IOP Conf. Series: Materials Science and Engineering **380** (2018) 012004 doi:10.1088/1757-899X/380/1/012004

Nickel zinc ferrite thick film as substrate overlay for improved performance of microstrip patch antenna

I H Hasan[1], M N Hamidon[1,2], A Ismail[2], I Ismail[1], M A M Kusaimi[1], S Azhari[1], N A M Azhari[1], and R Osman[1]

[1]Institute of Advanced Technology, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[2]Faculty of Engineering, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Email: i_helina@upm.edu.my

Abstract. In this paper, nickel zinc ferrite (NZF) nanopowder was mixed with organic vehicle which consists of linseed oil, m-xylene and α-terpineol. Then the mixture was sonicated for 1 hour at 40 ℃ in order to obtain homogenous paste, followed by printing it onto FR4 substrate using the screen printing technique to form the NZF thick film layer before dried at 100 ℃ and later fired at 200 ℃. A basic square shape patch antenna by using silver paste was printed onto the NZF thick film layer and was compared with another patch antenna which was been printed without the NZF layer. The results showed that the antenna with NZF thick film layer has return loss of -10.97dB, resonant frequency 6.42GHz, bandwidth 3.9 and Q factor of 1.646, which is better compared to the antenna without the layer by 32.81%, 3.22%, 86.60% and 44.69% respectively.

1. Introduction

Thick film technology is the most commonly used technology for producing electronic devices due to its inexpensive production and simple method by using thick film paste. Thick film circuits and devices are fabricated by screen printing active materials in a form of a viscous film paste on ceramic or polymer substrates. Thick film paste plays an important role in thick film technology, since it relies heavily on the characteristics of the paste. One of the ingredients in the paste is the active element which will determine the properties and characteristics of the paste [1]. In recent years, thick film technology has also been adapted to fabricate microstrip patch antennas, in addition to the conventionally used patch antenna fabrication using printed circuit board (PCB) etching technique [2]. Ferrimagnetic materials or ferrites are one type of magnetic materials, having a certain degree of susceptibility to magnetization. Ferrites are divided to two categories, which are hard and soft ferrites. Hard ferrites have high coercivity and high remanence after being magnetized, which makes them perfect as permanent magnets. Soft ferrites on the other hand, have low coercivity that makes the magnetic direction can be easily reversed to normal state with low loss energy. These types of ferrites also have high electrical resistivity and low magnetic losses at higher frequency range, which makes them suitable for microwave applications [3]. Ferrites are also being studied as substrates for microstrip patch antennas (MPA), which can be tuned when external magnetic field is applied [4]. Ferrite bulks have been considered as substrates to improve MPA performance, however it is difficult to control the permittivity and permeability of the magnetic materials, and the fabricated ferrite substrates tend to be brittle. Therefore, this work focuses on the use of NZF as thick film layer in MPA fabrication to improve the performance of MPA in terms of bandwidth and return loss.

2. Experimental method

In the paste preparation process, the paste was prepared by mixing 30 wt% of NZF nanopowder (<100nm particle size, 99.9% trace metals basis) with 70 wt% of organic vehicle which consists of linseed stand oil, m-xylene and α-terpineol, and mixed thoroughly using sonicator for 1 hour with 10 minutes interval after 30 minutes to obtain homogenous paste for thick film printing [5]. The prepared thick film paste was then printed onto flame-retardant 4 (FR4) substrate using screen printing method for characterization purpose. The thick film was printed using a silk screen frame with a 20 x 20 mm square design using a screen printing machine. Next, the prepared sample was dried first at temperature 100 ℃ for ten minutes, and later fired at temperature 200 ℃ for 30 minutes in a box furnace (HT4–1600–SIC, Malaysia). The thick film was then characterized using Field Emission Scanning Electron Microscope (FESEM) (Hitachi S-3400N). Permittivity, dielectric loss tangent and permeability of the samples were measured using Impedance Analyzer (Agilent HP4291B) for frequency ranging from 10MHz until 1GHz.

After thick film characterization was completed, fabrication of microstrip patch antenna was done by first printing NZF thick film onto FR4 substrate. After the thick film was dried and fired to ensure adhesion, a 10 x 10 mm square of conductive patch and microstrip transmission line was then screen printed onto the thick film layer using silver paste to form a radiating patch for the antenna, and afterwards dried and fired at 150 ℃ for 30 minutes. The return loss and resonant frequency for all prepared samples with different substrates and parameters were measured using Vector Network Analyzer (Keysight, PNA 5227A). The measurement frequency range is set between 2GHz up until 8GHz. Another patch antenna was also fabricated without NZF thick film as substrate overlay for comparison. Figure 1 shows the structure of the designed antenna and the actual fabricated MPA.

