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Study of etch processes for the fabrication of extreme ultraviolet phase-only diffraction elements

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The use of phase-only diffractive devices has long played an important role in advanced optical systems. Such devices include for example simple gratings, diffractive and holographic optical elements, diffractive lenses, and phase-shift masks for advanced lithography. Extending such techniques to the increasingly important regime of extreme ultraviolet (EUV) wavelengths, however, is not trivial. In the past, patterned relief substrate methods providing high efficiency have been demonstrated [1]. These methods, however, suffer from resolution limitations arising from the fact that the multilayer deposited on top of the relief substrate cannot grow perfectly conformable way.

To address this issue we consider rather patterning phase-modulating structures on top of or directly into the multilayer. Despite the fact that most materials strongly absorb at EUV wavelengths, Molybdenum (Mo) provides an excellent trade-off between absorption and phase shifting. For a π phase shift thickness of 86 nm at 13.5-nm wavelength, Mo still transmits 60% of the power supporting surprisingly efficient phase devices. Using the Mo method it is possible to create either transmission or reflection devices. The Mo method has been implemented in the past on transmission devices, but suffered from rather poor efficiency due to significant problems with the etch process.

Here we present an improved etch process enabling high-resolution patterning of Mo for use in EUV phase devices. Moreover we present etch and fabrication processes for high-resolution etching directly into a Mo/Si multilayer stack providing another method for fabrication of high numerical aperture diffractive devices or high resolution EUV masks. Figure 1 shows an example of the multilayer etch used to fabricated a 500-nm pitch π-phase-shift grating.

References

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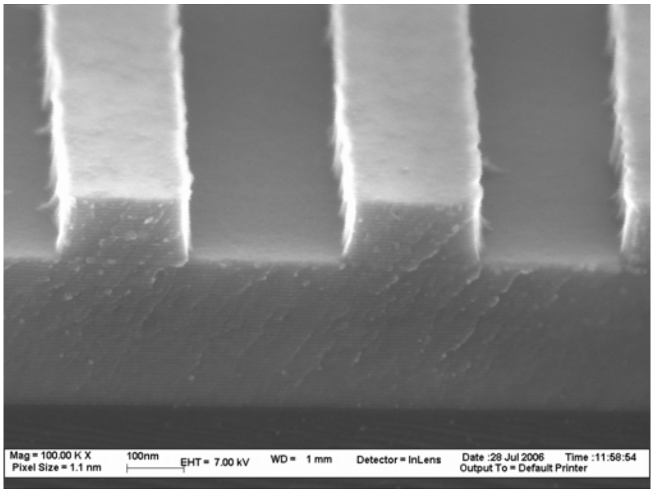

Fig. 1. Scanning electron micrograph of an etched multilayer grating with 500-nm period. The etch depth is set to approximately 115 nm, yielding a phase shift of 180°.

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