application in microstrip antenna were carried out with simulation software HFSS.

II. EXPERIMENTAL PROCEDURE

Calculated amounts of reagent-grade chemicals of MgO (99.5%), ZnO (99.0%), and TiO_2 (99.5%) were weighed and milled for 12 h using zirconia balls and deionized water as milling media, dried and added with binder, and then pressed into pellets with 10 mm in diameter and 5 mm in thickness. The pellets were sintered in air at 1100 °C for 4 h.

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Powder x-ray diffraction (XRD) analysis (Rigaku D/MAX-2500, Tokyo, Japan; scanning from 10 to 90°2θ, with steps of 0.02°) was used to analyze the crystal structure and quantitative determination of sintered samples. As derived in a multicomponent Rietveld analysis of the powder diffraction pattern, with the mass and volume of the unit cell, the weight fraction W of phase p is given by Eq. (1)[12]:

$$W_p = S_p(ZMV)_p / \sum_i S_i(ZMV)_i \quad , \qquad (1)$$

where S, Z, M, and V are, respectively, the Rietveld scale factor, the number of formula units per unit cell, the mass of the formula unit, and the unit cell volume.

Microwave dielectric properties of sintered samples were measured by a network analyzer (Agilent 8720ES, Santa Clara, CA) in the frequency range of 8–11 GHz. The dielectric constant was measured by the Hakki-Coleman method, as modified by Courtney,[13] and the unloaded Q values were measured by the cavity method.[14] The temperature coefficient of resonant frequency (τ_f) was determined from the resonant frequencies at the temperatures of 25 and 85 °C. The measurement error of dielectric constant, temperature coefficient of resonant frequency, and Qf value were: $<0.5\% \times \varepsilon_r$, 1.5 ppm/°C, and $5\% \times Qf$, respectively.

III. RESULTS AND DISCUSSION

A. Crystal structure and microwave dielectric properties of $Zn_{0.7}Mg_{0.3}TiO_3$

Figure 1 shows the XRD patterns of $(Zn_{1-x}Mg_x)TiO_3$ microwave dielectric ceramics sintered at 1100 °C for 4 h. To reduce noise, all data had been smoothed by Adaptive smoothing method and had deducted background using Powder X.[15] It was observed that when $x = 0$ and $x = 0.1$, the main phases of the system were not $ZnTiO_3$ (JCPDS No. 48-0323) and $MgTiO_3$ (JCPDS No. 48-0323) but were Zn_2TiO_4 (JCPDS No. 48-0323) and TiO_2 (JCPDS No. 48-0323). When $x = 0.2$, main phases of $ZnTiO_3$ and $MgTiO_3$ and second phases of Zn_2TiO_4 and TiO_2 were identified. When $x = 0.3$, no Zn_2TiO_4 were observed, and $(Zn_{0.7}Mg_{0.3})TiO_3$ with 2.37 wt% of TiO_2 was obtained. The weight fraction of TiO_2 was calculated directly from scale factors, which were obtained by the quantitative phase analysis using the Rietveld[16] refinement. A pseudo-Voight function was used to model the shape of the diffraction peaks. All parameters of interest including background, zero-point, scale factors for all phases, half-width, asymmetry parameters, unit cell parameters, atomic positional coordinates, and temperature factors were refined step-by-step for avoiding correlations. The $(Zn_{0.7}Mg_{0.3})TiO_3$ (ICSD No. 5529) reported by Liferovich and Mitchell[17] and TiO_2 (ICSD No. 16636) reported by Baur[18] were adopted as the starting model. Figure 2 shows the pattern plot after refinement of all parameters of interest. The calculated pattern is overlaid on the measured pattern and the differences between two profiles are plotted along the bottom. The parts of refinement results compared with Ref. 17 were shown in Table I.

