Analysis of RF MEMS Square Spiral Inductor

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Abstract— This paper involves analysis of a physical model for square spiral inductor on silicon. The impacts of changes in number of turns of square spiral inductor are studied extensively. The simplicity of the physical model enables a computational procedure for efficiently optimizing the inductance,resistance magnetic flux density. Square spiral inductor from 2.5 to 9.5 turns are studied in frequency range of 1 to 10 GHz.

Index Terms— Inductance, Self-resonance frequency, Spiral Inductor optimization

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1 INTRODUCTION

Availability of good quality integrated inductors is an important factor which determine the performance of radio frequency integrated circuits[1]. The inductor is a basic component and very vital in designing radio frequency (RF) matching networks, load circuits of voltage controlled oscillators, filters, mixers and many other RF circuits[2]. It is a fundamental device that can be found in almost any RF circuit. In the past several methods are adopted to improve performance of inductor. Inductance and self-resonant frequency (SRF) of the spiral inductor in CMOS IC technologies are limited by both high substrate capacitance and substrate loss.

II DESIGN OF INDUCTOR

Radio frequency inductor is designed using comsol multiphysics v 4.0. Comsol multiphysics is a finite element analyser, solver and Simulation software used in various physics and engineering applications.
Width of coil = 10 micrometer
Spacing between turns=10 micro-meter.
For 9.5 turns inductor
Internal diameter=40 micro-meter.
Outer diameter=510 micrometer.
After designing inductor port is given at input of fixed current density and output is grounded. Two outer box is created outside inductor which is given air and inductor is given silver material. Electric and magnetic insulation is provided at outside boundry. In this case internal diameter is kept constant and external diameter varies with number of turns. As number of turns increases inductance and magnetic energy increases. Inductance among materials is found highest for silver 6.83nH and lowest for chromium 6.54nH for these particular dimensions.
Figure 1.1&1.2 represents 2D and 3D structures of square Spiral inductor respectively. Inside diameter is 40 micrometers and turns are incresed there after till 9.5 innermost turn is connected to output with the help of air bridge.

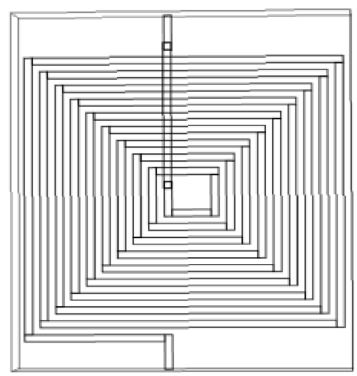

Figure1.1 2D VIEW OF 9.5 SQUARE SPIRAL INDUCTOR

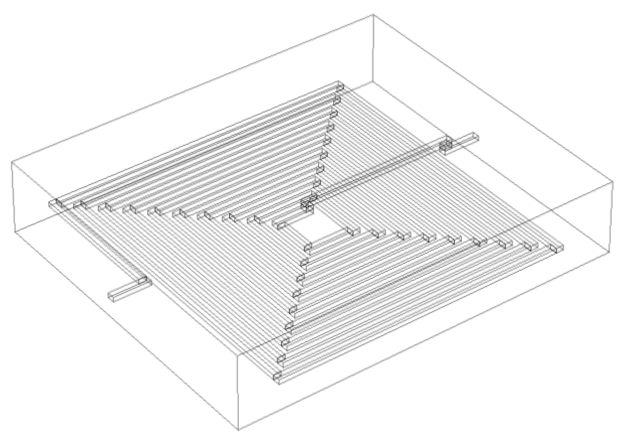

Figure1.2 3D VIEW OF 9.5 SQUARE SPIRAL INDUCTOR

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Figure 1.3 represents magnetic flux lines passing between turns of inductor on injection of current

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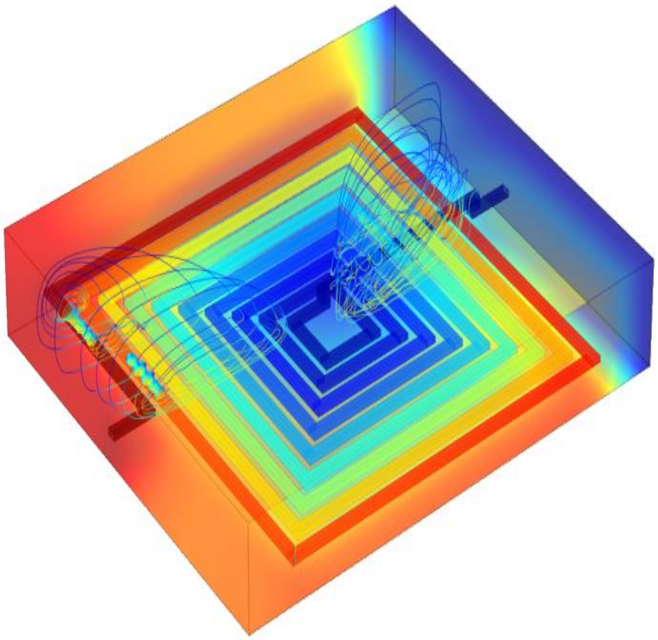

