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AC/DC Modeling and Experimental Impedance Verification of 3D MEMS Inductor Coils

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Introduction

In this work, an analysis is presented for a 3-dimensional RF MEMS coil using the COMSOL AC/DC module in conjunction with the CAD import module. The AC/DC module is chosen due to the coil having a transition from near pure resistor-like characteristics to a device with dominating inductor properties at higher frequencies of operation. The coil design involves a level of complexity beyond that of standard planar spiraled RF coils by incorporating multi-layer techniques, which are interconnected by vertical connection points, hence proving the necessity for the CAD import module. The realization of being able to produce such 3-dimensional RF coils allows for less surface area to be needed for similar inductor performance in comparison to larger planar RF coils by maintaining the same number of turns through super-positioning of the connected multi-turn layers. This analysis is verified in its accuracy by performing actual impedance testing using HP4194A and HP4395 analyzers. Specific transition to inductor-like properties is shown. The significance of this work is the use of COMSOL to accurately model RF inductor coils beyond the standard planar coils to a new generation of 3-dimensional MEMS devices.

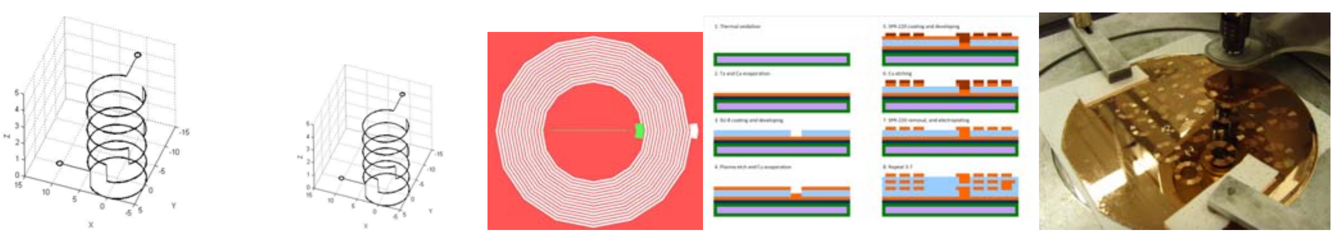

Figure 1: From left to right: Conceptual 3D MEMS coil (multilayer), spiral turns within each layer, multi-step process fabrication, finished prototype

Use of COMSOL Multiphysics

The analysis presented is an advanced form of an S-Parameter investigation for 3D RF MEMS inductors. The geometry of the coil is imported into the AC/DC module using the CAD import module. Using a quasi-static, electromagnetic setting, magnetic and electric insulations are prescribed for the boundary conditions. A parametric solver with time-harmonic analysis is used to create a linear solver system. Selection of the height of objects for meshing causes a significant change in the amount of elements for solving and correspondingly the run time for solutions. Optimal selection of the height was chosen based on each multi-turn's layer thickness. The final solution was an analysis of the impedance matrix versus frequency and the inductance versus frequency.

Expected Results

Results are expected to show the influence of multi-turns for single and multi-layer MEMS RF inductor coils. These results are then compared to actual results from impedance measurements performed on the real 3D MEMS inductor coils for modeling verification. Specific areas of interest include the cross-over frequency for when the devices begin to have inductor-like properties and the existence of self-resonance within the devices.

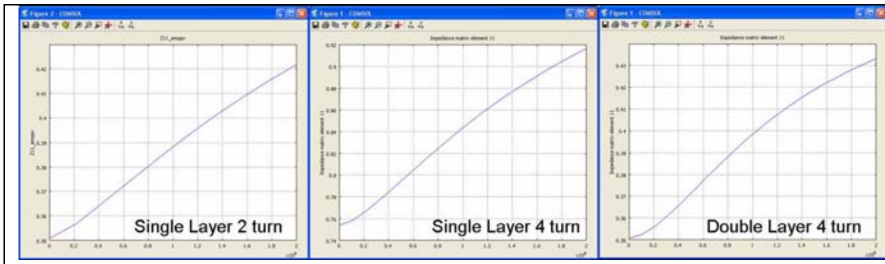

Figure 2. Preliminary results showing the trend for increasing inductance with frequency for multi-turn, single-layer and multi-turn, multi-layer coils

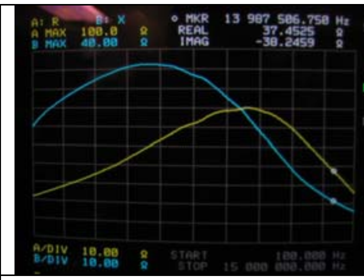

Figure 3. Real impedance analysis showing the cross-over frequency for inductor-like properties

Conclusion

The result of this work is to provide an analysis for 3D RF MEMS inductor coils. Its validity can be directly compared to actual impedance testing that is also included. The work extends beyond inductor modeling to incorporating complex geometry within COMSOL for analysis purposes and resolving issues with the complexity involved with optimizing meshing for fast computation time.