Hyper resolution in two-photon direct laser writing towards additive manufacturing nanostructures

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In the last years, the interest of researchers is focused on an effective way to improve the resolution of one- and two-photon polymerization with application in different nanoscale devices. The present manuscript reports on the possibility to use a simple but significant way to increase the performance of a generic TP-DWL process by exploiting Epsilon Near Zero (ENZ) metamaterials properties such as strong light selfcollimation and canalization. By exploiting a metal/insulator/metal/insulator (MIMI) geometry, an upgrade of the standard two-photon direct laser writing (TP-DLW) process to hyper resolution was enabled [1]. Fabricated 1D gratings reveals a voxel reduction of 89% and 50% in height and width respectively, with the height of the structures adjustable between 5 and 50 nm. The developed additive manufacturing process has been used for the fabrication of extremely thin all-dielectric metalenses showing exiting optical features as apochromatic behavior, focal length of 1.14 mm, depth of focus of hundreds of microns and total thickness of few tens' nanometers. The broadband and achromatic behavior was confirmed by the gamut plot which shows that, by using RGB light, a white light is obtained at the focal plane. Moving toward complex 3D nanostructures, the achieved hyper resolution enables the realization of a highly detailed dielectric 3D bas-relief of the Da Vinci's "Lady with an Ermine" with full height of only 500 nm showing an impressive fidelity of details. The improved technique will play a relevant role in nanotechnology since it can pave the way to fabricate, in a single additive manufacturing process, new generation of 2D/3D nanometric devices for the current and trendsetting research scenario in anticounterfeiting applications, flat optics and ultracompact photonics and imaging system.

[1] G. E. Lio, A. Ferraro, T. Ritacco, D. M Aceti, A. De Luca, M. Giocondo, & R. Caputo, R. Advanced Materials, 33, 2008644 (2021)