Argonne scientists design self-assembled "micro-robots"

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(PhysOrg.com) -- Alexey Snezhko and Igor Aronson, physicists at the U.S. Department of Energy's (DOE) Argonne National Laboratory, have coaxed "micro-robots" to do their bidding.

The robots, just half a millimeter wide, are composed of microparticles. Confined between two liquids, they assemble themselves into star shapes when an alternating magnetic field is applied. Snezhko and Aronson can control the robots' movement and even make them pick up, transport and put down other non-magnetic particles—potentially enabling fabrication of precisely designed functional materials in ways not currently possible.

The discovery grew out of past work with magnetic "snakes". This time, however, Snezhko and Aronson suspended the tiny ferromagnetic particles between two layers of immiscible, or non-mixing, fluids.

Without a magnetic field, the particles drift aimlessly or clamp together. But when an alternating magnetic field is applied perpendicular to the liquid surface, they self-assemble into spiky circular shapes that the scientists nicknamed "asters", after the flower.

Left to their own devices, the asters don't swim. "But if you apply a second small magnetic field parallel to the surface, they begin to move," said Aronson. "The field breaks the symmetry of the asters' hydrodynamic flow, and the asters begin to swim."

By changing the magnetic field, the researchers discovered they could

remotely control the asters' motion.

"We can make them open their jaws and close them," said Snezhko. "This gives us the opportunity to use these creatures as mini-robots performing useful tasks. You can move them around and pick up and drop objects."

They soon discovered that the asters form in two "flavors"; one's flow circulates in toward the center of the aster, and the other circulates outward. They swim in opposite directions based on flavor. These properties are useful because scientists can play the flows against one other to make the asters perform tasks.

For example, four asters positioned together act like a miniature vacuum cleaner to collect free-floating particles.

The asters can pick up objects much larger than themselves; in one video, an aster picks up a glass bead that weighs four times as much as the aster itself.

"They can exert very small forces on objects, which is a big challenge for robotics," Aronson explained. "Gripping fragile objects without smashing them has always been difficult for conventional robots."

The microrobots occupy a niche between laser-powered manipulation and mechanical micromanipulators, the two previous techniques developed for manipulation at the microscale. "You can grab microparticles with lasers, but the force is much smaller," Snezhko explained. "These asters' forces are more powerful, but they can handle items much more delicately than mechanical micromanipulators can."

The materials can even self-repair; if particles are lost, the aster simply re-shuffles itself.

The research is a part of the ongoing effort, funded by the DOE, to understand and design active self-assembled materials. These structures can assemble, disassemble, and reassemble autonomously or on command and will enable novel materials capable of multi-tasking and self-repair.

"For us, this is very exciting. This is a new paradigm for reconfigurable self-assembled materials that can perform useful functions," Aronson said.

The study, "Magnetic Manipulation of Self-Assembled Colloidal Asters", has been published in *Nature Materials*.

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