Direct ink writing of ZnO three-dimensional terahertz photonic crystals

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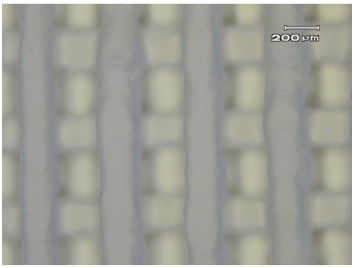
Photonic crystals are materials with periodic modulation in the dielectric constant that exhibit bandgaps in which the electromagnetic waves propagation is forbidden. There is a broad research on photonic crystals in the visible and infrared range, however this research is limited on the terahertz band. Recent developments in the generation and detection of terahertz waves and new technologies based in this range of frequencies have risen the interest in developing materials for guidance and processing of this kind of radiation.

In recent years, an intensive effort has been made to obtain photonic crystals that can be patterned in one single step. Direct ink writing (DIW) technique enables to fabricate three-dimensional photonic crystals in a single step [1,2]. This technique relies on direct writing of a continuous filament in a layer-by-layer built sequence.

This work is on the fabrication and characterization of periodic structures -photonic crystals- to guide and process radiation in the terahertz spectral range. We report three-dimensional photonic crystals for terahertz frequencies patterned by direct-ink writing in one-step and further sintering at 900 °C using ZnO. ZnO is a very suitable material to use in the THz frequencies due to its high dielectric constant [3]. Among the structures that support complete photonic bandgaps, the diamond and related woodpile structures stand out due to its wide and robust bandgap even with a moderate dielectric contrast. To fabricate our photonic crystal we chose the woodpile structure in order to get a complete bandgap [4]. The photonic crystal of woodpile structure was designed using CAD software.

A ZnO aqueous colloidal suspension was developed for DIW. Woodpile structures with rod diameter of 200 µm were fabricated from these inks by using DIW (Fig.1). The preparation and rheological behaviour of aqueous inks and the sintering process were systematically studied. Furthermore, the critical parameters for the design of a woodpile structure, such as the rod width and the rod spacing were determined by optimizing the bandgap in the THz frequency range.

(a)



(b)

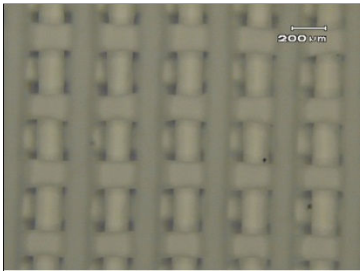


Figure 1: Optical microscopy image of a 3D woodpile structure assembled from aqueous ZnO ink. a) dried and b) after sintering at 900 °C for 2.5 hours.

References

[1] G. M. Gratson, M. Xu and J. A. Lewis, Nature, 428 (2004) 386.
[2] J. E. Smay, J. Cesarano III and J. A. Lewis, Langmuir, 18 (2002) 5429.
[3] Y. Kim, K. Ahn, B. G. Kim and D. Yee, Japanese Journal of Applied Physics, 50 (2011) 030203.
[4] M. Maldovan, E. L. Thomas, and C. W. Carter, Applied Physics Letters, 84 (2004) 362.