Fig 1.3. Magnetic flux density lines

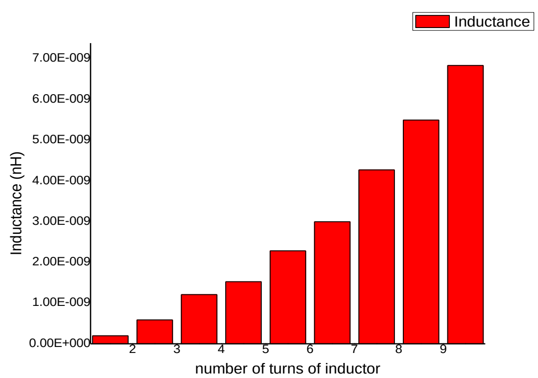

Figure 1.4 Inductance with respect to number of turns

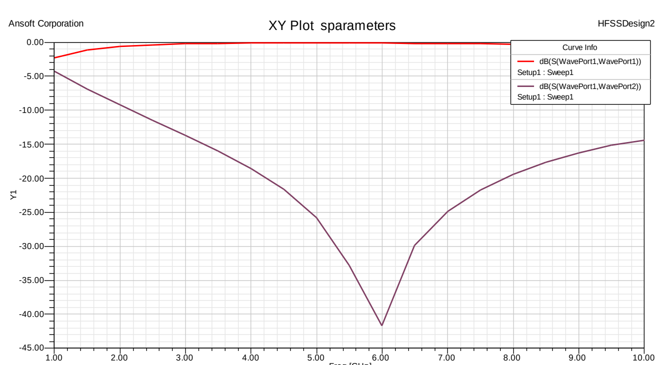

Figure 1.5 s-parameters of 9.5 turn inductor

Figure 1.4 shows inductance in nano henry v/s number of turns .9.5 turns inductor gives highest inductance value that is 6.8nH Inductance increases with number of turns.

Figure 1.5 shows S-parameters and Self Resonant frequency. Inductors have both inductive and capacitance tendencies. SRF is the frequency, that an inductor takes on enough of the capacitive tendencies that they cancel out the inductive tendencies, thus rendering this device useless as an inductor. At this frequency the inductor acts purely resistive and above this frequency will begin to act like a capacitor

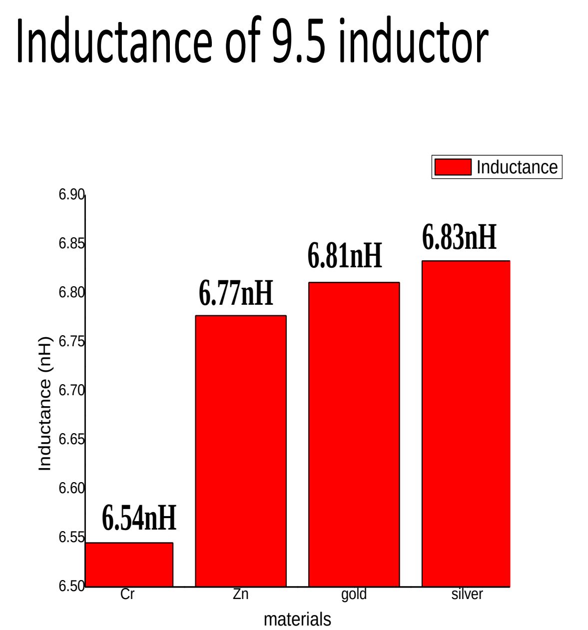

Fig.1.6 Inductance of 9.5 inductor v/s MEMS materials.

Inductance is ploted with respect to materials. Materials are Silver , Gold , Zinc and Chromium. Silver gives highest inductance of 6.83nH. Silver posses conductivity of 61e6 S/m. Gold conductivity is 45.6e6 S/m . Zinc conductivity is 16.7 e6 S/m and chromium conductivity is 7.9e6 S/m.
We obtain inductance value 6.54 nanohenry which is minimum for chromuium, next we get 6.77 nanohenry induc-

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tance of zinc and Gold material gives us 6.81 nanohenry inductance.

