A new kind of micro-mobility: Moving tiny particles using magnetic fields (w/ Video)

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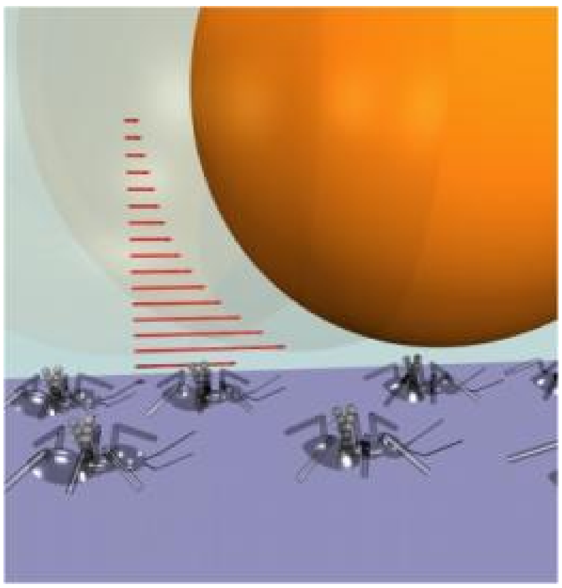

Chains of superparamagnetic colloidal particles rotate to produce flows on length scales much larger than the chain dimensions, allowing them to behave like "micro-ants" that can move large particles. Photo - Image: Charles Sing

(PhysOrg.com) -- A new microscopic system devised by researchers in MIT's Department of Materials Science and Engineering could provide a novel method for moving tiny objects inside a microfluidic chip, and could also provide new insights into how cells and other objects are transported within the body.

Inside organs such as the trachea and the intestines, tiny hair-like filaments called cilia are constantly in motion, beating in unison to create currents that sweep along cells, nutrients, or other tiny particles. The new research uses a self-assembling system to mimic that kind of motion, providing a simple way to move particles around in a precisely controlled way.

Alfredo Alexander-Katz, the Merton C. Flemings Assistant Professor of Materials Science and Engineering, his doctoral student Charles Sing, and researchers at Boston University and in Germany, devised a system that uses so-called superparamagnetic beads — tiny beads made of polymers with specks of magnetic material in them — suspended in liquid.

This visualization shows how the rotating chains of beads move along a surface, suspended in liquid. Credit: Alfredo Alexander-Katz

Due to the heavy magnetic material content, these beads sink to the bottom of the liquid. They placed the whole system inside two pairs of magnetic coils and used them to apply a rotating magnetic field, which caused the beads to spontaneously form short chains that began spinning. This motion created currents that could then carry along surrounding particles — even particles as much as 100 times larger than the beads themselves.

Alexander-Katz refers to the microscopic assembly of beads — each just a few microns (millionths of a meter) in size — as “micro-ants,” because of their ability to move along while “carrying” objects so much larger than themselves. A paper describing the research will appear the week of Dec. 14 in the Proceedings of the National Academy of Sciences.

He says the way the chains of beads moved is a bit like a person trying to do cartwheels while standing on an icy surface. “As they rotate, they slip a bit,” he says, “but overall, they keep moving,” and this imparts a directional flow to the surrounding fluid.

The new method could provide a simpler, less-expensive alternative to present microfluidic devices, a technology involving the precise control of tiny amounts of liquids flowing through microscopic channels on a chip in order to carry out chemical or biological analysis of tiny samples. Now, such devices require precisely made channels, valves and pumps created on a silicon chip using microchip manufacturing methods, in order to control the movement of fluids through them. But the new system could offer such precise control over the movement of liquids and the particles suspended in them that it may be possible to dispense with the channels and other plumbing altogether, controlling the movements entirely through variations in the applied magnetic field.

In short, software rather than hardware could control the chip's properties, allowing it to be instantly reconfigured through changes in the controlling software — an approach Alexander-Katz refers to as "virtual microfluidics." This could reduce the cost and increase the flexibility of the devices, which might be used for such things as biomedical screening, or the detection of trace elements for pollution monitoring or security screening. It might also provide even finer spatial control than can presently be achieved using conventional channels on chips.

Alexander-Katz says the work might also help scientists better understand the way cilia work, by providing a way to mimic their activity in the lab. "People are still trying to understand how you get hydrodynamic synchronization in the systems" of cilia in organisms — that is, having the individual cilia all working together in a pattern of motion that controls the flow of fluid over them. "This might be a way to test many of the theories."

David Weitz, a physicist at Harvard University who studies colloidal physics and biological systems, says that "The work is a beautiful example of the use of colloidal particles to mimic the behavior of cilia, which are used by cells for propulsion." The use of the beads in a magnetic field "actually causes the chains to move, and induces flow in the fluid. This effect is difficult to achieve by any means, and the method reported here is an elegant and simple means of accomplishing this."

In this video of microscope images of the experimental setup, chains of tiny plastic beads spin in a magnetic field. Seen from above, these spinning chains look like thin lines. Their motion causes the liquid to flow, pulling simulated cells (the round objects) along with it. By varying the magnetic fields, the researchers are able to control the motion, back and forth, with great precision. Credit: Alfredo Alexander-Katz

Weitz adds that in terms of applications, "The main utility of these observations is likely to be the understanding of the fundamental properties of these [cilia] structures. They could conceivably ultimately find use as miniature fluid pumps." He adds that Alexander-Katz "is likely to have considerable impact with work like this."

Such a system might someday even be developed to use in medical diagnostics, by allowing controlled delivery of particles inside the body to specifically targeted locations, for example while the patient is in a nuclear magnetic resonance (NMR) imaging system.

Although medical applications might take many years to develop because of the stringent requirements for safety testing, Alexander-Katz says, applications to creating a new kind of microfluidics chips could be achieved "within a year or so." This would essentially just be a matter of scaling up from the simple, basic systems that were tested in this study to more complex assemblies.

Provided by MIT

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