Single-Mode-Resonance interference in photoresist sub-micron waveguide for high exposure depth nanolithography

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Abstract: As nano-scale optical device becomes practical and commercialized, the efficient fabrication of nano-scale devices such as nano-grating and nano-scale photonic crystal is in great demand. We demonstrate a method to realize high resolution as well as high aspect ratio for nanolithography, which is not the characteristic of conventional interference lithography, evanescent wave interference lithography [1] and SPP interference lithography [2]. Meanwhile, it has higher efficiency and lower cost than Focused ion beam writing [3] and E beam writing [4]. In our method photoresist acts as a single mode sub-micron waveguide, in which single-mode interference fringes are realized in the photoresist (single-mode-resonance interference lithography, SMRIL). As for a thin planar dielectric waveguide, only TM_0 mode is supported in visible spectrum, which has only one antinode within the waveguide in the transverse direction. This feature is suitable for throughout exposure in the photoresist layer independent of the layer thickness. Furthermore, the longitudinal propagation constant of the mode can be considerably large, leading to very narrow fringes, i.e., very large resolution. Both of this result in high aspect ratio. A subwavelength grating (SG) is used to generate diffraction orders whose wave vector matches the propagation constant in the wave guide layer, thus, to couple incident wave into waveguide mode.

The configuration of SMRIL is shown in Figure1. Two parts are included. One is the coupling layers, which consists of glass, periodic ridge and match layer (PMMA). The other part is the photoresist coated on the substrate. A TM wave (wavelength 441nm) incidents from under, and is coupled in to photoresist layer by the subwavelength grating. High resolution fringes are obtained in the photoresist (Figure2). The thicker the photoresist layer is, the smaller the period will be. This leads to narrower fringe at thicker photoresist, i.e., larger aspect ratio (Figure2b-d). Interference fringes with period smaller than 140nm and depth larger than 900nm is obtained in simulation.

[1] R. J. Blaikie and S. J. McNab, Applied Optics 40, 1692-1698 (2001).
[2] Z. W. Liu, Q. H. Wei, X. Zhang, Nano Letters 5, 957-961 (2005).
[3] F. Watt, M. B. H. Breese, A. A. Bettiol and J. A. van Kan, Materials today 10, 20-29 (2007).
[4] M. A. McCord, Journal of Vacuum Sc ience and Technology B 15, 2125-2129 (1997).

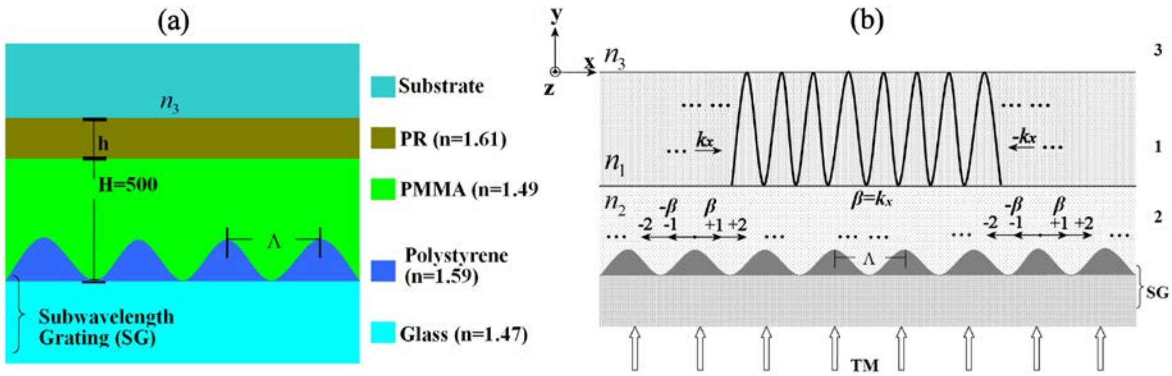

Figure 1: (a) Schematic of SMRIL. (b) Illustration of theoretical analysis.

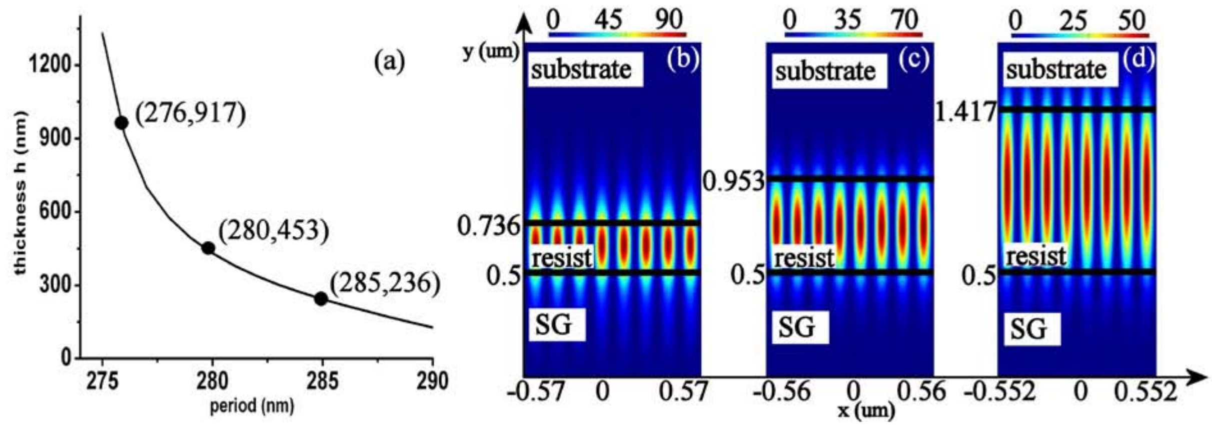

Fig. 2. (a) The relationship between photoresist thickness h and SG period at 441nm incident wavelength. (b), (c) and (d) are the light field distribution of SIMRL with being 285nm, 280nm and 276nm respectively. The thickness in the three cases is 236nm, 453nm and 917nm respectively.