Microwave dielectric properties of $\varepsilon = 24.44$, $Qf = 15{,}400$ GHz, and $\tau_f = -75$ ppm/°C were obtained for $Zn_{0.7}Mg_{0.3}TiO_3$ specimens sintered at 1100 °C for 4 h. Comparing to the previous reports, i.e., Refs. 7 and 19, the ε are slightly smaller and τ_f are larger, but the Qf value is obvious higher than those of previous reports. These results

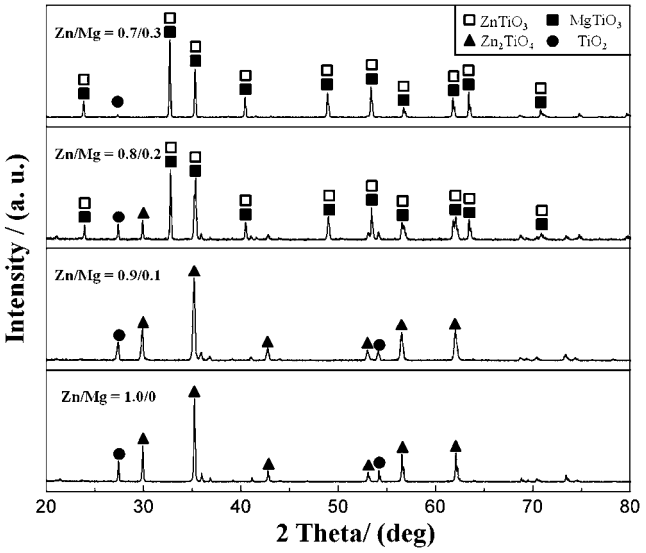


FIG. 1. The x-ray diffraction (XRD) patterns of $(Zn_{1-x}Mg_x)TiO_3$ ceramics sintered at 1100 °C.

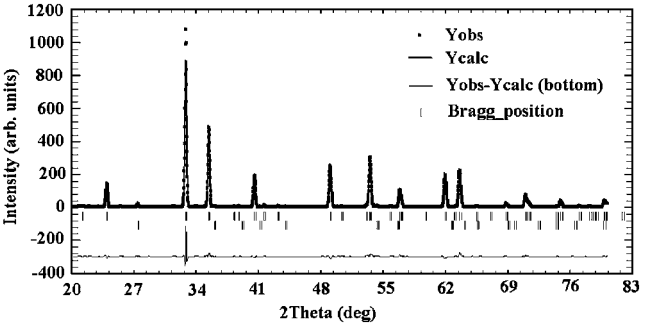


FIG. 2. The pattern of multiple refinement of $Zn_{0.7}Mg_{0.3}TiO_3$ ceramics.

TABLE I. Crystallographic data obtained from a Rietveld refinement for $Zn_{0.7}Mg_{0.3}TiO_3$ ceramics compared with Ref. 17.

	Lattice parameters (Å)			
	a	c	Vol (Å)	S ($\times 10^{-4}$)
$Zn_{0.7}Mg_{0.3}TiO_3$	5.0683	13.9287	309.8542	6.3074
$Zn_{0.7}Mg_{0.3}TiO_3$[a]	5.0711	13.9235	310.0900	–
TiO_2	4.5944	2.9618	62.5188	0.5871

Profile factor (Rp) = 8.33%, Weight profile factor (Rwp) = 13.5%, Goodness of fit indicator (GOF) = 0.8232.
[a]By Ref. 17.

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are possibly due to the differences of processing, but the basic factor which influences microwave dielectric properties was structural characteristics. To analyze the structural characteristics and the correlations between structures and properties of $(Zn_{0.7}Mg_{0.3})TiO_3$ in this work, the deviations between theoretical and observed dielectric polarizabilites, the packing fraction, and bond valence were calculated comparing with structure reported in Ref. 17.

At microwave frequencies, the dielectric constant is not only dependent on the dielectric polarizabilities but also on the structural characteristics such as the distortion, tilting, and/or rattling spaces of oxygen octahedral in unit cell.[20–22] The observed dielectric polarizability ($\alpha_{obs.}$) was calculated to evaluate the structural dependence of the dielectric constant comparing with the theoretical dielectric polarizability ($\alpha_{theo.}$). From the Clausius-Mosotti equation, the observed ($\alpha_{obs.}$) dielectric polarizability was calculated by Eq. (2)[23]:

$$\alpha_{obs.} = \frac{V_m(\varepsilon - 1)}{b(\varepsilon + 2)} \quad , \tag{2}$$

and from the additive rule of dielectric polarizability, the theoretical ($\alpha_{theo.}$) dielectric polarizability was calculated by Eq. (3)[23]:

$$\alpha_{theo.}(ABO_2) = \alpha_A + \alpha_B + \alpha_O \times 2 \quad , \tag{3}$$

where $\alpha_{obs.}$ and $\alpha_{theo.}$ are the observed and the theoretical polarizabilities; α_A, α_B, and α_O are the ionic polarizabilities of A-site ion, B-site ion, and oxygen; ε is the measured dielectric constant; b is $4\pi/3$, and V_m is molar volume, respectively. As shown in Table II, the deviation between theoretical and observed dielectric polarizabilites of $(Zn_{0.7}Mg_{0.3})TiO_3$ in this work was 0.16%.

