DETERMINISTIC LATERAL DISPLACEMENT *VIA* SELF-ASSEMBLY-BASED HEXAGONALLY ARRANGED TRIANGULAR POSTS

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ABSTRACT

Deterministic lateral displacement (DLD) is a microfluidic micro/nanopost array-based technique for size-based particle separations. A key challenge in scaling DLD for handling smaller particles is that creating such "nanoDLD" arrays can be cost-intensive with substantial technical hurdles. To circumvent such issues, here we explore a new "hexagonally arranged triangles (HAT)" DLD geometry that is based on patterns associated with nanosphere lithography (NSL). Finite element simulations and preliminary experiments with 0.86 µm and 4.7 µm particles suggest effective separation capabilities of the HAT-DLD approach, marking an important first step toward new classes of nanoDLD arrays fabricated through bottom-up, self-assembly-based NSL.

KEYWORDS: Deterministic Lateral Displacement, Nanosphere Lithography, Self-Assembly, Particles

INTRODUCTION

Since the first report of DLD [1], researchers have extended the approach to achieve passive microfluidic separations of a wide range of particles, including recent efforts for separating extracellular vesicles using nanoDLD arrays [2, 3]. Unfortunately, manufacturing such arrays typically relies on high-cost, low-throughput methods such as electron-beam lithography. Thus, here we evaluate the potential to leverage patterns associated with bottom-up, self-assembly techniques, such as NSL, to enable nanoDLD arrays capable of size-based particle separations.

THEORY

The HAT-DLD pattern is based on the triangle-shaped interstitial spacing between hexagonally packed spheres that can be realized using NSL to produce DLD arrays with triangular posts (**Fig. 1A-C**). The HAT array geometry

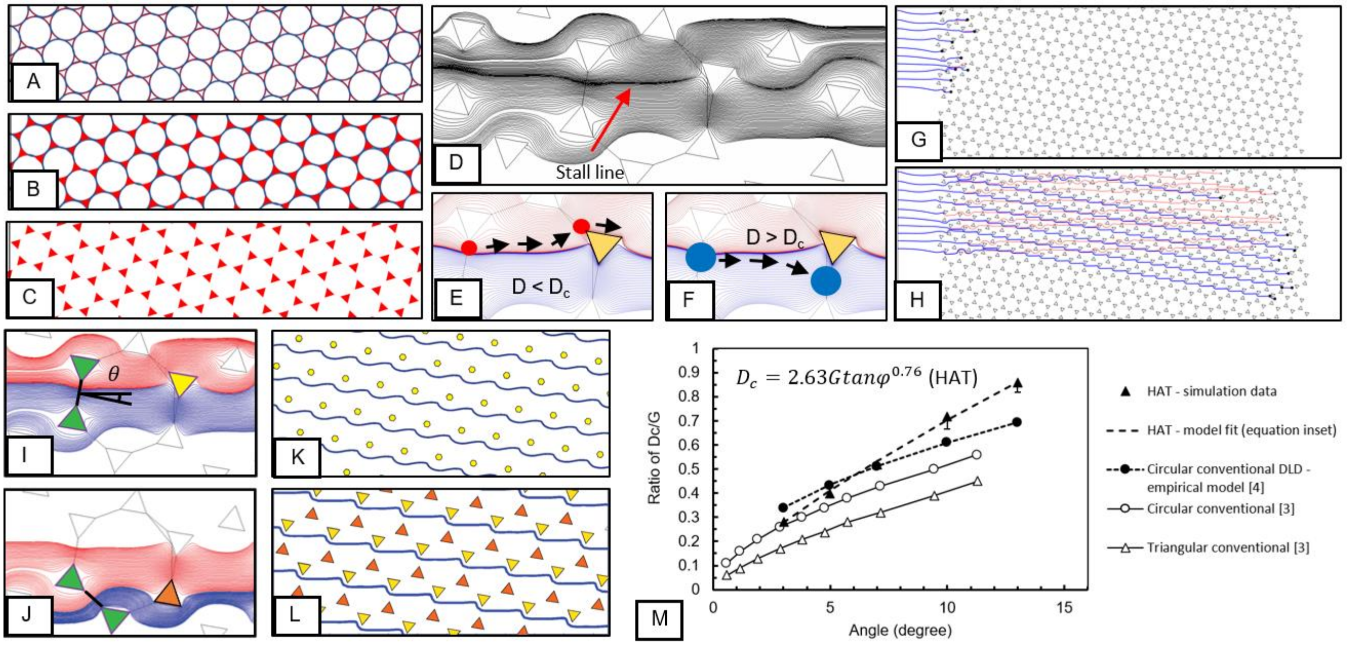

Figure 1: HAT array design and DLD simulation. (A) Single layer NSL. (B) Gaps filled through deposition process. (C) Templating nanospheres removed giving HAT pattern. (D) Streamline analysis on HAT arrays. (E) Smaller particle trajectory. (F) Larger particle trajectory. (G, H) Particle tracing implemented at channel (G) start and (H) end. (I, J) Stall line ending on (I) "downward directed" and (J) "upward directed" posts. (K, L) Displacement mode travel takes place on (K) every row in conventional DLD and (L) alternate rows in HAT array. (M) Comparing sorting characteristics to literature.

