Proof of Concept and Properties of Micro Hydraulic Displacement Amplifier

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Abstract

Introduction
The microhydraulic principle, which can be used to transfer power and displacement, has been gradually used in MEMS (Microelectromechanical Systems), for example, tactile actuator for navigation or reading [1, 2, 3] for visual impaired people. As shown in fig. 1, the liquid is encapsulated in a silicon chamber with two hyperelastic membranes sealing it from both sides. A displacement of the upper membrane occurs when a certain pressure is applied on the lower membrane. Due to complex fluidic and hyperelastic mechanics, they are coupled in a large deflection transmission system. It is a complex work to calculate the behaviour of this system.

Furthermore, to design an amplifier (e.g. tactile actuator) with amplitudes above 50 µm, the required force has to be characterized to select the proper driver. Therefore, it is necessary to optimize the chamber geometry to minimize stress concentration, area and thickness of membranes to get the required deflection ratio and force of the system.

Use of COMSOL Multiphysics®
2D axi-symmetric fluid-structure interaction finite element simulation of an amplifier which has an upper cylinder of 200 µm connected to a lower one of 400 µm radius (see Fig. 1). Both membranes are made out of PDMS. The conveyer was filled with silicone oil. Finally, a ramp function of pressure was applied on the lower membrane.

Results
The fluid motion in the chamber when the pressure is applied can be seen in fig. 2. The deflection response and deflection ratio of the upper and lower membranes in relation to the applied pressure is shown in fig. 3. The pressure distribution inside the amplifier is shown in fig. 4.

Conclusion
The required adhesion between the membranes and silicon chambers are predicted by simulation in relation to an applied pressure. Further simulations can be done to reach the desired transferred deflection ratio under a certain pressure. A real prototype will be build according to the simulation results.

Reference

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[2] Xavier Arouette, Yasuaki Matsumoto, Dynamic Characteristics of a Hydraulic Amplification Mechanism for Large Displacement Actuators Systems, Sensors (2010) 2946-2956
[3] Y. Matsumoto, X. Arouette, T. Ninomiya, Y. Okayama and N. Miki, Vibrational braille code display with MEMS-based hydraulic dispcaement amplification mechanism, Micro Electro Mechanical Systems (MEMS), IEEE 23rd International Conference (2010) 19-22

Figures used in the abstract

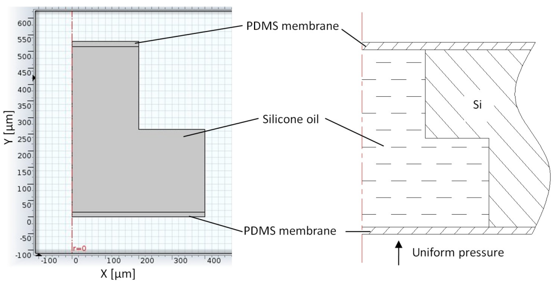

Figure 1: 2D-Axisymmetric cross section view in Comsol (right) and schematic (left) of FS displacement amplifier

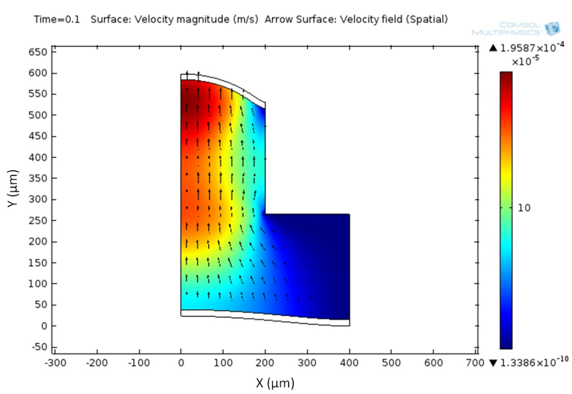

Figure 2: Fluid motion inside the chamber of amplifier with 10KPa pressure applied

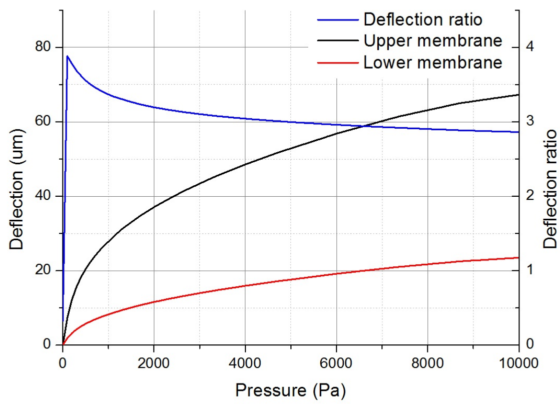

Figure 3: Deflection ratio and deflection of membranes versus pressure

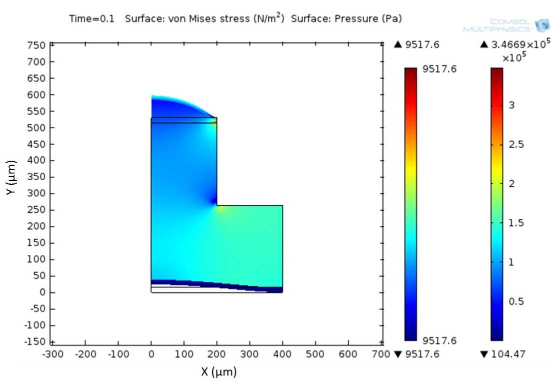

Figure 4: Pressure distribution in the amplifier