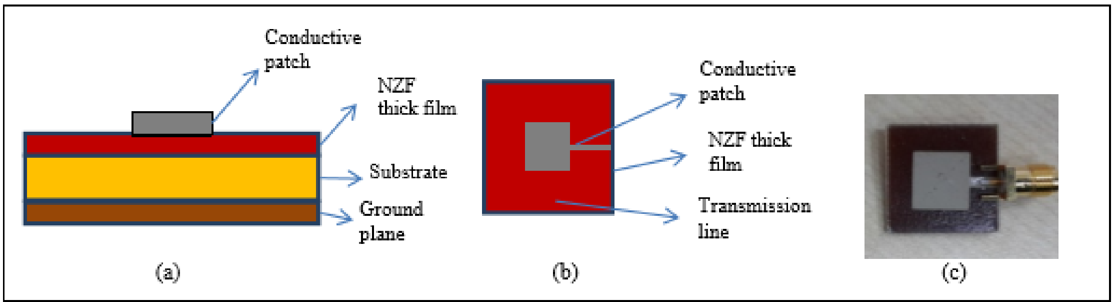

Figure 1. Fabrication of MPA: (a) side view, (b) top view, (c) actual fabricated MPA (top view only).

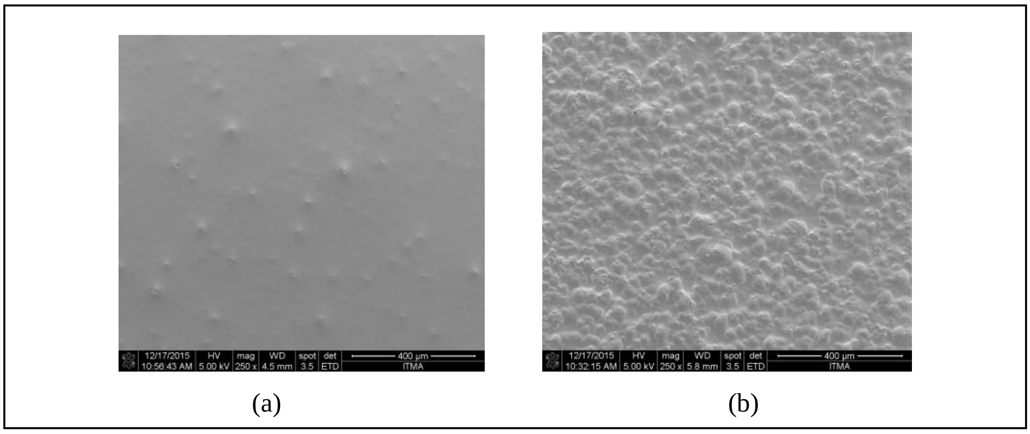

Figure 2. FESEM images of NZF thick film: (a) before firing, (b) after firing at 200°C.

IOP Conf. Series: Materials Science and Engineering **380** (2018) 012004 doi:10.1088/1757-899X/380/1/012004

3. Results and discussion

Figure 2 shows the FESEM images of the NZF thick film before and after firing at 200°C. Before the thick film is fired at a certain temperature, the upper layer of the thick film was covered by the organic vehicle which is in liquid form. When the film is subjected to a certain fixed temperature, the organic vehicle dried off and evaporated while at the same time holding the nanoparticles and bound them to the substrate. Linseed stand oil which is also known as drying oil polymerizes when exposed to a certain temperature. This makes the oil suitable as a vehicle as well as a binder in thick film paste. After firing process is completed, it can be observed from Figure 2(b) that the particles are visible as compared to the thick film before firing. The particles however seemed to agglomerate due to particle size of NZF nanopowders, making the particles attached to each other to minimize energy loss.

Permittivity and permeability of NZF thick film for frequency ranging from 10 MHz to 1 GHz are shown in Figure 3. The permittivity is 2.2, whereas the permeability of the material is 1.12 Based on these results, NZF has low permeability but high permittivity, which makes it a good dielectric material for antenna fabrication.

Finally, Figure 4 shows the return loss or S_{11} parameter and resonant frequency of the fabricated patch antenna compared with MPA without NZF thick film layer. It can be clearly seen that by adding on NZF thick film layer onto the substrate, the return loss and -3dB bandwidth improved, while the resonant frequency (f_r) shifted by only 0.2GHz, which is only 3.22% increment. The return loss improved by 32.81% which is from -8.26dB without NZF thick film and -10.97 with the NZF thick film. The bandwidth (BW) has also improved significantly by 86.60%, which is from 2.09 increased to 3.90. As a result, the Q factor of the antenna which can be derived from equation has decreased from 2.976 to 1.646 due to wider BW.

$$Q = \frac{f_r}{BW} \tag{1}$$

When a magnetic material in included in the volume between a radiating patch and the ground plane, the current amplitude induced becomes smaller due to permeability of the material. When this happens, automatically the energy stored in the volume is decreased, therefore decreasing the quality factor of the antenna. The decreased Q factor will then increase the bandwidth of antenna [6], thus enhance the performance of MPA.