is markedly different from existing parallelogram and rotated-square type DLD arrays as the triangles of the HAT array are rotated 60° relative to each other *versus* maintaining constant orientation with respect to the flow stream. Theoretical analysis of HAT particle separation was conducted using COMSOL Multiphysics®. Streamline analysis (**Fig. 1D**) was used to determine array critical diameter (D_c) (**Fig. 1E, F**). The "particle tracing" module was then implemented to verify the separation of particles with $D>D_c$ and $D<D_c$ as they traverse the channel (**Fig. 1G, H**).

EXPERIMENTAL

The proof-of-concept DLD device with a critical diameter of 3.2 μm was fabricated by adapting our previously reported protocols for using "direct laser writing" to print a negative master mold [4], and then replicating the pattern using polydimethylsiloxane (PDMS). Two sizes of fluorescent particles, 0.86 μm (red) and 4.7 μm (green), suspended in DI water and 3% Tween 20, were used for experimental validation through fluorescence imaging.

RESULTS AND DISCUSSION

Simulation and experimental results confirm the size-based particle separation ability of HAT arrays. A unique feature of the HAT geometry is the existence of two orientations of triangular posts in the flow stream. Stall lines ending on "downward directed" posts pass through triangular posts aligned perpendicular to the array angle (**Fig. 1I**), promoting particle separation. In contrast, stall lines ending on "upward directed" posts pass through post gaps not aligned with the array angle (**Fig. 1J**) and do not promote particle separation. Consequently, unlike conventional DLD posts where any row causes larger particles to travel in bump mode (**Fig. 1K)**, in HAT arrays, only alternate rows of posts induce bump mode travel (**Fig. 1L)**. **Fig. 1M** compares theoretical results for HAT D_c/G *vs.* array angle with experimental data from [5] for circular and triangular posts and the well-known empirical model for circular-post DLD arrays [6]. The results indicate favorable Dc/G ratios for HAT arrays compared to conventional DLD, especially at small array angles. Images of the particle streams show both particles mixed at the beginning of the DLD network (**Fig. 2A**) By the end of the channel the larger particles (green) have separated from the smaller particles (red) to a different stream (**Fig. 2B**) validating the functionality of this design.

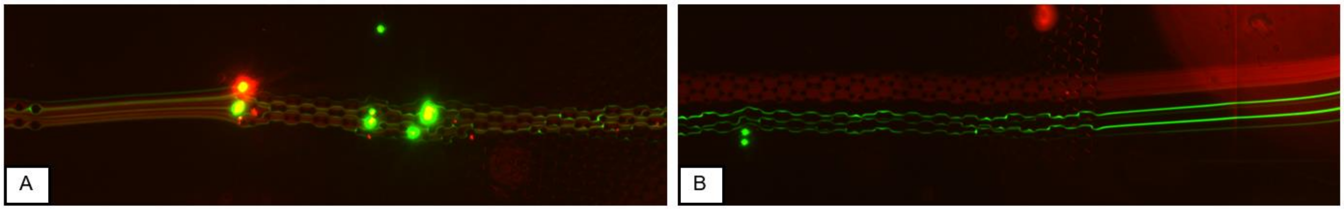

Figure 2: Experimental results for HAT-DLD particle separations with 0.86 μm (red) and 4.7 μm (green) diameter particles. (A) Particles are mixed at the start of the array. (B) Larger particles (green) exhibit separate flow streams at the array's end.

CONCLUSION

Theoretical and experimental analysis of HAT arrays demonstrate size-based DLD particle sorting ability. The results provide a strong basis for future implementation of low-cost, bottom-up templated nanoDLD systems.

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REFERENCES

[1] L. R. Huang et al., *Science*, 304 (2004), pp. 987–990.
[2] B. H. Wunsch et al., *Nature Nanotech*, 11 (2016).
[3] J. T. Smith et al., *Lab Chip*, 18 (2018), pp. 3913–3925.
[4] A. T. Alsharhan et al., Journal of Microelectromechanical Systems, 29 (2020), pp. 906–911.
[5] K. Loutherback et al., *Microfluid Nanofluid*, 9 (2010), pp. 1143–1149.
[6] D. W. Inglis et al., *Lab Chip*, 6 (2006), pp. 655–658.

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