Based on crystal structural considerations, the packing fraction, defined by the summation of the volume of packed ions over the volume of a primitive unit cell, could be obtained from Eq. (4) for an ilmenite compound:

$$\begin{aligned} \text{packing fraction}\,(\%) &= \frac{\text{volume of the atoms in the cell}}{\text{volume of primitive unit cell}} \\ &= \frac{\text{volume of the atoms in the cell}}{\text{volume of unit cell}} \times Z \\ &= \frac{4\pi/3\times(r_{Zn}^3\times 0.7 + r_{Mg}^3\times 0.3 + r_{Ti}^3 + r_O^3\times 3)\times 6}{V_{cell}} \quad , \end{aligned} \tag{4}$$

where r_{Zn}, r_{Mg}, r_{Ti}, and r_O are the effective ionic radii at each coordination number, V_{cell} is volume of unit cell, and $Z = 6$ for a ilmenite compound. The packing fraction of $(Zn_{0.7}Mg_{0.3})TiO_3$ in this work and in Ref. 17 was shown in Table III. The packing fraction of $(Zn_{0.7}Mg_{0.3})TiO_3$ in this work was obviously higher than that in Ref. 17. It indicated that the high *Qf* value of $(Zn_{0.7}Mg_{0.3})TiO_3$ in this work is related to the high packing fraction of it. This result, which is high *Qf* value related to high packing fraction, was in accordance with previous researches.[24,25]

Another important dielectric property for microwave applications is the temperature coefficient of resonant frequency (τ_f), which determines the thermal stability of materials and devices. τ_f of materials basically results from the temperature dependence of the dielectric constant (τ_ε) related with the chemical nature of constituent ions, the distance between cations and anions, and the structural characteristics originating from the bonding type. These structural characteristics could be evaluated by the bond valence of ions.[26–28]

The bond valence of atom i, V_i, was defined as the sum of all the valences from a given atom i, and that was calculated in the Eqs. (5) and (6)[26]:

TABLE II. Comparison of observed and theoretical polarizabilities of $Zn_{0.7}Mg_{0.3}TiO_3$ specimens sintered at 1100 °C.

Theoretical density (g/cm^3)				Observed				
					Z			
$Zn_{0.7}Mg_{0.3}TiO_3$	TiO_2	Volume fraction of $Zn_{0.7}Mg_{0.3}TiO_3$ (%)	Theoretical α_{theo} (Å^3)	$\varepsilon_{obs.}$	$Zn_{0.7}Mg_{0.3}TiO_3$	TiO_2	$\alpha_{obs.}$ (Å^3)	△(%)
4.7895	4.2444	0.9686	10.784	24.44	6	2	10.8013	0.1602

TABLE III. Packing fraction of $Zn_{0.7}Mg_{0.3}TiO_3$.

	r_{Zn} (Å) (CN = 6)	r_{Mg} (Å) (CN = 6)	r_{Ti} (Å) (CN = 6)	r_O (Å) (CN = 4)	Unit cell volume (Å^3)	Z	Packing fraction (%)
$Zn_{0.7}Mg_{0.3}TiO_3$	0.74	0.72	0.61	1.38	309.8542	6	68.9652
$Zn_{0.7}Mg_{0.3}TiO_3$[a]	0.74	0.72	0.61	1.38	310.0900	6	68.9127

[a]By Ref. 17.
CN, coordination number.

