Broadband EUV Transmission Gratings

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Abstracts: *A broad-band and uniform efficiency EUV transmission grating has been developed for high-order harmonics application, such as spectroscopy, beam splitting, and beam monitoring. This free-standing transmission grating, fabricated by using e-beam lithography and dry-etching will realize a compact design and straightforward alignment EUV spectrometer. In addition, the grating parameters are easily customized depended on customers' requirements, including groove numbers, target wavelength, and duty ratio.*

Extreme ultraviolet (EUV) light source are interested for lots of science and high-tech field. High-order harmonics are tabletop sources for attoscience, inner-shell electron dynamics measurements and angle-resolved photoelectron spectroscopy (ARPES) experiments [1], and x-ray free electron lasers (XFELs) are opening a door for new material sciences [2, 3]. Soft-x-ray lasers are useful for understanding damage mechanism of material surface [4]. For high-tech region, relent explosive innovation of laser produced plasma (LPP) light sources have realized EUV lithography as an industrial tool [5]. For these EUV applications, many kinds of optical components are installed in experimental beamlines and/or industrial systems. Mirrors, thin-film filters, reflective gratings, and detectors are basic optical components for these systems, and there are many commercial products both standard and customized model. In the other hand, there are limited reports and demonstration of a transmission gratings (TGs), although it is a major component in visible, ultraviolet, and x-ray region.

Narrow-bandwidth EUV light is a one of a most important tool in both science and industrial field. Energy resolution of photoelectron spectroscopy experiments is limited by the light source bandwidth, and a few ten meV region bandwidths are required for leading-edge investigations. For EUV lithography and EUV inspection tool, bandwidth of plasma light source is narrowed around 2% by using Mo/Si multilayer mirrors combinations. Many material science field, reflective gratings based monochromator are used for obtain the narrowband EUV beam before sample irradiation. TG has advantages comparing with conventional reflective gratings or multilayer mirrors. i) Only it can monochromise EUV light with straightforward optical setting. ii) It has a broadband and uniform efficiency. And iii) by using TG, much compact and easier alignment spectrometer will be constructed.

In this paper, we propose and introduce two types of free-standing EUV TG for narrowband EUV applications. One is made of Ta/SiN bi-layer bars and optimized to water window wavelength diffraction. The other one is made of SiN single layer bars and optimized to 13.5 nm. Fig. 1(a) and 1 (b) show calculated 1st order diffraction efficiency of free-standing EUV TG, optimized to water-window and 13.5 nm, respectively. These parameters are shown in Table 1. Both TG are fabricated by using e-beam lithography and dry/wet etching combination, and easily customized parameters such as groove numbers, optimized wavelength and bar/space ratio.

In the first step of grating fabrication, 100 nm of SiN is deposited on both side of Si (100) wafer by low-pressure chemical vapor deposition (LP-CVD). Then, on a deposited 100 nm of Ta layer, photoresist for e-beam lithography is coated [Fig. 2(a)]. After e-beam lithography process, Ta is dry-etched [Fig. 2(b)]. In the third step, photoresist is removed and window pattern is

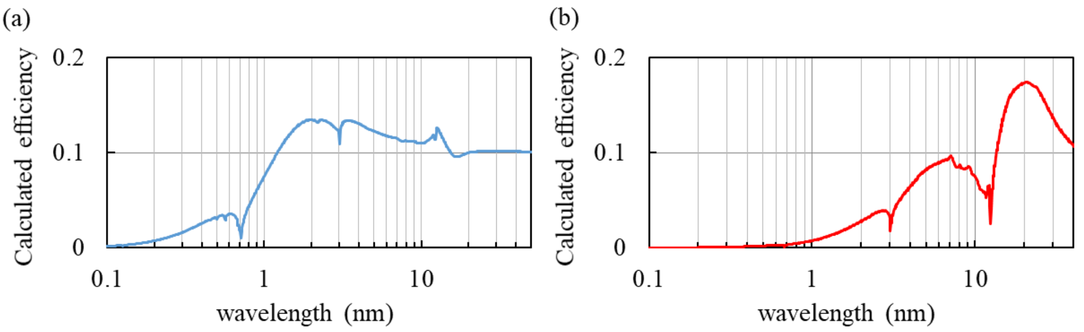

Fig. 1 Designed EUV transmission gratings for (a) Ta/SiN bi-layer TG and (b) SiN single layer TG

