Numerical Modeling of MEMS Sensor with Planar Coil for Magnetic Flux Density Measurements

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Introduction: There are two existing types of micromechanical magnetic field sensors. Cantilevers with ferromagnetic layer or planar winding on a surface are commonly used. In the second case, the Lorentz force causes a beam deflection. An optoelectronic sensor can be used to measure it (fig.1). Traditional microetching process was used to produce the silicon beams. Figure 1 shows the section of the structure with aluminium layer (winding, mirror). Results of modeling of various beam-winding structures using COMSOL Multiphysics 4.3 for 3D models are shown in the paper. The point of the study was to compute the deflections of the beams as a function of direct magnetic flux density and direct winding current.

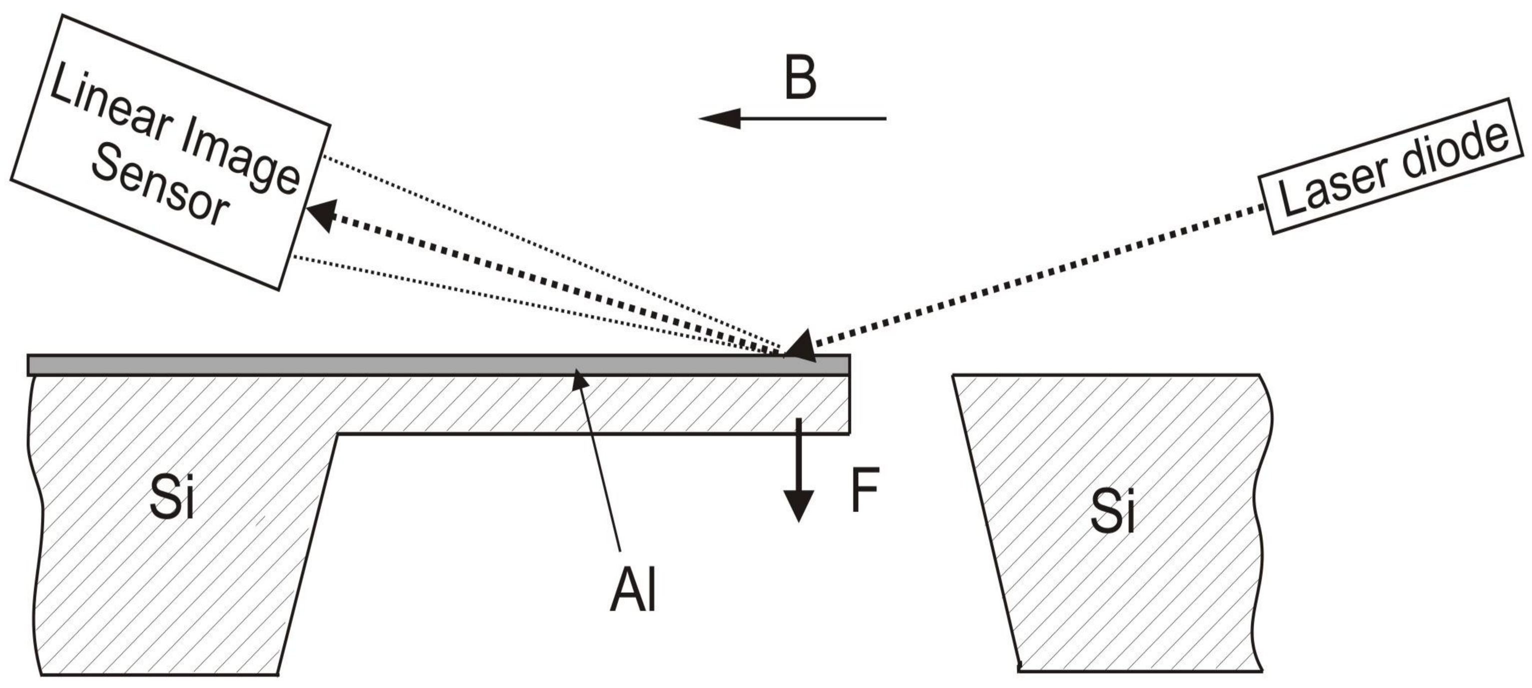

Figure 1. The scheme of the magnetic transducer

Modeling: Lorentz force affects the conductive layer on the beam surface,

$$\boldsymbol{F} = \boldsymbol{J} \times \boldsymbol{B}$$

J- current density, ***B***- magnetic field density

Using the AC/DC FEM 3D model, Lorentz forces for various magnetic fields and currents can be computed for each conductive path. Normal components of the force for each path in our model cause the moment bending the beam. Clearly, for a direction of a magnetic field along the Y-axis the displacement along the Z-axis is observed.
The deflections of the beams were computed using a FEM 3D model - structural mechanics module was combined with MEMS material library. Boundaries on one side of the beam were indicated as a fixed constraint. Three various constructions of planar windings were analyzed – a winding on a whole surface (fig.2), a winding on a surface as shown in fig.3, a winding with different widths of the conductive paths (fig.4).

