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Single-Layer Microfluidic Current Source via Optofluidic Lithography

In the project, we were attempting to use in-situ photopolymerization to create single-layer microfluidic devices which serve as ultra-low Reynolds Number (Re) current sources. The goal of such application is to regulate the desired fluid flow rate independently from operating pressures. In order to make majority of the existing fluidic applications to perform optimally, specific pressure and/or flow rate conditions are required in different situation. In our project, we designed and tested multiple single-layer microfluidic current devices which are combinations of springs and pistions systems. The device is a channel made with poly-dimethylsiloxane(PDMS) and undergoes a soft-lithography process. The spring and piston are fabricated through photo sensitive liquids under explosion of UV light (as shown in figure 1)– to passively constrain fluid flow rate to a value independent of operating pressure. The device consists of a freely-moving piston mounted to a spring which moves in and out of a narrow microchannel according to pressure and shear hydrodynamic forces exerted on it. The motion of the piston enables a negative feedback system to take place in the current source; so that the device functions as a current source and is independent of flow rate.

The device itself is an application of Pouseuille's Law. Poiseuille's Law states that, for low Re systems, flow rate (Q) is proportional to pressure drop (ΔP) divided by hydrodynamic resistance R. In the case of smooth flow, the volume flowrate is given by the pressure difference divided by the viscous resistance. (as shown in Figure 2) Overall, resistance is proportional to the length of a channel (L) and its resistivity (r), a factor which is determined by the width of the channel. When the channel becomes the narrowest, the resistivity (r) is the highest. For this device, resistance is a roughly linear function, dependent only on x, the length of the piston contained within the narrow channel, along with piston resistivity (r) and parasitic resistance R0. By balancing the piston stresses (σ) with the spring restoring force (k), R(x) and Q can be determined as:

$$R(x) = R_0 + rx \qquad Q(x) = \frac{k\,x}{\sigma + r\,x}$$

These equations demonstrate that Q tends toward a flat value while the spring is free to extend, as is demonstrated by our experimental results.

Design of Transistor :

Sometimes a gain in pressure is desired to operate a microfluidic device that requires a larger fluid pressure than the supplied fluid pressure. The gain in pressure (P) is accomplished by having a larger gain piston (g) area (A) and a smaller source piston (s) area in the channel (Figure 3). The change in pressure make our design a transistor.

Piston net force F = PgAg – PsAs. We connect exhaust to atmosphere (Pe = 1 atm) and derive the gain to be approximate: Gain ≈ Ps/Pg = Ag/As

Modified transducer:

In order to make a microfluidic device with a gain operate, a channel is introduced from source to drain. The design is based on the gain mechanism which can be approximated by Gain ≈ PsPg . Pressure at the right side of piston is roughly Ps and the exhausts are connected to atmosphere. We tested the flow rate versus Ps by sweeping Pg values. The device operates properly for about 200mbar. The medium value of pressures at which the device operates is chosen to be Ps value with the specific Pg.

This semester, I also worked on modifying the opening and closing gate of the device. It has been proved that in order for the gate to work properly, it is critical for the length and thickness of the connector to be in appropriate shape. The ability of the gate to recover after no pressure is applied depends on the strength of the connector as well. Overall, the connectors with 350um in length and 40 in thickness works the best, as shown in fig 4.

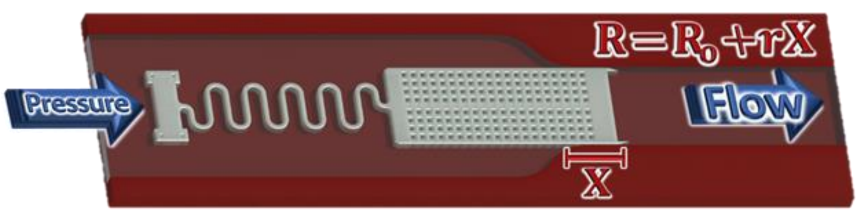

Figure 1

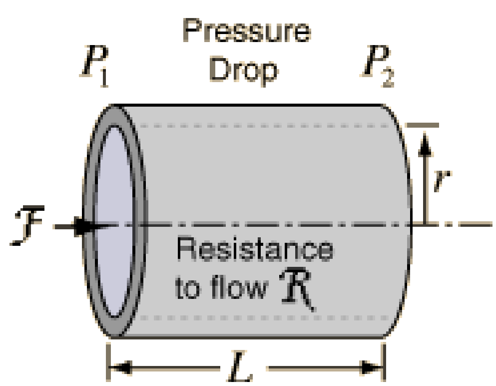

figure 2

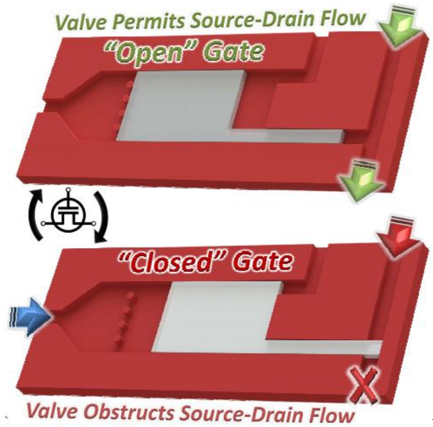

Figure 3

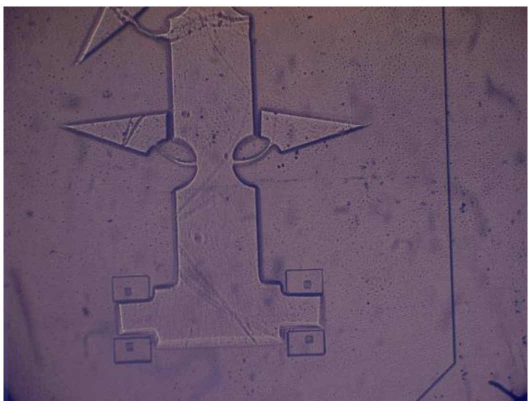
Figure 4