LARGE AREA PERIODIC NANOSTRUCTURES: INFLUENCE OF SEVERAL PROCESS PARAMETERS

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Abstract

Laser Interference Lithography (LIL) is a method to easily pattern large areas (in the range of 10cm diameter) with nanogratings or nanogrids [1]. The tool used for this work is known as "Lloyd's Mirror" and uses the interference of a coherent laser beam (λ = 325nm). The set-up is depicted in Fig. 1. A layer of photoresist is deposited on the substrate (a Si wafer for example), and then is placed 90º with respect to a mirror, in front of the laser beam. Due to the light reflected from the mirror, an interference pattern is created and recorded into the photoresist. The period of this pattern is easily adjusted fixing the angle of the mirror-substrate set, according to the expression $\sin\theta = \lambda / 2P$. This expression shows the theoretical restriction for the minimum period achievable, λ/2 (162,5nm). Gratings or holes and columns grids can be obtained exposing the substrate once, or twice in different angles.

Lines width or holes and columns diameter can be controlled by adjusting the exposure dose. The exposure dose is defined to be the energy deposited per unit area and it is the power of laser at the substrate per unit area multiplied by the exposure time [2]. A graph of holes diameter vs exposure dose made to this work can be seen in Fig. 2. Similar graphs have been published by other authors using different LIL set-up [3].

The intensity of the laser spot has a Gaussian distribution in the plane perpendicular to the beam direction, which maximum is aligned to the center of the mirror-substrate set [2]. Substrate points farther from the center receive less exposure dose. According to the data showed in Fig. 2, wafers exposed to higher doses will have larger uniform areas. Fig. 3 shows pictures of wafers where zones with different tones in their color can be seen due to the difference in exposure dose. The wafer in Fig. 3.a has received less exposure dose than the other wafer. The right edge of this wafer has received very low dose and the pattern has not been recorded into the photoresist. The wafer in Fig. 3.b has received high exposure dose and features size had a high uniformity. The pink zone on the left side of both wafers is the shadow produced by the mirror.

Once obtained the photoresist pattern, features size of final nanostructure can be adjusted using O_2 Reactive Ion Etching (RIE). Fig. 4 shows a graph that relates hole diameters of a grid with O_2 plasma time, with rf-power 75W and chamber pressure 10mTorr.

Finally, the photoresist pattern is transferred to the substrate using RIE again [4]. All plasma parameters are controlled to obtain different etch depths (gas, flow gas, chamber pressure, rf-power, time, etc.). Images of several nanostructures can be seen in Fig. 5.

References

[1] H.I. Smith, Physica, E 11 (2001), 104-109.
[2] T.B. O'Reilly and H.I. Smith, J. Vac. Sci. Technol. B 26(6) (2008), 2131-2134.
[3] Cheng-Wei Chien, Jyh-Chen and Ju-Yi Lee, Applied Optics, Vol. 45 No.32 (2006), 8278-8287.
[4] J. Bravo, I. Cornago, S. Domínguez and J. Irigoyen. Easy large area Nanopatterning. NanoLitho 2009, Madrid.

