Fabrication and analysis of 3D-printed metamaterials

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The creation of fascinating optical effects such as negative refractive, optical magnetism, and cloaking has become a human dream since the late 1940s, when artificially designed materials, so-called optical metamaterials, were investigated. Such materials enable strong light-matter interaction over a broad range of the electromagnetic spectrum not achievable by any existing material in nature. They are therefore highly interesting for many future applications in the field of telecommunication, optoelectronics, nanomaterials, and energy harvesting. However, the fabrication of 3D optical metamaterials, which would enable the use of their full potential, remains challenging due to the limitations of conventional manufacturing techniques. An approach that has been proved to be suitable to overcome this challenge is multi-photon lithography (MPL)[1], which is a true 3D printing technique with high resolution down to sub-100 nm.
In this work, the high potential of using MPL for metamaterial research is further underlined by demonstrating a procedure to process metamaterials operating at THz frequency and generate novel devices for complete circuits or electronic devices such as perfect absorbers and electromagnetic waves attenuators that can be used in complete circuits and electronic devices. Simulation by Finite Differential Time Domain (FDTD) method were done to design the materials' geometry giving the best possible dimensions and properties for the structure, as FDTD is the most accurate way to solve presicely Maxwell's equations for electromagnetic waves interacting with matter. As a photosensitive material for the MPL an organic – inorganic photopolymer SZ2080 was used. SZ2080 has the best chemical and mechanical properties for the fabrication and development process. After MPL processing, the structures were further processed using selective electroless plating to cover the polymer material with silver via chemical procedure, so the spectral characterization (absorbance, transmittance, reflectance) can be done at THz frequencies.

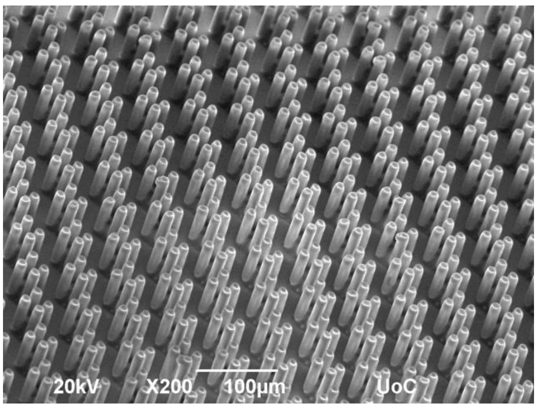

Figure 1: SEM image of the metasurface coated with silver via chemical procedure, showing the resolution of MPL method

[1] Farsari, M., Chichkov, B. Two-photon fabrication. *Nature Photon* **3,** 450–452 (2009), https://doi.org/10.1038/nphoton.2009.131