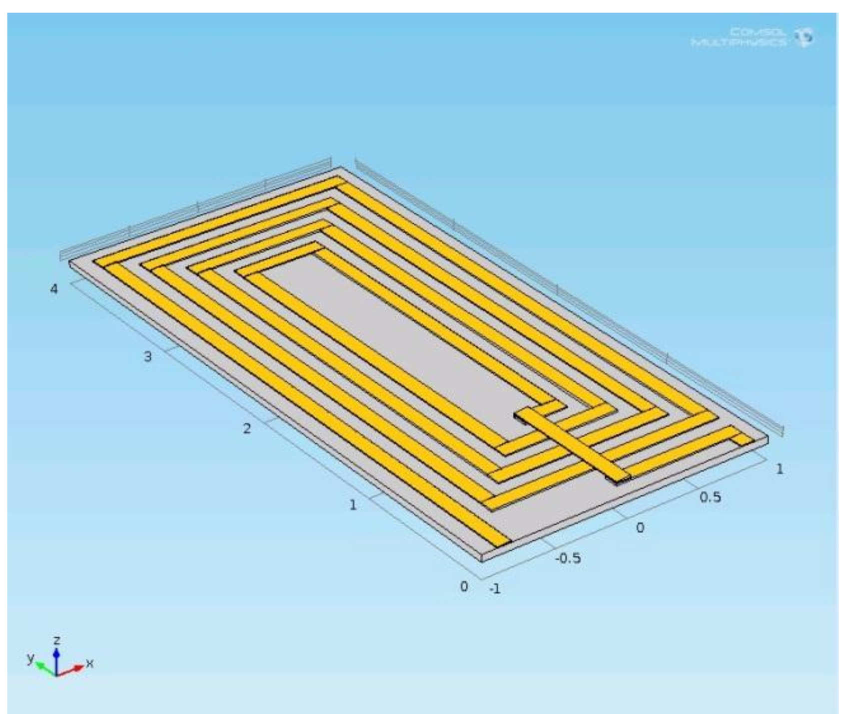

Figure 2. Planar winding A

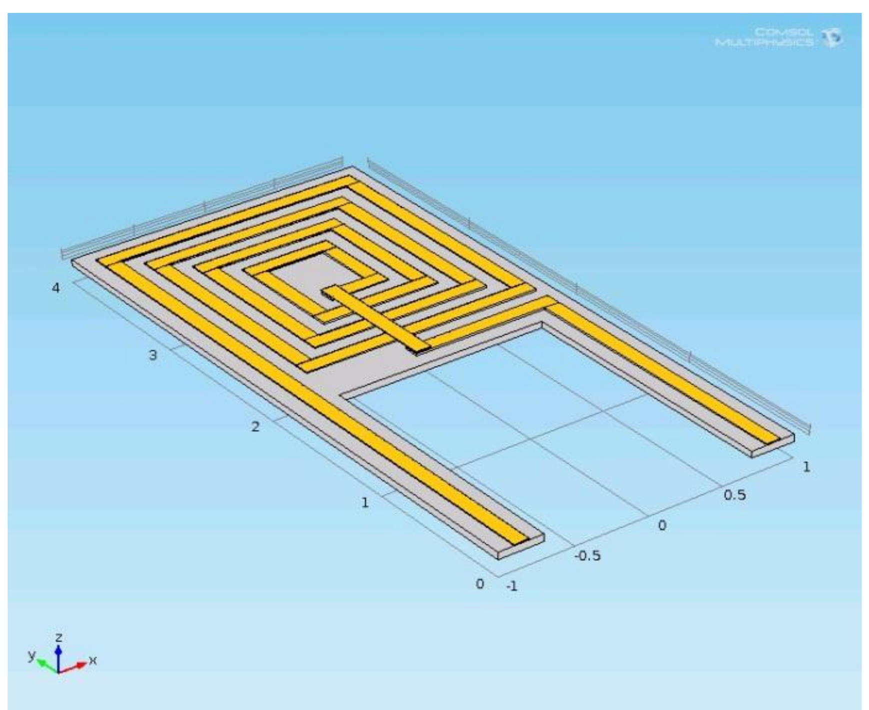

Figure 3. Planar winding B

Results: Silicon beams of sizes varying from 1 to 10mm length and 1 to 5 mm width (thickness: 20-50μm) were analyzed. Figure 5 and 6 show the results of computed bending for the 4mm x 2mm size beam (thickness 50μm). The dependencies between deflection and current, and magnetic field for the analyzed structures are shown in the fig. 8 (A, B).