Table 1 Parameters of Ta/SiN TG and SiN TG

	Ta/SiN type	SiN type
Material	Ta (100 nm) and SiN (100 nm)	SiN (100 nm)
Grating area	2 × 2 mm	
Groove density	100 – 1200 lines/mm	
Support bar	500 nm width, 50 μm pitch	
Flame	10 × 10 × 0.625 mm Si	

formed from back surface by using photolithography and KOH wet process [Fig. 2(c)], and the top SiN between Ta bars are removed [Fig. 2(d)]. And as a final step, the fabricated Ta/Sin bi-layer free-standing gratings are separated 10 mm x 10 mm chips. For SiN single layer grating, the main fabrication processes are almost as same as Ta/SiN TG processes; SiN deposition, e-beam lithography, dry-etching, window patterning and dicing.

The advantages these processes are as blow; i) grating parameters such as bar/space ratio and bar thickness are easily customized depended on requirements, ii) edge verticality is 88 – 90 degrees, which values is better than that of the other processes for example imprinting processes and lift-off processes, and iii) compact outer dimension will be useful for constructing compact spectrometer.

SEM image of fabricated Ta/SiN TG and outer image are shown in Fig. 3 (a) and (b), respectively. The high-sharpness and low-roughness TG is expected to obtain an ideal diffraction efficiency. This new EUV optical components will be used for many kinds of applications such as spectroscopy, microscopy, as well as industrial fields.

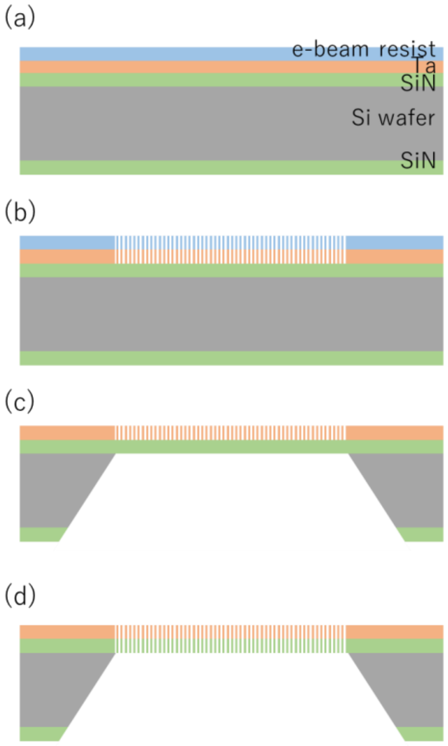

Fig. 2. Fabrication processes of Ta/SiN TG. (a)deposition, (b) e-beam lithography and Ta etching, (c) window formation, and (d) SIN etching.

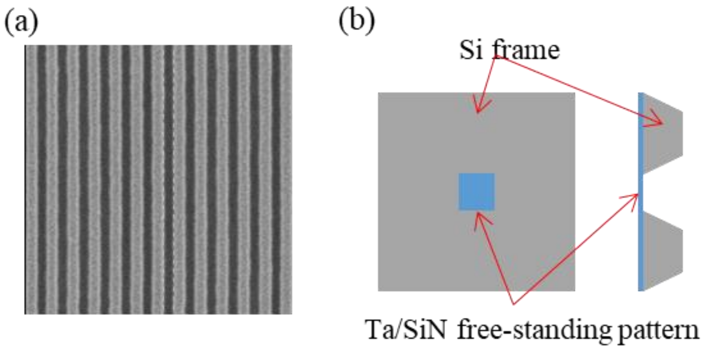

Fig. 3 (a) SEM image and (b) outer image of fabricated Ta/SiN TG

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