Maskless Subwavelength Nanopatterning Using Vortex Phase Plates and Absorbance Modulation

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The reach of optical lithography, the primary driving force behind the fabrication of micro and nano scale devices, is limited by the far-field diffraction barrier[1]. Recently it has been reported that thin photochromic films can be used as an absorbance-modulation layers in order to fabricate one-dimensional periodic sub-wavelength nano-scale patterns[2, 3]. In this presentation we report the extension of absorbance-modulation-optical-lithography (AMOL) to pattern two-dimensional arbitrary geometries using an array of optical vortices.

The principle of AMOL to fabricate patterns below the diffraction limit involves the exposure of a thin layer of a two-state photo-switch-able photochromic material (Figure 1A) to an optical node at a wavelength λ_2 and a peak at another wavelength λ_1 simultaneously to generate a subwavelength transparent region (aperture) (Figure 1B) in the photochromic film. Absorption at the first wavelength λ_1 (ultraviolet) converts the photochromic layer into a transparent form, while absorption at the 2nd wavelength, λ_2 (visible) renders the photochromic layer opaque. An underlying photoresist layer can capture λ_1 light that transmits through the aperture and thereby record a "dot-pixel" of a pattern. The size of the exposed dot depends on the ratio of the intensities of λ_2 and λ_1 and shrinks with increasing ratio (Figure 1C). By scanning such dot-pixels in 2D using a nano-positioning stage, it is possible to generate arbitrary patterns.

The creation of the 2D node in the λ_2 beam is achieved by means of an array of vortex phase plates (Figure 1D, E) fabricated by grayscale lithography (Figure 1F). We present a means of recording the optical intensity profile of this nodal array on the photochromic layer (Figure 1G). Next, this array of optical nodes is used in conjunction with λ_1 illumination to pattern the photoresist to generate sub-wavelength features and a stage is used to scan relative to the exposures to generate arbitrary 2D patterns. Figure 2B shows the dot pixels recorded in the resist layer from one of the optical nodes for various doses. Keeping the exposure time constant, the size of the dot can be shrunk by increasing the ratio of illumination of the two radiations as per the principle of AMOL.

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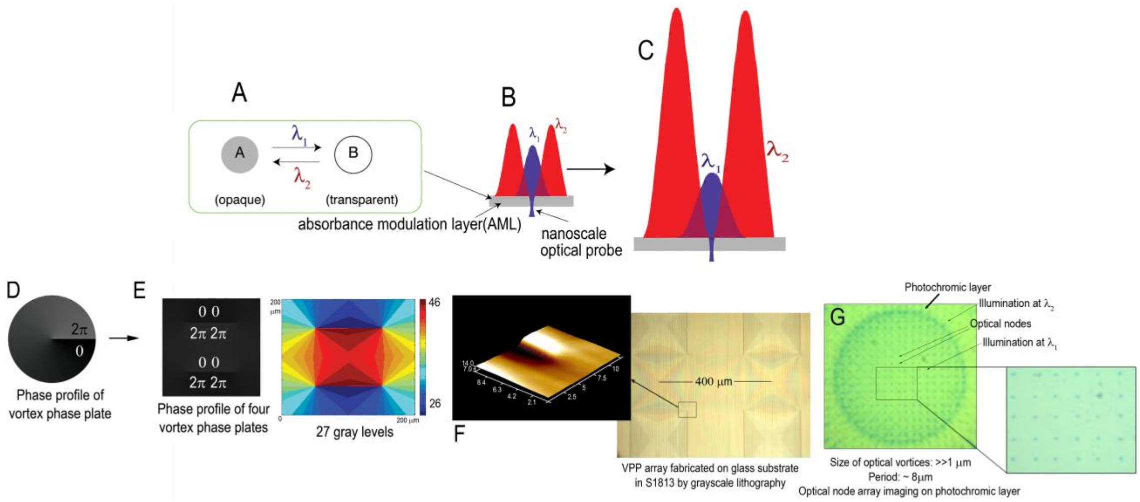

Figure 1: Two dimensional patterning by AMOL: (A) Photo-switch ability of the photochromic material. (B) Schematic of AMOL. (C) Pattern scaling as ratio of intensities of illuminating radiations. (D) Vortex phase plate (VPP). (E) Array of VPPs – design. (F) Array of VPPs fabricated on Shipley1813 on glass by grayscale lithography. (G) Array of optical nodes recorded on top surface of photochromic layer.

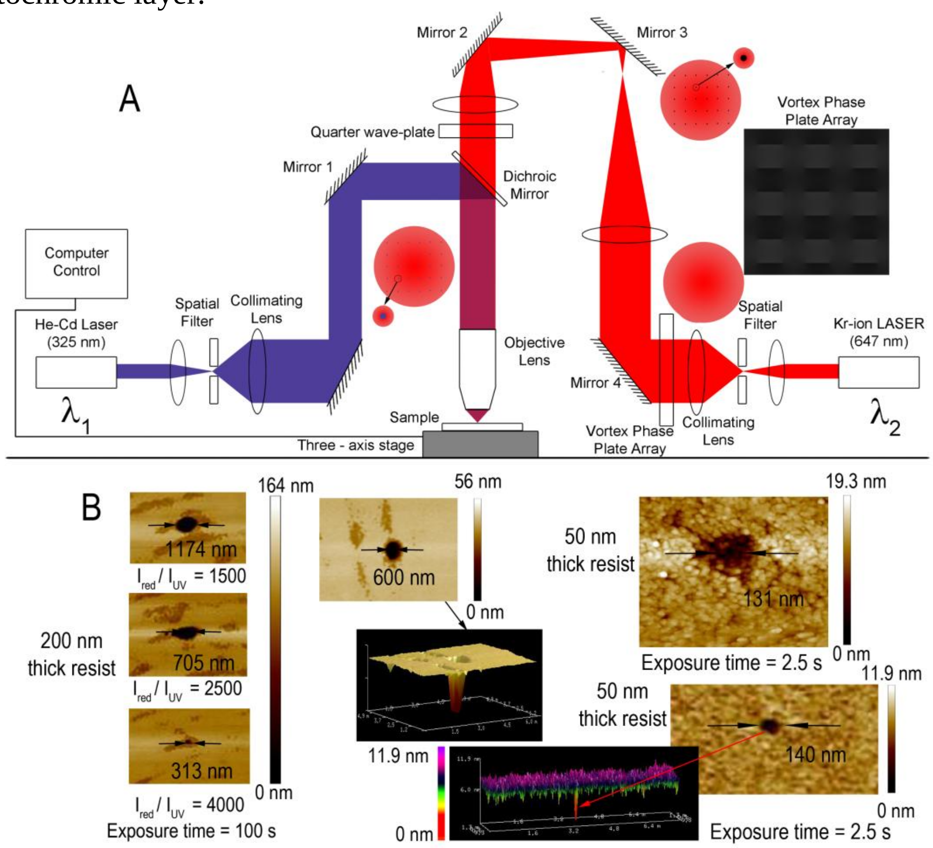

Figure 2: Two dimensional patterning by AMOL: (A) Schematic of the optical set-up. (B) Lithographic results.