On-Chip Cell Transportation and Rotation Using Vibration-Induced Flow

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Primary CNF Tools Used: ABM Contact Aligner, Heidelberg Mask Writer - DWL2000, Dicing Saw - DISCO, P7 Profilometer

Abstract:

We present a system for cell manipulation based on vibration-induced flow (VIF), the science of acoustic streaming generated around the microstructure on a chip using circular vibration. This technique is easy to handle and applicable to an open-surface chip structure. It is a simple method involving a chip on an XY piezoelectric stage and is known for its simplicity. Thus, large cells can be manipulated by the applied flow velocity in the order of 100 .m/s close to the micropillar arrays. We designed the micropillar array to control the mouse oocytes' transportation, rotation, and manipulation. The induced flow around the micropillars can be controlled by the applied frequency, amplitude, and shape/arrangement of the micropillar structure.

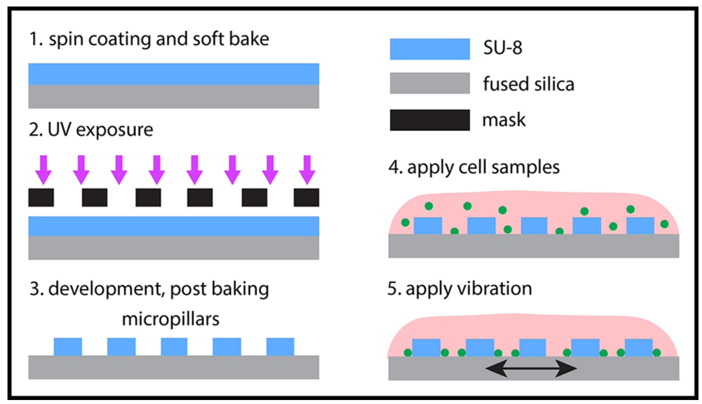

Figure 1: Schematic of fabrication process and experiment procedure.

Summary of Research:

Recent advances in micro/nanofabrication and microfluidics have improved the manipulation of small biological objects, such as cells or microorganisms [1]. We present a transportation method based on vibration-induced flow (VIF) to move the mouse oocytes through the micropillar arrays on the open surface chip [2]. This chip is a candidate for being simple, low-cost, and easy to use, while offering accessible (open-structured) microfluidic channels for cell pickup. As shown in Figure 1, we fabricated the micropillars with a one-step photolithography process. First, SU-8 100 was poured on a fused silica wafer with a thickness of 500 μm and spun at 1500 rpm for 30 seconds. Next, the wafer was baked for 25 minutes at 65°C and for 70 minutes at 95°C. Then we exposed the baked wafer to UV light for one minute with an ABM contact aligner, followed by post-exposure baking at 95°C for 20 minutes. Finally, we submerged the wafer in SU-8 developer for 17 minutes before hard baking. The pillars' thickness was 200 μm, as measured by P7 Profilometer. Subsequently, the chips were separated using Dicing Saw DISCO, and a photograph of one of the chips is shown in Figure 2a. We fixed the chip on the XY piezoelectric stage. We generated the circular vibration with two sinusoidal wave signals with 90 . offset in phase to the piezo driver via the waveform generator. The applied frequency and voltage were 200 Hz and 1 V, respectively. A culture medium containing mouse oocytes was directly dropped onto the chip (Figure 2b).

Figure 2c shows the concept of transporting and trapping cells into the center of the chip. By applying a circular vibration, a whirling flow is induced around each pillar, and since the pillars' pitch is designed to interfere with each other, a whirling flow is induced through the micropillar array. Since this system has enough power to generate fluid force to manipulate large cells, we can move the cells to any desired destination by adjusting the micropillar array and the distance between each pillar. For example, we fabricated the arrays in a spiral pattern to gather the mouse oocyte cells to the center of the chip. As a result, this technique can be utilized for flow control and cell transportation on an open-surface chip for any type of cell.

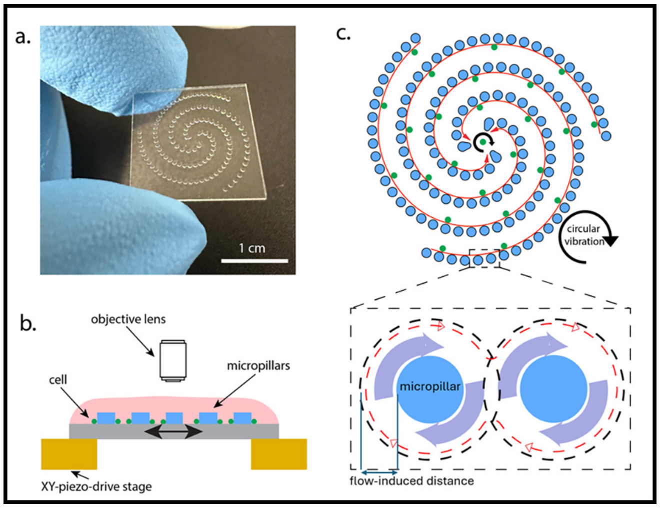

Figure 2: a. Photograph of the fabricated chip. b. Schematic of experimental setup. c. Concept of cell transportation using vibration-induced flow.

Conclusion:

We experimentally investigated the effect of VIF on mouse oocyte transportation and manipulation. Cells can be extracted easily since the chip has easy access to an external environment. Therefore, an operator can detect the cells with their eyes, collecting them with microinjectors, and there is no worry of losing the cells on the chip.

References:

[1] Reyes, D. R., Iossifidis, D., Auroux, P.-A. & Manz, A. Micro total analysis systems. 1. Introduction, theory, and technology. Anal. Chem. 74, 2623-2636 (2002).

[2] Hayakawa, T., Sakuma, S. & Arai, F. On-chip 3D rotation of oocyte based on a vibration-induced local whirling flow. Microsystems & Nanoengineering 1, 1-9 (2015).