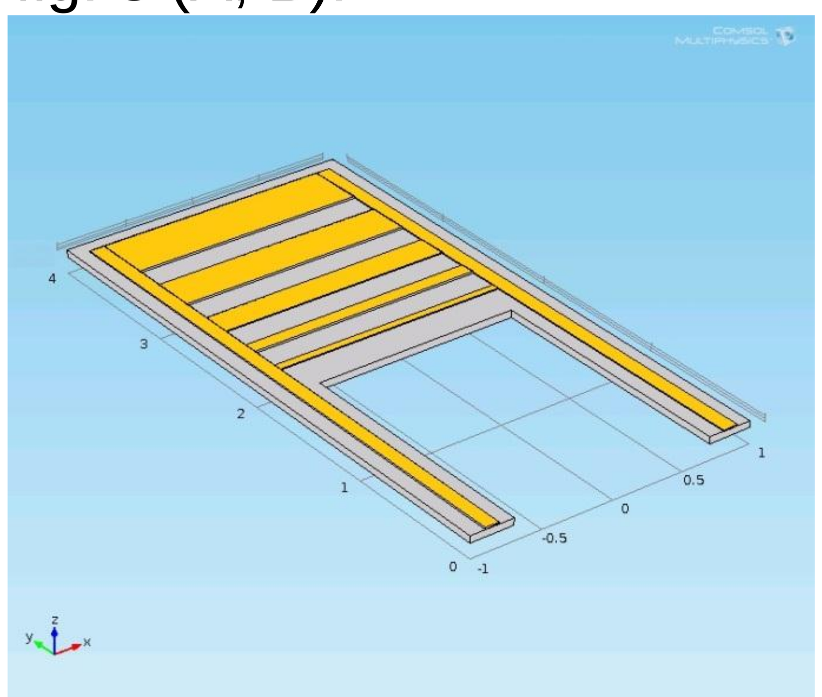

Figure 4. Planar winding C

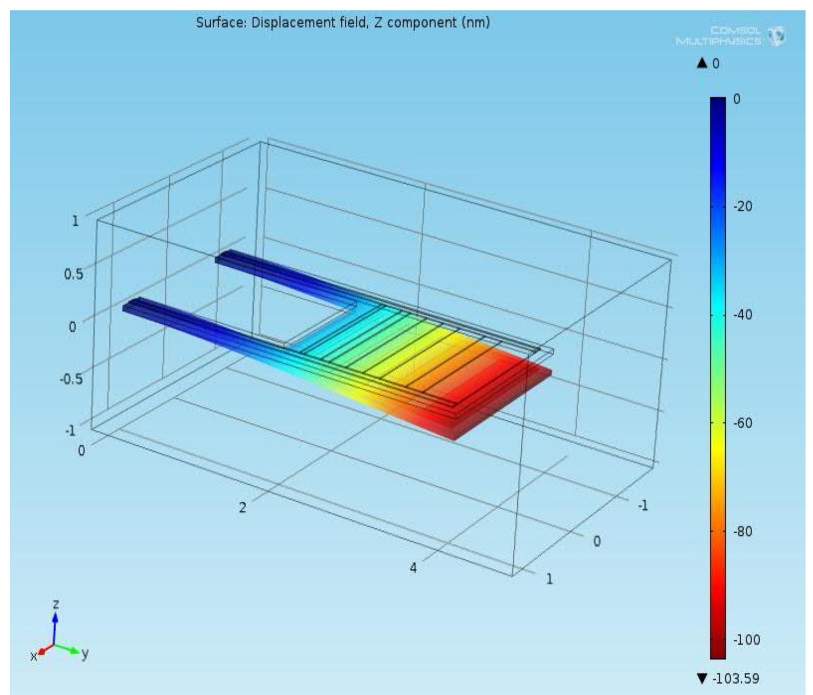

Figure 5. Surface deformation for winding C

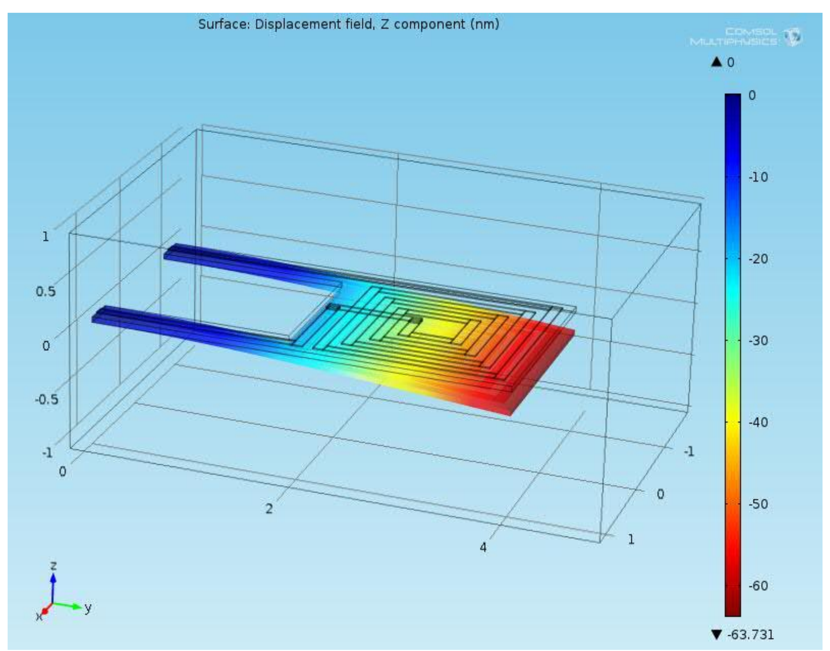

Figure 6. Surface deformation for winding B

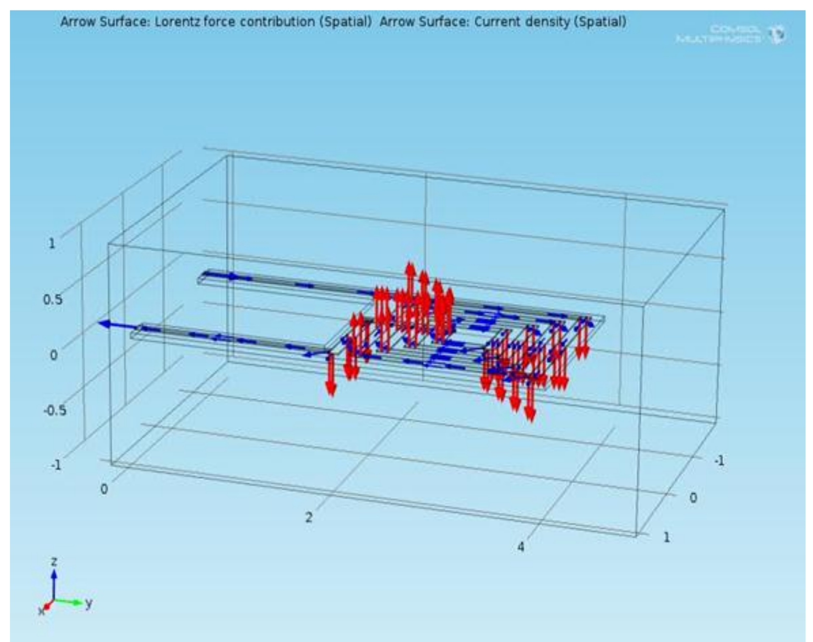

Figure 7. Lorentz force for winding B

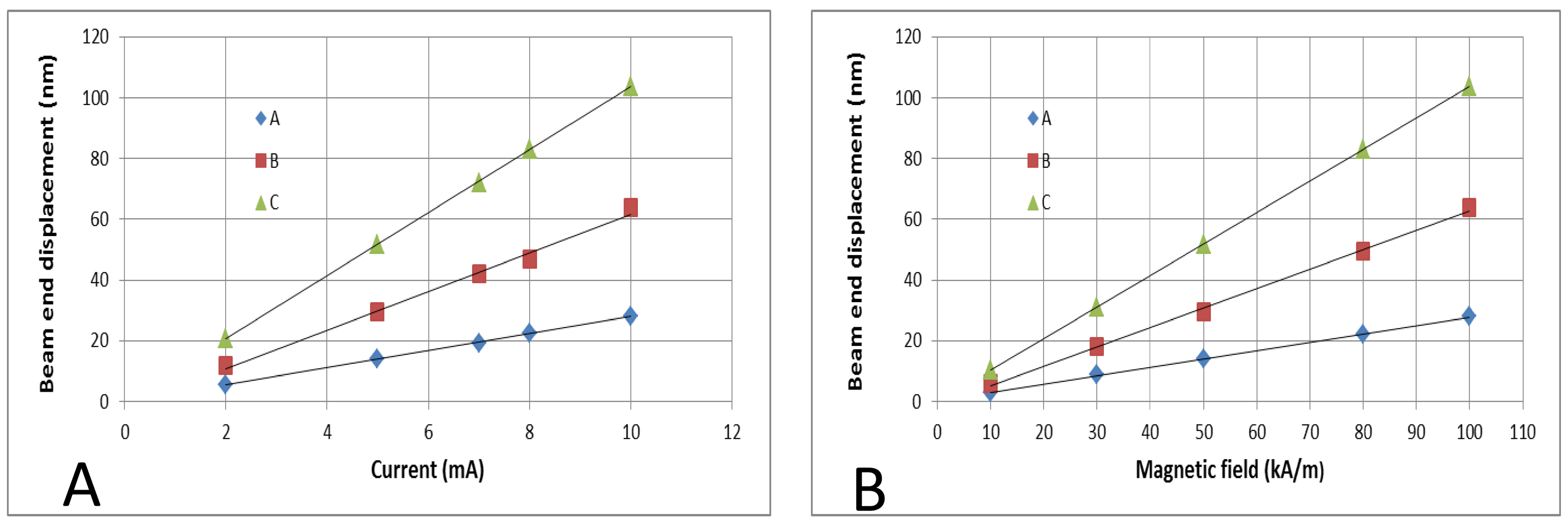

Figure 8. Beam end displacement as a function of winding current (A) and magnetic field (B)

Conclusions: Design of a MEMS magnetic field sensor consists of a creation of a micromechanical structure (size and shape) and analysis of a magnetic field distribution and Lorentz force. AC/DC and MEMS modules occur to be really useful. The presented results prove to be a compromise between the miniaturization of the sensor, its sensitivity and costs. For the analyzed structures, the cut causing a loss of stiffness of the beam structure and use of the winding named as the construction "C" (the same direction of Lorentz force in all cross conductive paths) occurred to be the most beneficial. However, the fact of an increasing impact of torsional moment caused by the magnetic field along the X-axis must be considered in more detailed analysis.

References:

1. M.Bau, V.Ferrari, D.Mariolli, Contactless excitation of MEMS resonant sensors by electromagnetic driving, Proc. Comsol Confer., Milan, 2009
2. J.Golebiowski, Microelectromechanical transducer with optical readout for magnetic flux density measurements, Electrical Review,no5, 22-26, 2012

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