

Active Matter Gets Solid

Researchers have determined the mechanical properties of a tiny beam made of active particles, laying the groundwork for future micromachines.

By **Rachel Berkowitz**

Coaxing tiny, self-propelled particles into cohesive structures suggests an approach for making micromachines inspired by living systems. Taking a step toward that goal, researchers have poked and prodded strands of material made from such “active” particles and measured their responses [1]. Understanding the mechanics of structures like these will be essential for the design of devices such as cilia sheets or autonomous microrobots that perform tasks in materials assembly or medicine.

Active matter refers to collections of objects that can move on their own via some energy-consuming process. For 15 years, researchers have studied active fluids that, for example, model the emergent behaviors typical of flocking birds or schooling

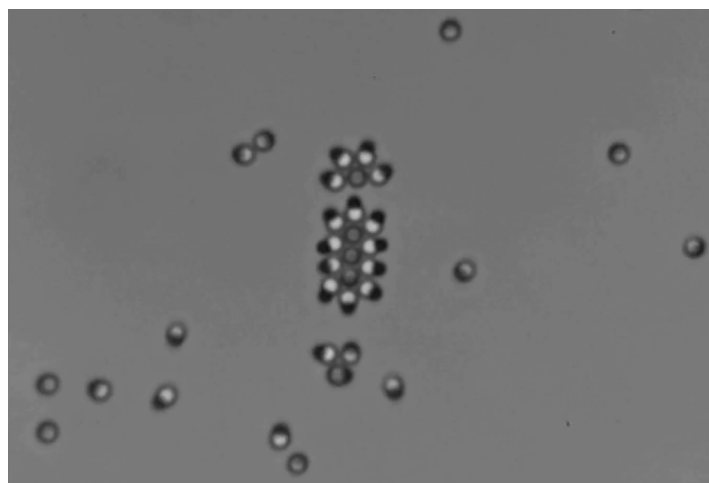
fish. More recently, researchers have begun to explore active solids—semirigid structures made from active particles. These structures could, in principle, change their shapes in controlled ways or adapt their locomotion to suit their surroundings.

Jérémie Palacci of the Institute of Science and Technology Austria and his colleagues previously designed an active solid made from 2- μm -diameter particles submerged in water [2]. Each particle is a plastic sphere with a hematite cube fixed to its surface. When exposed to blue light, the hematite reacts with hydrogen peroxide in the water and emits the reaction products, a bit like an underwater jet.

During their active solid assembly process, the researchers use laser traps to organize the particles into a 3-particle-wide and up to 20-particle-long strand. The core particles orient their hematite “jets” vertically, providing attraction to their neighbors, while the edge particles turn their jets horizontally outward, further reinforcing the structure.

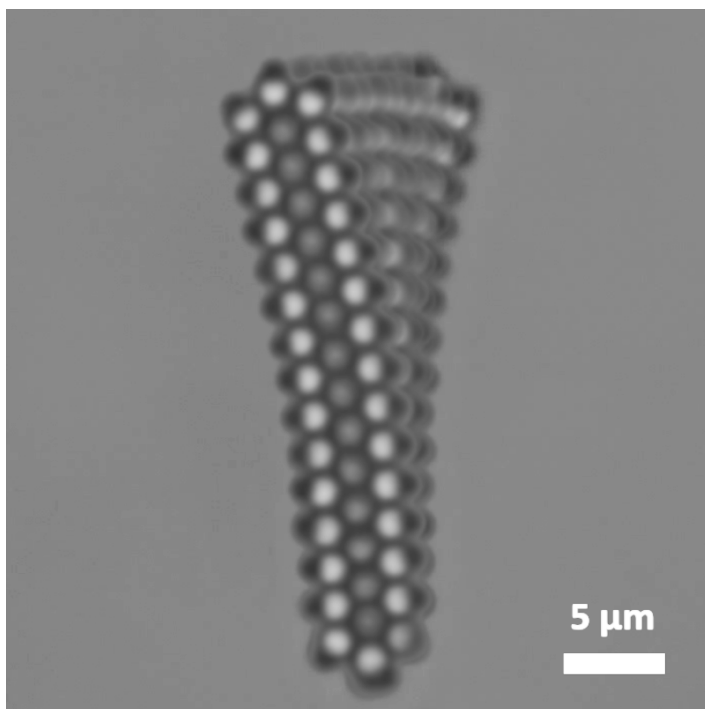
To determine possible uses for these objects, which can be treated as miniature beams, the researchers have now examined their mechanical properties in experiments that Palacci describes as “basic civil engineering but at the microscale.” The constant jiggling produced by the constituent particles makes for an unconventional beam, however: Described in terms of an effective temperature, these beams are more than 10 times hotter than the water bath, the team calculated.

First, they observed each beam’s wiggling, an effect of the active particles, and estimated the beam’s persistence length, which is the length over which the beam acts as a rigid body. This parameter is a measure of flexibility. Next, they clamped both ends of the beam and stretched it to measure its stiffness.



An array of laser traps places active particles into a rod-shaped structure. After the trap is turned off, the structure remains intact and displays wiggles or shape fluctuations.

Credit: Q. Martinet *et al.* [1]



Like a flower in the wind. When clamped at one end, a microbeam's back-and-forth oscillations are driven by the active particle at the end.

Credit: Q. Martinet *et al.* [1]

In another test, the researchers clamped one end of a beam so that it stood upward like a flower stem. To their surprise, it started to sway back and forth with a period of nearly 20 seconds, remarkably slow for such a microscopic system. "That was completely unexpected," says Palacci. This oscillation period remained unchanged, regardless of the beam length.

To explain their observations, the researchers developed a

first-principles model of a vertical elastic beam in a viscous fluid. The particle at its unclamped end drives the beam's movement and can swivel in any direction. This active particle is aligned by the flow of water around it—the faster it moves, the more it remains pointed in a particular direction. The particle's activity causes the beam to bend until the force trying to straighten the beam becomes comparable to the active particle's drive force. At this point, the motion slows, allowing the particle to swivel to a direction more aligned with the straightening force. Then another cycle begins.

According to Corentin Coulais, an active-matter researcher at the University of Amsterdam, measuring the behavior of active solids at this small scale has been challenging. "The findings could be further leveraged to create machines that exploit noise for enhanced functionality," he says. For example, he imagines a micromachine that could switch between shapes or locomotion styles in response to its surroundings.

"This is the first step toward active solids at the microscale," Palacci says. He envisions structures that are triggered by their environments to change their properties—such as their stiffnesses—without needing control circuitry, which would otherwise consume limited space and energy.

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REFERENCES

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2. A. Aubret *et al.*, "Metamachines of pluripotent colloids," *Nat. Commun.* **12**, 6398 (2021).