

Magnetic materials for mobile communication antennas substrate application

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Abstract. In this work, $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$ and $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$ had been fabricated successfully by conventional ceramic process. Crystallographic structure and electromagnetic properties of two kind of hexagonal ferrite with different sintering temperature were investigated. X-ray Diffraction (XRD), Agilent-N5230A Network Analyzer were used to measure ferrite samples. The mobile phone antenna performance was analysed by HFSS. The results revealed that the main phase of two ferrite samples generated at lower temperature due to additive. The optimized parameters of ferrite are sintering temperature at 1000°C . And to emulate antenna model by HFSS find that Z-type and Y-type ferrite substrate can contribute to antenna frequency shifting, radiation efficiency were affected a little.

1. Introduction

As the miniaturization and high frequency of mobile phones, the size of antenna needs to be reduced.

According to the equation of $\lambda = \frac{c}{f_r \sqrt{\mu_{eff} \times \epsilon_{eff}}}$ and $Z = \sqrt{\frac{\mu}{\epsilon}} = \eta_0 \sqrt{\frac{\mu'}{\epsilon'}}$, increasing the

permeability and permittivity of medium can reduce physical dimension of the antenna. And when permeability (μ) is equal to permittivity (ϵ), characteristic impedance of the antenna is match to that of free space. Absorption and radiation efficiency (RE) of antenna can become better.

In this paper, in order to reduce the size of antenna, Z-type and Y-type hexagonal ferrite are studied. Using ferrite as the substrate of antenna, ferrite possesses both permeability (μ) and permittivity (ϵ), it can move the resonant frequency of antenna to lower frequency, so we can design smaller antenna. Z-type and Y-type hexagonal ferrite have high resonant frequency, there are many research of them under 900MHz for mobile antenna application in recent years. We investigate the effects of sintering temperature on electromagnetic properties of Co_2Z and Co_2Y at GHz in this paper.

2. Experimental

$3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3(\text{Co}_2\text{Z})$ and $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}(\text{Co}_2\text{Y})$ are synthesized through conventional ceramic techniques, with Fe_2O_3 (99.54wt%)、 BaCO_3 (99wt%)、 Co_2O_3 (99wt%) , and SrCO_3 (99wt%) . The raw materials were mixed, dried and calcined at 1240°C for Co_2Z and 1200°C for Co_2Y , both Z and Y calcined powders were ground by a ball mill with 3wt% Bi_2O_3 , after drying, the powder were granulated with polyvinyl alcohol (PVA) and pressed to shape of



toroid. The toroidal samples were sintered at 1000°C, 1100°C, 1200°C for Z and 900°C, 950°C, 1000°C, 1050°C for Y.

Crystallographic structure were analysed by using X-ray Diffraction (XRD). Agilent-N5230A Network Analyzer was used to obtain complex permeability and complex permittivity in the frequency from 0.5GHz to 4GHz. S11 and RE of antenna were simulated by HFSS.

3. Results and discussion

The XRD patterns of $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3(\text{Co}_2\text{Z})$ sintered at 1000°C, 1100°C, 1200°C and $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}(\text{Co}_2\text{Y})$ sintered at 900°C, 950°C, 1000°C, 1050°C are shown in Fig.1, all of the samples have been verified to be a primary Z-type hexagonal phase with a minor non-magnetic BaFe_2O_4 phase, when sintering temperature decreases from 1200°C to 1000°C, the more Y-type hexagonal phase appear. Z-type phase dose not form through once process by those oxides (Hongguo Zhang et al.,2001). It produces M-type ($\text{BaFe}_{12}\text{O}_{19}$) phase and Y-type phase first, then, Z-type phase starts to form as the temperature increases. In the experiment, the additive of 3wt% Bi_2O_3 was used in the second ball mill, it can reduce the sintering temperature. So, the main Z-type phase can form at 1000°C. All of the Y-type samples have been verified to be a primary Y-type hexagonal phase, this confirms that changing the sintering temperature can't give any other phases.

