Research Activities on EUV Lithography at NewSUBARU Synchrotron Light Facility

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EUV lithography started to be employed as a lithographic production technology for 7-nm-logic device in 2019 and 5-nm-logic device in 2020 for the smart phones MPU. It took about 35 years for this technology to be used in mass production.

At the University of Hyogo, EUVL basic technology development began in 1996, and has been involved and led four national projects for about 20 years since 1998 in Japan. The commissioning of NewSUBARU started in January 2000. Furthermore, we have promoted the joint-collaboration research with many domestic and foreign companies. The results of these studies led to the practical usage of EUVL.

In 1997, we started the development of the exposure tool so called ETS-1 (ETS: engineering test stand) consisting of three aspherical imaging optics with a collaboration research of Nikon, Hitachi Central Research Laboratories and our group. Using this tool, it was the first successful replication of 56-nm-line-and-space resist pattern in an exposure area of 10 mm × 2 mm on a wafer. Furthermore, the national project of ASET in Japan succeeded to replicate 60-nm-line-and-space resist pattern in a large exposure area of 10 mm × 10 mm on a wafer. These pattern replications were the first time in the world. As a result, R&D of EUVL has progressed with the goal of introducing it into the semiconductor mass production.

The NewSUBARU synchrotron radiation facility is the largest synchrotron radiation facility among universities in Japan. The new injector has been installed in 2020 and the commissioning started on April 20th, 2021 (Fig.1). As shown in Fig.2, total nine beamlines are being operated, and three beamlines are used only for EUVL R&D. And the Center for EUVL, Laboratory of Advanced Science and Technology for Industry, University of Hyogo, was established in October 2010 with the aim of accelerating EUVL basic technology research.

Recently, the EUVL technical issues are 1) EUV resist material and processing technology, 2) mask technology including metrology, and 3) EUV light source with high power and high stability.

The technical issue of EUV resist is the simultaneous achievement of 1) high resolution, 2) high sensitivity, 3) low line width roughness (LWR), and 4) low outgassing. In this technical issue, there are technical trade off relationship between resolution, sensitivity, and LWR. The most difficulty are the simultaneous achievement of high sensitivity and LWR.

At NewSUBARU, it has been developed many equipment and installed at the beamline for the fundamental EUV resist researches [1], such as 1) flood exposure tool for the evaluation of the exposure sensitivity, 2) EUV interference lithographic tools for the resolution evaluation less that 10-nm-width patterning, 3) carbon contamination growth on Mo/Si witness sample using in-situ ellipsometry, 4) soft X-ray absorption spectroscopy for the analysis of chemical reaction during EUV exposure, 5) transmission measurement, 6) resonant soft X-ray scattering tool for layer analysis and chemical contents distribution analysis, and so on.

For the mask [2], it has been developed 1) the normal size and the world largest size reflectometers for the evaluation for the mask and collector mirror in EUV light source, respectively, 2) high EUV power exposure tool introducing hydrogen gas for the material analysis of the hydrogen brittle, 3) out of band (OoB) reflectometer, and so on.

All the equipment are opened for the joint research.

Fig. 1: NewSUBARU synchrotron light facility with new injector.

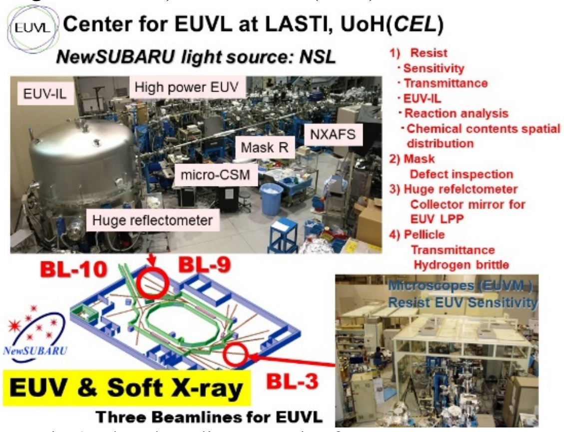

Fig. 2: Three beamlines operating for EUVL R&D at NewSUBARU.

References

[1] T. Watanabe, T. Harada and S. Yamakawa. *J. Photopolym. Sci. Technol.* **34** (2021) 49.

[2] T. Watanabe, T. Harada and S. Yamakawa. *Proc. SPIE* **11908** (2021) 1190807.