Automated Design of Micromechanical Gyroscopes

by Dr. Vladislav Apostolyuk

Introduction

Micro-mechanical gyroscopes or angular rate sensors have huge potential applications as primary information sensors. They represent an important inertial technology because other gyroscopes, such as solid-state gyroscopes, laser ring gyroscopes, and fibre optic gyroscopes cannot be miniaturized. The emergence of several state-of-the-art fabrication technologies now allows vibratory gyroscopes to be produced at low cost and be relatively small. The most common way is with the use of microelectronics technologies to produce micro-machined sensors, sometimes referred to as microelectromechanical systems (MEMS). Recent applications have resulted in the need for sensors with improved performances that could be achieved by means of improving the sensitive element and circuit design.

Gyroscope design

One of the ways to improve performances of micro-mechanical vibratory gyroscopes is to analyse their dynamics and errors. During our research into micro-mechanical gyroscopes, we considered a common approach to the analysis of the dynamics and errors of different types of micro-mechanical gyroscopes as well as calculation of their performances for application in their design. Such an analytical approach allows both prediction of the performances and determination of the dynamic parameters that are necessary to achieve high performance micro-mechanical gyroscopes.

Design software

In order to design gyroscopes with easily predicted primary natural frequency values and natural frequency ratios, it is necessary to have fine control over mechanical parameters such as mass and stiffness, which is currently lacking in most development software. Therefore, Astrise Corporation has developed the micro-gyroscope CAD (MGCAD), its own sensitive element design software. A screenshot of the main editor field is shown in the Figure 1.

The editor can be used to incorporate design parameters such as mass, spring and comb into the sensitive element. Colours in Figure 1 correspond to the functionality of the elements - primary, secondary and ground. Mechanical parameters like mass of the corresponding functionalities, their frequency, ratios between frequencies and overlapping area of the capacitors as well as geometry of the elements can be edited. Each of the elements can also be assigned to unlimited differing layers. This information on layer assignment is necessary in order to export design data appropriately into a mask file at the end of the design process. MGCAD allows not only the design but the analysis of final performances of the gyroscope as well. In order to obtain performance evaluations it is necessary to define some of the initial parameters such as material properties, generalised electronics information and damping conditions.

Finally, when the design of the sensitive element is complete, all layer and geometry information can be exported into either standard GDS II or CIF mask file, which can then be directly used in the fabrication of the sensitive element. Figures 2 and 3 are pictures of fabricated gyroscope and its sensitive element.

It is easy to see similar elements of the gyro in the editor in Figure 1 and in these pictures. Thus the design of the micro-mechanical gyroscope is no longer an intuitive process but based on the fulfilment of specific requirements. This allows the design of sensitive elements with almost any performance and accuracy desired.

