

*For Immediate Release
April 9, 2002*

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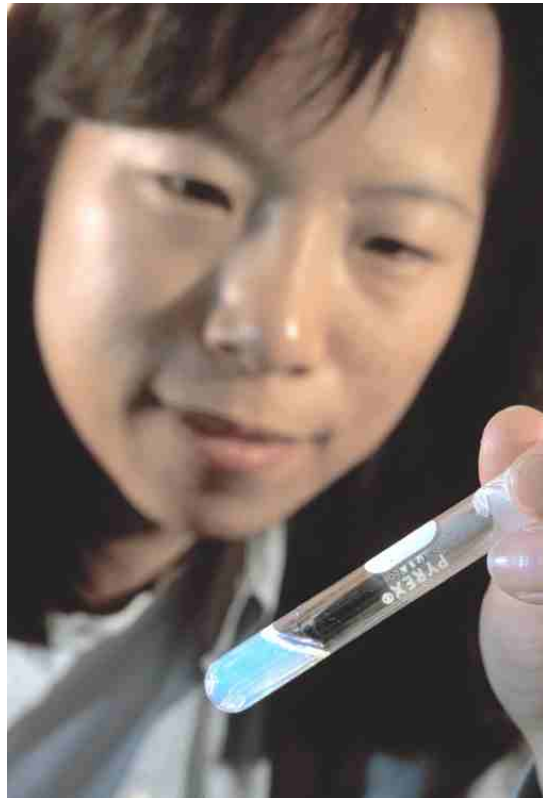
SOFT HYDROGEL NANOPARTICLES PROVIDE FOUNDATION FOR OPTICALLY TUNABLE PHOTONIC CRYSTALS VIA CONTROLLED DE-SWELLING

Researchers at the Georgia Institute of Technology have developed a family of hydrogel-based nanoparticles that can be used to form photonic crystals whose optical properties can be precisely tuned by thermally adjusting the particles' water content.

The soft and conformable spherical particles could be the basis for a "photonic fluid" that would be custom processed to form self-assembled periodic structures able to transmit specific wavelengths of light. Potential applications include optical switching and optical limiting in telecommunications and – by using particles that respond to biological molecules – new types of medical diagnostics.

"We have a very simple and easy processing method for taking one type of particle and creating a whole host of optical materials from it, as opposed to having to synthesize a new particle for each optical material you would like," said Andrew Lyon, assistant professor of chemistry and biochemistry at Georgia Tech. "We have a polymer solution that can be processed in normal ways – spin coating, casting and molding – which typically cannot be done with other types of colloidal photonic materials."

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Graduate Student SaetByul Debord holds a sample of hydrogel photonic crystals assembled from 190 nm particles.

Lyon presented details of the project at the 223rd national meeting of the American Chemical Society April 8 in the symposium on "Self-assembled Photonic Band Gap Materials."

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Lyon and his colleagues have fabricated nearly 100 different types of mono-disperse hydrogel particles, in sizes ranging from 50 nanometers to 1 micron in diameter. The temperature at which the particles transition to a crystalline state can be controlled chemically during the synthesis process in a range from 10 degrees C to 60 degrees C.

The nanoparticles are synthesized from poly-N-isopropylacrylamide (pNIPAm) lightly cross-linked with N,N-methylenebis(acrylamide)(BIS). After precipitation polymerization in aqueous media, the particles are separated from the surrounding water by simple centrifuging. The resulting glassy gelatinous material, which has a faint blue, green or red hue, is more viscous than honey.

To give it desirable optical properties, the material must be annealed by heating it past the volume phase transition temperature of the component hydrogel particles, at which the photonic crystal loses its order and the nanoparticles begin to give up water content. After removing small amounts of water, the material is allowed to cool, re-absorb water and re-crystallize. This thermal cycling process serves to pack the soft hydrogel particles into an ordered 3-D hexagonal array, which produces the periodic dielectric structure needed for optical properties.

The annealing step is repeated as many as 15 times until the resulting crystalline structure has the desired optical properties. Crystals produced so far by Lyon and collaborators Justin Debord, Saet Byul Debord and Clinton Jones reflect bright blue, green or red colors.

“While the assembly of colloidal crystals from such particles has been reported previously, this represents the first report where the softness and thermoresponsivity of the component particles is used to create a color-tunable colloidal crystal via particle compression,” Lyon said. “Such soft assemblies may present new opportunities for the fabrication of particulate and templated materials for photonic applications.”

By closely controlling the hydration of the particles, the researchers can tune the colors by one-nanometer steps over a wavelength range of more than 200 nanometers. “We have very good control, both with respect to the breadth of the transition and the accuracy with which we can design the color of the material,” Lyon said.

When heated above the transition temperature, the material readily flows in a liquid form and can be cast, molded or spin coated onto a surface using standard polymer processing techniques.

Though practical applications may be a long way off, the researchers envision uses in the telecommunications industry, where the precisely-tuned photonic crystals could be used to extract information carried on optical fibers at specific wavelengths. Sending signals coded at different wavelengths allows fibers to carry large volumes of information in a process called multiplexing. The tunable crystals produced through the Georgia Tech process would transmit only a narrow range of wavelengths, allowing specific streams of data to be retrieved from the optical fibers.

In addition to the temperature-responsive nanoparticles, Lyon’s group has also made particles that transition in response to pH levels and to the presence of metal ions. They are working on particles that would respond to specific proteins or other biological molecules that could be useful in medical diagnostics to detect the markers of disease. Though much work remains to be done on materials engineering issues, Lyon envisions production of a nanoparticle powder that could be produced and distributed with a “recipe” for producing crystals able to reflect specific wavelengths.

“Since these materials are self-assembled, they live in a deep thermodynamic well so that their optical properties are the result of the thermodynamically preferred arrangement of the particles,” he explained. “That allows us to produce materials that are intrinsically very stable. They form very fast, and because we understand the annealing using thermal responsivity, that allows us to make a material that is disordered and give it a temperature kick to help it find its thermodynamically-preferred phase. The speed, the reproducibility and the stability by which these can be assembled are huge advantages.”

Development of the hydrogel nanoparticles has been funded by the Georgia Tech Research Corporation. A paper on the work has been accepted for publication in *Advanced Materials*, and earlier work was published in the July 13, 2000 issue of the *Journal of Physical Chemistry*.

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