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TABLE IV. Oxygen octahedral distortion and bond valence of cations of $Zn_{0.7}Mg_{0.3}TiO_3$ ceramics in this work compared with Ref. 17.

		d(cation-O) (Å)	*R*	υ	*V*	Volume of oxygen octahedral (Å^3)	$\triangle_{octahedral}$ (%)
$Zn_{0.7}Mg_{0.3}TiO_3$	Zn site	2.1924	1.704	0.2671	1.8277	12.424	4.2625
		2.1924		0.2671			
		2.1924		0.2671			
		2.1009		0.3421			
		2.1009		0.3421			
		2.1009		0.3421			
	Ti site	2.0592	1.815	0.5169	4.2916	9.410	10.7892
		2.0592		0.5169			
		2.0592		0.5169			
		1.8484		0.9137			
		1.8484		0.9137			
		1.8484		0.9137			
$Zn_{0.7}Mg_{0.3}TiO_3$[a]	Zn site	2.2415	1.704	0.2339	1.9269	12.387	9.6426
		2.2415		0.2339			
		2.2415		0.2339			
		2.0354		0.4083			
		2.0354		0.4083			
		2.0353		0.4084			
	Ti site	2.0854	1.815	0.4815	4.1271	9.8290	11.6191
		2.0855		0.4814			
		2.0854		0.4815			
		1.8563		0.8944			
		1.8564		0.8941			
		1.8564		0.8941			

[a]By Ref. 17.

$$V_i = \sum_j \upsilon_{ij} \quad , \tag{5}$$

$$\upsilon_{ij} = \exp\left(\frac{R_{ij} - d_{ij}}{b'}\right) \quad , \tag{6}$$

where R_{ij} is the bond valence parameter, d_{ij} is the length of a bond between atom i and j, and b' is commonly taken to be a universal constant equal to 0.37 Å. The bond valence parameters followed the values in the previous report.[29] The bond valence of cations of $(Zn_{0.7}Mg_{0.3})TiO_3$ ceramics compared with that in Ref. 17 was shown in Table IV, and it has been reported in Ref. 26 that the τ_f was strongly dependent on the oxygen octahedral distortion. With increase of oxygen octahedral distortion, the τ_f would increase. But in this work, as shown in Table IV, $(Zn_{0.7}Mg_{0.3})TiO_3$ did not show much large oxygen octahedral distortion. Therefore, the relative large τ_f was mainly attributed to the small bond valence on Zn site. Small bond valence on Zn site indicated that the bonding strength between oxygen and Zn^{2+} ion is weaker. This suggests that the Zn cations of the specimens rattle easily, which means that the contribution of rattling effect to the polarizabilities of the specimens increased, and subsequently the dielectric constant temperature coefficient also gets increased.

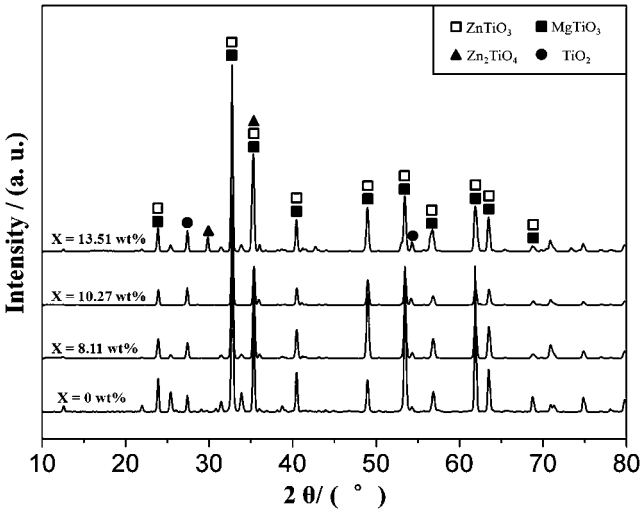


FIG. 3. The XRD patterns of $Zn_{0.7}Mg_{0.3}TiO_3$–$x$$TiO_2$ ceramics sintered at 1100 °C.

B. Microwave dielectric properties of TiO_2 added $(Zn_{0.7}Mg_{0.3})TiO_3$

To adjust τ_f, $(Zn_{0.7}Mg_{0.3})TiO_3$ was added with 2.84, 3.14, 5.41, 8.11, 9.19, 10.53, and 13.51 wt%TiO_2. Figure 3 shows the XRD patterns of $(Zn_{0.7}Mg_{0.3})TiO_3$–$x$$TiO_2$ ceramics. The ε, *Qf*, and τ_f of $(Zn_{0.7}Mg_{0.3})TiO_3$-$x$$TiO_2$ ceramics were shown in Fig. 4, Fig. 5, and Fig. 6, respectively.

