Thin Film Metamaterial Split Ring Resonators at Microwave Frequencies

Nees Paul[1,2], Sikha K. Simon [1], Bindu C.[1,3], Jolly Andrews[1] and V. P. Joseph[1]

[1] Dept. of Physics, Christ College (Autonomous), University of Calicut, Thrissur, 680125, Kerala, India.
[2]Dept. of Physics, St.Thomas' College (Autonomous), University of Calicut, Thrissur, 680001, Kerala, India.
[3]Dept. of Physics, Government College, University of Calicut, Chittur, 678104, Kerala, India.
jmalieckkal123@gmail.com

Abstract – **In this paper we present a metamaterial Split Ring Resonator (SRR) made of thin films of nanometer thickness working in microwave frequencies. Since the thickness of nano-film used for fabricating metamaterial structures is below the skin depth, unique resonance behavior is observed in comparison to the resonance curves of its conventional counterpart made with thick films. At thickness less than skin depth, the film becomes resistive which in turn results in a wide band magnetic resonance. Silver thin film resonators of thickness 350 nm, 550 nm and 750 nm prepared on glass substrates using RF sputtering technique are used for the study. Absorption characteristics of the SRR and Broad-side Coupled SRR (BCSRR) are analyzed.**

I. Introduction

This era has witnessed intense research in thin film technologies to meet the need for miniaturization and quality enhancement of devices and gadgets. Metamaterials, owing to their exotic and unique characteristics, are extending their applications into diverse fields of technology searching for new horizons in the state of the art. In this paper, we report a new addition to the metamaterial resonators realized using thin films working in microwave frequencies.

The highly conducting metals like silver, gold and copper are mainly used for making SRRs so as to produce maximum magnetic resonance in the system[1, 2]. Here we discuss the resonance properties of metallic Split Ring Resonators (SRRs) made with silver thin films of thickness below the skin depth. The films are prepared by RF sputtering technique and the transmission spectra of this novel resonator is measured using Vector Network Analyzer (VNA) in the frequency range of 3 - 9 GHz.

II. Materials and methods

The thin film silver SRRs of different thickness are prepared using RF magnetron sputtering technique. The glass substrate is cleaned using traditional cleaning techniques with ultrasonic bath and isopropyl alcohol. Then one side of the oven-dried slide is covered with high temperature resistant kapton tape. The resonator structure is then stenciled on the tape and is then fixed in the sample holder of the sputtering chamber facing the target. The silver target used is 50 mm diameter and 99.99% pure. The plasma was activated by a 13.56 MHz RF power of 25 W in argon pressure of 3 X 10^{-3} Torr with argon flow of 20 sccm. After coating, the mask (kapton tape) is carefully removed to get the ring resonators on the glass substrate. SRR and BCSRR structures of thickness 350 nm, 550 nm and 750 nm in square shape are prepared using this technique by varying the sputtering duration. Figure 1 gives the photograph of thin film SRR fabricated on a glass substrate. For the BCSRR, rings are fabricated on both sides of glass substrate of thickness 1.3 mm. The resonators are then placed between the monopole antennas connected to the transmitting and receiving probes of a Vector Network Analyzer (VNA) for the transmission measurement[3, 4].

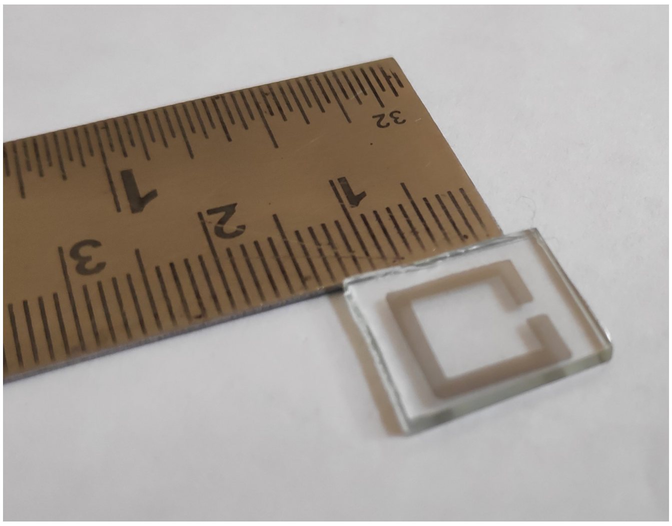

Fig. 1: Photograph of the thin film SRR fabricated on a glass substrate.

