Variation in phase defect volume on extreme ultraviolet mask before and after coating reflective multilayer

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Extreme ultraviolet Lithography (EUVL) is considered to be the most promising next-generation lithography after the point where 193-nm immersion lithography will not be able to deliver smaller features. But the path to establish the EUVL is not without technical difficulties. From the viewpoint of EUV mask fabrication, reducing the number of phase defects is one of the most demanding tasks to be addressed. Because the phase defects are classified as reflective multilayers defects and are hard to repair. [1] Therefore, to detect the phase defects and to pinpoint their locations, phase defect inspection technique like an at-wavelength dark-field inspection tool is proposed. [2] To evaluate the defect detection capability and detection yield, it is useful to inspect a programmed phase defect mask that has many designed phase defects. However, few experimental results on the variation in size of the each phase defect have been reported.

In this study, we prepared a programmed phase defect mask and measured the defect volumes using scanning probe microscope (SPM). The prepared mask consisted of 10 pit-type phase defects for each designed size. The defect volume was calculated as illustrated in Figs. 1. Figure 1(a) shows the SPM image of the multilayer surface that includes the pit-type phase defect. Figures 1(b) show the line profiles of the image. The phase defect volume was defined as the sum of the colored area in Figs. 1(b). Figure 2 shows variation of the calculated defect volume after coating the multilayer. The defect-to-defect variations of the measured volumes were very large, specifically from 5800 to 7200 nm^3, even if the designed size was same. To evaluate the root cause of the variation, we measured the defect volumes both before and after coating the reflective multilayer. As a result, the defect volume on the multilayer had a direct correlation with the defect volume before coating the multilayer. This result also indicates that measuring volume of each phase defect is essential in order to evaluate the defect detection yield using inspection tool.

This work was supported by New Energy and Industrial Technology Development Organization (NEDO).

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[1] D. V. Heuvel, R. Jonckheere, J. Magana, T. Abe, T. Bret, E. Hendrickx, S. Cheng, and K. Ronse, Proc. SPIE **7823**, 78231T (2010).

[2] T. Terasawa, Y. Tezuka, M. Ito, and T. Tomie, Proc. SPIE **5446**, 804 (2004).

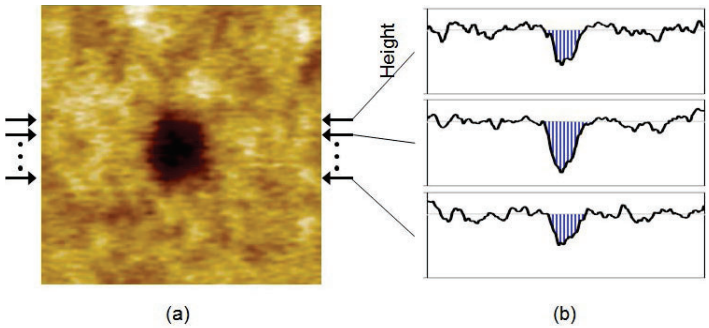

Figure 1: Calculation method of the phase defect volume: (a) A captured SPM image, (b) Line profiles of the SPM image along the lines between the arrows indicated in the image (a). Colored areas show the profile of the pit-type defect to be added to calculate the defect volume.

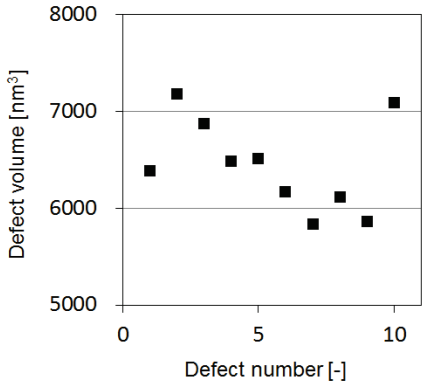

Figure 2: Variation of the calculated defect volumes after coating the multilayer. The designed defect size was 60-nm-wide and 2.0-nm-deep.