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Microfluidic low-cost devices for Mars-sample handling by ultrasounds

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Abstract

Application of ultrasounds on microfluidic devices present certain advantages to perform handling and sorting of small samples in suspensions and aerosols, They drive each single particle toward certain positions of acoustic equilibrium where remain stable and can be delivered separated from their host sample. This work presents low cost chips to perform particle sorting, fixation or clustering.

1. Introduction

A capillary attached to a piezoelectric actuator is able to perform a free-label particle handling by the action of the ultrasounds at frequencies close to 1MHz. The principle of operation is based on the establishment of a standing wave generating a radiation force to push the particles toward a location of equilibrium inside a cavity (channel) at a frequency f=1153kHz, at which the capillary cavity behaves as a half-wavelength 2D resonator. This force is described by equation (1) (Gor'kov [1]), assuming the particle with volume V_p, density (ρ_p) and compressibility (β_p), much smaller than the wavelength of the incident wave, λ, applied with a pressure amplitude P_0 on a liquid with density ρ_l and compressibility β_l:

$$FR = -\frac{\pi P_0^{2} V_p \beta_l}{2\lambda}\phi(\beta,\rho)\sin\left(\frac{4\pi x}{\lambda}\right) \qquad (1)$$

where $\phi(\beta,\rho) = \frac{5\rho_p - 2\rho_0}{2\rho_p + 2\rho_0} - \frac{\beta_p}{\beta_0}$ is known as the acoustic contrast factor. It defines the particle collection at the pressure nodes (for $\phi>0$) or the antinodes of acoustic pressure (for $\phi<0$). The radiation force is directly proportional to the particle volume (cubic power of spherical particle radii). Therefore, slight variations in the particle size give rise to strongly different values of the radiation force. This effect is used to carry out differentiated particle collection and enrichment, with applications of particle sorting or separation.

2. Ultrasonic devices for the particle handling

A glass capillary with inner square cross section (700µmx700µm) is attached to a pz26 piezoelectric square plate (30mmx30mm) (Figure 1).

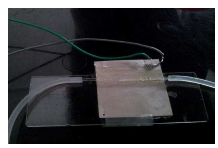
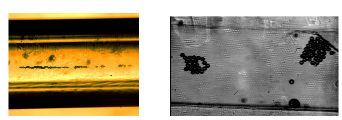


Figure 1. Acoustic device including a glass capillary attached on a piezoelectric pz26 ceramic.

Dilute aqueous suspensions of polystyrene particles (diameters of 6um and 20um) were used in the experiments. Driven by the radiation force the particles collect at the pressure node locations, established along the central axis of the capillary at f=1153kHz (Fig 2.a), and at other positions varying slightly the acoustic frequency (Fig 2.b). They remain fixed at these positions during the acoustic application.



(a) (b)

Figure 2: particle collection at P=0 established along the central axis at f=1153kHz (a) and close to the sidewalls at f=1020kHz (b)

Polymeric chips implemented by ultrasonic actuators have been developed by the authors to perform particle separation [2]. They are low cost devices able to achieve very high efficiencies of actuation with inorganic samples. Figure 3 shows one of these chips, which includes an upper layer of SU-8 including a channel along which the samples flow over a PMMA substrate with a thickness approximately three times higher.

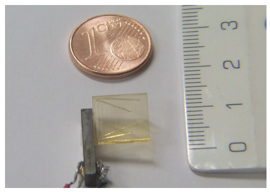


Figure 3: a polymeric chip with a piezoelectric ceramic attached to its lateral edge

The device is a lab-on-a-chip that comprises a technological advantage since it uses a polymer as its constitutive material instead of other more rigid material used in conventional devices for ultrasonic micromanipulation [3]. The chip behaves as a multilayer system resonating at frequencies close to 1MHz. A strategic combination of the widths of the layers (taking into account their relationship with the acoustic wavelength) allows the establishment of a node of pressure inside the channel at a desired location. Separation, sorting or other applications define such a position and the number of outlets for the differently sized particle delivery.

These devices have been also used to perform tumor cell extraction processes from peripheral blood samples as an early diagnosis method [3], based in a mass transfer between two media flowing in parallel along the channel of treatment. The Radiation Force exerted on epithelial cells (whose diameter is approximately 20 microns) is larger than that on experience by the leukocytes (8-12um),

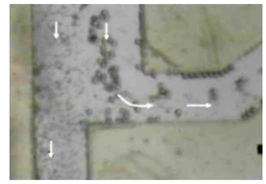


Figure 3: The 20um-sized particles leave the chip separated from 6um- particles, through different outlets

6. Summary and Conclusions

Application of these devices to perform particle handling in Mars or other planetary missions is evidenced, either for particle sorting or, on the contrary, to fix some samples at certain positions.

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