Supplementary Information

Controlling the Spatio-temporal Transport of Particles in Fluid-filled Microchambers

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Analyzing the formation of four particle-islands in a square domain

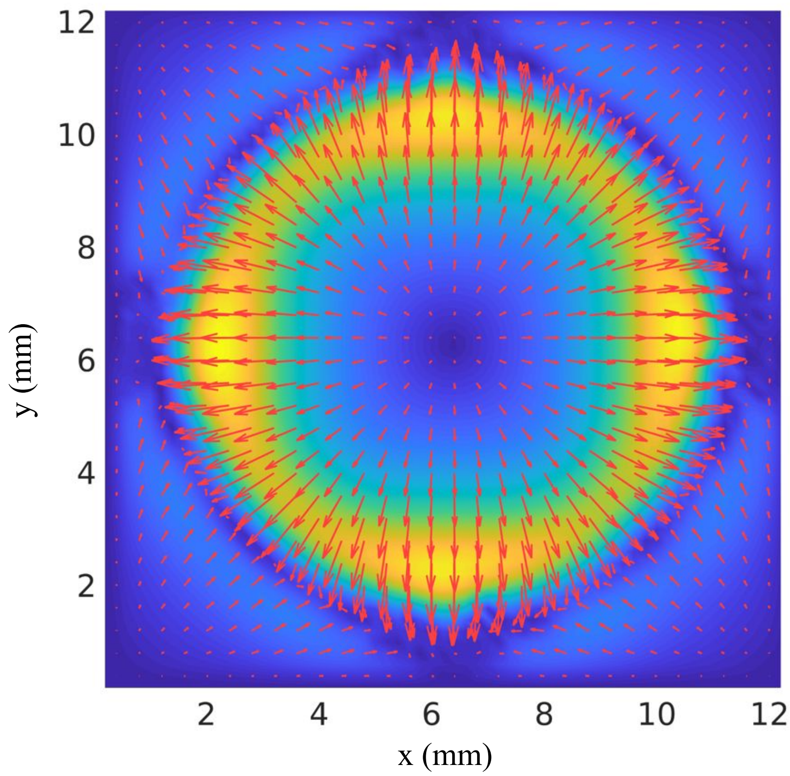

Figure SI1. Formation of secondary vortices at the corners of the chamber. The generation of H_2O_2 at the center of the chamber and the position of the catalase patch away from the center creates secondary fluid vortices. These vortices are strongest at the corner of the chamber, where three walls meet, and essentially non-existent in the middle of an edge, where the bottom surface meets with a sidewall. The background color indicates the speed of the fluid velocity; blue represents regions with slow velocity and brighter colors represent regions with higher velocity.

To initiate the cascade reaction, glucose is added to the solution. The central GOx-coated patch catalyzes the decomposition of this reactant into lighter products (gluconic acid and H_2O_2).

The latter reaction generates an inward flow, which moves the fluid toward the central region along the bottom wall and thus causes the particles to localize into this central domain. A fraction of the generated H_2O_2 moves radially outward from the center, going from a high concentration to a lower concentration at the edges of the square simulation box. As H_2O_2 reaches the catalase-coated domain, it activates the catalytic decomposition of the H_2O_2 into light products (water and oxygen). Since the H_2O_2 encounters the inner circular edge of the CAT-coated region before the CAT at the corners of the domain, the catalytic reaction generates a second inward flow at the circular edge where the lighter product-rich fluid rises upward, and circulates back toward this edge on the bottom surface. As the initial input of glucose is depleted, this second inward flow effectively drives the particles away from the center and toward the edges of the box.

This second inward flow, however, exhibits different flow profiles along different azimuthal angles. Namely, the corners of the cubic simulation box are bound by two side walls, as well as the top and bottom surfaces. Away from the corners, the edges of the box are bounded by the just the top and bottom surfaces. This structural difference leads to differences in the flow profiles within the cubic domain. In particular, the flow forms vortices at the corners that are not present along an edge. To highlight this point, we focus on the azimuthal angles θ = 0 and 45^o in a square chamber, which has four-fold rotational symmetry. In particular, consider a line from the center of the chamber (x = 6*mm*, y = 6*mm*) to the side of an edge (x =12*mm*, y = 6*mm*) along θ = 0. The horizontal component of the fluid velocities away from the center increases from zero at the center to a maximum at x = 10*mm* and then decreases to zero around x= 12*mm* (see Fig. S1). Note that the direction of the horizontal flow is always outward from the center. Now consider the line from the center of the chamber to a corner (x =12*mm*, y =12*mm*), along θ = 45^o. The horizontal velocity of the flow first increases from zero at the center to a maximum (at x = 9*mm*, y = 9*mm*), and becomes zero (at x = 10*mm*, y=10*mm*). Then the direction of the flow along θ = 45^o becomes radially inward from the corner. This change in the direction of the horizontal flow indicates the presence of a fluid vortex at the corner of the chamber. The strong flow produced by the vortices along θ = 45, 135, 225, and 315 degrees drive the particles away from the corner areas and cause the partices to form four islands at the middle regions of four edges, given by θ = 0, 90, 180, and 270 degrees with respect to the x axis.

Description of supplementary videos

SV1: Chemically-powered conveyer belt. The introduction of the reactants in a specific order activates appropriate enzymatic patches that lead to the transport of microparticles between different patches.

SV2: Cascade reactions fueling autonomous periodic transport of particles between concentric patches.

SV3: Cascade reactions fueling autonomous periodic transport of particles between distinct patches in a rectangular domain.