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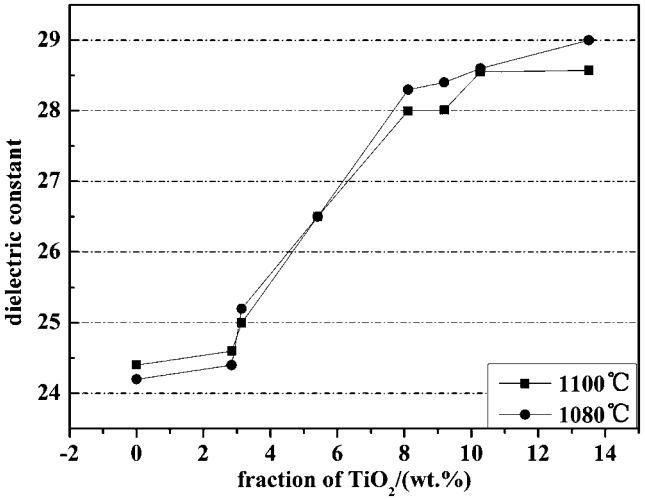


FIG. 4. The dielectric constant of $(Zn_{0.7}Mg_{0.3})TiO_3$–$xTiO_2$ ceramics.

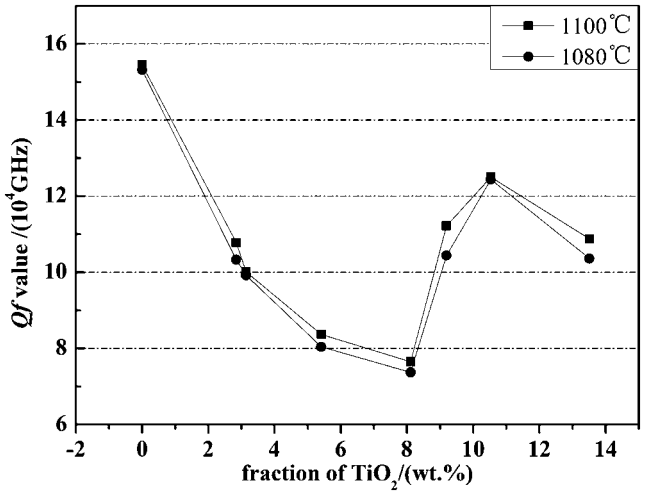


FIG. 5. The *Qf* value of $(Zn_{0.7}Mg_{0.3})TiO_3$–$xTiO_2$ ceramics.

The dielectric constant of the system increased from 24 to 29 and τ_f decreased from −80 to 1 ppm/°C along with the increase of TiO_2 content. This was in good agreement with Lichnetecker law since TiO_2 has a large dielectric constant (100) and positive τ_f (+420 ppm/°C).[30]

The *Qf* values ranged from 73,000 to 154,500 GHz. As shown in Fig. 5, when TiO_2 content was less than 8.11 wt%, the *Qf* values decreased with the increase of TiO_2 content. When the addition of TiO_2 was more than 8.11 wt%, the *Qf* values increased to a maximum and thereafter decreased. The explanations were: the *Qf* values decreased with the increase of TiO_2 content because the *Qf* values of TiO_2 is lower than that of $ZnTiO_3$. Adding more TiO_2 could inhibit the decomposition of $ZnTiO_3$ and reduce the amount of Zn_2TiO_4 due to the following chemical reaction: $Zn_2TiO_4 + TiO_2 \rightarrow 2ZnTiO_3$. Thus, *Qf* values increased slightly. However, when the TiO_2 content exceeded 10.53 wt%, there existed unreacted TiO_2 with

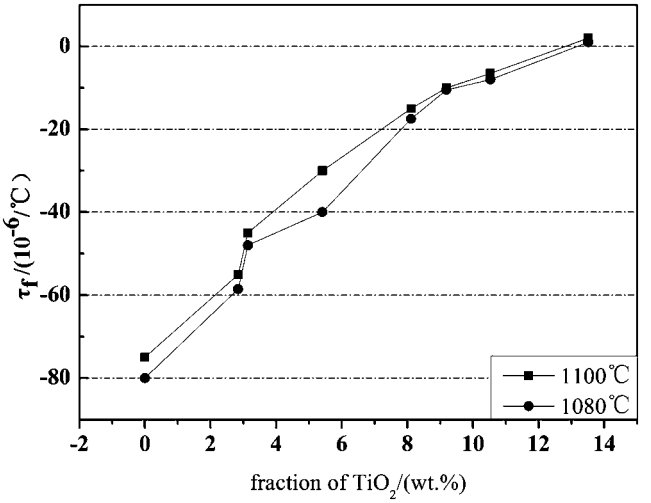


FIG. 6. The τ_f of $(Zn_{0.7}Mg_{0.3})TiO_3$–$xTiO_2$ ceramics.

