Biology rides to computers' aid

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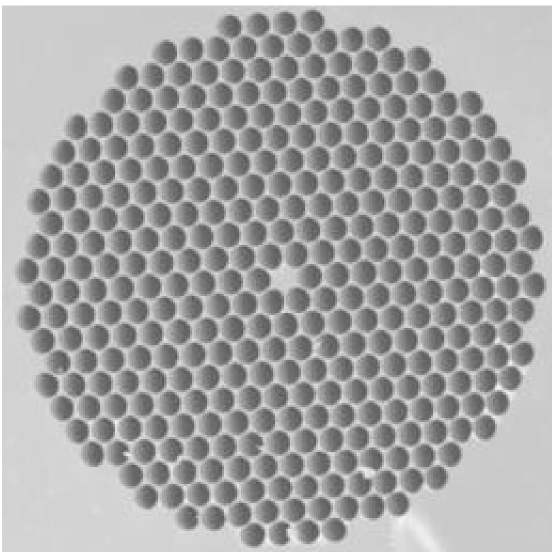

A scanning-electron micrographs of a photonic-crystal fiber produced at the U.S. Naval Research Laboratory. Image: U.S. Naval Research Laboratory

Photonic crystals are exotic materials with the ability to guide light beams through confined spaces and could be vital components of low-power computer chips that use light instead of electricity. Cost-effective ways of producing them have proved elusive, but researchers have recently been turning toward a surprising source for help: DNA molecules.

In a paper that appeared Oct. 18 in the journal Nature Materials, MIT researchers, together with colleagues at the Scripps Research Institute and the University of Rochester, demonstrated that tiny particles of gold and balls of protein known as virus-like particles, both with strands of DNA attached to them, would spontaneously organize themselves into a lattice-like structure. Although the materials themselves aren't useful for making photonic crystals, the distances between the particles are exactly those that would enable a photonic crystal to guide light in the visible spectrum.

Photonic crystals are made from materials with very different refractive indices: That is, they bend light to different degrees. Depending on the distances between the materials, the crystals will reflect light of a particular wavelength with virtually no loss. Tuning a photonic crystal to light in the visible spectrum requires spacing materials mere nanometers apart, which is difficult to do with existing manufacturing techniques. To date, the only photonic crystals that work in the visible spectrum are two-dimensional: They can reflect light traveling in one plane but not in the perpendicular plane. A photonic crystal with the dimensions of the researchers' new gold-and-protein lattice, however, would reflect light in three dimensions, a crucial requirement for moving light through the multiple layers of a computer chip.

Strange bedfellows

Abigail Lytton-Jean, a postdoc at MIT's Koch Institute for Integrative Cancer Research and one of the new paper's two lead authors, began using DNA to create self-assembling crystals as a graduate student at Northwestern University. She and her adviser, Chad Mirkin, together with Sung Yong Park, who is now at the University of Rochester and is a coauthor on the new paper, too, showed that attaching DNA strands of different sequences to gold nanoparticles would cause them to self-organize into crystals with different structures. But this is the first time the trick has been performed with multiple materials.

Although gold and protein aren't in themselves useful for photonic crystals, Lytton-Jean says, “this is mostly showing that we have two incredibly different materials. We have a soft protein that is biological in nature, and then you go to the other end of the spectrum, where you have a hard metallic sphere. And if we can do this with these two types of materials, you could do this with almost any type of material.” Future photonic crystals, she explains, could very well use combinations of metals and plastics — again, soft and hard materials.

But Orlin Velev, Invista Professor in the North Carolina State Department of Chemical and Biomolecular Engineering, says, “I think that the more exciting application is the joined co-assembly of organic and inorganic particles into a single structure.” He points out that nanoscale devices that combine biological molecules and metals could serve as drug-delivery devices and as low-cost sensors that would be small enough to circulate through the body.

According to Daniel Anderson, an associate professor in the Harvard-MIT Division of Health Sciences and Technology and a coauthor of the paper, that’s another application that the MIT researchers are investigating. He mentions, for instance, the promising new field of RNA interference (RNAi), in which short strands of RNA are used to interrupt destructive biological processes. Nanodevices that combine organic and inorganic molecules, Anderson says, could “take potentially therapeutic molecules and get them where they need to go.” Indeed, the researchers’ work was supported by the National Institutes of Health and the Skaggs Institute for Chemical Biology, as well as the W. M. Keck Foundation,

Velev points out that the researchers’ work is basic science, and that it “won’t be used tomorrow for practical applications.” Lytton-Jean acknowledges that in order to self-assemble into regular crystalline structures, nanoparticles must be of uniform size, and manufacturing them to precise specifications is by no means trivial. “A decade ago, this probably would not have been possible, because the synthesis of gold nanoparticles had not developed as much as it has today," she says. Moreover, she adds, one of the reasons that she and her colleagues used gold and protein particles in their latest round of experiments is that the chemistry for attaching DNA to gold and to protein is well-understood. But, she adds, "A great deal of work has been done on the modification of polymer nanoparticles. The chemistry is probably not a big problem."

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