Towards automated fabrication of 3D photonic devices by Focused Ion Beam

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The direct patterning capabilities of focused ion beam (FIB) systems offer the unique opportunity to fabricate and characterize multiple photonic designs rapidly after another. Any findings can be directly used to optimize process parameters or to modify the design. FIB based patterning does not require any conventional nanofabrication processes such as resist deposition, resist exposure or plasma etching. The short development cycles reduce the overall design time significantly.

Top down fabrication of photonic crystals (2D) by FIB has been exploited for many years. Initially one was often restricted to simple shapes and sequences or combinations thereof, which has been time-consuming and generally not efficient. While electron beam lithography systems are generally capable of handling complex designs, and can interface with FIB microscopes, the use of gas chemistries and FIB-optimized scanning strategies has been very limited. Novel developments on DualBeam FIB/SEM systems make it possible to import complex CAD files directly, without the use of an electron beam lithography system [1]. When a CAD file consists of multiple layers, these layers can be sequentially deposited or milled and aligned with respect to another (Fig. 1). Process parameters such as exposure dose, time and order of sequence can be modified easily. Contrary to lithography processes, alignment marks can be generated on-the-fly by FIB and used for accurate alignment as part of the nanofabrication process.

In order to exploit the full theoretical capabilities of photonic band gap devices, the preparation of 3D photonic structures is essential [2]. Since the 2D nanopatterning process is maturing, new possibilities for 3D nanopatterning arise. 3D photonic structures can be advantageously manufactured in a FIB system by patterning the substrate from multiple different angles, which can be done in an automated sequence thanks to automated alignment capabilities.

The example (Fig. 2,3) below describes a possible approach in which the substrate is tilted in multiple directions towards the focused ion beam automatically. In the first step most of the surrounding material is being removed around the area of interest. Then the substrate is tilted and after automatic alignment the photonic arrays are milled through the revealed structure. The 3D design in this case is described by a sequence of layers patterned at different stage tilt angles.
This proof of concept demonstrates the viability of fabricating complex, truly three-dimensional structures using FIB. The automated alignment capabilities enable an automated sequence of complex processing steps, resulting in novel structures and enabling new geometries to be realized.

References

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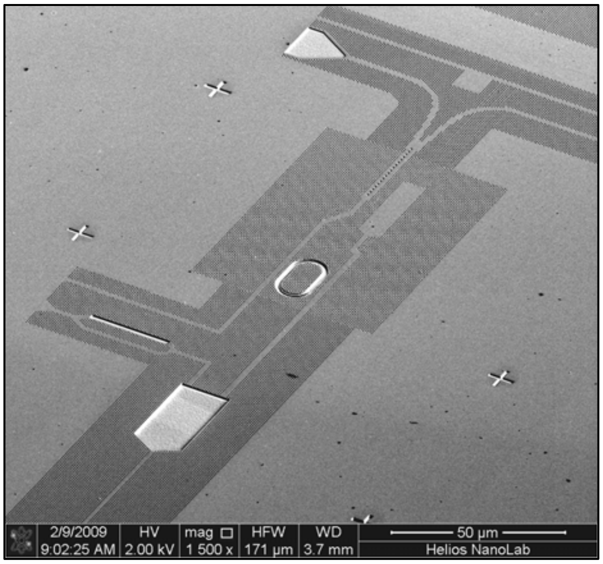

FIG. 1. A 2D nanophotonic proof of concept structure milled in an InP substrate

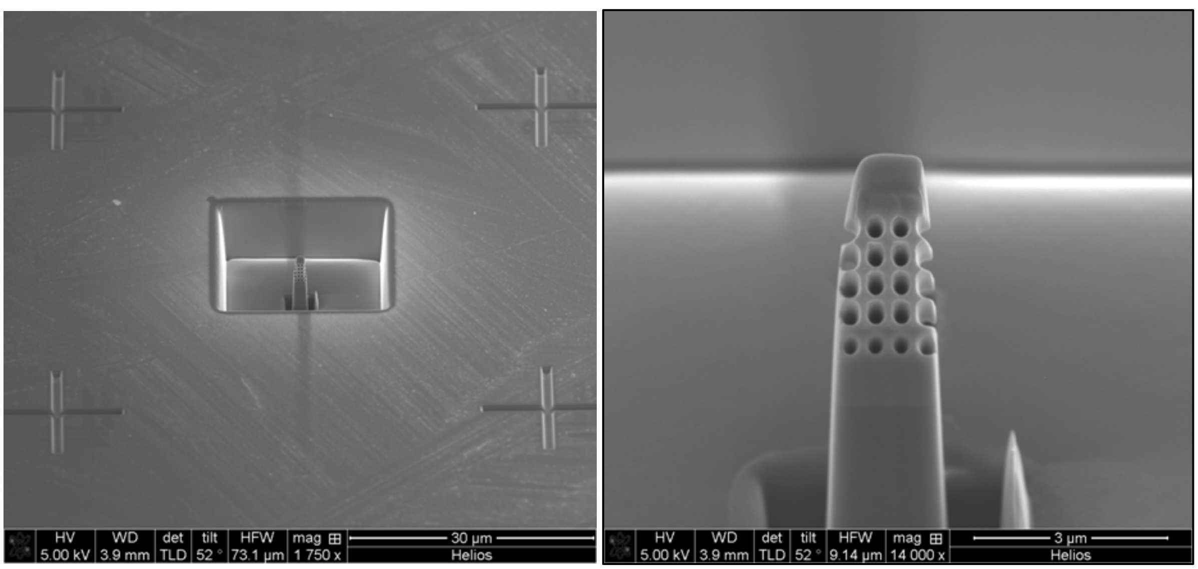

FIG. 2 & 3. A 3D nanophotonic proof of concept structure milled in Si automatically milled from 2 different tilt angles.