Chemically assembled metamaterials may lead to superlenses

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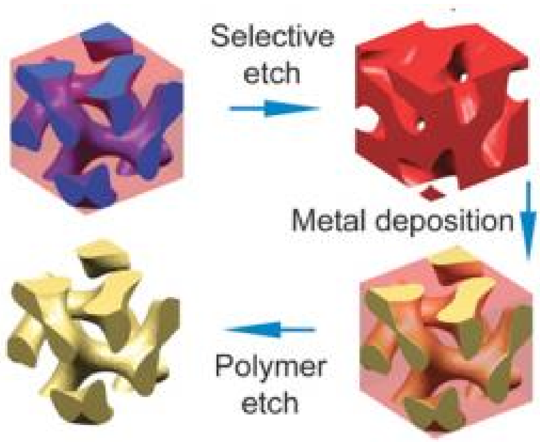

Two polymer molecules linked together will self-assemble into a complex shape, in this case a convoluted "gyroid." One of the polymers is chemically removed, leaving a mold that can be filled with metal. Finally the other polymer is removed, leaving a metal gyroid with features measured in nanometers. Credit: Wiesner Lab

(PhysOrg.com) -- Nanomanufacturing technology has enabled scientists to create metamaterials -- stuff that never existed in nature -- with unusual optical properties. They could lead to "superlenses" able to image proteins, viruses and DNA, and perhaps even make a "Star Trek" cloaking device.

Other metamaterials offer unique magnetic properties that could have applications in microelectronics or data storage.

The limitation, so far, is that techniques like electron-beam lithography or atomic sputtering can only create these materials in thin layers. Now Cornell researchers propose an approach from chemistry to self-assemble metamaterials in three dimensions.

Uli Wiesner, the Spencer T. Olin Professor of Engineering, and colleagues present their idea in the online edition of the journal Angewandte Chemie.

Wiesner's research group offers a method they have pioneered in other fields, using block copolymers to self-assemble 3-D structures with nanoscale features.

A polymer is made up of molecules that chain together to form a solid or semisolid material. A block copolymer is made by joining two polymer molecules at the ends so that when each end chains up with others like itself, the two solids form an interconnected pattern of repeating geometric shapes -- planes, spheres, cylinders or a twisty network called a gyroid. Elements of the repeating pattern can be as small as a few nanometers across. Sometimes tri-polymers can be used to create even more complex shapes.

After the structure has formed, one of the two polymers can be dissolved away, leaving a 3-D mold that can be filled with a metal -- often gold or silver. Then the second polymer is burned away, leaving a porous metal structure.

In their paper the researchers propose to create metal gyroids that allow light to pass through, but are made up of nanoscale features that interact with light, just as the atoms in glass or plastic do. In this way, they say, it should be possible to design materials with a negative index of refraction, that is, materials that bend light in the opposite direction than in an ordinary transparent material.

Special lenses made of such a material could image objects smaller than the wavelength of visible light, including proteins, viruses and DNA. Some experimenters have made such superlenses, but so far none that work in the visible light range. Negative refraction materials might also be configured to bend light around an object -- at least a small one -- and make it invisible.

The Cornell researchers created computer simulations of several different metal gyroids that could be made by copolymer self-assembly, then calculated how light would behave when passing through these materials. They concluded that such materials could have a negative refractive index in the visible and near-infrared range. They noted that the amount of refraction could be controlled by adjusting the size of the repeating features of the metamaterial, which can be done by modifying the chemistry used in self-assembly.

They tried their calculations assuming the metal structures might be made of gold, silver or aluminum, and found that only silver produced satisfactory results.

Could these materials actually be made? According to graduate student Kahyun Hur, lead author on the paper, "We're working on it."

Provided by Cornell University

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