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Laser Interference Lithography

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Introduction

Laser Interference Lithography (LIL) is a high-resolution patterning technique that utilizes the interference of coherent light beams to create periodic structures on a substrate. This method offers several advantages over traditional lithography techniques, such as high throughput, low cost, and the ability to produce large-area patterns with uniform feature sizes.

LIL has the potential to revolutionize various industries by enabling the fabrication of nanostructures with unprecedented precision. One promising application lies in the manufacturing of diffractive gratings, which are essential components in numerous optical systems. Unlike conventional electron beam lithography, which suffers from low throughput, LIL can efficiently produce high-quality gratings for a wide range of applications, from automotive headlights to advanced optical sensors in smartphones.

Moreover, LIL can be employed to create metasurfaces, ultrathin structures that can manipulate light in unique ways. These metasurfaces hold immense promise for developing innovative optical devices, such as augmented reality headsets, where compact and efficient light management is crucial.

This study aims to investigate the capabilities of the Skylark laser for LIL by evaluating its performance in patterning different photoresists. The high power and spectral purity of the Skylark laser are expected to contribute to improved feature resolution and uniformity in the resulting nanostructures.

Methodology

Experimental Setup

A Skylark 349NX continuous-wave single frequency laser operating at a wavelength of 349 nm and with a power output of 100 mW was employed as the light source. The laser beam was expanded and collimated before being split into two coherent beams using a beam splitter. These beams were then recombined at a specific angle on the sample surface to generate an interference pattern. A Lloyd's mirror configuration was utilized for this experiment.

Substrate Preparation

Silicon substrates were used as the base material. For the first set of experiments, a negative photoresist layer with an approximate thickness of 1 μm was spin-coated onto the silicon substrate. In the second set of experiments, a chromium layer with an approximate thickness of 35 nm was deposited on the silicon substrate, followed by the application of a positive photoresist (MIR701).

Exposure and Development

The prepared substrates were exposed to the interference pattern for a predetermined time. After exposure, the photoresist was developed to reveal the underlying pattern.

Characterization

The resulting patterns were characterized using scanning electron microscopy (SEM) to determine the pattern dimensions and quality.

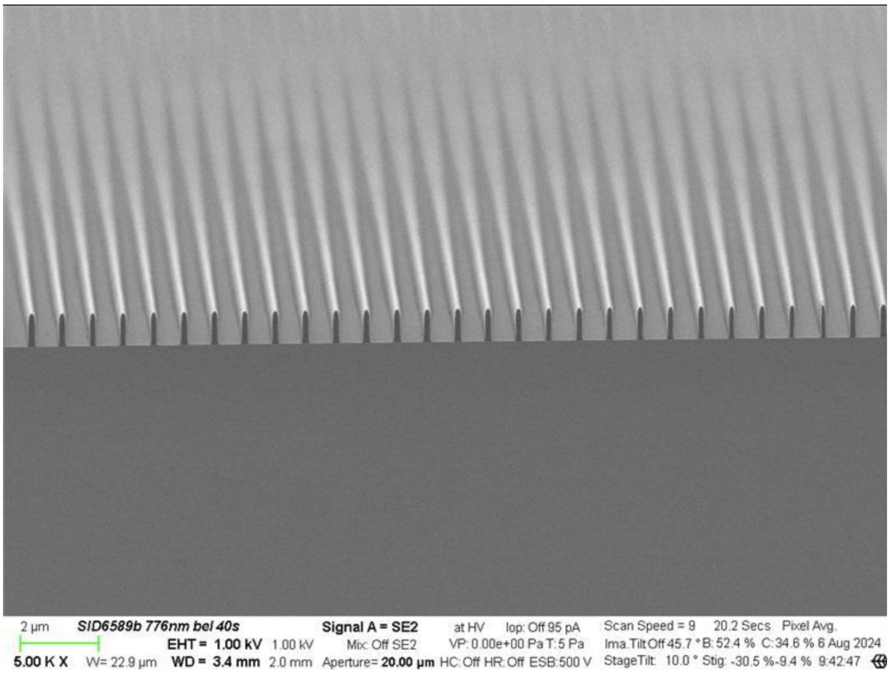

Figure 1: SEM image of a cross-section of a negative photoresist layer on silicon, showing a periodic pattern with a spacing of 776 nm.

