Sub-22nm High Throughput Maskless Nanolithography Using Quasi-3D Plasmonic Lens

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Concentrating optical energy at deep sub-wavelength scale is a great challenge because of the diffractive nature of light and it has numerous applications in lithography, data storage, biosensing, spectroscopy, molecular trapping, and so forth. Great efforts have been devoted to achieving smaller light spot sizes with high intensity. By working in the optical nearfield, people can access features far smaller than diffraction limit but usually suffer from the extremely low efficiency. Focusing light with orders of magnitudes higher efficiency can be realized by focusing surface plasmon polaritons (SPPs) and various structures have been proposed and demonstrated in past[1]. Among them, plasmonic lens (PL), is a particular type designed for generating a nanoscale light spot with high intensity which can be used as a virtual probe for high speed maskless lithography and many other applications[2-3].

In this work, a maskless high-throughput plasmonic nanolithography scheme (Fig. 1) is proposed which uses a novel quasi-3D PL so called the push-pin plasmonic lens (PPL) to obtain high efficiency optical focusing for super fine feature sizes reaching 10 nm and below, and a plasmonic flying head based on passive advanced airbearing surface (ABS) and active thermal actuation technologies to achieve scanning speeds at tens of meters per second while maintaining the required working gap between the PPL arrays and the spinning substrate at sub 5 nm size. As confirmed by experiments (Fig. 2), PPL design is capable of achieving high efficiency optical focusing through strong off-plane coupling making it an ideal candidate for many applications including lithography, imaging, sensing, and data storage. This low-cost scheme has orders of magnitude higher throughput than other maskless techniques[4-5] and promises a new route towards the next generation of nanomanufacturing.

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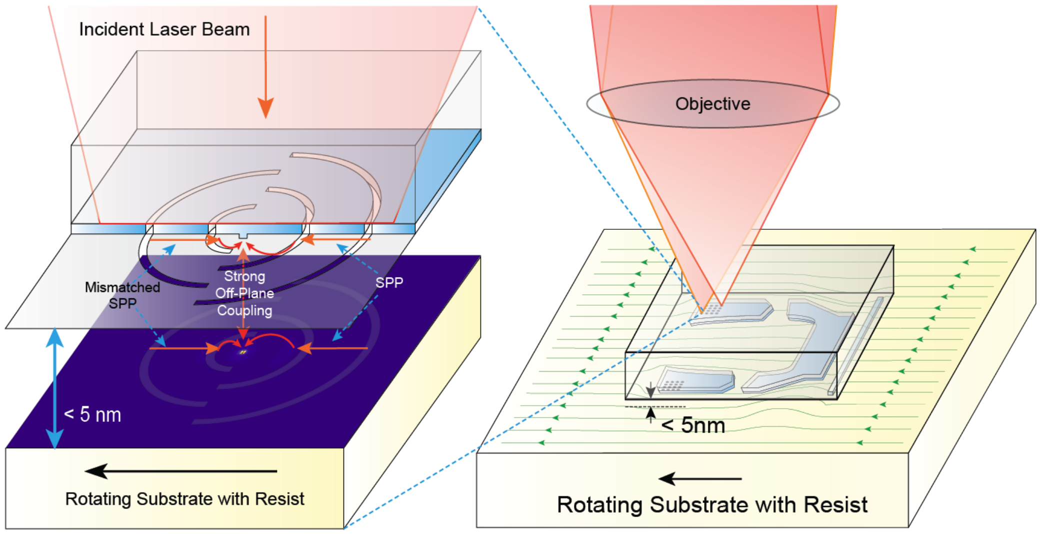

Figure 1: Quasi-3D push-pin plasmonic lens (PPL) for sub-22nm high throughput maskless nanolithography: (left) Our quasi-3D approach allows creating the features at sub-22nm scales by using mismatched SPPs to enhance the off-plane coupling between the lens and the substrate. The PPL, consisting of two sets of mismatched half ring grooves and a centered pin structure, is made of a metallic thin film and optimized for illumination of linearly polarized light along its symmetry axis. (right) A plasmonic flying head uses the advanced airbearing surface (ABS) and active thermal actuation technologies to maintain the gap between the PPL arrays and the substrate at sub 5 nm at linear scanning speeds of tens of meters per second.

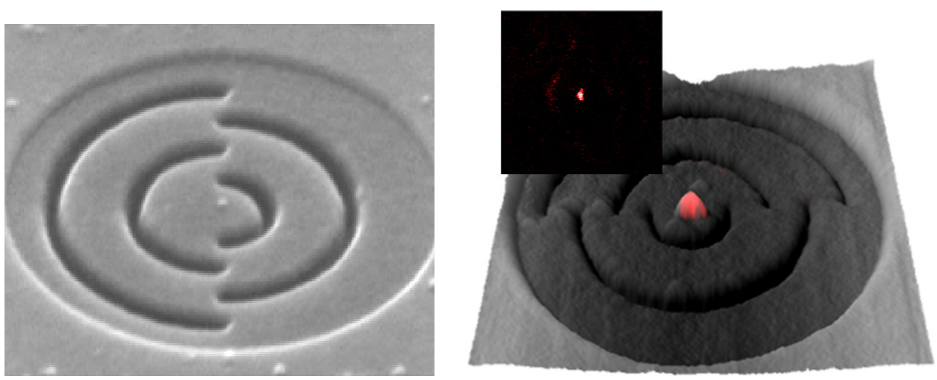

Figure 2: Fabricated gold push-pin PL structure and nearfield aperture-less NSOM image: (left) oblique view of P PL SEM images. (right) Aperture-less NSOM measurement image superposed with AFM measurement in an oblique view. The insert shows the top view of the NSOM measurement.