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Electrostatically Driven In-Plane Silicon Micropump for Modular Configuration

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Abstract: In this paper, an in-plane reciprocating displacement micropump for liquids and gases which is actuated by a new class of electrostatic bending actuators is reported. The so-called "Nano Electrostatic Drive" is capable of deflecting beyond the electrode gap distance, enabling large generated forces and deflections. Depending on the requirements of the targeted system, the micropump can be modularly designed to meet the specified differential pressures and flow rates by a serial and parallel arrangement of equally working pumping base units. Two selected, medium specific micropump test structure devices for pumping air and isopropanol were designed and investigated. An analytical approach of the driving unit is presented and two-way Fluid-Structure Interaction (FSI) simulations of the micropump were carried out to determine the dynamic behavior. The simulation showed that the test structure device designed for air expected to overcome a total differential pressure of 130 kPa and deliver a flow rate of 0.11 sccm at a 265 Hz driving frequency. The isopropanol design is expected to generate 210 kPa and pump 0.01 sccm at 21 Hz. The device is monolithically fabricated by CMOS-compatible bulk micromachining processes under the use of standard materials only, such as crystalline silicon, silicon dioxide and alumina.

Keywords: micropump; electrostatic actuation; nano e-drive; in-plane reciprocating displacement micropump; MEMS

1. Introduction

In many application fields, such as microchannel-cooling [1,2], miniaturized chemical analysis [3,4], gas-chromatography [5,6], and mobile on-chip applications [7,8], there is a need for a microscale pumping device that exhibits, besides a specific flow rate and pressure difference, low power consumption and a reduced device size. Electrostatic-driven silicon micropumps are a part of Micro-ElectroMechanical Systems (MEMS) and can often meet these demands [9–11]. Their advantages in terms of scalability of the drive mechanism, simplicity in their fabrication, low power consumption, and fast response time, make them an attractive choice for many applications. The majority of these devices function with an out-of-plane mechanism of a mechanically reciprocating membrane clamped at its perimeter. Here, the challenge is to precisely design the diaphragm and the drive, in order to reach a sufficient stroke volume, i.e., a compression ratio [12,13], for the pumping effect and a failure-free operation. The small deflections of micro-actuators further complicate this task.