MICRO CORIOLIS MASS FLOW SENSOR FOR CHEMICAL MICROPROPULSION SYSTEMS

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Novelty: We have designed a micromachined micro Coriolis flow sensor for the measurement of hydrazine (N_2H_4, High Purity Grade) propellant flow in micro chemical propulsion systems. The sensor measures mass flow up to 10 mg/s for a single thruster or up to 40 mg/s for four thrusters. The sensor will first be used for measurement and characterization of the micro thruster system in a simulated space vacuum environment. Integration of the sensor chip within the micro thruster flight hardware will be considered at a later stage. The new chip has an increased flow range because of an integrated on-chip bypass channel.

Previous work: In [1] we proposed to fabricate a micro Coriolis mass flow sensor using silicon nitride as the tube material. This resulted in a very thin (1.2µm) tube wall, so that the mass of the tube is small compared to the mass of the moving fluid. This was a significant improvement over [2] and [3], which use silicon as the tube material, leading to a relatively heavy and stiff tube. We demonstrated that a silicon nitride sensor could reach a resolution in the order of 3 µg/s [1], however at that time no readout structures were integrated and a laser vibrometer was needed to optically measure the out-of-plane Coriolis motion of the tube. In [4, 5], we added an integrated capacitive readout and we demonstrated liquid flow measurement with a full scale range of 0.3 mg/s and a measurement accuracy of 1% of full scale.

Operation principle: A Coriolis type flow sensor consists of a vibrating tube. An important advantage of Coriolis sensors is that they are only sensitive to the true mass flow, independent of flow profile, pressure, temperature and properties of the fluid (density, viscosity, etc.). Figure 1 shows a schematic drawing of the new Coriolis sensor based on Lorentz force actuation and capacitive sensing. The tube is actuated in a torsion mode. A mass flow Φ_m inside the tube induces Coriolis forces that excite the other vibration mode, resulting in a vibration amplitude proportional to the mass flow. Both the actuation and the Coriolis movements are detected using two capacitors at the outside of the loop. The mass flow can be extracted from the two output signals by detecting the phase difference, which is exactly proportional to the amplitude ratio of the Coriolis and actuation movements. By applying a bypass ratio of approximately 1:31 respectively 1:124 the measurable flow range can be extended from 0.3 mg/s up to 10 respectively 40 mg/s. Figure 2 shows a photograph of a fabricated sensor chip which measures 7.5 x 15 mm. Figure 3 shows the layout of the new chip.

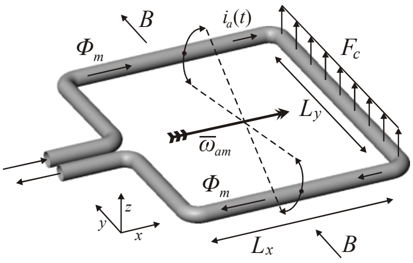

Figure 1: Operating principle.

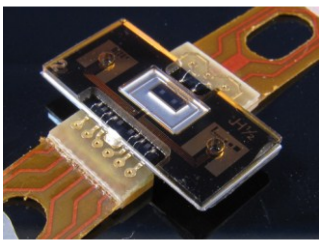

Figure 2: Chip photograph.

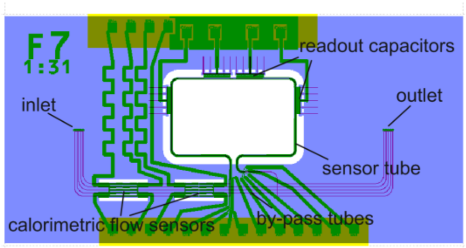

Figure 3: Mask layout.

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