Impact of pattern profile on surface plasmon polaritons in computational lithography

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When the resonance frequency of laser light falls within the sensitivity range of a photoresist for the plasmonic nanolithography, the extraordinary optical transmission beyond the conventional diffraction limitations is observed at wavelengths as large as ten times the mask patterns in a metal film [1-3]. The enhanced optical field close to the metal surface can locally cause increased exposure of resist thin layer directly below the mask. The physical origin of this enhanced transmission is the excitation of the surface plasmon polariton (SPP), which is the coupled mode excitation of an electromagnetic wave and free charges on a metal surface. Understanding the mechanism of the plasmonic lithography is interested to know plasmonic phenomena and expected to show novel concepts and methods to solve challenging problems of this lithography.

In this study, plasmonic phenomenon is described in simulation with the basis of experiment. SPP effects on pattern formation inside resist will be discussed on basis of simulation results.

Figure 1 shows simulation results for the TE and TM diffraction efficiencies in a commercial mask structure by using a RCWA method. When a mask pattern is smaller than an incident wavelength, the effects of diffractive directions can’t be ignored. When this pitch ratio is smaller than 1, the TE polarizations of Figs. 1(c), (d), and (e) become different with the TM polarizations of Figs. 1(f), (g), and (h), and the diffraction efficiencies of the diffracted orders become small [4].

Figure 2 shows experiment results of Figs. 2(a)-(d) and simulation results of Figs. 2(e)-(h) for SPP effects.

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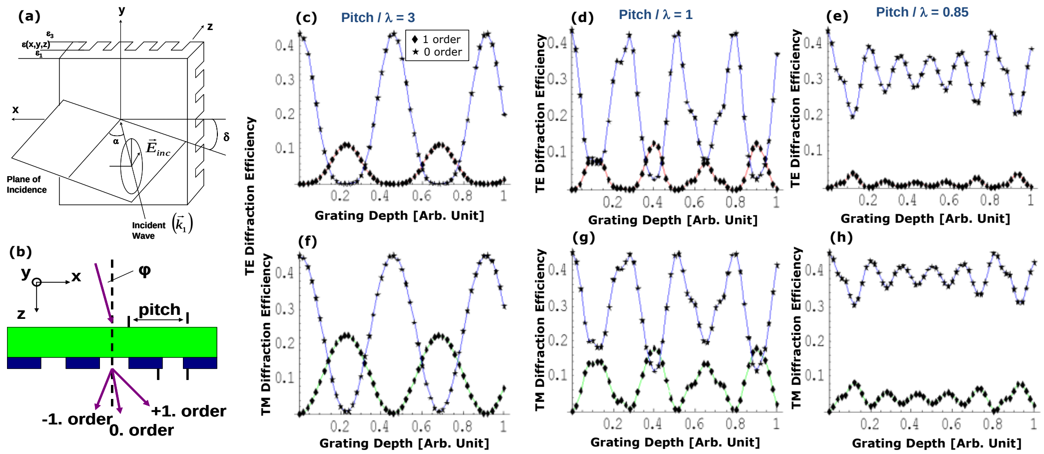

Figure 1: Mask structure of (a) three-dimensions and (b) the simplified three regions of the mask, and simulation results for the TE and TM diffraction efficiencies: (c)-(e) TE at pitch (p) / wavelength (λ) = 3, 1, and 0.85, (f)-(h) TM at p/λ = 3, 1, and 0.85.

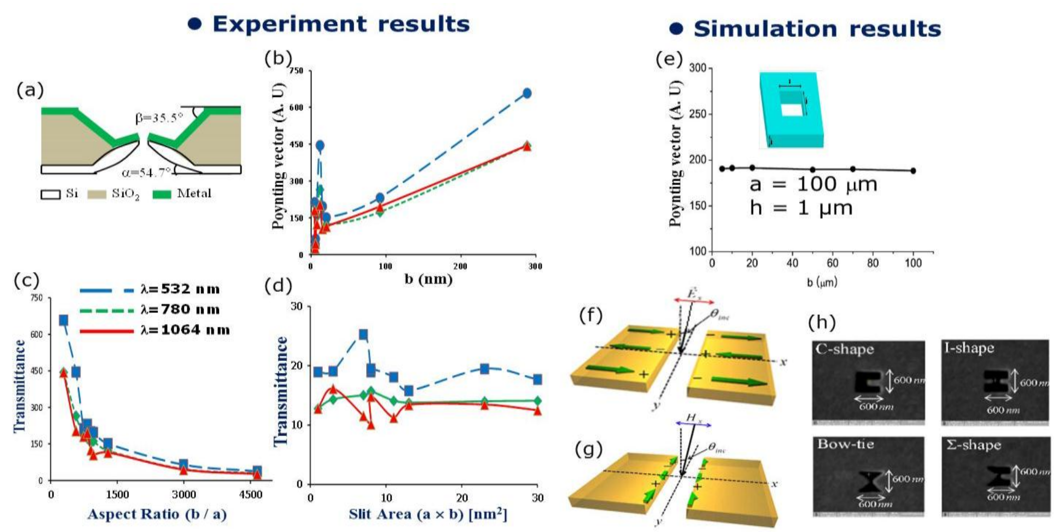

Figure 2: Mask structure of (a) three-dimensions, (b)-(d) experiment results for transmittance due to the mask size, and simulation results: (e) poynting vector due to pattern size, schematic mask structure of (f) perpendicular-to-slit E filed (TE) and (g) perpendicular-to-slit H filed (TM) with nanoslit ($a >> h$), and (h) various shapes of nano-aperture.