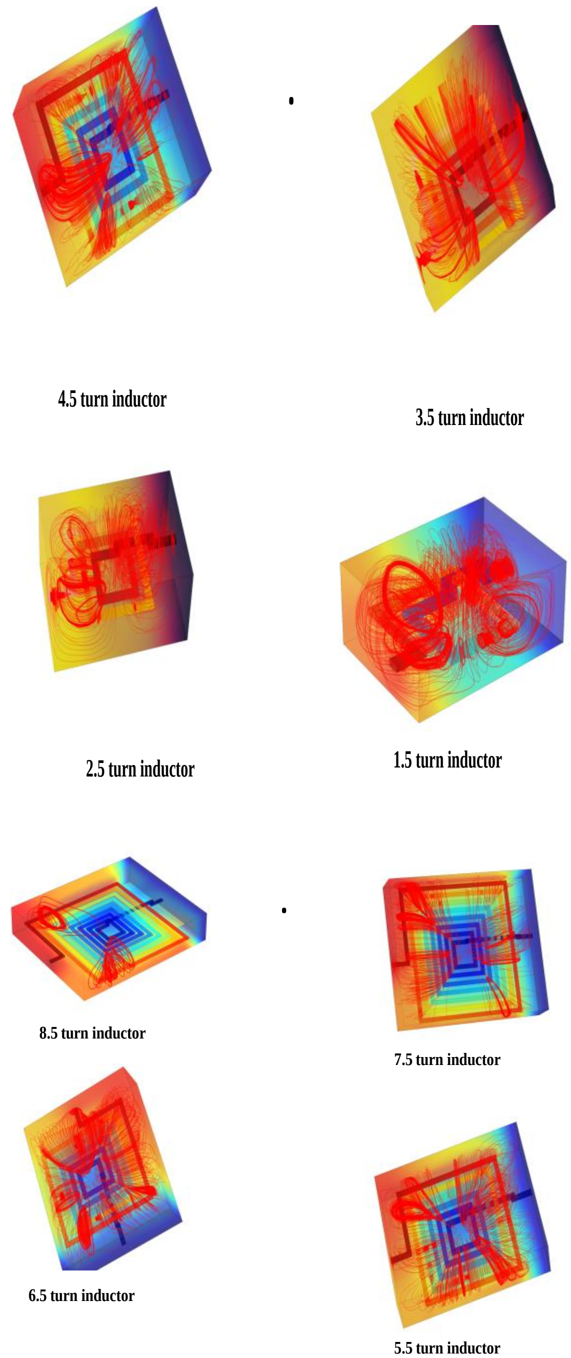

Figure 1.7 1.5 to 8.5 turns of inductor

Conclusion and results

Inductors are studied extensively from 2.5 to 9.5 turns in comsol muliphysics ac/dc module. We found that inductance, magnetic energy, and resistance increases with number of turns. Inductance among materials is found highest for silver6.83nH and lowest for chromium 6.54nH

Table1.1 RF MEMS Inductor (silver) inductance, resistance and energy with respect to number of turns

Number of turns in square spiral inductor(Ag)	Inductance (Henry)	Resistance (ohm)	Total Magnetic Energy (Webber/m)
1.5 turn inductor	1.982e-10	0.0142	9.912e-11
2.5 turn inductor	5.860e-10	0.3042	2.930e-10
3.5 turn inductor	1.207e-9	0.5118	6.038e-10
4.5 turn inductor	1.523e-9	0.7532	7.614e-10
5.5 turn inductor	2.283e-9	1.0615	1.141e-9
6.5 turn inductor	2.995e-9	1.0581	1.497e-9
7.5 turn inductor	4.267e-9	1.8294	2.133e-9
8.5 turn inductor	5.491e-9	2.288	2.745e-9
9.5 turn inductor	6.834e-9	2.786	3.417e-9

References

[[1] J.M. Lopez-Villegas, "Improvement of quality factor of RF Integrated inductors by Layout optimization", Microwave Theory and Techniques, IEEE Transactions on pp.: 76 – 83,Jan 2000
[[2]See Guan Hue "RF Spiral Planar Inductor Designs",Asia-Pacific Conference on Applied Electromagnetics pp. 1-20 ,july 2004.