Impact of image contrast on pattern inspection using electron microscopes

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Pattern inspection is one of the key issue for mask and wafer fabrication processes, with the continued shrinkage of pattern size which meant difficulties in detecting small defects. Improvement in image resolution can be realized with electron beams, which are also used in scanning electron microscope (SEM)-type and projection-type electron microscopes (e.g. low energy electron microscope (LEEM), projection electron microscope (PEM) and mirror electron microscope (MEM)). [1] In projection-type inspection systems, patterns are recognized by the gray-scaled image contrast similar to optical inspection systems employing deep ultraviolet (DUV) light sources.[1-2] However, image contrast is affected by pattern size and charging effect even in cases where stacked structures are identical. As shown in Fig.1 (a-1) and (a-2), the line is darker than the space in half pitch (hp)-100-nm-line-and-space (LS), but, the line is brighter than the space in hp 45 nm. Given the same pattern size of hp 64 nm, the pattern contrast is varied due to charging effect as shown in Fig. 1 (b-1)-(b-3). Especially for the case of Fig. 1 (b-3), there is little difference of the gray level between line and space. These show that the gray level difference is not sufficient for pattern inspection. On the other hand, applying contour extraction techniques for pattern inspection resulted in improved the defect detection capability. However, as patterns shrink to sub-20nm levels, the proximity of the SEM-detected white bands on the side of line patterns (i.e. edge-peaks on both sides of patterns) becomes too close and near inexistent, causing a blurring of the line contours. In this case, gray level difference detection method becomes the more practical measurement option. Considering these factors, we have developed an inspection algorithm which allows detection of sub-10-nm-sized defects on hp 45 nm and hp16 nm LS patterns. In this paper, defect detection capability will be comprehensively discussed from the view point of SEM image contrast (due to various conditions) and inspection algorithm condition.

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[1] S. Iida, R. Hirano, T. Amano, and H. Watanabe. Investigation of defect detectability for extreme ultraviolet patterned mask using two types of high-throughput electron-beam inspection systems. J. Micro/Nanolithogr. MEMS, MOEMS 15, 013510 (2016).

[2] S. Iida, R. Hirano, T. Amano, and H. Watanabe. Simulation technique for pattern inspection using a projection electron microscope. J. Vac. Sci. Technol. B 33, 06FN02 (2015).

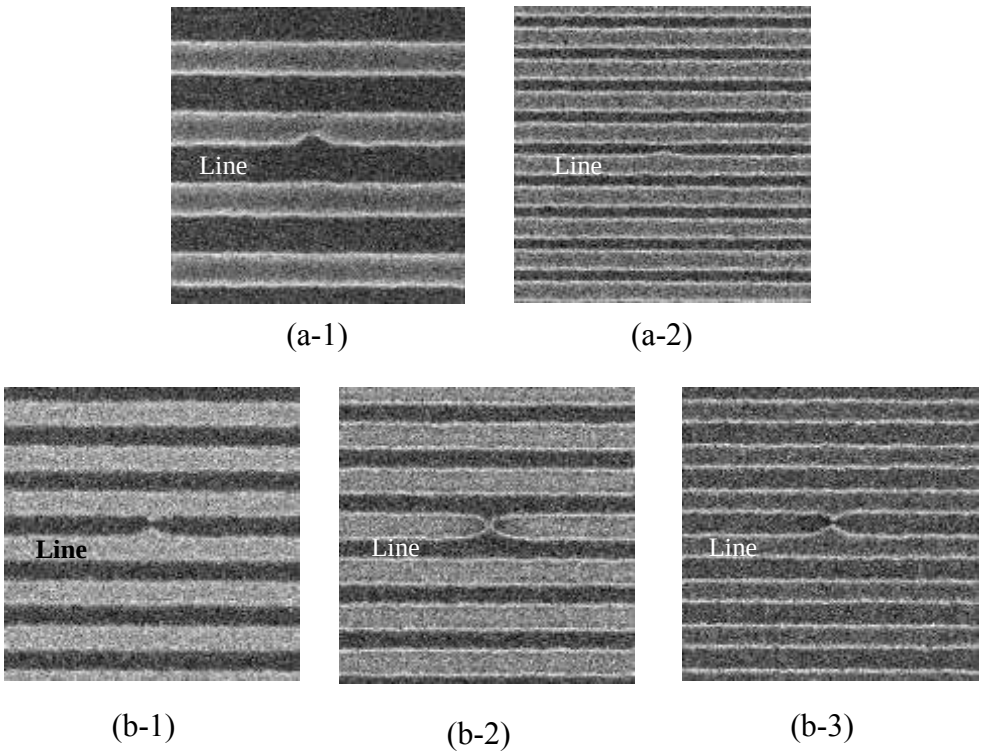

Figure 1: SEM images of a extrusion defect on line-and-space patterns; (a-1) hp 100 nm, (a-2) hp 45 nm, (b-1) hp 64 nm with charged space and (b-2) with charged line, and (b-3) with suppressed charging. All the stacked structures of these samples are identical.