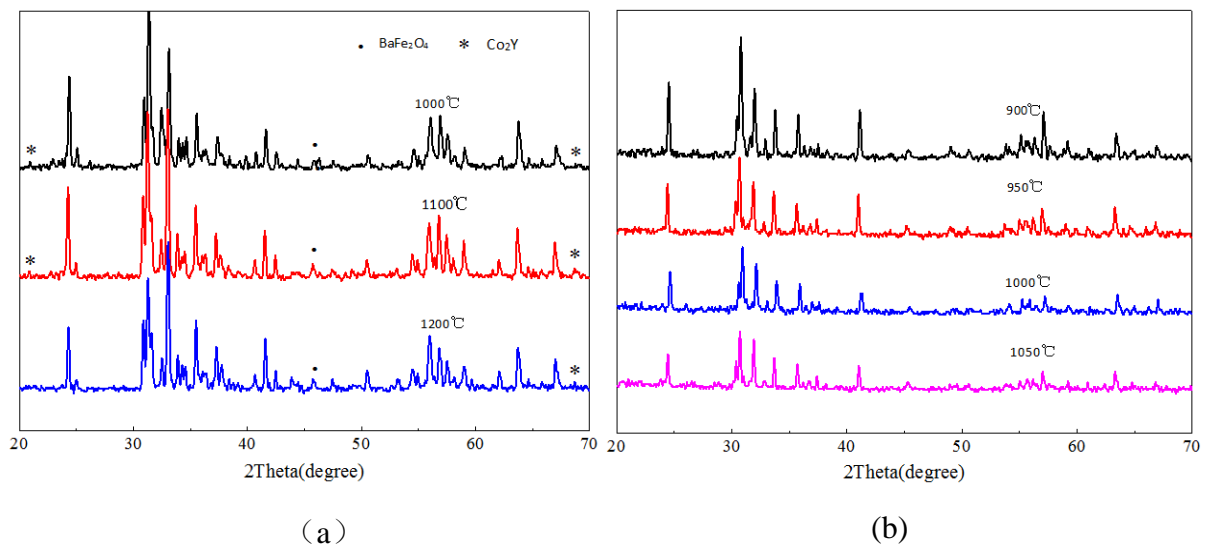
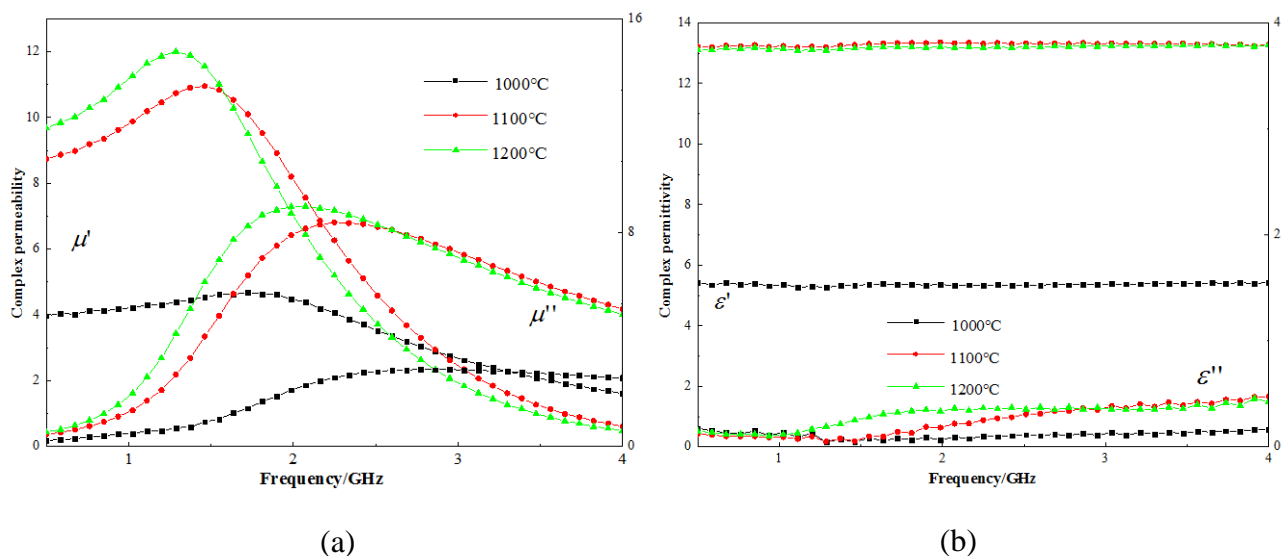