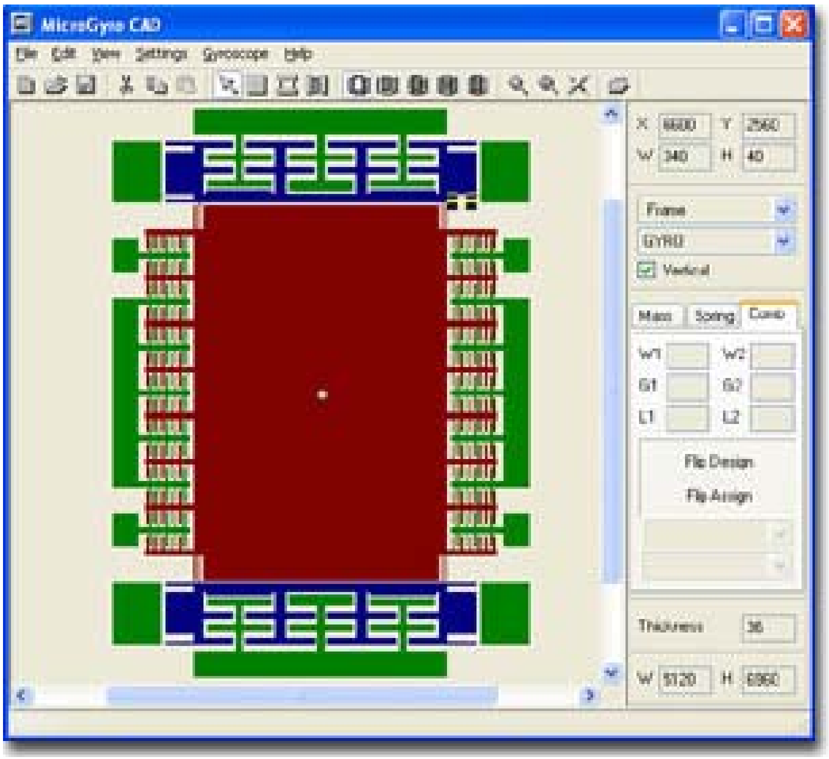

Figure 1. Micro-gyroscope design software

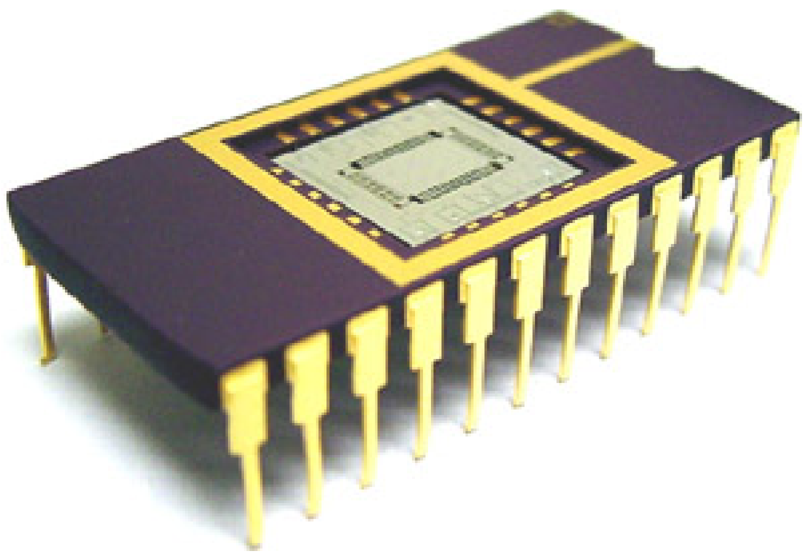

Figure 2. Fabricated micro-mechanical gyroscope

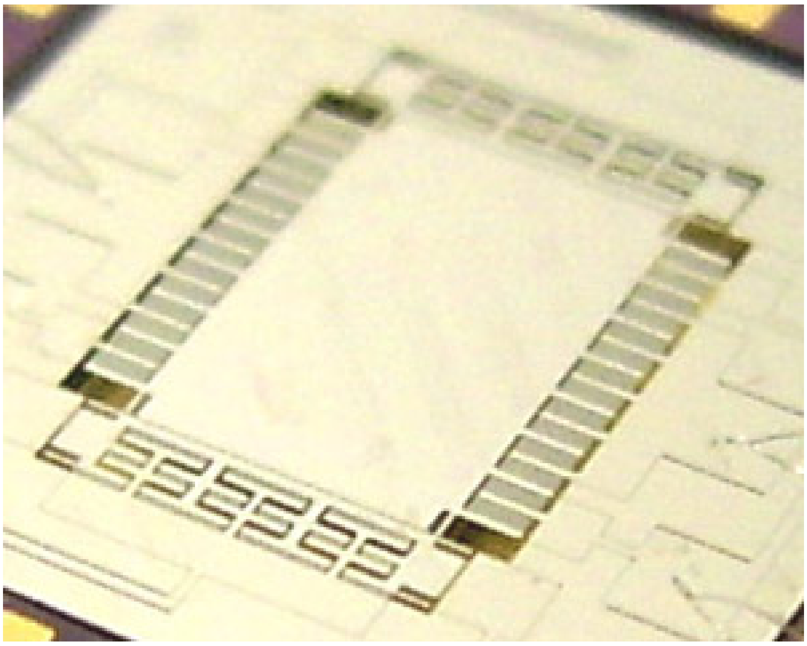

Figure 3. Sensitive element

Additional information

V. Apostolyuk, V.J. Logeeswaran, F. Tay, *"Efficient design of micromechanical gyroscopes"*, Journal of Micromechanics and Microengineering, Vol. 12 (2002), pp. 948-954.

V. Apostolyuk, F. Tay, *"Dynamics of Micromechanical Coriolis Vibratory Gyroscopes"*, Sensor Letters, Vol. 2, No 3-4 (2004), pp. 252-259.