Results

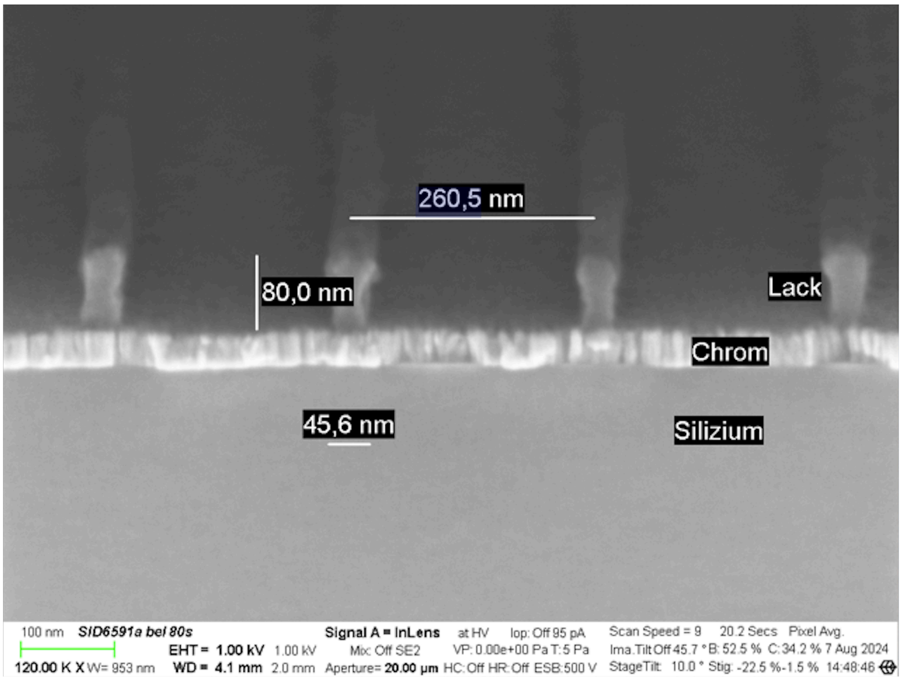

Figure 2: SEM image of a cross-section of a chromium and positive photoresist layer on silicon, showing a periodic pattern with a spacing of 260 nm, line width of approximately 45 nm, and line height of approximately 80nm.

Pattern Formation

Initial experiments focused on utilizing a negative photoresist on a silicon substrate. The resulting SEM image revealed a periodic pattern with a spacing of 776 nm between the lines (see Figure 1). While this result demonstrates the feasibility of pattern formation using the Skylark laser and Lloyd's interferometer, further optimization is required to achieve smaller feature sizes.

To investigate the potential for higher resolution patterning, a chromium layer was deposited on a silicon substrate followed by the application of a positive photoresist (MIR701). The resulting SEM image (Figure 2) showcased a significant improvement in pattern dimensions. Periodic lines with a spacing of 260 nm were successfully fabricated. The average line width was measured to be approximately 45 nm, and the line height was estimated at 80 nm.

Discussion

The results obtained in this study demonstrate the potential of the Skylark laser for high-resolution pattern generation using LIL. The successful fabrication of sub-100 nm features highlights the laser's ability to create precise interference patterns. However, further optimization of experimental parameters, such as photoresist selection, exposure time, and development conditions, is necessary to achieve even smaller feature sizes and improve pattern uniformity.

Reveal the unseen,
detect the imperceptible,
measure the unknown.

The demonstrated capability of producing high-quality nanoscale patterns opens up possibilities for various applications, including the fabrication of diffractive optical elements, metamaterials, and sensors. Additional research is required to fully explore the potential of this technique and translate these findings into practical devices.

Conclusion

This study successfully demonstrated the feasibility of utilizing the Skylark 349NX laser for laser interference lithography (LIL) in producing high-resolution periodic patterns. By employing a Lloyd's interferometer configuration, sub-100 nm features were achieved using a combination of chromium and positive photoresist. While initial results using a negative photoresist were promising, further optimization is required to attain comparable feature sizes.

The long coherence length of the Skylark laser, exceeding 100 meters, ensured a stable interference effect throughout the optical path. Furthermore, the extremely high wavelength stability of less than 0.2 pm contributed significantly to the observed pattern uniformity. Since the pattern pitch is directly influenced by the laser wavelength, minimal fluctuations are crucial for maintaining pattern integrity and preventing distortions.

The ability to fabricate nanoscale structures with precise control offers significant potential for a wide range of applications, including photonics, electronics, and materials science. Future research should focus on refining the LIL process to achieve even smaller feature sizes, improving pattern uniformity, and exploring the integration of these patterns into functional devices.

The results of this study highlight the potential of the Skylark laser as a valuable tool for nanofabrication and provide a foundation for further development in the field of laser interference lithography.

Author Information

Dr. Jack Ng is a Business Development Manager at Skylark Lasers with a PhD in laser direct writing. He specializes in nanostructured materials and holds a patent for a novel photolithography process. With over a decade of experience, Dr. Ng brings extensive knowledge to the applications of advanced laser technologies.
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