Fabricating 3D Photonic Crystals

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(PhysOrg.com) -- “In photonic crystals, the ability to control the structure of a material in full three dimensional space, allows you to control the way that light flows through it,” John Rogers tells *PhysOrg.com*. “This approach to photonic materials can be useful in applications ranging from communications to lasers to optical waveguides.”

Rogers, a scientist at the University of Illinois at Urbana-Champaign, and his colleagues at the University of Illinois and a team from Sandia National Laboratories in Albuquerque, New Mexico, have developed a simple technique that allows for the fabrication of silicon photonic crystals in 3-D. Their process is described in *Applied Physics Letters*: “Three dimensional silicon photonic crystals fabricated by two photon phase mask lithography.”

“Theoretical studies of idealized structures of this general type suggest their promise for manipulating of the flow of light through devices,” Rogers continues, “but from a practical standpoint, the fabrication has been difficult. Often, these crystals are patterned in a two dimensional plane defined by a silicon wafer. If you want something three dimensional, you stack them up to form a thin structure that has some level of 3D character. Unfortunately, with this method, you have more steps, making it more involved and expensive.”

The team from the University of Illinois and Sandia decided to use phase mask lithography to create a full three dimensional silicon photonic crystal from the outset. Silicon is used because it has a high index of refraction, making it ideal for applications that make use of light. “The technique we’ve achieved is the culmination of six years of work as we tried to figure out how to optimize this process.”

In order to create 3-D photonic crystals, the team used rubber optical elements and a specially prepared polymer. Using a laser, it is possible to create a pattern out of the polymer to define the crystal geometry of the crystal - a mold. Next, Rogers said, the three dimensional structure mold was used as a template. “We grew silicon on the polymer template, similar to what is done in two dimensions in the microelectronics industry.” Finally, the polymer template is burned away, leaving the silicon photonic crystal behind.

“One of the key aspects of this fabrication process is that it is scalable,” Rogers says. “Not only are we facilitating patterning up front, but we’re also talking about a process that we can do over large areas, such as a square meter. In addition, it has the advantage of being adaptable to technology that already exists.”

The ability to create silicon photonic crystals that are larger, using a process that is less expensive and elaborate than what is normally used, offers some potential for applications dealing with light. Rogers points out that this fabrication process would be useful for reflective (or even anti-reflective) coatings, creating optical diodes and even accomplishing high speed data routing. He even sees potential to adapt the process to work on a micro level, integrating these types of techniques with electronics. “There are a number of applications that could benefit from this fabrication process, since it offers high quality, low-cost photonic crystals.”

More information: Shir, D., et. al. “Three dimensional silicon photonic crystals fabricated by two photon phase mask lithography.” *Applied Physics Letters* (2009). Available online:

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