Nature Provides Inspiration for Breakthrough in Self-regulating Materials

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Research conducted at UMass Amherst documents a new platform for interactive soft materials.

Scientists have long sought to invent materials that can respond to the external world in predictable, self-regulating ways. Now, new research conducted at the University of Massachusetts Amherst and appearing in the Proceedings of the National Academy of Sciences brings us one step closer to that goal. For their inspiration, the scientists looked to nature.

Lampreys swimming, horses walking, and insects flying: each of these behaviors is made possible by a network of oscillators—mechanisms that produce a repetitive motion, such as wriggling a tail, taking a stride, or flapping a wing. What's more, these natural oscillators can respond to their environment in predictable ways. In response to different signals, they can rapidly change speed, switch between different modes, or stop changing altogether. "The question," says Hyunki Kim, the paper's co-lead author, along with Boston University's Subramanian Sundaram, a recent recipient of a Ph.D. in polymer science and engineering from UMass Amherst, "is can we make soft materials, such as plastics, polymers, and nanocomposite structures, that can respond in the same way?" The answer, as the team documents, is a definitive yes.

One of the key difficulties that the team solved was in getting a series of oscillators to work in unison with each other, a prerequisite for coordinated, predictable movement. "We have developed a new platform where we can control with remarkable precision the coupling of oscillators," says Ryan Hayward, James and Catherine Patten Endowed Professor of Chemical and Biological Engineering at the University of Colorado Boulder, and one of the paper's co-authors. That platform relies on yet another natural force, known as the Marangoni effect, which is a phenomenon that describes the movement of solids along the interface between two fluids driven by changes in surface tension.

A classic, real-world example of the Marangoni effect happens every time you wash the dishes. When you squirt dish soap into a pan filled with water on whose surface is evenly sprinkled with the crumbs from your dinner, you can watch as the crumbs flee to the edges of the pan once the soap hits the water. This is because the soap changes the surface tension of the water, and the crumbs are pulled away from areas of low, soapy surface tension, towards the edges of the pan where the surface tension remains high.

“It all comes down to understanding the role of interfaces and the profound impact of combining polymeric and metallic materials into composite structures,” says Todd Emrick, co-author and professor in polymer science and engineering at UMass. Instead of soapy water and pans, the team used hydrogel nanocomposite disks made up of polymer gels and nanoparticles of gold, which were sensitive to changes in light and temperature. The result was that the team was able to engineer a diverse array of oscillators that could move in unison with each other and respond predictably to changes in light and temperature. “We can now engineer complex coupled behavior that responds to external stimuli,” says Kim.

Read the original article on University of Massachusetts Amherst.