BARIUM FERRITE MAGENTIC COMPOSITES FOR MICROWAVE APPLICATIONS

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Introduction

A long-standing goal of the ferrite devices and material science communities is to reduce the weight, size and cost of microwave circulators used in communication systems. This is accomplished by using self-biased ferrites. The chemical stability and large uniaxial crystalline anisotropies of highly oriented hexagonal M-type ferrites, such as $BaFe_{12}O_{19}$ (BaM), have led researchers to consider their use in self-biased, microwave circulator applications[1-4]. Magnetic saturation is achieved by the equivalent anisotropy field rather than by the traditional external biasing magnet, which is typically heavy, bulky and costly. Furthermore, the elimination of this biasing magnet also allows for the potential integration of the microwave circulator into a monolithic microwave circuit. To achieve a self-bias state, the coercivity must be greater than the saturation to counteract the influence of the shape-dependent demagnetization field. For microwave applications, ferrite thicknesses on the order of 0.5 mm are necessary. In this work a novel composite material consisting of $BaFe_{12}O_{19}$ nanopowder and an epoxy binder is evaluated as a low cost solution for self-biased circulator applications.

Fabrication Methodology

The bulk barium ferrite samples considered herein were made from a combination of commercially available barium ferrite powder and 30 minutes epoxy with a ratio 80/20. The mixing procedure was done by hand for approximate 3 ½ minutes.

A small amount of the mixture was placed in a 1.5 cm (diameter) hole of a 0.5mm thick alumina substrate and pressed by a modified 0.5 ton press. Two permanent magnets were mounted on the top and bottom chucks of the press. With the press closed, the magnetic field strength between the magnets was about 1.2 T. The sample was kept in this high magnetic force environment for 48 hours. After the pressing process was completed, each sample was then polished. This process yielded a barium ferrite puck that was rigidly secured in the center hole of the substrate. With ferrite mixture so fabricated and in place in the substrate, the circulator was created by sputtering metal using 100 nm of titanium and 4 μm of copper. The ground plane on the one side was formed by sputtering metal on the entire surface and on the other side the microstrip traces were formed and defined using a stainless steel stencil mask. Fig. 1 shows the picture of the circulator.

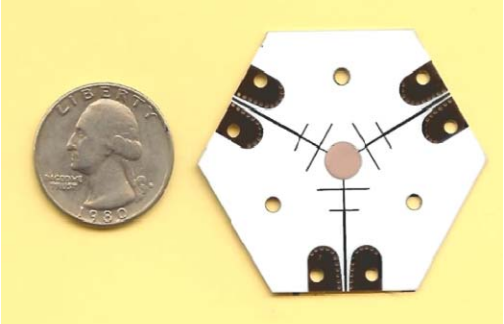

Fig. 1. Top view of the circulator

Experimental Results

The bulk magnetic properties of the ferrite sample are determined from the in-plane and out-of-plane hysteresis loops. Figure 4 shows a typical set of magnetic hysteresis loops associated with an 80/20 mixture for both in-plane and out-of-plane directions measured by VSM. For this particular sample, we observe a squareness of 0.89, a coercive field of 4127 Oe, a saturation of 2469 G and a remnant magnetization of 2201 G (see Fig. 2). Given that the coercivity is significantly greater than the saturation, this particular sample is well suited for self-bias applications.

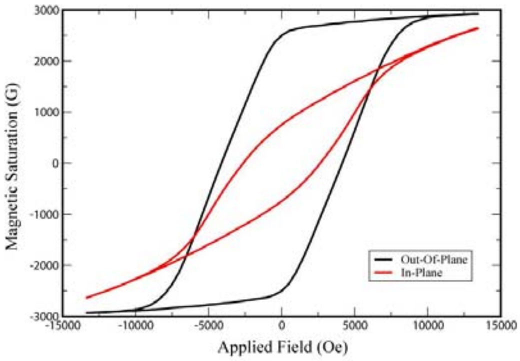

Fig. 2. VSM data for the in-plane (red) and out-of-plane (black) hysteresis loops for a barium ferrite thick film with 80/20 ratio.

The circulator placed in an RF test fixture that allowed for a connection to the microstrip traces via coaxial transitions, the device was characterized using a microwave network analyzer that measures the S-parameters of the device as a function of frequency. Results of the measurement are shown in Fig. 3. the network analyzer measures S_{11} (return loss, which is the relative strength of the reflected wave at port one), S_{12} (insertion loss, which is the attenuation of a signal traveling from port two to port one), S_{21} (isolation, which is the attenuation of a signal traveling from port one to port two) and S_{22} (return loss, which is the relative strength of the reflected wave at port two). In terms of dB, return losses and isolations of 14 dB or higher are desirable; insertion losses less than 1 dB are also attractive. The device is deemed highly non-reciprocal when $S_{12} \neq S_{21}$, which suggests that large discrepancies between the insertion loss and isolation have been achieved. There are several interesting features in this data that deserve comment. First, we see a strong non-reciprocity effect in the vicinity of 25.8 GHz as seen in the spread of 17.0 dB between S_{21} and S_{12}. Second, S_{21}, S_{11} , S_{22} exhibit good isolation and return losses performance of 28.5 dB, 17.0 dB and 12.7 dB, respectively. The adverse feature is the insertion loss associated with S_{12} of 11.5 dB.

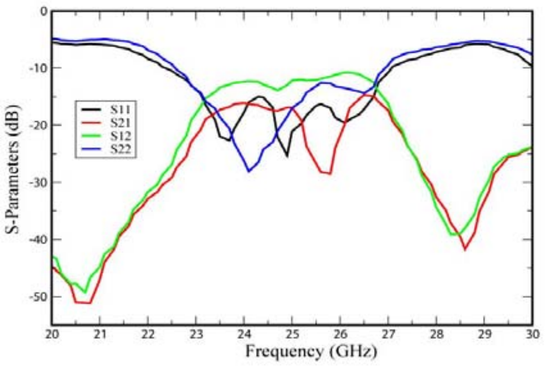

Fig. 3. S-parameter data for the circulator

Conclusions

This paper has endeavored to show how a simple method can be used to fabricate a self-bias circulator for microwave applications. The magnetic data demonstrates that a self-bias condition is achievable; the S-parameter data exhibits a strong circulator effect around 26 GHz.

References

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