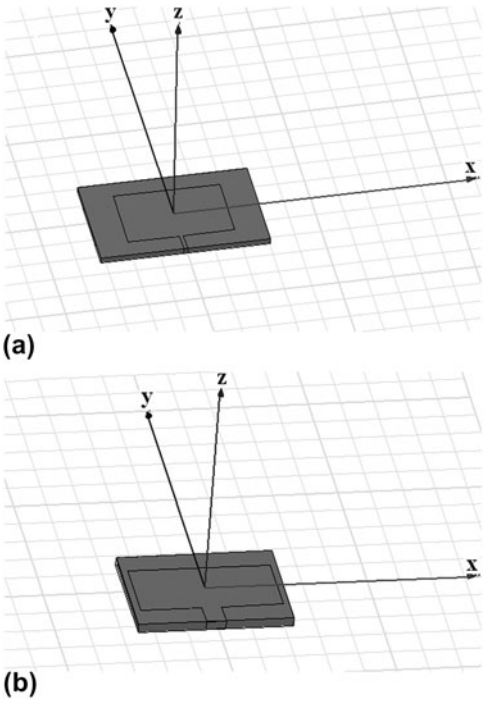


FIG. 7. The antenna simulation model using substrates (a) FR4 and (b) proposed dielectric.

a low *Qf* values. As a result, the *Qf* values of system decreased again.

The $0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$ microwave dielectric ceramics, which satisfied the requirement as a substrate material for microstrip patch antenna, showed a microwave dielectric properties as: $\varepsilon = 28.5$, $Qf = 125{,}050$ GHz, and $\tau_f = -6.5$ ppm/°C.

C. Fabrication of dielectric microstrip antenna

To prove the advantages of $0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$ ($\varepsilon_r = 28.5$) microwave dielectric ceramics to be

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TABLE V. Parameters of the simulation model using substrates: (a) FR4 and (b) proposed dielectric $0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$.

Subject	Size, $x \times y \times z$ (mm^3)	Boundary
Substrate	(a) 62 × 42 × 2 (b) 24 × 19 × 1.4	
Conducting ground	(a) 62 × 42 × 0 (b) 24 × 19 × 0	Finite conductivity
Microstrip patch	(a) 39 × 27 × 0 (b) 22 × 11 × 0	Finite conductivity
Feed	(a) 1.5 × 7.5 × 0 (b) 3 × 4 × 0	Finite conductivity
Radiation boundary	(a) 92 × 72 × 100 (b) 24 × 24 × 50	Radiation

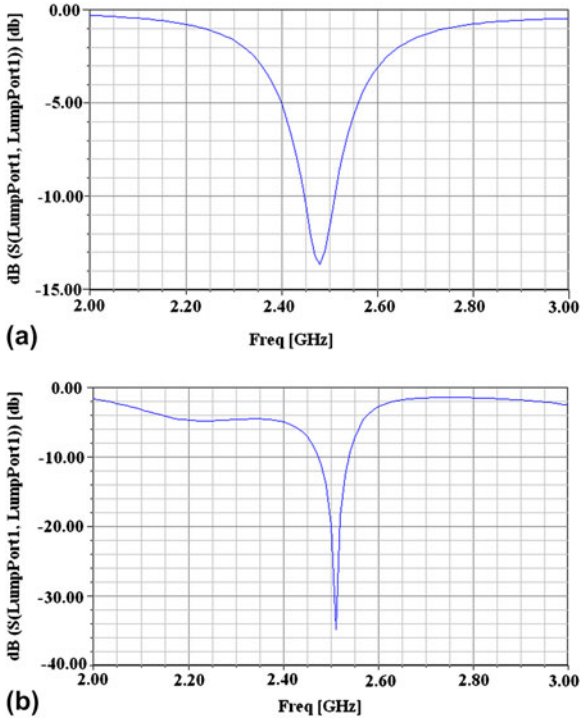


FIG. 8. Input reflection coefficients of the microstrip antenna using substrates (a) FR4 and (b) proposed dielectric.

used as a substrate material for microstrip patch antenna, a rectangular microstrip antenna was designed and fabricated compared with FR4 ($\varepsilon_r = 4.4$).

