Table top nanopatterning by de-magnified Talbot Effect

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We describe the extension of the coherent imaging by Talbot effect as an alternative to nanofabrication of periodic arrays of a unit cell containing arbitrary design. A periodic object composed of a two dimensional array of tiles, forms highly accurate real images of itself at distances that are integer multiples of the Talbot distance without the necessity of any optics. Illuminating the periodic transmission mask with a convergent coherent extreme ultraviolet (EUV) beam, we demonstrated the possibility to print de-magnified replicas of the mask.

The ability to form a projected self-image of a complex periodic object using coherent Talbot imaging is an interesting alternative in nano-fabrication if one could extend the resolution of the printing to the nanometer region. The recently availability of highly coherent table-top lasers in the EUV spectral region (46.9 nm) has made this alternative possible in a compact set-up.

The Talbot mask was fabricated on a 25 nm thick membrane of Si_3N_4 with a transmission T ≅ 13.5% at 46.9 nm wavelength using standard electron-beam lithography. The pattern was created in a 65 nm thick hydrogen silsesquioxane (HSQ) photoresist layer that efficiently absorbs the radiation at 46.9 nm, with a transmission approximately 3%. The Talbot mask was illuminated by a convergent EUV laser beam. A scheme of the experimental set up is shown in figure 1.

A photoresist coated Si wafer was placed in the vicinity of the calculated working distance of the different Talbot planes, approximately 1mm where the self-image of the Talbot mask was generated and recorded by the photoresist. Figure 2a) and 2b) shows AFM scans of the exposures at the first Talbot plane showing a de-magnification of approximately 20%. The scans shown in figure 2 are a small section of the total exposed surface (approximately 600μm × 600μm).

A century-old self-imaging phenomenon is now combined with EUV laser technology development to open new possibilities for the nanofabrication of structures without the need of complex optical systems. Talbot imaging opens the door to novel application of nanolithography of periodic patterns, such as high-density memory chips, nano-antennas, or surface enhanced Raman scattering structures where a regular pattern is repeated over large areas.

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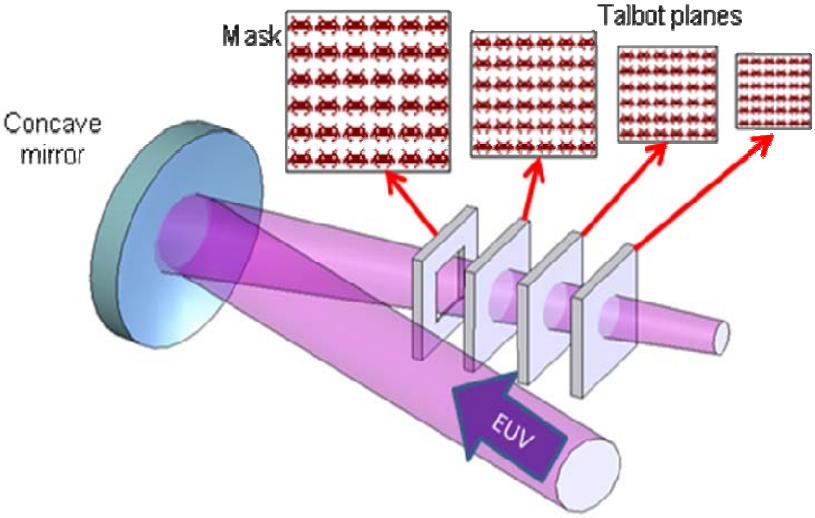

Figure 1. Experimental set up for de-magnified Talbot nanolithography

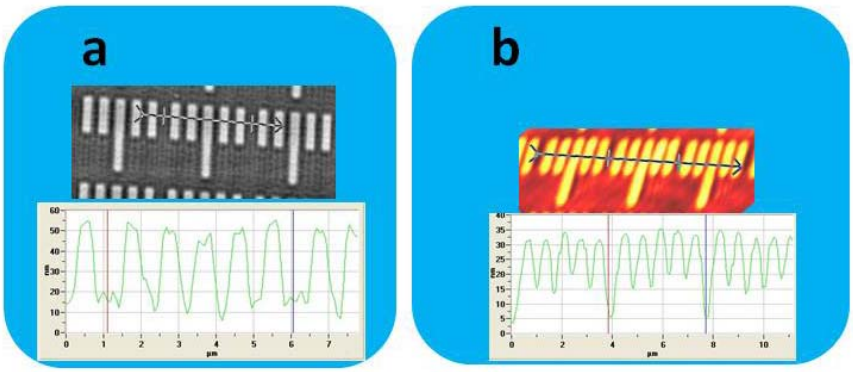

Figure 2. a) AFM scan of a test pattern printed in the first Talbot plane with a non-focused beam. b) Same mask illuminated with a convergent beam produces a 20% de-magnified image. The line-outs under the scans are the profiles along the arrows indicated in the scans.