3D structuring of a novel Kinoform lens for x-ray focusing beyond zone plate diffraction limit

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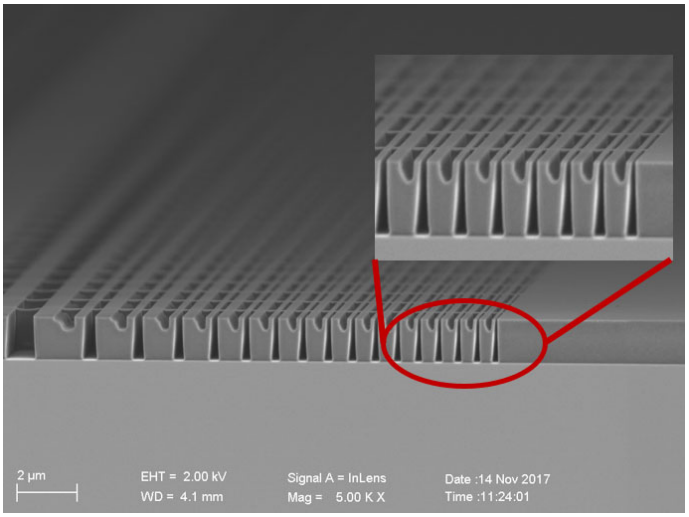
For hard x-ray beyond 20 keV of the photon energy, conventional diffractive optics such as metallic Fresnel zone plates (FZP) are not the best choice due to their limited attenuation lengths and low diffraction efficiency. Instead, refractive Kinoform lens can be a promising candidate for the focusing of high energy X-ray due to its high transmission efficiency. Its theoretical limit can reach 100% when lossless materials are used. Even with metals such as Au or Ni, the efficiency can still be well above the theoretical limit of FZPs. The main obstacle is the technical challenge for achieving vertical sidewall of the 2D cylindrical lenses with the height of at least 200 mm required for practical use, using the inductively coupled plasma (ICP) to carry out deep dry etch on Si.

To overcome the technical difficulty, this paper proposes a novel approach to fabricate Kinoform lenses by grayscale e-beam lithography (EBL) followed an accurate electroplating process. This can be done only after the lens configuration is converted from the cylindrical shape into the one in a 2D plate. To obtain the 3D structure with a narrow opening at the top of PMMA and a wide bottom, a brand new process called forward scattering assisted electron beam lithography (FSAEBL) is applied. A lower dose, with which only the top several hundred nanometers of PMMA can be dissolved, is assigned just adjacent to the larger area. But adding the forward scattering electron beam, it will be large enough for the developer to dissolve the bottom part of PMMA which is much wider comparing with the opening. In FSAEBL on PMMA, Monte Carlo simulation for charge distribution in e-beam exposure was first carried out and the resultant lens profile was obtained by modelling the developing process based on the measured contrast/dissolution rate curves. Using the theoretically simulated lithography parameters as a guide, the lens profiles in PMMA as templates are obtained as shown in figure. Subsequently, electroplating of Au was carried out to transfer the lens profile from PMMA to Au.

By summary, a novel and feasible method to fabricate Kinoform lens by forward scattering assisted e-beam lithography process has been developed. The Kinoform template with the outermost width of 300 nm is obtained. It is believed that this work provides a promising avenue to achieve X-ray lenses with the efficiency beyond the zone plate limit (40%).



The SEM image of the Kinoform lens pattern fabcicated by FSARBL on 1.4 μm PMMA.