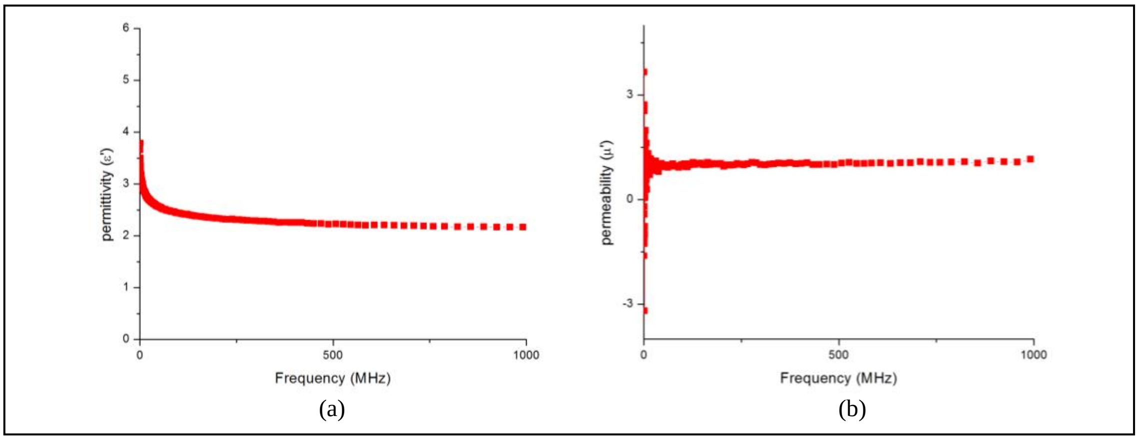

Figure 3. (a) Permittivity and (b) permeability of NZF thick film.

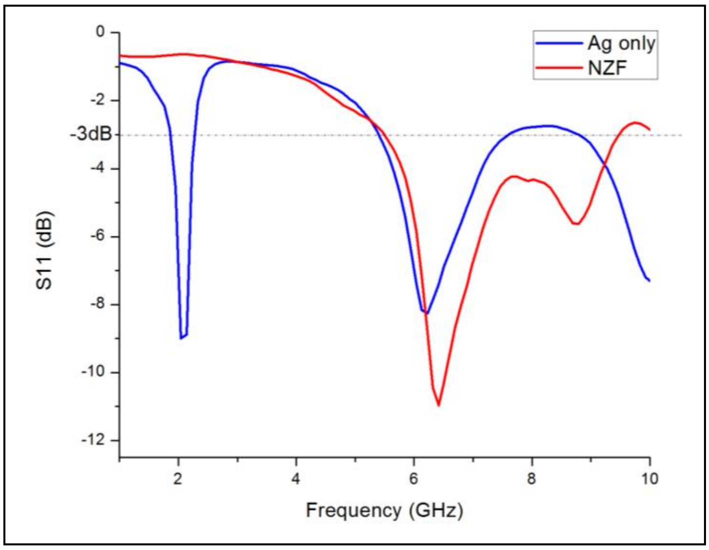

Figure 4. Results of MPA with silver (Ag) patch only vs. MPA with Ag and NZF thick film as substrate overlay.

4. Conclusion

This paper studied the inclusion of NZF thick film as substrate overlay to MPA system to improve the bandwidth and return loss of the MPA. The results showed that the bandwidth improved significantly, therefore decreasing the q factor of the MPA. The work proved that by adding ferrite based thick film layer to MPA during fabrication, the performance of the MPA can be greatly enhanced, specifically the bandwidth of the antenna which has always been the issue when using MPA.

5. Acknowledgments

The authors wish to acknowledge financial support from Ministry of Science, Technology and Innovation (MOSTI) under Sciencefund grant (03-01-04-SF1860), Universiti Putra Malaysia under Putra grant (GP-I/2014/9439400) and Ministry of Higher Education under NanoMITe grant (LRGS/2015/UKM-UPM/NanoMITe/04/02). Authors also wish to thank staffs and students of Functional Devices Laboratory and ITMA for helping with the equipment facilities, simulation and fabrication process of the antenna.

6. References

[1] Prudenziati M 1994 *Handbook of Sensors and Actuators 1: Thick Film Sensors* vol 1, ed S Middelhoek (Amsterdam: Elsevier) p 113
[2] Rashidian A, Shafai L, Sobocinski M, Peräntie J, Juuti J and Jantunen H 2015 IEEE Trans. *Microw. Theory Techn.* **63** pp 2720-29
[3] Schloemann E 2000 *J. Magn. Magn. Mater.* **209** pp 15-20
[4] Mishra R X, Pattnaik S S and Das N 1993 *IEEE Trans. Antennas Propag.* **41** pp 230-233
[5] Hasan I H, Hamidon M N, Ismail I, Osman R and Ismail A 2017 *Proc. IEEE Reg. Symp. Micro and Nanoelectronics (RSM)* Batu Ferringhi Penang pp 131-134
[6] Ikonen P M T, Rozanov K N, Osipov A V, Alitalo P and Tretyakov S A 2006 *IEEE Trans. Antennas Propag.* **54** pp 3391-99