Protection and reduction of surface oxidation of Mo/Si multilayers for EUVL projection optics by control of hydrocarbon gas atmosphere

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1. Introduction

Extreme ultraviolet lithography (EUVL) is a leading candidate for the manufacture of next-generation semiconductor devices later this decade. It is strongly demanded to protect the surface of the lithographic optics from contamination and degradation in order to constantly maintain the throughput of the EUVL tool. The lifetime of the projection optics is limited by two effects: carbon deposition and oxidation. It was known that mitigation of oxidation was not enough even if we used oxidation-resistant capping layer of Ru atop multilayers [1]. Last year, we reported that both oxidation and carbon deposition can be controlled by balancing the amount of water vapor and ethanol gas [2]. Recently, we investigated the effect of protection and reduction of surface oxidation of Ru-capped Mo/Si multilayer that was exposed to EUV radiation in the presence of hydrocarbon gas atmosphere.

2. Experiments and Results

The details of our contamination evaluation system were described elsewhere [3]. Ru-capped Mo/Si multilayer samples were irradiated by an undulator emitted EUV beam under the vacuum condition of water vapor pressure of 1.3 E-5 Pa in addition to iso-propyl alcohol (IPA) vapor which pressures were changed from 1.3 E-7 Pa to 1.3 E-4 Pa. The reflectivity changes under various IPA gas atmosphere are shown in Fig. 1 as a function of EUV dose. The relative reflectivity was maintained almost constant in the case of IPA gas was introduced only at 1.3 E-7 Pa.

The elemental concentration maps of carbon and oxygen around the EUV irradiated area are shown in Fig. 2(a) and 2(b), respectively, which are taken by in situ soft X-ray absorption spectrometry (XAS) method [2]. The carbon density increases with increase in the IPA pressure, however the oxygen density decreases.

For the oxide reduction experiment, at first, the Ru-capped multilayer sample was exposed to EUV radiation in the presence of only water vapor to oxidize its surface. Next, it was exposed to EUV radiation in the presence of only ethanol vapor. The reflectivity change was sequentially measured and is shown in Fig. 3. The relative reflectivity decreased about -1.5% at first by irradiating in the presence of only water vapor with EUV dose of 1000 J/mm^2. The reflectivity of the sample was recovered to +0.5% and atomic concentration of oxygen at the irradiated area decreased by EUV irradiation in the presence of ethanol.

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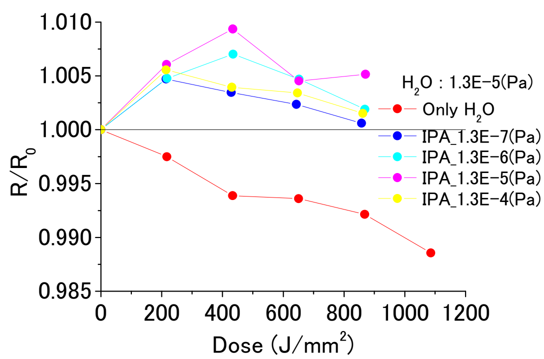

Fig. 1 Reflectivity change under various IPA gas atmosphere as a function of EUV dose.

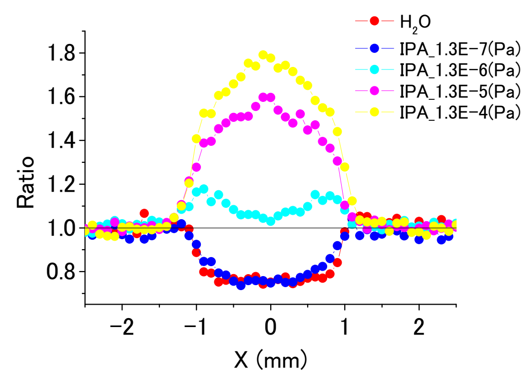

Fig. 2(a) Elemental mapping of carbon (C) at the EUV irradiated area under various IPA gas atmosphere taken by XAS method.

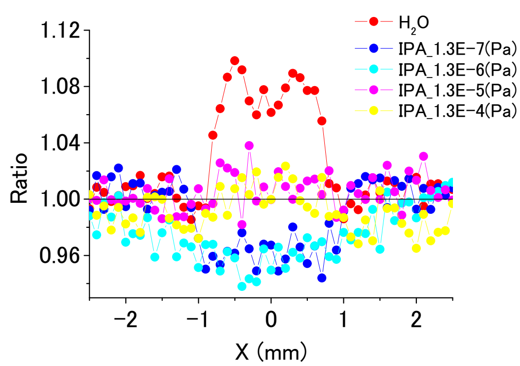

Fig. 2(b) Elemental mapping of oxygen (O) at the EUV irradiated area under various IPA gas atmosphere taken by XAS method.

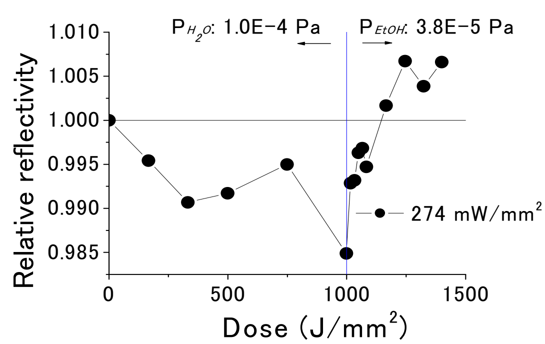

Fig. 3 Reflectivity drop by oxidation and recover by reduction of oxidized Ru-capped Mo/Si multilayer by ethanol introduction. The change is shown as a function of EUV dose.