Three-dimensional waveguides fabricated in self-assembled photonic crystals

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CHAMPAIGN, Ill. — Scientists at the University of Illinois have fabricated features within self-assembled photonic crystals, greatly enhancing the potential functionality of this class of photonic band gap materials.

The fabrication technique – which uses multi-photon polymerization and a laser scanning confocal microscope – can be used to create three-dimensional waveguides or optical cavities inside the self-assembled structures.

"We have demonstrated, for the first time, that we can take a self-assembled colloidal crystal and create an embedded feature with very high precision," said Paul Braun, a UI professor of materials science and engineering and corresponding author of a paper to be published later this month in Advanced Materials.

Most photonic crystals with embedded features are built layer by layer using conventional fabrication techniques, which can be a tedious and expensive process.

"Colloidal self-assembly is an easier and cheaper alternative, especially for the generation of large-area photonic crystals," said Braun, who also is a researcher at the UI's Frederick Seitz Materials Research Laboratory and the Beckman Institute for Advanced Science and Technology.

To fabricate features, Braun and his colleagues – postdoctoral scientist Wonmok Lee and graduate student Stephanie Pruzinsky – begin by assembling a colloidal crystal of uniform silica spheres that are 1.58 microns in diameter. After removing the solvent, the researchers add a photoactive monomer – a liquid that changes into a polymer when exposed to light – to fill the spaces between the spheres. Then they shine laser light through a microscope and into the crystal, polymerizing the monomer at the microscope's focal point. Finally, they remove the unpolymerized liquid, leaving the desired shape supported by the colloidal crystal matrix.

"By carefully moving the microscope's focal point through the crystal, complex three-dimensional patterns can be created," Braun said. "Unlike layer-by-layer techniques, we can move through the crystal in any direction, because the patterning is not a planar process."

The polymerization process creates a region with a different index of refraction that can transmit light like an optical fiber, but with one very important exception. "If you bend a fiber optic cable too far, the light leaks out," Braun said. "With waveguides generated in photonic band gap materials, you can bend light around much sharper corners."

Using multi-photon polymerization as a pathway for pattern generation within colloidal assemblies, researchers can create waveguides with very sharp bends that would be difficult to achieve by conventional fabrication techniques.

"This means we could take light that is generated on a chip and route it nearly anywhere else on the chip, creating optical circuitry in three dimensions," Braun said. "We could also perform on-chip integration of many optical components."

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