# Study on Silicon Thermal Resistive Fluidic Inertial Sensors Utilizing Microelectromechanical Systems (MEMS) Technology

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This thesis presents a study on MEMS (Micro Electro Mechanical Systems) fluidic inertial sensors, including gas gyroscopes and gas accelerometer, whose working principles are based on the convective heat transfer and thermoresistive effect of p-type silicon. Since the sensing element is made of lightly doped p-type silicon with high TCR (temperature coefficient of resistance) compared with conventional metal resistors, the sensitivity is much improved. Furthermore, silicon sensing element can be mass fabricated by standard MEMS technology with high productivity and reproducibility. Compared with spring-mass based inertial sensors, the proposed sensors have no seismic mass; therefore, it can eliminate the inherent problems, such as potential fragility, low shock-resistance, and vibration noise from driving mode.
In this thesis, the design, simulation, fabrication and characterization of the fluidic inertial sensors are presented. Moreover, a novel configuration of an in-plane 3-axis angular rate sensor is proposed.
The thesis consists of 10 chapters.

Chapter 1 gives an overview of the existing silicon based inertial sensors.

Chapter 2 introduces the working principle of the fluidic gyroscope and accelerometer.

Chapter 3 presents the fundamental and advanced matters on fluid dynamic, thermal resistive effect and heat transfer phenomena, which later are used for design the sensors.

Chapter 4 describes the design, simulation and optimization of the gas gyroscope. By using piezoelectric pump with optimized nozzle structures, the gyroscope effectively creates the circular laminar jet flow for sensing angular rate. Sensitivity and frequency response analyses have been performed based on force convection heat transfer and thermo-resistive effect. The simulation results show that the sensitivity of the gyroscope is about 50 times greater than that of conventional metal-based gyro.

Chapter 5 presents the design and simulation of a gas accelerometer, which consists of a central heater surrounded by four silicon thermistors, packaged in a hermetic chamber. Free convection heat transfer is applied to simulate the sensor performance.

Chapter 6 describes the fabrication process of the sensors based on MEMS technology.

Chapter 7 presents the characterization and experimental results of the sensors' performance, including the sensitivity, cross sensitivity, non linearity, off-set stability, frequency response and the affect of ambient environments. The measurement results confirmed the simulated results discussed in chapter 4, i.e. the sensitivity is 50 times greater than that of metal-based gyroscope.

Chapter 8 introduces the new designs of sensing elements which aim to reduce the thermally-induced stress, and therefore, increases the signal to noise ratio of the sensors.

Chapter 9 proposes a novel configuration of the first MEMS fluidic gyroscope of which all sensing thermistors are arranged in the same plane. The proposed gyroscope can detect three components of angular

rate independently. The design, simulation and proposal fabrication process are presented.

Chapter 10 concludes the thesis and mentions the future work.