Mobile Targeted Objects Steered by Chemical Micropumps

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Abstract:

Catalytic nanomotors are bimetallic nanorods that move spontaneously in a solution of hydrogen peroxide (H_2O_2). However, these nanomotors move in random pathways. This research aimed to steer these nanomotors using chemical micropumps, such as calcium carbonate ($CaCO_3$) microparticles, which generate radial diffusioosmotic flows. Here we have shown a nanorod moving with directionality using three $CaCO_3$ micropumps. We also investigated the fabrication of a large, tunable array of micropumps by growing $CaCO_3$ in microwells on a lithographed, PDMS surface. Currently the method of growing $CaCO_3$ in this array of microwells is being refined and we hope to eventually use this method to steer nanorods in strategically-patterned arrays.

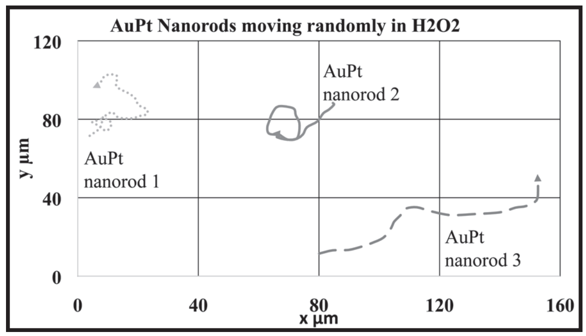

Figure 1: Graph showing the simultaneous, spontaneous movement of AuPt nanorods in a H_2O_2 solution.

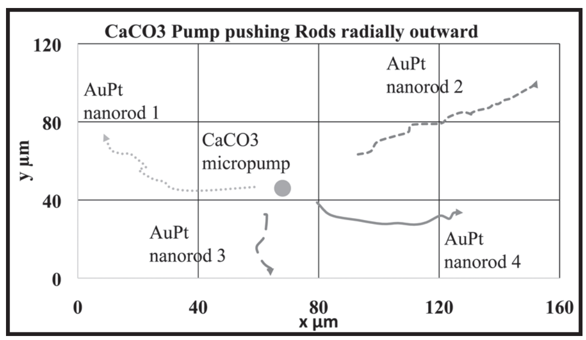

Figure 2: Graph showing AuPt nanorods moving radially away from a $CaCO_3$ micropump.

Introduction:

In our lab, we study micron-sized particles, such as gold platinum (AuPt) nanorods, that spontaneously move in a solution of H_2O_2, as shown in Figure 1. The movement of these nanorods in H_2O_2 occurs due to a phenomenon known as autoelectrophoresis. The catalytic reaction of H_2O_2 around the bimetallic nanorods creates a self-generated electric field, which then propels the nanorods forward [1]. Recently it has been found that chemical micropumps operate under a similar phenomenon known as autodiffusiophoresis. The dissolution of salt microparticles, such as $CaCO_3$, in an aqueous solution generates radial electric fields due to differences in the diffusion rates of the dissolved ions. Depending on the direction of the electric field and the charge of the mobile objects in solution, objects can be pulled toward these micropumps. Once the mobile objects are near the micropumps, radial diffusioosmotic flows sweep these objects along the charged surface of the substrate on which the micropumps rest, as shown in Figure 2 [2].

The spatiotemporal nature of the micropumps creates exclusion regions around the pumps where we predict the movement of catalytic nanomotors will be restricted. We envision that a strategically-patterned surface of $CaCO_3$ micropumps could direct nanomotors by making them move orthogonal to the radial flows of the micropumps.

Therefore, our research question was: can we start with the random pathways of the catalytic nanomotors and get more directionality by strategically placing an array of micropumps around these nanomotors?

Experimental Procedure:

AuPt nanorods were obtained from the Chemistry Department at Penn State. $CaCO_3$ microparticles of roughly 7-10 μm were made through a precipitation synthesis. A solution of 0.33 M calcium chloride ($CaCl_2$) was added to a 0.33 M solution of sodium carbonate (Na_2CO_3), and after minutes of vigorous

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stirring, the solution was washed with deionized water. Diluted $CaCO_3$ microparticles and AuPt nanorods in deionized water were added on top of a borosilicate glass slide. A standard microscope was used to capture images and videos at 10×-50× magnification.

An array of microwells in a polydimethylsiloxane (PDMS) surface was made by using standard photo- and soft-lithography on a Karl Suss MA/BA6 contact aligner [3]. $CaCO_3$ was grown in the microwells by first passing a $CaCl_2$ solution horizontally over the microwells. Then after evaporation of this first solution, a solution of Na_2CO_3 was passed horizontally over the microwells and removed after about ten minutes.

Results and Conclusions:

The random pathway of the catalytic nanomotors and the radial pumping of the $CaCO_3$ can be observed in Figure 1 and Figure 2, respectively. When adding a second $CaCO_3$ microparticle and H_2O_2, the movement of the nanomotors was still largely haphazard. However, the spacing of the micropumps in this system may need to be further fine-tuned in order to obtain more directionality by limiting the degree of freedom in the movement of the nanorods.

When adding a third $CaCO_3$ and taking away H_2O_2, a single AuPt nanorod not only moved without H_2O_2, but also moved in a linear path away from the chemical micropumps, as shown in Figure 3. This is the key result of this research and shows that AuPt nanorods can be steered at a local level by chemical micropumps. This system is also important because it may allow for other charged objects to be steered, not just nanomotors.

Figure 4 shows a dark formation, which is believed to be $CaCO_3$, in one 15 μm well of an array of microwells on a PDMS surface. Growing $CaCO_3$ in an array of microwells on a PDMS surface is a promising method to make large, tunable arrays of chemical micropumps.

Future Work:

We hope to further refine the growing method in order to produce large, tunable arrays of micropumps to study long-range, directed motion as well as directed motion with strategic patterns. In the future, comparison of the experimental data to mathematical models of the flows could also give insight to the specific mechanisms by which the chemical micropumps move and steer the nanorods.

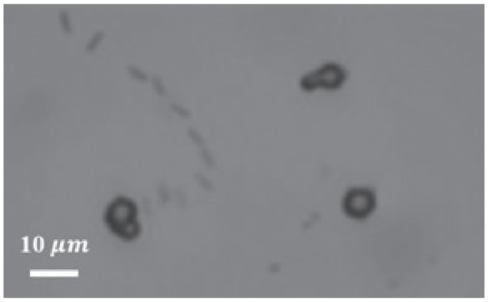

Figure 3: Time lapse image showing a single AuPt nanorod moving with directionality by the radial pumping of three $CaCO_3$ micropumps.

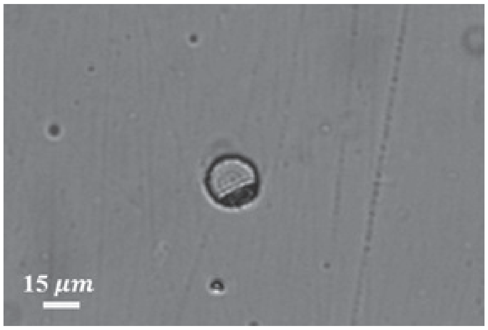

Figure 4: An image of a dark formation, which is believed to be $CaCO_3$, in a 15 μm well on a PDMS surface.

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References:

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