High Aspect Ratio, Triangular Silicon Pillars for Bump Array Concentration of Pathogenic Bacteria

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High-resolution, continuous-flow particle separations using deterministic lateral displacement (Bump Array) have been successfully applied to a wide range of spherical objects using microfabricated post arrays. Separations include the sorting of 100nm and 200nm fluorescent beads in nanoimprinted devices[1] to the fractionation of whole blood (1um-30um size range) in devices made with standard photolithography[2]. Recently it has been shown that triangular posts can break the symmetry of the Poiseuille flow profile between posts, resulting in more efficient separations and increased flowrates[3]. Here we demonstrate precise high aspect ratio silicon micromachining of triangular shaped pillars with well controlled spacing and show on-chip concentration of rod-shaped, pathogenic bacteria species such as *E. coli and Listeria M.* for applications in rapid diagnostics.

We fabricated high aspect ratio silicon pillar arrays by deep reactive ion etching and oxidation narrowing. As target bacteria flow through the asymmetric array they are displaced laterally at each pillar relative to the flow direction and are concentrated to the device edge for collection and downstream analysis. The size specific separation relies critically on the gap between the pillars, G. We tailored the silicon pillar etch to ensure smooth, vertical sidewalls and an equidistant gap spacing between the triangle tip and the flat base of the adjacent pillar to the full device depth. We also used a simple conformal thermal oxidation (table-top oven at 1000°C, in atmosphere) of the silicon pillars to further reduce the pillar spacing with nanometric control and tunability (Figure 2a.). Microfluidic devices were then tested with live, labeled bacteria species using a fluorescent microscope and CCD camera to track cell trajectories and bacteria concentration efficiencies (Fig. 2b.).

Using precision deep silicon etching along with oxidation narrowing we have demonstrated on-chip concentration of rod-shaped pathogenic bacteria species that are increasingly important targets for applications in rapid diagnostics.

[1] K.Morton, O.Tsui, C.Tung, J.Sturm, S.Y.Chou, and R.Austin. New J. Phys. 12, 085008 (2010).
[2] K.Morton, D.Inglis, K.Loutherback, O.Tsui, J.Sturm, SY.Chou and R.Austin, PNAS, May 2008
[3] K.Loutherback, *et.al.* Micro and Nanofludics, 9, 6, May 2010

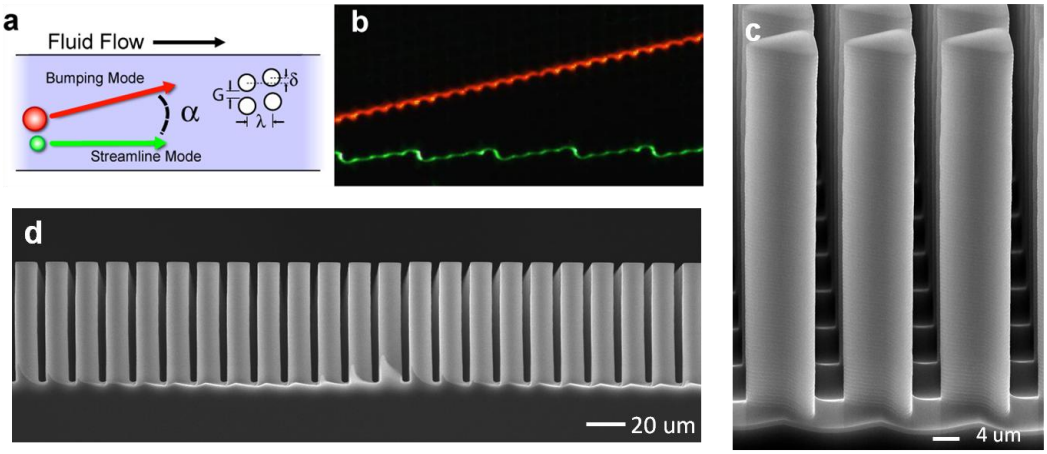

Figure 1: The Bump Array: a) Schematic of bump array function showing circularly shaped pillars and array design parameters, such as the pillar spacing, G, the array angle, α, and the pitch, λ. b) Time exposure of suspended fluorescent beads flowing though a bump array: Larger particles (red) track along the array axis at an angle and smaller particles (green) zig-zag between the posts following local flow around the posts, but matching the overall direction of the flow through the device. c,d) SEM images of triangular shaped pillars etched into silicon using optimized DRIE to maintain sidewall smoothness and uniform gap distance to ensure consistent separation efficiency. Triangular pillar shapes and device depths were chosen to maximize volume flowrate.

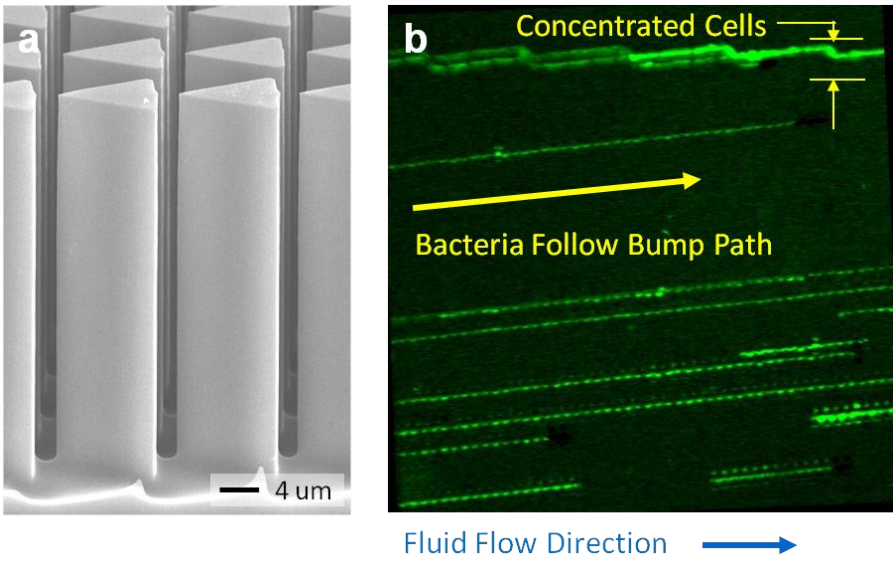

Figure 2: a) SEM image of 40um tall, gap-narrowed triangular pillars with sub 2um tip to base spacing c,d) Video frame sum showing fluorescently labelled bacteria tracking and concentration in the bump array mode.