ABSTRACT

Accelerometer is a device, which measures acceleration of a moving or vibrating system. Accelerometers are widely used in different fields, such as in automotive industry, robotics, aerospace, electronic gadgets etc. Micromachining technology offers a reliable platform to develop accelerometers having small size at low cost. However, the integration of MEMS (Micro Electro Mechanical Systems) based sensor with a CMOS (Complementary Metal Oxide Semiconductor) signal conditioning circuit is a challenging task. On the other hand, the sensors developed on CMOS-MEMS process have many advantages, namely, better signal processing, low cost, reliable performance due to batch fabrication and packaging of the die. Accelerometers usually use proof mass to detect the acceleration. The proof mass creates instability and reduces shock survival rating. Moreover, it also increases the fabrication cost. These problems do not exist for thermal accelerometer, which has no solid proof mass. In this accelerometer, a heated gas bubble acts as the proof mass. However, the major limitation of thermal accelerometers (particularly which are realized using CMOS platform) is its low sensitivity due to limited on-die cavity size and low thermal sensitivity of the available temperature sensor material.

The objective of this research work is to improve the sensitivity of dual axis thermal accelerometer in CMOS-MEMS platform. We have started our experiment by predicting the temperature profile of a simplified spherical thermal accelerometer using governing equations. The governing equations based temperature profile has been compared with that obtained by using commercially available numerical simulation tool. Though, the temperature profile of such simple structures can be analyzed by the governing equations, it is difficult to perform the same for a practical device. Hence, few case studies have been carried out using the numerical simulator to observe the effect of different parameters of thermal accelerometer such as, cavity size, heater shape and size, cavity depth and temperature sensor position. To improve the sensitivity of thermal accelerometer, two heater structures namely, square ring shaped and cross shaped heaters have been proposed. For demonstration, we have designed two accelerometers having square ring shaped and cross shaped heaters with 1mm×1mm cavity size in a CMOS-MEMS process. The sensitivity of square ring shaped and cross shaped heaters are 0.335 K/g and 0.36 K/g, respectively with the heater temperature of 600 K. The sensitivity of the thermal accelerometer has been

further improved by two new cavity structures namely, multi-cavity and cavity with silicon islands. In the proposed cavity structures, the sensitivity for multi-cavity and cavity with silicon islands are 0.373 K/g and 0.725 K/g, respectively. The sensitivity achieved by proposed heater and cavity structures is higher than the thermal accelerometer structures reported in the literature. The proposed heater and cavity structures have been designed according to the design and process rules of CMOS foundry. The test chip containing different accelerometer architecture has been fabricated from the commercial foundry. However, the condition of the dies in the cavity region has been found to be not good. Standalone testing of the circuits has been carried out. We believe that, this research work would lead to a high sensitivity, low power dual axis thermal accelerometer.

Keywords: Thermal accelerometer, Thermal accelerometer on CMOS-MEMS platform, Heater structure, Cavity structure.