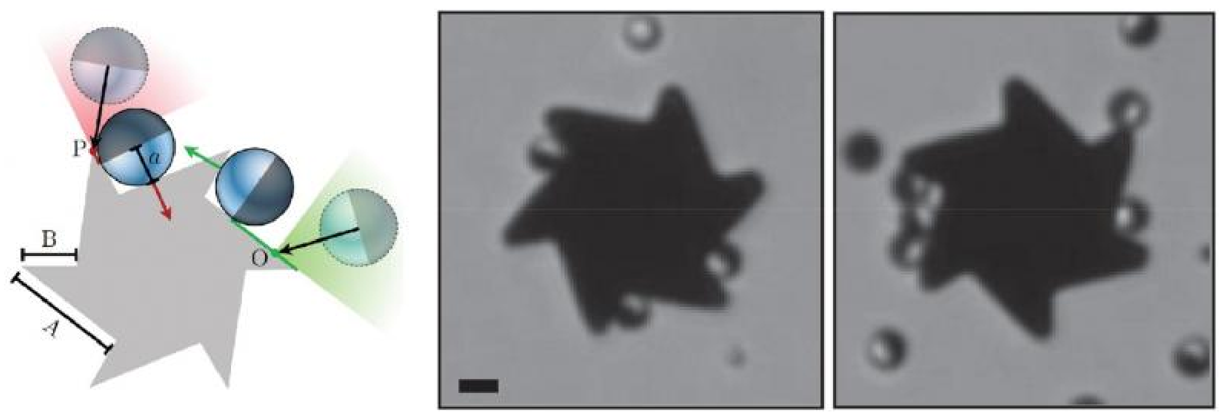
Microgears rotate when pushed by tiny motors

January 11 2016, by Lisa Zyga



Janus particles dock in between the teeth of a microgear to propel it forward. Credit: Maggi, et al. ©2015 Small Journal

(Phys.org)—Researchers have designed a new type of microgear that spins when micromotors become lodged into the corners of the gear's teeth. The micromotors use the surrounding hydrogen peroxide solution as fuel to propel themselves forward, which in turn causes the microgears to spin. In the future, the tiny gears could be used as the building blocks for making autonomous micromachines.

The researchers, Claudio Maggi, et al., from Italy, Germany, and Spain, have published a paper on the microgears in a recent issue of the journal *Small*.

"The modern tools of nanotechnology can be used to shape matter at the micron and nanoscale with a high degree of structural and morphological control," Maggi, at the University of Rome, told *Phys.org*. "Recently researchers have started to investigate possible strategies to 'give life' to these structures and provide them with some mechanism for self-propulsion. The whole effort of miniaturizing machines becomes useless, however, if large and expensive equipment is still required to drive and control propulsion at the micron scale. For this reason, we are working on the development of advanced materials, collectively referred to as 'active matter,' that can convert some embedded energy source into directed motion."

The active matter materials used here are micromotors in the form of Janus particles. Like the two-faced Roman god, Janus particles have two faces, or surfaces, that give them an asymmetric character. Here, one side of each 5-µm particle is coated with platinum, so that when the particles are immersed in a hydrogen peroxide solution, they move in one direction.

In a solution containing both Janus particles and passive 8-µm microgears, some of the self-propelled Janus particles collide with the microgears. The Janus particles then autonomously orient themselves so that their propelling direction runs along the sides of the gears, and their forward momentum locks them in place in the gears' teeth. Up to six Janus particles can be lodged into the microgears' six teeth.

This strategy is similar to previous methods of moving microobjects that use the collective motion of bacteria or synthetic microswimmers. However, all of these previous methods have required high bacteria/microswimmer concentrations and moved in a highly random way, making it difficult to control and reproduce the motion.

The biggest advantages of the new method are that it works with lower particle concentrations and the motion is highly deterministic. The researchers found that the microgear's spinning speed increases linearly as the number of Janus particles locked into the gear increases from 1 to 3. With 4 particles and beyond, the speed flattens out and then begins to decrease, which is likely because the additional Janus particles deplete the hydrogen peroxide fuel so that the speed of all the particles decreases.

"We have now demonstrated that active Janus colloids can self-assemble around a micro-fabricated rotor in reproducible configurations with a high degree of spatial and orientational order," said coauthor Roberto Di Leonardo at the Italian National Research Council, and the coordinator of the research group. "The interplay between geometry and dynamical behavior leads to the self-assembly of autonomous micromotors starting from randomly distributed particles. Besides having a clear technological interest, our results demonstrate that understanding fundamental aspects of interactions in active matter systems opens the way to highly reproducible and controllable micromachines for lab-on-chip applications."

In the future, the researchers plan to investigate how tuning the concentration of hydrogen peroxide can be used to control the rotational speed of the micromotors. Controlling the speed is essential for lab-on-chip micromachines and other applications.

The research was funded by two ERC Starting Grants and combines recent advances in catalytic propulsion (Grant n. 311529) and statistical mechanics of active matter (Grant n. 307940).

More information: Claudio Maggi, et al. "Self-Assembly of Micromachining Systems Powered by Janus Micromotors." *Small*. DOI: 10.1002/smll.201502391