Electronic Supplementary Material (ESI) for Soft Matter.

Supplemental information:

Assembly and complex manipulation of colloidal particles by active thermocapillary stress

Video-1:

Video-1 describes self-assembly of *3 μm* diameter sized polystyrene micro particles at the base of the bubble due to the inward flow created by the bubble itself. As time progress, they form a complete ring at the bubble base.

Video-2:

Here we show that the bubble can be used to self-assemble different sized particles besides *3 μm,* for example *Video-2a* shows self-assembly of *1 μm* diameter sized polystyrene micro particles at the bubble base. Similarly, in *Video-2b*, we can see that relatively larger polystyrene particles of *10 μm* diameter in size can also be easily self-assembled at the base of the bubble. Notable that they can be transported controllably by the same bubble.

Video-3:

Video-3 shows another example of self-assembly by the bubble, where Streptavidin coated magnetic spherical micro particles of *3 μm* diameter are accumulated at the base of the bubble.

Video-4:

In *Video-4*, we show self-assembly of completely different types of mesoscopic particles, metallic nano and micro particles, which are very hard to capture using the conventional optical trapping mechanism due to very large scattering by those particles. *Video-4a* shows that gold micro particles of sizes *5~10 μm* are self-assembled at the bubble base, where in *Video-4b*, we can see a cluster of silver nano-particles attached to the base of the bubble. Importantly, they can be manipulated and transported controllably by the bubble here as well, which has been shown in *Video-4b*.

Video-5:

In *Video-5*, we show simultaneous accumulation and pumping at different axial positions using a single bubble with an in-plane temperature gradient (created by two laser beams focused on the bubble surface) across it. Micro-particles on the same focal plane as the image accumulate on the surface of the bubble where the flow streamlines converge, whereas those at a different axial plane (unfocused micro-particles) are pumped away.

Video-6:

Video-6 shows sorting of probe micro particles by a pair of micro-bubbles, where the left bubble is bigger than the right bubble (Size ratio ~ 2.3:1). The strength of the flow is proportional to the size of the bubble and hence the left bubble accumulates more particles than the right bubble. The separatrix is tilted towards the smaller bubble as the other one has a larger flow basin.

Video-7:

Video-7 also shows sorting of probe micro particles by a pair of micro-bubbles, where both the bubbles are almost of the same sizes. As a result, the strength of the flow is similar and they accumulate roughly the same number of particles. Here the separatrix bisects the line joining the centers of the bubbles.

Video-8:

Video-8 shows the exact opposite case of *Video-6*, where the right bubble is bigger than the left bubble (Size ratio ~ 1.75:1), and hence it accumulates more particles than the left bubble. Needless to say, the separatrix is tilted towards the left bubble in this case.

Video-9:

Video-9 shows the circular trajectory of polystyrene micro-particles in the vicinity of two bubbles grown along the same SOM pattern. The particles – which appear unfocused - are at different axial planes with respect to the focal plane of the image, and undergo opposite circular trajectories around each bubble.

Video-10:

Video-10 shows anti-clockwise movement of the probe micro particle around the left bubble of a two bubble system on the same linear pattern. Here the left bubble is greater in size denoting that the corresponding bubble base is hotter than the right bubble.

Video-11:

Video-11 shows clockwise movement of the probe micro particle near the right bubble of a two bubble system on the same linear pattern. Here also the left bubble is greater in size denoting the corresponding bubble base is hotter than the right bubble. Notable that when the temperature gradient is from the left towards the right bubble, antisymmetric flows are observed around the left bubble and clockwise rotational flows are observed about right bubble.

Video-12:

Video-12 shows axial rotation of a probe micro particle near the left bubble of a two bubble system on the same pattern.

Video-13:

Video-13 also shows the axial rotation of a probe micro particle near the right bubble of a two bubble system on the same pattern. Note that here the sense of rotation is opposite to the previous one (*Video-12*).

Video-14:

Video-14 shows that the rotational motion (demonstrated in the previous videos) is indeed arising due to the in-plane temperature gradient, created by two bubbles on the same pattern. In this video, when the left bubble is kept as it is, the laser corresponding to the right bubble is turned off. As a result, the right bubble shrinks down and the hot spot vanishes, so that the azimuthal symmetry is no longer broken, and therefore the motion about the left bubble stops immediately.