DELILA - Development of Lithography Technology for Nanoscale Structuring of Materials Using Laser Beam Interference

Overview: The project "Development of Lithography Technology for Nanoscale Structuring of Materials Using Laser Beam Interference (DELILA)" focuses on researching and developing a new production technology for fabrication of 2D and 3D nano structures and devices. In particular, DELILA will enable low cost and large volume production of surface structures and patterns with a feature size better than 40nm. DELILA is a specific targeted research project (STREP), funded by the European Commission under the 6th Framework Programme (FP6). The consortium consists of 5 partners: the Manufacturing Engineering Centre (MEC) of Cardiff Univ in the UK (coord), the Optoelectronics Research Centre (ORC) of Tampere Univ of Technology in Finland, SILIOS Technologies SA (SILIOS) in France, the Institute of Applied Physics (IAP) of Russian Academy of Sciences, and the Dept. of Microelectronics, Centro de Estudios e Investigaciones Técnicas de Gipuzkoa (CEIT) in Spain.

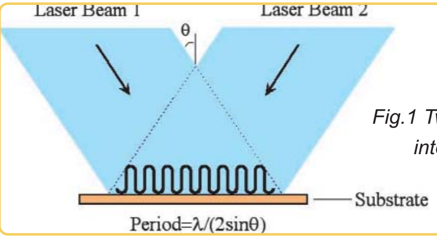


Fig.1 Two-beam laser interference.

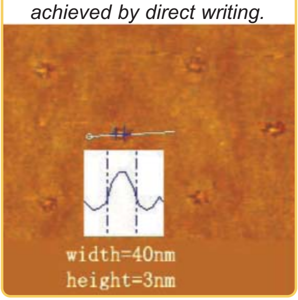
Laser interference lithography: Laser interference lithography (LIL) is concerned with the use of interference patterns generated from two or several coherent beams of laser radiation for the structuring of materials. The interference patterns can be arrays or matrices of laser beam lines or dots. The pattern period is basically governed by as shown in Fig. 1. The intensity distribution of the interference patterns exposes materials with a pitch of sub-wavelength of the interfering light. When using such radiation to interact with materials, feature sizes down to a fraction of the laser wavelength can be created. This technology provides a way for nano patterning periodic and quasi-periodic patterns that are spatially coherent over large areas. LIL is highly innovative in nanolithography due to the facts that its high efficiency, large working areas and low cost in nanoscale structuring of materials as compared to the ion beam lithography (IBL) or electron beam lithography (EBL) technology. With respect to the scanning probe lithography (SPL) technology the advantage of LIL is the non-contacting projection mode with a large working distance and extremely efficient fabrication which are two decisive advantages with respect to emerging nanotechnology production requirements.

In general, LIL has the following advantages compared with other nanolithography technologies: (1) Very high throughput (1 pattern/pulse in ~10ns); (2) low cost; (3) programme controlled re-configurable patterns (with different periods, feature sizes and pattern shapes); (4) surface contamination-free; (5) creation of structures on large areas (up to hundreds of mm in diameter); (6) long working distance (flexible within coherence lengths and modification energy thresholds of materials); and (7) environment friendly.

System architecture: The scheme of a multi-beam laser interference lithography system for formation of laser interference patterns consists of nine parts: laser radiation, beam shaping, beam splitting, phase control, interference control, polarization control, beam monitoring, sample positioning and system control. The role of laser radiation is to supply coherent light with an appropriate wavelength, power and coherence length. As for almost all lasers, the intensity of laser beam is Gaussian distribution, and it must be transformed into a flat-top distribution before interference so that a uniform pattern can be produced. Beam splitting is needed to obtain several coherent beams for a laser interference nanolithography system. Phase control is significant for a laser interference nanolithography system, as it is related to pattern orientation or localization of a pattern. Interference control is concerned with the arrangement of the coherent beams to form required interference patterns. Polarization control is related to the arrangement of the polarization states of interfering beams to form required interference patterns. Beam monitoring is concerned with the monitoring of a multi-beam interference nanolithography process. Sample positioning is related to the positioning of samples (x, y, z), repeated patterning of large samples (x, y), changing of the incident angles of the laser beams and the periods to keep the sample in a position for patterning (z) and rotation of the angle between the sample and the incoming beams to have more flexibility to the shape of patterns that can be defined.

Technological potential: The technological potential of the multiple beam laser interference lithography technology is closely related to the following parameters: writing mode – both direct writing and indirect writing, pattern feature size – a feature size down to ~λ/10, pattern period – a period of ~ λ/2 (without interpolation), pattern type – gratings (2-beam interference) or arrays of dots/holes (multi-beam interference), pattern size – up to hundreds of millimetres in diameter, exposure mode – single or multiple pulses, exposure duration – ~ 10ns, exposure repetition – ~ 10Hz, depth of focus – large (flexible), and throughput – high (1 pattern/pulse).

Fig. 2 A feature size of ~40nm achieved by direct writing.



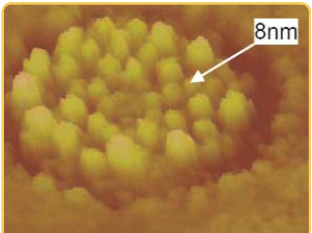


Fig. 3 Quasi-periodic nano islands or features down to around 8nm induced by pulsed laser interference patterns.

Fig.2 shows a surface pattern with a feature size of ~40nm achieved by direct writing and Fig.3 shows quasi-periodic nano islands or features down to around 8nm induced by pulsed laser interference patterns.

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