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NEWS

Single exposure step creates 3D structures

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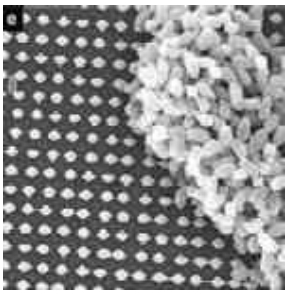
A US team explains how to pattern large area photopolymer surfaces using just a single exposure to a high intensity laser beam. The aim is to eventually fabricate 3D photonic crystals by the square meter.

Researchers at the University of Illinois and Argonne National Laboratory in the US have developed a single-step, two-photon lithography technique that offers sub-wavelength 3D resolution over a large area (*Optics Express* **14**, 2300).

"Our approach enables two-photon lithography to be performed in a completely parallel fashion," John Rogers from the University of Illinois told *Optics.org*. "This is in sharp contrast to conventional 2 photon methods that involve serial scanning of a focussed beam to write 3D structures. The parallel operation of our method increases fabrication speeds and scalability by many orders of magnitude."

The team hopes to use this method to fabricate 3D photonic crystals by the square meter. Rogers explains that the group is interested in low cost approaches to fabricating 3D nanostructures in ways that are scalable to large areas.

"We expose the 2-photon sensitive photopolymer directly in proximity to the surface of a phase mask," he explained. "This generates a 3D distribution of intensity so separate manipulation of beams and pulse overlapping is not required. In this way, we bypass the difficulties associated with conventional 2-photon lithography and achieve a new method that allows fully parallel patterning."

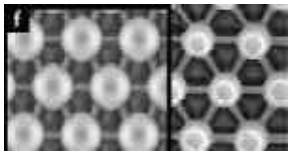


Structures from 2-photon process

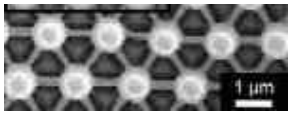
The team used a 1kHz, 810 nm Ti:sapphire laser beam, 600 microns in diameter, to generate 120 fs pulses, 250 microJ in energy. These produced a peak intensity of ~0.7TWcm^{-2}, the necessary output to enable sufficient 2-photon excitation and cross-linking the photopolymer.

Shining this light through the phase mask, the team then exposed the target photopolymer to the 3D intensity distribution, created passing the light through the 2D mask.

Exposure times of between 120 and 240 seconds generated sufficiently high concentrations of photocatalyst in the polymer. These areas could then be crosslinked and made insoluble after a 65 degreeC 'post-baking' procedure. The unexposed areas were dissolved away using a developer solvent, to leave the patterned surface.



For comparison, Rogers and coworkers also generated 3D structures using a 1-photon effect with a 355 nm light source. The optical microscopy measurements showed "striking differences" between the one and two photon cases, with far



Structures using different masks

higher image contrasts found for the 2-photon surfaces.

The team also used full vector modeling of the optics to determine, for a given mask, the distribution of intensity near the photopolymer surface and, therefore, the geometry of the 3D structures that is produced.

However, it still remains to be seen, whether this process can be reversed. "We are currently working on a more powerful modeling tool...to determine how one can generate a phase mask to produce a desired 3d structure," said Rogers. "With this type of tool we will be able to more fully exploit the power of this patterning approach."

The researchers say that they have already demonstrated some applications in microfluidics, where 3D structures are written directly into microchannels. These structures can act as integrated particle filters as well as passive fluid mixers, which convert laminar fluid flow into a turbulent flow.

"It also turns out that we can make nanoparticles with controlled shapes using this same approach," added Rogers.

Author

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