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SnO film as an absorptive material for EUVL mask

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Introduction

Extreme ultraviolet lithography (EUVL) is being developed for large-scale integrated (LSI) devices fabrication of 22 nm node and beyond. It utilizes EUV of about 13.5 nm wavelength. As there is no refractive lens in EUV region, an optical system for EUVL is composed of reflective mirrors and a reflective photomask. An EUVL mask consists of a Mo/Si multilayer (ML, typically 40 pairs) as high reflective region and an absorber pattern as low reflective region formed on the ML. An issue for EUV lithography is to reduce the so-called shadowing effect attributed to oblique incidence of EUV light on the mask. In order to mitigate the problem, a thinner absorber layer thickness for the EUV mask is preferred. A method for reducing the absorber thickness, while insuring mask contrast, is to use a more absorptive material.

In this report, we present EUV (13.5 nm wavelength) optical properties of a SnO film as an absorptive material for EUVL mask.

Experimental

A magnetron sputter system with O_2 and Ar sputtering gas was used to deposit a SnO film on a Si wafer substrate in order to evaluate film properties. We firstly evaluated optical constants n (refractive index) and k (extinction coefficient) by means of R-θ method [1]. Reflectance was measured at 13.5 nm wavelength by varying incident angle using an optical elements evaluation system at BL-12A. For the R-θ data, curve fitting analysis was performed for derivation of optical constants on the basis of reflection theory for layered media and the least-squares method. Additionally, we analyzed the SnO film concerning composition ratio and crystallinity by using XPS and XRD, respectively.

Results

Fig. 1 shows the measured reflectance and the result of curve fitting for the SnO film on Si substrate, which are in good agreement. Through the fitting, optical constants were derived (n = 0.936, k = 0.0722). Based on the result, we calculated EUV mask contrast as OD = – log (Ra/Rm). Here, Ra/Rm represents reflectance at absorber/ML region, respectively. Fig. 2 compares OD values as a function of absorber thickness for a typical Ta-based absorber (n = 0.958, k = 0.0369) and the SnO absorber on Ru (2.5 nm thick)-capped ML (40 pairs). Shown in Fig. 2, if we need OD = 1.6, the SnO absorber requires 24 nm thickness, which is the half thickness of the Ta-based absorber. Through XPS analysis, composition ratio of the SnO film was estimated O/Sn = 1.3. Fig. 3 shows XRD pattern of the SnO film. As seen a hallow peak for 25-35 degrees, the SnO film seems to be amorphous structure.

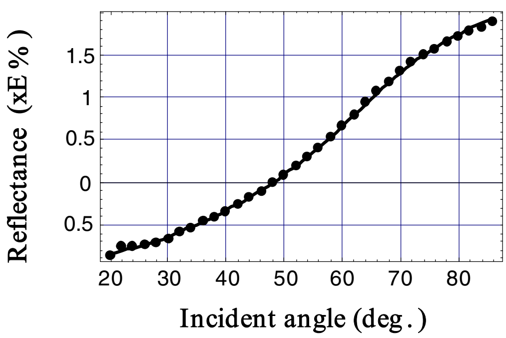

Fig. 1: Measured reflectance and fitting curve of a SnO film at 13.5nm wavelength.

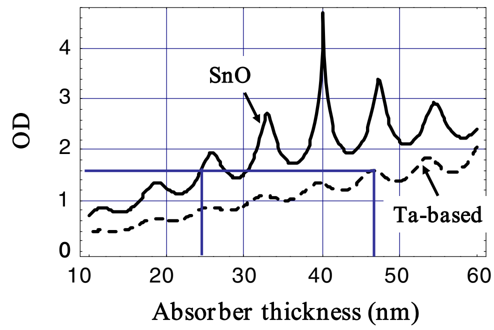

Fig. 2: OD vs. SnO or Ta-based absorber thickness. (Absorber / Ru (2.5 nm thick) / ML 40 pairs)

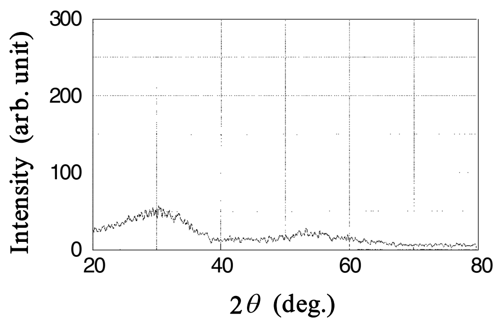

Fig. 3: XRD pattern of the SnO film.

[1] M. Yanagihara et al., Appl. Opt. **30**, 2807 (1991)

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