III. RESULTS AND DISCUSSIONS

The magnetic resonance in SRRs are analyzed from the transmission spectra obtained from VNA. The resonance absorption spectra of SRRs of different thickness are presented in Fig. 2. As the thickness of the film increases, the frequency shifts toward the lower values. It is quite evident from the graph that resonance curve is of wide-band nature owing to the resistive nature of the resonator due to the lowering of thickness below skin depth, which is around 1 μm at the resonating frequency. We also observe a shift in resonant frequency towards higher end as the thickness decreases which may be due to the increase of the evanescent field with the corresponding reduction in thickness. For thicknesses beyond the skin depth the resonance frequency remains the same with a reduced narrow bandwidth owing to the disappearance of observed resistive component. Figure 3 shows the transmission spectra for the BCSRR made using thickness t = 750 nm along with the resonance observed for its single ring. We observe a reasonable shift in resonance frequency for the BCSRR in comparison with the resonant frequency of its single ring due to the mutual coupling between the rings.

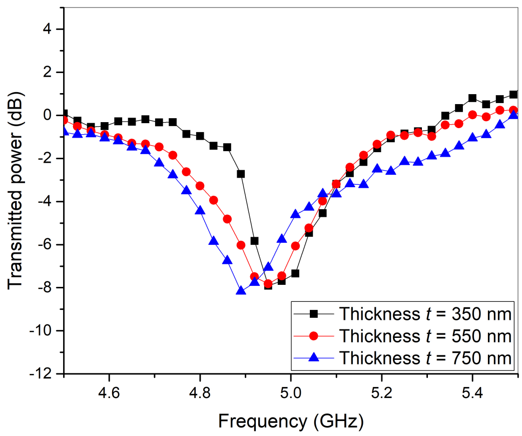

Fig. 2: Magnetic resonance in single square ring SRRs of different thicknesses t of 350 nm, 550 nm and 750 nm respectively made on glass substrate with dimensions - length l= 10 mm, width w = 2 mm and split width s = 1 mm.

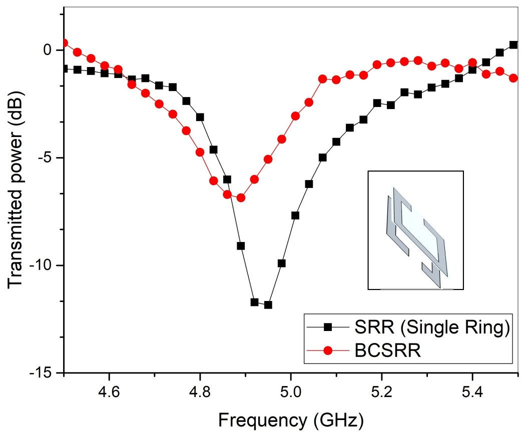

Fig. 3: Magnetic resonance in BCSRR of thickness t = 750 nm made on glass substrate with dimensions length l = 10 mm, width w = 2 mm, split width s = 1 mm and separation between rings d = 1.3 mm along with the resonance curve for a single SRR with same values of l, w and s.

IV. Conclusion

Thin film metamaterial Split Ring Resonator structure working at microwave frequency is fabricated for the first time and its resonant behavior is analyzed. It is observed that this novel SRR made in nanometer thickness, a value lower than the skin depth, exhibits wide band resonance characteristics. Since the accompanying evanescent wave component is higher for this type of SRR, the possibility of actualizing ultra sensitive sensors can be realized using this novel SRR. This resonant structure exhibits all the advantages of thin film technology such as miniaturization, enhanced quality etc. and hence it may find a lot of potential applications in various microwave related fields.

Acknowledgement

Sikha K. Simon wish to acknowledge the financial support from the Government of India through UGC Maulana Azad National Fellowship (MANF).

References

[1] H. Guo, N. Liu, L. Fu, T.P. Meyrath, T. Zentgraf, H. Schweizer, H. Giessen, "Resonance hybridization in double split-ring resonator metamaterials," *Optics express* vol. 15(19),p. 12095, 2007.

[2] R. Marqués, F. Mesa, J. Martel, F. Medina,"Comparative analysis of edge- and broadside- coupled split ring resonators for metamaterial design - theory and experiments," *IEEE Transactions on antennas and propagation*, vol. 51(10), p. 2572, 2003.

[3] Chakyar SP, K Simon S, Bindu C, Andrews J, Joseph V,"Complex permittivity measurement using metamaterial split ring resonators",*Journal of Applied Physics*, vol. 121(5),p.054101, 2017.

[4] Umadevi K, Chakyar SP, Simon SK, Andrews J, Joseph V, "Split ring resonators made of conducting wires for performance enhancement",*EPL (Europhysics Letters)*, vol. 118(2), p.24002, 2017.