Figure 1. XRD patterns for (a) $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$ ferrite at 1000°C, 1100°C and 1200°C, (b) $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$ ferrite sintered at 900°C, 950°C, 1000°C and 1050°C.



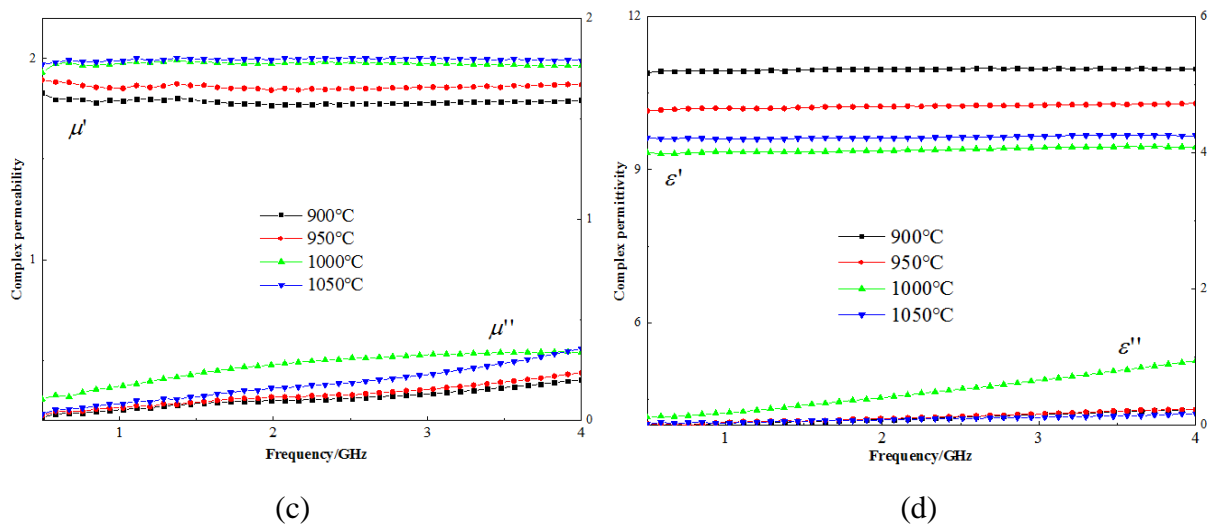


Figure2. Complex permeability spectra for (a) $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$ ferrite at 1000°C, 1100°C and 1200°C; (c) $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$ ferrite sintered at 900°C, 950°C, 1000°C and 1050°C. Complex permittivity spectra for (b) $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$ ferrite at 1000°C, 1100°C and 1200°C; (d) $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$ ferrite sintered at 900°C, 950°C, 1000°C and 1050°C.

Fig.2 indicate the permeability and permittivity changes of $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$ and $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$ (Co_2Y) ferrite with the sintering temperature. Both the real and imaginary permeability of $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$ increase at 1GHz, the peaks of μ'' transfer to a lower frequency with the increasing of sintering temperature and the resonant frequency at GHz. We can see the permeability and permittivity of $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$ remain nearly constant at all the frequency of 0.5GHz to 4GHz. It can be predicted the phase of Y-type has already formed at 900°C, it's due to Bi_2O_3 additive. It also can be state that Y-type ferrite has a very high resonant frequency in this paper.

