SEPARATION OF DEFORMABLE HYDROGEL MICROPARTICLES IN DETERMINISTIC LATERAL DISPLACEMENT DEVICES

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ABSTRACT

To better understand how deformable and non-spherical particles behave in sorting devices based on deterministic lateral displacement we generate models of biological particles with tunable size, shape and mechanical properties using stop-flow lithography and we explore how these parameters play a role in our separation devices.

Hollow and solid cylinders are compared with respect to their deformability and their overall behavior in the device. Future work will expand the approach to a range of particle shapes and to particles with varied hydrogel composition to independently control the mechanical properties of the material.

KEYWORDS
Deformability, hydrogels, deterministic lateral displacement, separation.

INTRODUCTION

Classification of biological and non-biological particles is of paramount importance in many fields of research and industry including biology, medicine and tissue engineering .Common criteria in label-free separation are usually the size, shape and mechanical properties of particles. So far, deterministic lateral displacement (DLD) devices have shown superior resolution in sorting based on size [1], but also much promise for shape [2] and deformability [3] based separation. In DLD devices, the trajectories of particles through arrays of obstacles are determined by the effective size of the particles (figure 2a) which in turn depends on orientation of non-spherical particles and on deformation for soft particles. To understand how exactly these parameters act together is a complex problem and not fully understood. Our objective is to gain further understanding about our previous experimental results [2, 3].

EXPERIMENT

In stop-flow lithography (SFL) [4] an aqueous solution, consisting of polyethylene glycol (PEG), photo-activator and rhodamine B is polymerized in a microfluidic channel by UV illumination through a photomask (figure 1a). We fabricated particles with a variety of shapes and sizes in range 10-16μm and tested them in a DLD device, designed to separate particles with diameters in the range of 9-21 μm. In one part of experiments we looked at the deformation of different shaped and sized particles near the posts at various shear rates. We also compared the distribution of these particles near the exit of the array to gain information about their effective sizes.

CONCLUSION

Figure 1b-g shows both hollow and solid cylinders with outer diameters of 16 μm and lengths of 11μm, fabricated using SFL. Despite having the same outer dimensions, image analysis revealed different behaviors of these two types of particles, as plotted in figure 2c-d. By varying the applied pressure we change the shear forces deforming the particles, which in turn changes their effective sizes. This is measured by observing the resulting lateral displacement of each particle at the exit of the device. In the case of solid cylinders, they showed a constant peak in distribution in lateral displacement of 15 gaps for all applied pressures up to 1 bar. The first peak near zero displacement is due to small debris present in the sample. Hollow particles on the other hand show no displacement - in effect they behave as if they are smaller than the solid cylinders. This difference in distribution (and effective size) can be explained by the greater deformability of the hollow cylinders.

Figure 2b shows a hollow (square) cylinder deforming as it moves past a post. The applied pressure is 200 *mbar* corresponding to the velocity of 7.2 *mm/s*. The hallow-structured particle rotates with the angle of about $\pi/2$ as it passes near a post. At very low applied pressures, when no deformation was observable for hollow particles, they rotated at higher angles (not shown here). On the other hand, even at the highest pressure differential, solid-structured particles despite rotating at high angles (as in the case of hollow particles at low pressures) did not reveal any detectable deformation. This difference in the behavior of hollow and solid particles confirms their different distribution in the DLD array.

In future experiments, detailed analysis of different behavior of hollow and solid structures as well as comparing the results of experiments with the simulations are necessary to gain further knowledge of the rotation and deformation of soft non-spherical particles in the DLD device. An interesting factor to investigate is the influence of the aspect ratio of the particles in their rotation and deformation behavior. Moreover, the deformability rate of these particles can be measured in DLD devices with various depths.