D. Analysis of rectangular microstrip antenna

According to the analytic method of transmission line model, the antenna's parameters can be calculated with the formula:

$$W = \frac{1}{2f_0\sqrt{\mu_0\varepsilon_0}}\left(\frac{\varepsilon_r+1}{2}\right)^{-\frac{1}{2}} \quad , \tag{7}$$

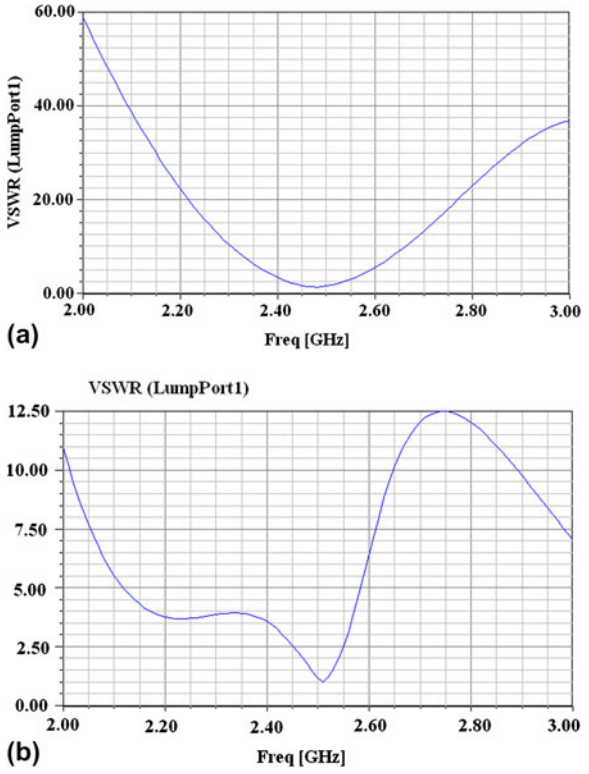


FIG. 9. Voltage standing wave ratio (VSWR) of the microstrip antenna using substrates (a) FR4 and (b) proposed dielectric.

$$L = \frac{1}{2f_0\sqrt{\varepsilon_e}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \quad . \tag{8}$$

If $W/h \geq 1$, then

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} \quad , \tag{9}$$

or

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} + 0.04(1-W/h)^2 \quad , \tag{10}$$

$$\Delta L = 0.412h\frac{(\varepsilon_e+0.3)(L/h+0.264)}{(\varepsilon_e-0.258)(L/h+0.8)} \quad , \tag{11}$$

in which, f_0 is the central frequency of the antenna, ε_0 is the permittivity of vacuum, μ_0 is the permeability of vacuum, ε_r is the relative permittivity of the substrate, ΔL is the equivalent radiation slot width, ε_e is the effective dielectric constant, and h is the thickness of the dielectric between the conducting ground plane and the microstrip.

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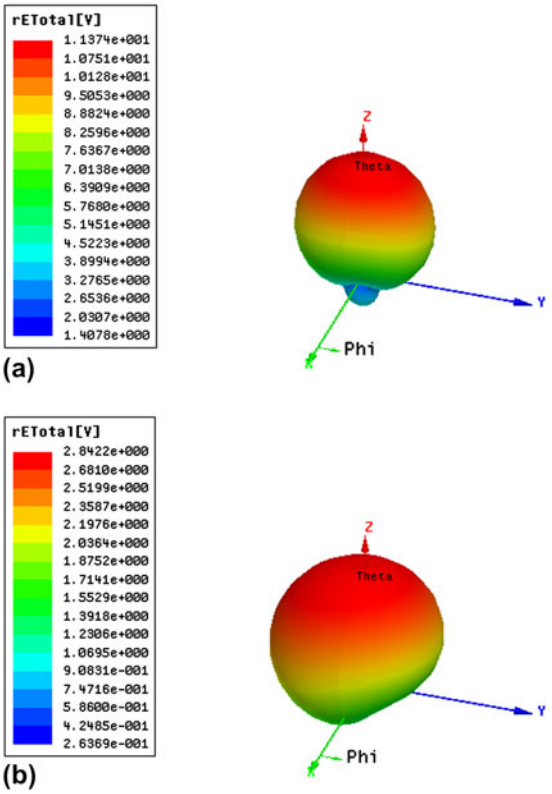


FIG. 10. Antenna pattern of the microstrip antenna using substrates (a) FR4 and (b) proposed dielectric.

