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Assessment of a massively parallel non-linear polymerisation process using scalar light propagation simulation tools

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Triplet-Triplet Annihilation (TTA) polymerization and two-photon polymerization (TPP) have a non-linear light intensity dependence. Thanks to this property, the polymerized region induced by TTA or two-photon absorption is confined around the focus plane of the beam. One-photon absorption (OPA) however has a linear light intensity dependence, the polymerization induced occurs across the whole optical focusing cone. TTA polymerization and TPP are extremely interesting to fabricate 3D micro or nano-structures. While expensive ultra-short pulsed lasers are required to achieve TPP, the TTA process can be achieved with a continuous wave laser. Given that the TTA process has low power requirements (one order of magnitude less than TPP), the parallelization of thousands of voxels per exposure is made possible. Therefore, TTA polymerization, a potentially low-cost technique of fast additive micro fabrication in 3D, could open new frontiers in many fields such as health, optical micro-devices, security holograms...

To fully exploit the power of TTA polymerization, a Spatial Light Modulator (SLM) composed of 1920x1080 pixels is used to parallelize the fabrication process. The SLM modulates the intensity of a light field pattern that is projected into the resist, a continuous wave laser and an ultra-sensitive resist based on the TTA mechanism are used. An autofocus system is used to adapt the focus plane to the position of the sample and the non-planarity of the resist layer.

Fabrication of sub micrometric structures in 3D requires an understanding of the interaction between the light field and the resist. We have digitally simulated the interactions between the beams to understand their light propagation and overlap from an optical point of view using a scalar model based on Fresnel diffraction. The good correlation between experimental records of the light field and optical simulations demonstrates the validity of the model. To consider chemical aspects of the resist, micro-structures have been fabricated to calibrate simulations. Parameters in the simulation have to be adjusted to give results as close as possible to reality. This improved understanding of the interaction has recently helped us to fabricate different types of structures such as micro-lenses, a cornea implant and our first fully 3D structures.