Table1. The parameters (at 1.5GHz) of Co_2Z and Co_2Y at 1000°C

Sample	ϵ'	$\tan\delta_\epsilon$	μ'	$\tan\delta_\mu$
$3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$	5.5	0.01	4.6	0.19
$\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$	9.53	0.03	2	0.11

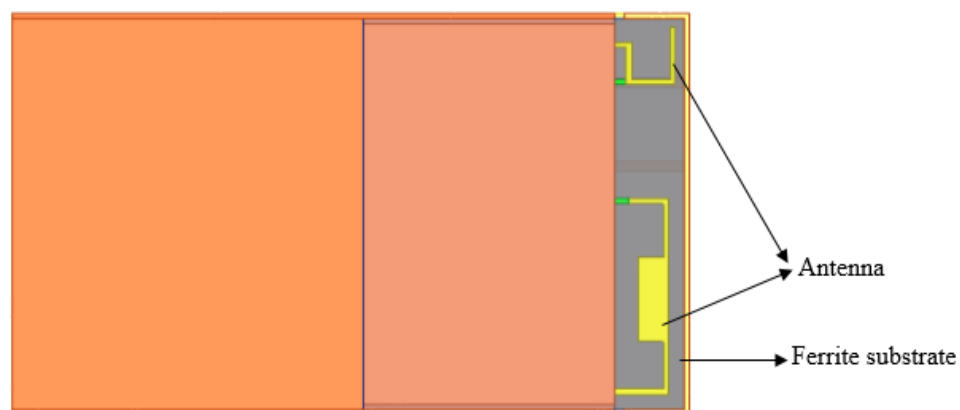


Figure3. The mobile phone antenna model.

Table1 is material parameters when we emulate by using HFSS. The focus frequency of antenna are all set at 1.5GHz. The antenna model is shown in Fig.3. Ferrite substrate covers the antenna radiation element. The S11 and RE of antenna can be seen from Fig.4, and Table2.

