Abstract Title

Theoretical study of the dynamical response of a MEMS-based gyroscope

Symposium Track

7. Applications to Nanodiagnostics and MEMS

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Abstract body

The paper deals with the description of the dynamical response of a tuning fork microgyrometer. A very accurate analytical model has been developed to perform the dynamical analysis. In particular, the attention has been focused on the structural components that influence the performance of the whole instrument, i.e. on the two beams of the drive mode.

Each beam is thought as a continuum body. The damping due to air in the drive motion (lateral damping) and in the sense one (squeeze damping) has been considered utilizing the Reynolds equation and including the rarefaction effect. By means of dimensional analysis, two parameters useful for the characterization of the air damping effects have been identified. The first parameter depends on the system geometry only, the other is related to the air viscosity.

The analysis has shown in particular that when the distance between the beam and the substrate increases, the system response improves. The response of the system when matching of the natural frequencies in the two planes is imposed, has been studied for its relevance, but also the influence of the structural damping and of the system angular velocity on the beam motion has been investigated. It has been shown that the structural damping cannot be neglected when the air damping coefficient is small, as in the case of the drive motion.

The results of the analytical model here proposed have been compared, at last, with the ones obtained by means of a 3D FEM analysis of the system. This has allowed the validation of some of the assumptions introduced in the formulation of the analytical model.

Keywords

MEMS, microgyroscope, angular rate sensor, tuning fork, damping, mechanical vibrations

References

1 : Yoichi Mochida, Masaya Tamura, Kuniki Ohwada, "A micromachined vibrating rate gyroscope with independent beams for the drive and detection modes", Sensors and Actuators, 80 (2000) 170-178

2 : Toshiyuki Tsuchiya, Yasuyuki Kageyama, Hirofumi Funabashi, Jiro Sakata, "Polysilicon vibrating gyroscope vacuum-encapsulated in an on-chip micro chamber", Sensors and

Actuators, A 90 (2001) 49-55
3 : K.Maenaka, T. Fujita, Y. Konishi, M. Maeda, "Analysis of a highly sensitive silicon gyroscope with cantilever beam as vibrating mass", Sensors and Actuators, A 54 (1996) 568-573
4 : Xinxin Li, Minhang Bao, Heng Yang, Shaoqun Shen, Deren Lu, "A micromachined piezoresistive angular rate sensor with a composite beam structure", Sensors and Actuators, 72 (1999) 217-223
5 : S. Sassen, R. Voss, J. Schalk, E. Stenzel, T. Gleissner, R. Gruenberger, F. Neubauer, W. Ficker, W. Kupke, K. Bauer, M. Rose, "Tuning fork silicon angular rate sensor with enhanced performance for automotive applications", Sensors and Actuators, 83 (2000) 80-84
6 : Ofir Bochobza-Degani, Dan J. Seter, E. Socher, Y. Nemirovsky, "A novel micromachined vibrating rate-gyroscope with optical sensing and electrostatic actuation", Sensors and Actuators, 83 (2000) 54-60
7 : Heng Yang, Minhang, Bao, Hao Yin, Shaoqun Shen, "A novel bulk micromachined gyroscope based on a rectangular beam-mass structure", Sensors and Actuators, A 96 (2002) 145-151
8 : Timo Veijola, Heikki Kuisma, Juha Lahdenpera, Tapani Ryhanen, "Equivalent-circuit model of the squeezed gas film in a silicon accelerometer", Sensors and Actuators, A 48 (1995) 239-248
9 : Timo Veijola, Tapani Ryhanen, Heikki Kuisma, Juha Lahdenpera, "Circuit simulation model of gas damping in microstructures with non trivial geometries", Helsinki University of Technology, Circuit Theory Laboratory, Otakaari 5A, Finland
10 : Bernard J. Hamrock, "Fundamentals of Fluid Film Lubrication", McGraw Hill, 1994
11 : EA. Avallone (cd), "Standard Handbookfor Mechanical Engineers", McGraw-Hill, New York, 1987, pp. 5-69.
12 : W. G. Cady, "Piezoelectricity: an introduction to the theory and application of electromechanical phenomena in crystal", McGraw Hill, 1943
13 : Stephen D. Senturia, "Microsystem Design", Kluwer Academic Publishers, 2004

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