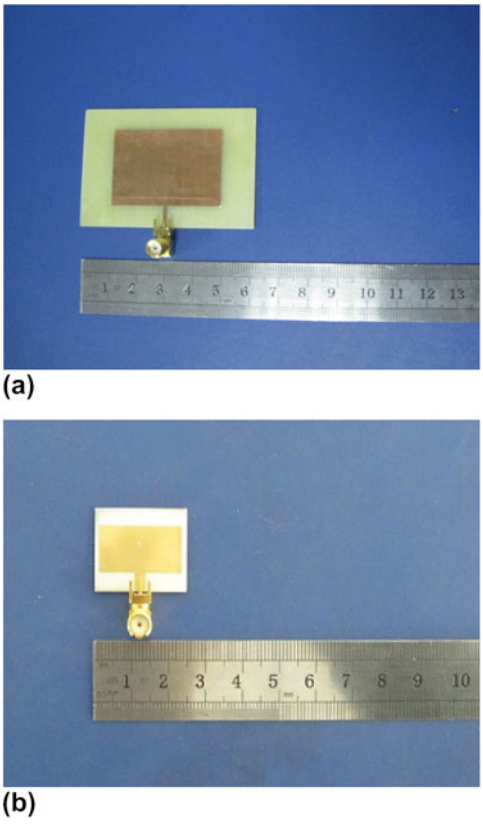


FIG. 11. Real photos of the microstrip antenna using substrates (a) FR4 and (b) proposed dielectric.

E. Simulation on Ansoft HFSS

High frequency structure simulator (HFSS) is a design tool utilizing finite element method (FEM) to solve electromagnetic problems in which the simulation of antenna is a common application. Since the design formula above is empirical, and the simulation result is based on actual situation, there exists difference between the simulation result and the theory. This kind of deviation may be improved through the antenna simulation model adjustment. Figure 7 shows the antenna simulation model with respect to different dielectric substrates in HFSS. Main parameters are shown in Table V.

F. Result of the antenna simulation

(i) Figure 8 demonstrates that the central frequency of the two antenna using different substrates are both around 2.5 GHz, and the return loss at central frequency are −13.84 and −34.96 dB.

(ii) Figure 9 illustrates that voltage standing wave ratio (VSWR) are 1.28 and 1.05, respectively, which satisfies the requests in the antenna system that the ratio is smaller than 1.5. The VSWR is the ratio of maximum to minimum voltage in a standing wave pattern. It is a measure of impedance mismatch between the transmission line and its load. The higher the VSWR, the greater the mismatch.

(iii) Figure 10 shows that the antennas are both very directive in the direction of *z*-axis (red color means strong radiation intensity).

Figure 11 shows the real photos of the microstrip antennas using FR4 and the proposed dielectric as substrate materials, respectively. In comparison with FR4, the antenna using the proposed dielectric not only shows a tremendous reduction in the insertion loss but also demonstrates a considerable reduction in size.

IV. CONCLUSIONS

$0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$ using as a substrate material for microstrip patch antenna was investigated. On inhibiting the decomposition of $ZnTiO_3$ by adding sufficient amount of MgO, high quality factor microwave dielectric material $(Zn_{0.7}Mg_{0.3})TiO_3$ was obtained firstly. The high *Qf* value of $Zn_{0.7}Mg_{0.3}TiO_3$ in this work is related to the high packing fraction of it, and the relative large τ_f was mainly attributed to the small bond valence on Zn site. To adjust τ_f, TiO_2 was added to $(Zn_{0.7}Mg_{0.3})TiO_3$ and $0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$ with an ε_r of 28.5, a *Qf* of 125,050 GHz, and a near-zero τ_f which satisfied the requirement as a substrate material for microstrip patch antenna was obtained at 1100 °C.

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The study of $0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$ showed that it was promising for applications in microwave devices (antennas for instance), where the miniaturization, high radiation efficiency, and temperature stability of the devices were crucial. A dielectric microstrip antenna was successfully designed using $0.82(Zn_{0.7}Mg_{0.3})TiO_3$–$0.18TiO_2$ ceramics as substrate. The return loss was −34.96 dB at 2.5 GHz, and the temperature variation of the resonance frequency was low.

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