Deep subwavelength patterning via Absorbance Modulation

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Abstract

Absorbance modulation is a novel optical patterning technique that can overcome the far-field diffraction barrier.[1,2] In absorbance modulation, a thin film of photochromic molecules is irradiated by a focused spot at one wavelength, λ_1 and a focused node at a second wavelength, λ_2. These molecules are designed such that they turn transparent when exposed to λ_1 and opaque when exposed to λ_2. Hence, the simultaneous illumination at both wavelengths will lead to a dynamic equilibrium resulting in a narrow transparent region in the vicinity of the node. Photons at λ_1 can penetrate through this aperture and expose the underlying photoresist (Fig. 1A).

In this presentation, we will describe an implementation of absorbance modulation where a standing wave at λ_2 is overlaid with a uniform beam at λ_1. Furthermore, the sample is mounted on a single-axis high precision scanning stage that will enable multiple exposures. A schematic of this system is shown in Fig. 1B. Sequentially stepping the stage between repeated exposures will result in dense pattern geometries as illustrated in Fig. 1C. The standing-wave illumination is provided by a helium-neon laser at λ_2 = 633nm, while the uniform illumination is from a light-emitting diode with a center wavelength, λ_1 = 310nm. The full-width at half-maximum bandwidth of the LED was about 10nm. We used a non-chemically amplified positive-tone photoresist (Shipley 1813). This resist has no sensitivity to λ_2 photons. Therefore, the appearance of a grating pattern in the resist after development validates the principle of absorbance modulation (Fig. 2). Furthermore, the period of the resist grating is the same as that of the λ_2 standing wave.

The photoresist layer is separated from the photochromic layer by a barrier layer composed of poly-vinyl alcohol (PVA). Moreover, the small photochromic molecules are typically doped into a support polymer matrix such as PMMA for easy spin-casting. After exposure, the photochromic layer and the barrier layer are removed prior to development. In this presentation, we will describe alternate processes that do not require such a barrier layer primarily via the proper choice of solvents and/or polymers for the top layer. Finally, we will report on our process for transferring the pattern from the thin imaging layer into the underlying substrate.

References:

[1] R. Menon & H. I. Smith, *J. Opt. Soc. Am. A*. 23, 2290 (2006).
[2] T. L. Andrew, H-Y. Tsai & R. Menon, *Science* **324** 917 (2009).

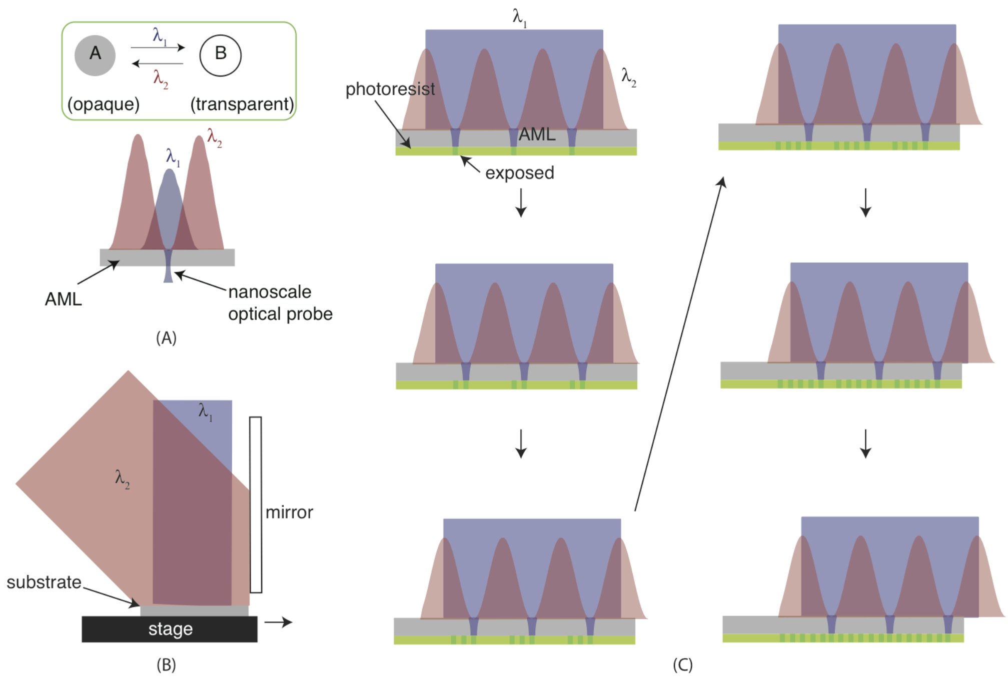

Figure 1: *(A) Schematic of absorbance modulation. (B) Schematic of experimental system. (C) The substrate is mounted on a single-axis scanning stage that enables precise relative positioning of the nodes of the standing wave. Sequential exposure as illustrated enable dense features.*

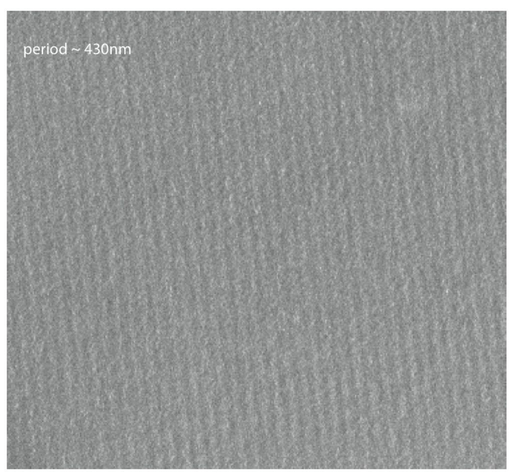

Figure 2*: Scanning-electron micrograph of a grating pattern from a single-exposure with absorbance modulation. The period of the λ_2 standing wave was about 430nm.*

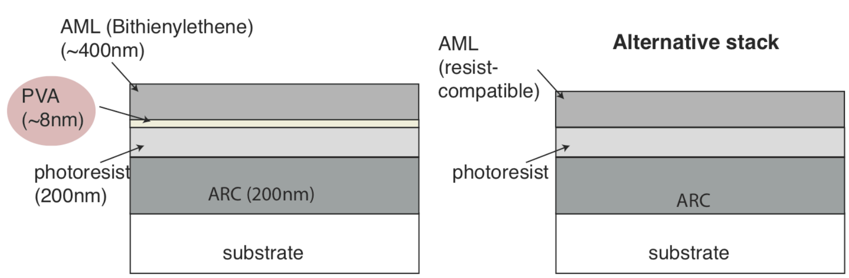

Figure 3: *Schematic of two different multi-layer stacks used in absorbance modulation.*