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Ultrasounds for Regolith and dust particles manipulation

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Abstract

1. Manipulation of dust particles or regolith with variable sizes is a challenge in microgravity or different gravity conditions than Earth. Rovers and sensors payloaded are subjected to the impact of micron-sized particles, which frequently remain adhered to their surfaces, generating or even inhibiting part of their functionality. Noninvasive techniques can be applied on these elements to prevent particle aggregation and sometimes blinding effects. Application of acoustic waves on these surfaces allow removal of the settled particles as a cleaning "mechanisms", preventing their loss in efficiency or, even, disabling.

2. Introduction

Acoustic chamber resonators generate a standing waves with pressure patterning including nodes. Inside the chamber resonating each particle, with a volume V_c much smaller than the acoustic wavelength λ, experiences a primary acoustic radiation generated by the acoustic standing wave with amplitude P_0 according to its specific properties [40] (Gor'kov 1962):

$$FR_c = \frac{\pi P_0^2 V_c \beta_l}{2\lambda} \varphi(\rho_c, \beta_c, \rho_l, \beta_l) \sin\left(\frac{4\pi x}{\lambda}\right) \quad (1)$$

where $\varphi(\rho_c, \beta_c, \rho_l, \beta_l) = \frac{5\rho_c - 2\rho_l}{2\rho_c + \rho_l} - \frac{\beta_c}{\beta_l}$ is the acoustic contrast factor. It defines the relationship between the densities and adiabatic compressibilities of both, cells (ρ_c, β_c,) and liquid (ρ_l and β_l) respectively. The distance from the cell to the node of pressure established inside the channel is defined by "*x*". The sign of φ indicates the motion of the particles, either toward the nodes ($\varphi > 0$) or to the antinodes in the standing wave ($\varphi < 0$) respectively.

Figure 1 shows three equal beads approaching from three different distances toward a pressure node in a standing wave established inside a micfoluidic channel during the flow motion.

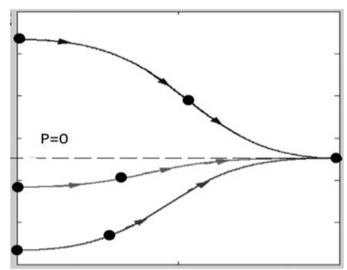

Figure 1. Numerical estimate (Matlab) of trajectories of three equal particles approaching a pressure node from different initial positions while circulating in a transverse direction.

The time required by the cells to reach a certain position "x" driven by the acoustic radiation force from any distance inside the resonating cavity can be numerically derived from Equation (1) as a function of all the parameters involved in this equation:

$$t = \frac{3\eta}{4\Phi(k R_c^2) E_{ac}} \ln\left[\frac{\tan[k \cdot x(t)]}{\tan[k \cdot x(0)]}\right] \quad (2)$$

It is possible to perform particle-size or density-based sorting of Lunar Regolith and dust in other planetary atmospheres using ultrasonic standing waves. Instead of particle-size sorting systems of Lunar & Mars Regolith using electrostatic or magnetic fields (Adachi et al in 2016 [1,2], we have developed different strategies for particle sorting based on the use of ultrasounds in microfluidic resonators and plate vibration systems respectively [YYY-ZZZ]. Our devices, tested on Ground, have demonstrated the ability of the ultrasounds to perform particle and cell separation and isolation.

These devices have also shown a high efficiency on the isolation of tumor cells as liquid biopsies.. Figure 2 shows the scheme of operation of our ultrasonic particle sorters.

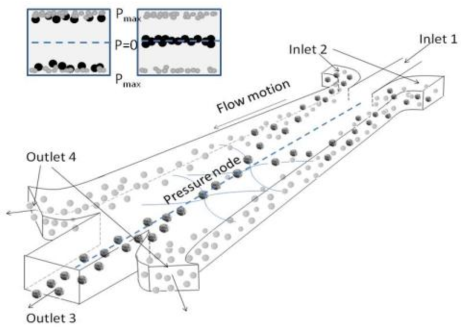

Figure 2: principle of operation of our ultrasonic particle separators.

The use of acoustic standing waves for particle manipulation can address this problem, as widely experimentally verified on Ground [3-5].

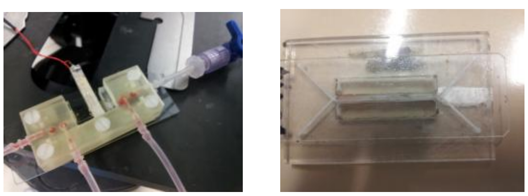

Figure 3: some of our chips for particle and cell manipulation

The efficiency of the acoustic waves to drive the particles depends also on the particle concentration as they influence the medium properties, efficiency also depends on the concentration of particles since they influence the properties of the medium, the more the greater their presence. A limit case is the grain matter, where other principles apply. Thus the importance of preventing settling down of large amounts of particles on surfaces exposed to the action of the particles impact. Therefore, the development of new methodologies to overcome these accumulation and clogging particle effects at different gravity conditions (including microgravity) is a challenge. The efficiency to remove the particles also depends on their concentration since they influence the properties of the medium: the greater their presence, the less fluid. In the limit case of regolith with a compacted grain matter and minimal interstitial spaces, another principle associated to the acoustics must be considered for the particle manipulation rather than the acoustic radiation force exerted through the fluid, and nonlinear or shock low frequency waves should be applied for the bulk grain motion by means of a shake of the grain matter.

Acknowledgements

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