Figures

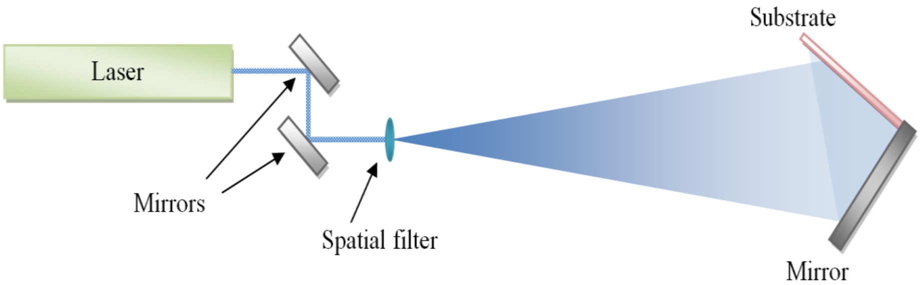

Fig. 1. Lloyd's Mirror set-up

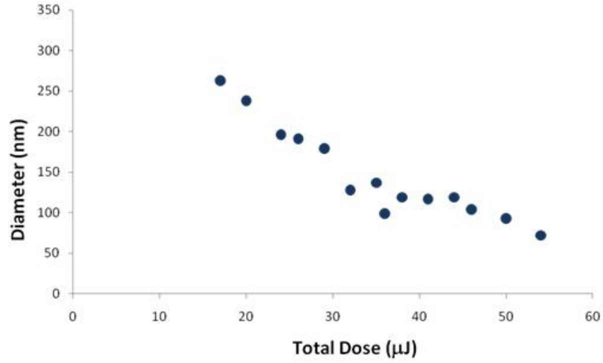

Fig. 2. Relation between holes diameter and exposure dose

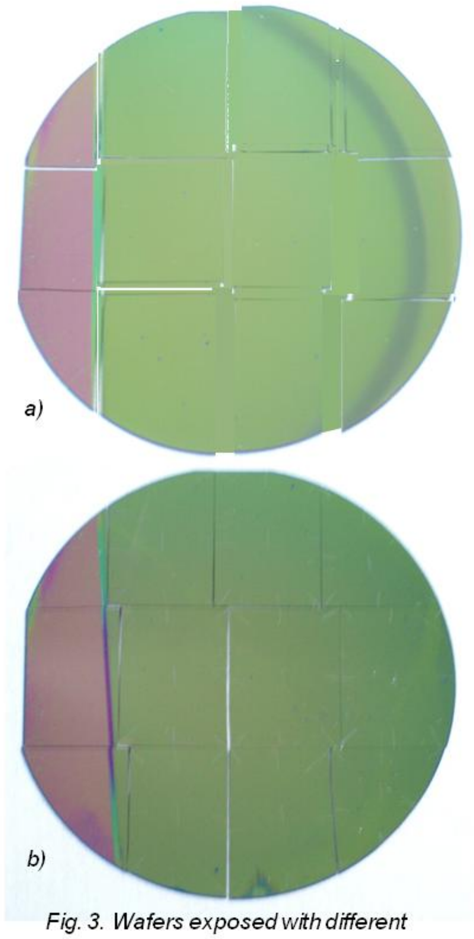

Fig. 3. Wafers exposed with different doses. a) 24µJ; b) 45µJ . They were cleaved for their inspection

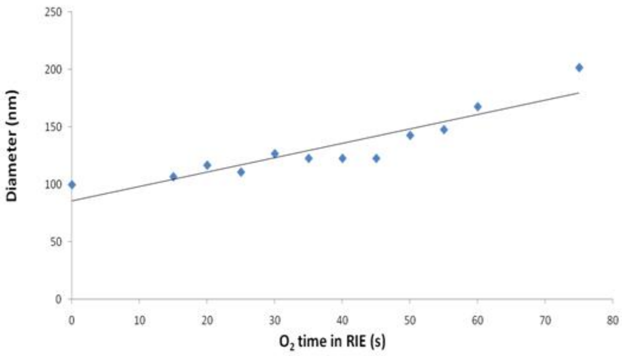

Fig. 4. Relation between holes diameter and O_2 plasma time in RIE

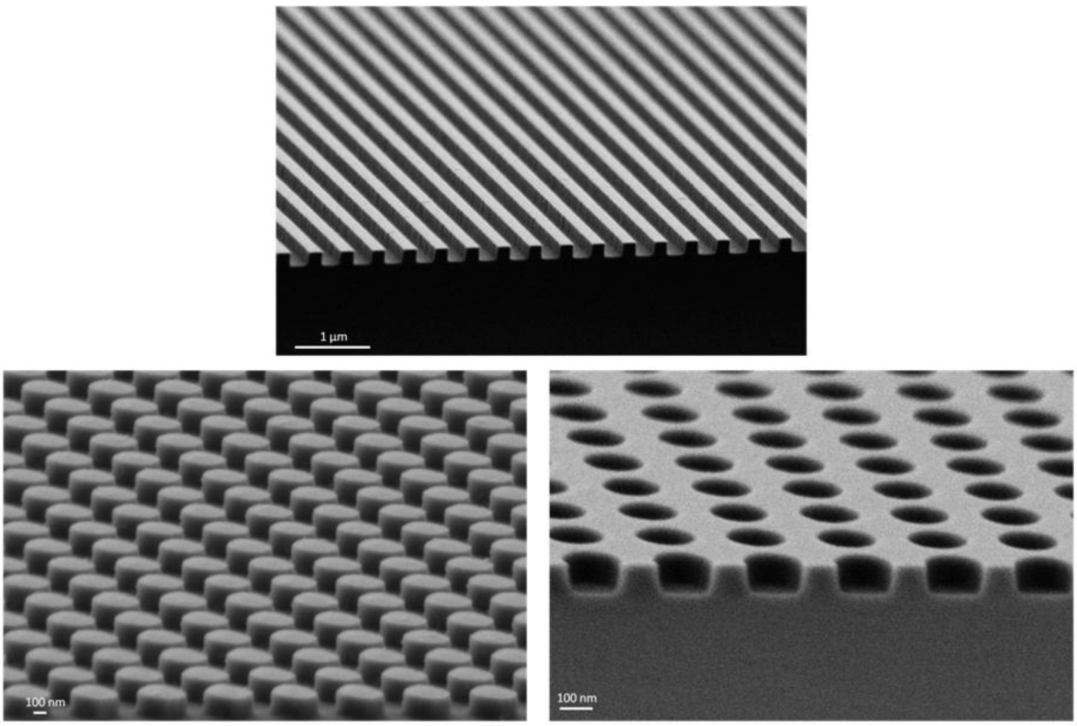

Fig. 5. SEM images of lines, columns and holes nanostructures