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Development of a Microfluidic Device for Low-Volume Sample Lysis

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Abstract : We developed a microchip device that uses surface acoustic waves for rapid lysis of low level of cell samples. The device incorporates sharp-edge glass microparticles for improved performance. We optimized the lysis conditions for high efficiency and evaluated the device's feasibility for point-of-care applications. The microchip contains a 13-finger pair interdigital transducer with a 30-degree focused angle. It generates high-intensity acoustic beams that converge 6 mm away. The microchip operates at a frequency of 16 MHz, exciting Rayleigh waves with a 250 µm wavelength on the LiNbO3 substrate. Cell lysis occurs when Candida albicans cells and glass particles are placed within the focal area. The high-intensity surface acoustic waves induce centrifugal forces on the cells and glass particles, resulting in cell lysis through lateral forces from the sharp-edge glass particles. We conducted 42 pilot cell lysis experiments to optimize the surface acoustic wave-induced streaming. We varied electrical power, droplet volume, glass particle size, concentration, and lysis time. A regression machine-learning model determined the impact of each parameter on lysis efficiency. Based on these findings, we predicted optimal conditions: electrical signal of 2.5 W, sample volume of 20 µl, glass particle size below 10 µm, concentration of 0.2 µg, and a 5-minute lysis period. Downstream analysis successfully amplified a DNA target fragment directly from the lysate. The study presents an efficient microchip-based cell lysis method employing acoustic streaming and microparticle collisions within microdroplets. Integration of a surface acoustic wave-based lysis chip with an isothermal amplification method enables swift point-of-care applications.

Keywords : cell lysis, surface acoustic wave, micro-glass particle, droplet
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