New magnetic herding technique proposed to manipulate the very small

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Engineers have introduced a new magnetic shepherding approach for deftly moving or positioning the kinds of tiny floating objects found within organisms, in order to advance potential applications in fields ranging from medicine to nanotechnology.

The authors of a new research article said their method avoids pitfalls of using tiny light beams, electric currents or even a competing magnetic approach to micromanipulate so-called "colloidal" objects.

"Biology is composed primarily of colloidal materials, things larger than a few billionths of a meter that are suspended in solution and don't settle rapidly," said Benjamin Yellen, who developed this "magnetic nanoparticle assembler" technique while obtaining his doctorate at Drexel University.

"They could be cells or large molecules; they are also being investigated for a variety of new devices, such as miniature lasers or semiconducting components," added Yellen, who in September will become an assistant professor of mechanical engineering and materials science at Duke University's Pratt School of Engineering.

Yellen is first author of a research paper on the method, already available on-line and to be published in print in the Tuesday, June 21, 2005, issue of Proceedings of the National Academy of Sciences (PNAS). His coauthors are Gary Friedman, the Drexel professor of electrical and computer engineering who supervised his Ph.D. work, and

Drexel graduate student Ondrej Hovorka.

The research was supported by the National Science Foundation and Department of Defense.

According to the paper, other investigators are currently focusing either on using laser light beams or electric fields to "transport, sort or assemble microscopic objects." But Yellen's research group contends that "neither technique has demonstrated sufficient flexibility required for widespread adoption."

Yellen, who is a postdoctoral researcher at Children's Hospital of Philadelphia, said in an interview that while high-intensity lasers -- like fictional Star Trek tractor beams -- can move around tiny objects, they can also destructively overheat biological materials. In addition, micromanipulating large numbers of particles can require confining unmanageable numbers of individual light beams in small spaces.

Meanwhile, using electricity as a micromanipulator requires space-consuming grids of electrical circuitry, he added. And electrical fields can also trigger disruptive chemical reactions.

"The big advantage to using magnetism is that very few things in nature are magnetically susceptible," he said.

The PNAS authors' paper described how they demonstrated their technique by first patterning permanent rectangular and circular "magnetic traps," each with millionths of a meter dimensions, on silicon or glass wafers. Each trap was made of cobalt, an element that, like iron, is magnetic.

Over those trap-patterned wafers the authors then added a fluid containing swarms of suspended magnetic iron oxide nanoparticles, with each particle measuring only about 10 billionths of a meter ("nano" means "billionths").

Into this "ferrofluid" (the prefix "ferro" refers to "iron") they then floated non-magnetic microscopic beads of the colloid latex, each bead measuring between 90 and 5,000 nanometers.

Finally, the researchers set up an additional switchable external magnetic field that, when switched on, could alter the magnetic field surrounding the permanent magnetic traps.

This arrangement allowed the non-magnetic latex beads to be herded around, even arranged into a variety of complex patterns, by varying how the dueling magnetic fields influenced the shepherding swarms of magnetic iron oxide nanoparticles.

Under the direction of changeable magnetic fields, the particle swarms acted collectively like nano-scale tugboats to push and pull the comparatively large beads of colloids. The beads themselves were color-labeled so their movements could be traced under microscopic observation.

"In a way, bead movement is analogous to the movement of a train along a railroad track," wrote the authors in their PNAS paper.

While "trap magnetization establishes the track," fields from the switchable external magnet "provide locomotion," they explained. Moreover, the track could be switched to new orientations by adjusting the interplay of fields between the permanent traps and the switchable magnetic source.

The authors suggested that the micromotions of this magnetic nanoparticle assembler might be made programmable by modifications of today's magnetic recording technology.

They listed a number of potential applications, ranging from the speedier assembly of molecules for biosensors or hybridization experiments, to precision arrangements of cells, bacteria and viruses in futuristic medical diagnostic devices, to the assembly of advanced microelectronic components, such as nanowire transistors.

Their paper also noted that a competing magnetic micromanipulation technique already exists that requires pre-bonding to "magnetic particle carriers."

"You have to do a lot of chemical steps along the way, so it's not so convenient," Yellen said of that competing approach. "It would be much more convenient to just simply mix the nonmagnetic materials with a ferrofluid and have them moved around without having to attach them to a magnetic carrier."

Once he arrives at Duke, Yellen said he plans to apply his magnetic nanoparticle assembler approach to designing advanced biosensors and cell membrane probes.

Source: Duke University

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