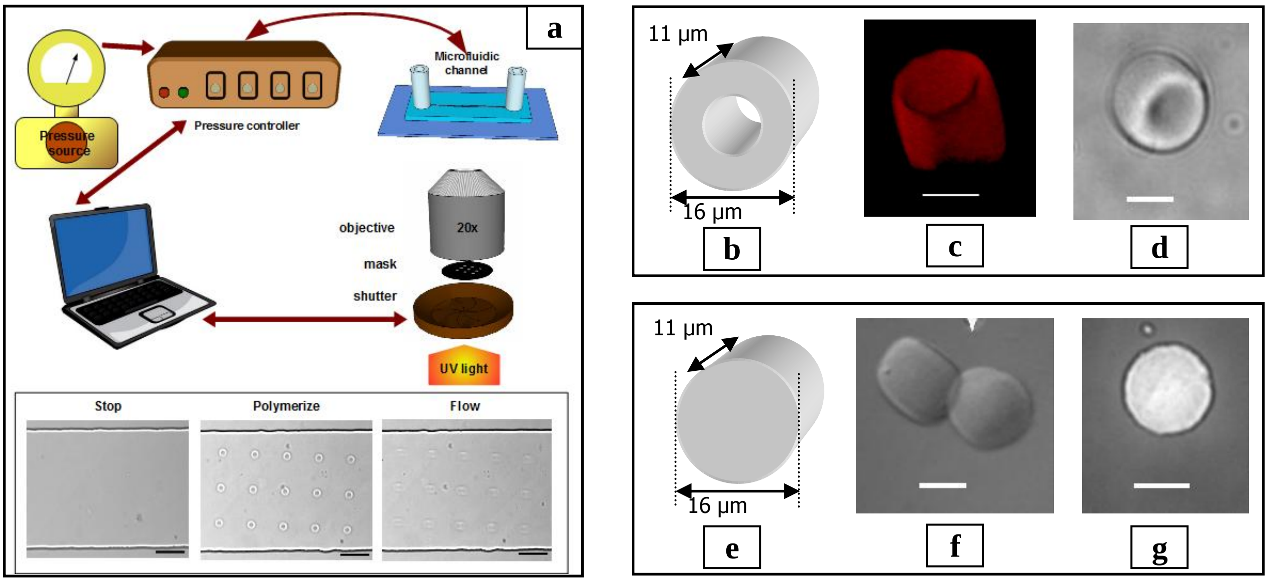

Figure 1.(a) Basic principle of SFL: a monomer solution is polymerized into shapes defined a photomask upon illumination by UV light in stop-polymerize-flow cycles. Scale bars in (a) are 50 µm. (b) Schematic, (c) confocal and (d) fluorescence images of hollow cylinders. (e) Schematic, (f) DIC and (g) fluorescence images of solid cylinders. Scale bars in (b)-(g) are 10 µm.

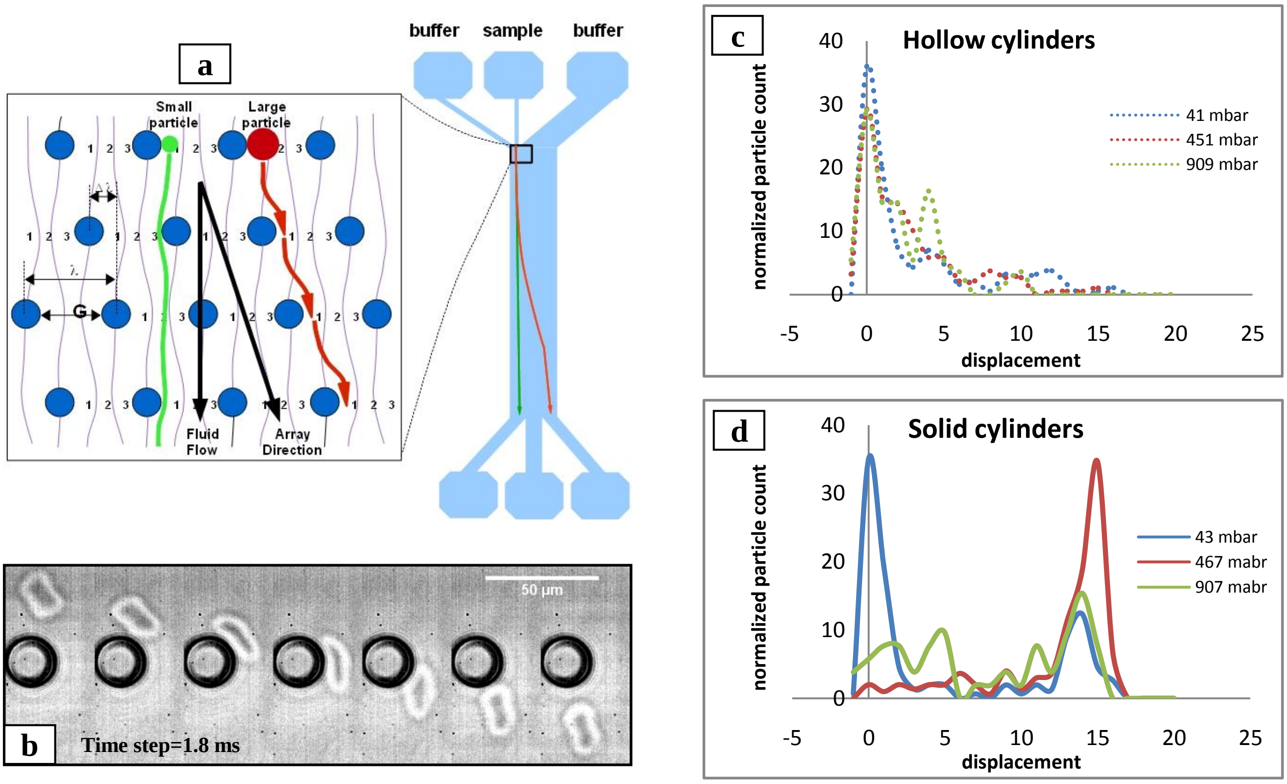

Figure 2. (a) Basic principle of DLD. Particles follow specific trajectories based on their effective size in a DLD. Particles with size greater than a critical size are deflected whereas smaller particles follow the flow. (b) Consecutive images of a polymeric particle (a hollow square cylinder, 13 µm outer dimensions) being deformed as it passes around a post in a DLD device. Normalized particle counts versus gap number (reflecting the amount of displacement and thus the effective particle sizes) for hollow cylinders (c) and solid cylinders (d).

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