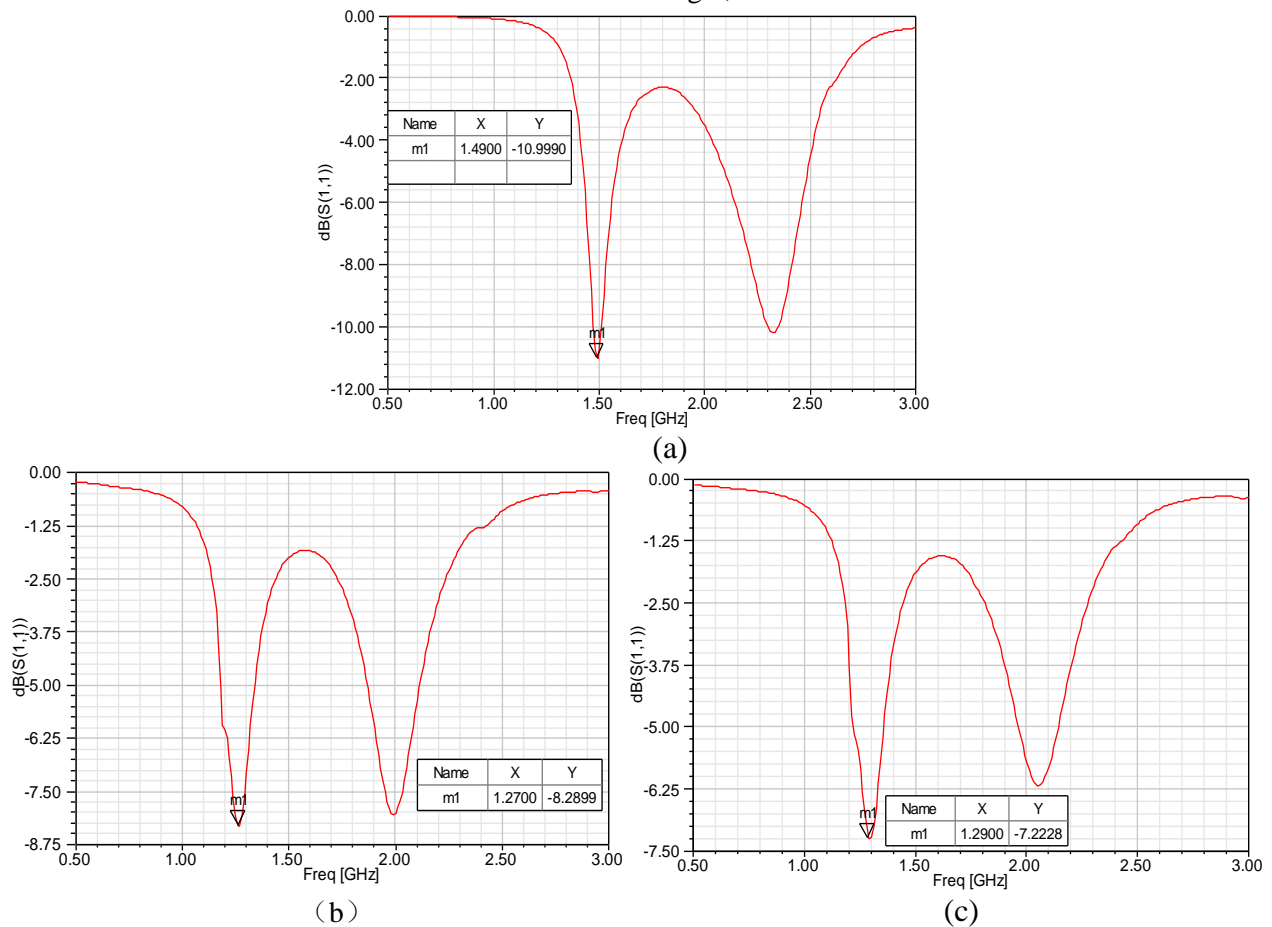


Figure4. The S11 parameter of antenna at 1.5GHz. (a) Without ferrite substrate; (b) Z-type ferrite substrate; (c) Y-type ferrite substrate.

Table2. The RE of different substrate antenna at 1.5GHz.

Substrate	RE (radiation efficiency)
None	82%
Z-type	64.37%
Y-type	68.39%

It can be seen when radiation efficiency and reflectivity of antenna is satisfied. Comparing with the antenna without ferrite substrate, the resonance frequency (at 1.5GHz) of antenna with ferrite substrate shift to lower frequency about 200MHz-220MHz, not only Z-type ferrite has good effect but Y-type ferrite affect well. From Table1, μ' and ϵ' of $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$ ferrite can be realized nearly to match, therefore, electromagnetic wave (EM) can enter the antenna structure easier. On the other hand, the magnetic tangent loss and dielectric tangent loss are little relatively, the energy of EM

can't lose much in the structure. Permittivity (ϵ') of $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$ do not match well with μ' , but it has lower magnetic loss than $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$. It's all known that physical dimension of antenna decrease with increasing of frequency. Thus, it is possible to design a smaller size antenna to achieve miniaturization of a little low-frequency antenna.

4. Conclusion

To get high cut-off frequency of hexagonal ferrite, it can sinter at 1000°C with the aid of Bi_2O_3 , permeability parameter and sintering temperature are in the direct ratio. As antenna is the most important part of mobile phone, to miniature antenna size, it is proposed to find the electromagnetic parameter of $3\text{Ba}_{0.7}\text{Sr}_{0.3}\text{O} \cdot 2\text{CoO} \cdot 10.8\text{Fe}_2\text{O}_3$ and $\text{Ba}_2\text{Co}_2\text{Fe}_{12}\text{O}_{22}$ at 1000°C to apply in magnetic substrate. At 1.5GHz, the resonance frequency 200MHz-220MHz of antenna can move 200MHz-220MHz, and RE diminish not much.

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