Finite-element predictive 3D modelling and optimization of membrane-based thermoresistive MEMS accelerometers

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The scope of applications of the linear acceleration MEMS sensors is constantly growing. Nowadays each smartphone is equipped with built-in accelerometers and gyroscopes, and, according to Yole Développement estimations [1], the MEMS accelerometer market is about 1.5 billion dollars and will not decrease in the coming years. Unmanned aerial vehicles (drones) and Internet of Things should become the next market drivers and further expand the application areas for MEMS sensors, including accelerometers. In addition to increasing sensitivity and reducing costs, modern accelerometers require high reliability, resistance to dynamic and shock loads and a significant reduction in weight and size. MEMS technology has long established itself in the field of mass production of sensors. There are several types of MEMS accelerometers that measure acceleration using different physical phenomena [2], each of which has its advantages and disadvantages. In this work we propose the thermoresistive MEMS accelerometer, which measures the heat distribution under acceleration instead of measuring the deviation of the moving mass. Avoiding the use of moving parts offers a lot of advantages in terms of sensor reliability, impact resistance and zero-g offset stability.

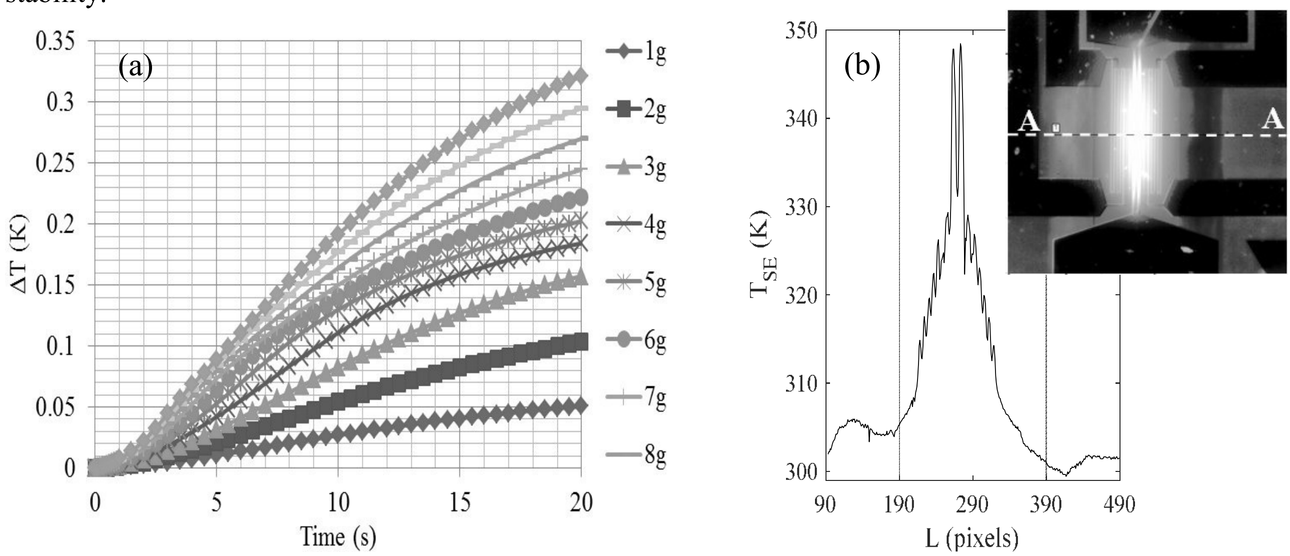

Fig. 1. (a) Time dependence of the temperature drop on the lateral thermistors of the MEMS accelerometer as a function of acceleration. (b) Experimental thermal profile due along the A-A cross-section of the sensitive thermoresistive element due to its current heating in the absence of horizontal acceleration.

Numerical simulation of the characteristics of thermoresistive MEMS accelerometer was carried out using the finite-element three-dimensional model of thermal gas dynamics of the device (Fig. 1a). This model was developed in Comsol MultiPhysics software based on fitting the simulation results to the experimental data of the thermal distribution in the sensing element of MEMS accelerometer [3] in the absence of horizontal acceleration. The presented model can be used in the future to evaluate the performance of various topologies of the thermal MEMS accelerometer in order to increase its sensitivity.

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1. Yole Developpement, “Status of the MEMS Industry 2015”, Yole Developpement, France, 2015.
2. V. Narasimhan, H. Li, and M. Jianmin. "Micromachined high-g accelerometers: a review". J. Micromech. Microeng., **25**, p. 033001, 2015.
3. N. Djuzhev et al. “Application of the streamlined body for properties amplification of thermoresistive MEMS gas flow sensor”. Solid State Phenomena, **245**(201), pp. 247-252, 2016.