Modeling and Process Design for Laser Interference Lithography Used in Fabricating Two-Dimensional Periodic Structures

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Abstract

'Laser Interference Lithography' (LIL) is a technique that can be successfully used for realization of 2D periodic structures, with excellent uniformity over large areas[1]. However, detailed modeling is needed in order to extract the optimum design parameters. In this paper, we refer to a design procedure for LIL applied to fabricating photoresist templates for photonic crystal semiconductor slabs with periodic lattices of holes.

The exposure process is simulated with a computer program based on a mathematical model, taking as inputs: a) parameters of UV laser exposure (irradiance, exposure time); b) geometry of the 2D periodic lattice; c) geometrical and optical properties of materials involved. The output of the program is the 3D spatial distribution of electromagnetic dose recorded in photoresist. Results for two-beam and three-beam interference approaches are shown and compared.

The recorded dose is useful for estimating the relief of photoresist remaining after development. The effect of a vertical standing wave pattern on the geometry of photoresist pillars is analysed. We conclude that, in the presence of a standing wave pattern with a strong modulation, the thickness of the photoresist layer and its uniformity have a critical influence on the stability of pillars and on the filling factor of the 2D periodic lattice. Use of an antireflection coating (ARC) proves to be necessary for improving the quality of the 2D lattice of photoresist pillars standing on a high refractive index substrate (e.g. silicon).

The two-beam interference pattern has a low spatial contrast which makes difficult the direct generation of a lattice of holes. Instead, a pattern of photoresist pillars can be realized, and an additional step, lift-off, is needed for inverting the mask[2].

Three-beam interference pattern[3] has an improved spatial contrast and is possible to obtain, directly after development, a photoresist mask with holes. The standing wave pattern does not affect the stability of this structure and the exposure is done in a single step, but the three-beam interference shows less flexibility in tuning the lattice constant.

References

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