EUV Lithography Activities

According to the ITRS 2011 report (International Technology Roadmap for Semiconductors), extreme UV lithography (EUVL) will be the first choice for next-generation lithography (NGL) with a resolution down to 22 nm and beyond. In contrast to e-beam writing, EUVL can mass-produce nano devices with a mask by adopting the principles of optical lithography.[1] All key semiconductor companies have already expended much effort to develop EUVL technologies. The semiconductor companies in Korea and Taiwan also stepped into EUVL since 2009. The EUVL development is just like an arrow on a bowstring.

EUVL uses photons of wavelength 13.5 nm (energy 92.5 eV) to pattern the nano devices. EUVL differs much from the traditional DUV lithography because it must be performed in a high-vacuum environment, and reflective optics (lens, mirror, mask) are adopted instead of refractive optics (Fig. 1). A new resist with a distinct photo-chemical mechanism is required. In particular, a new lamp or light source must be developed to meet the EUVL requirements.

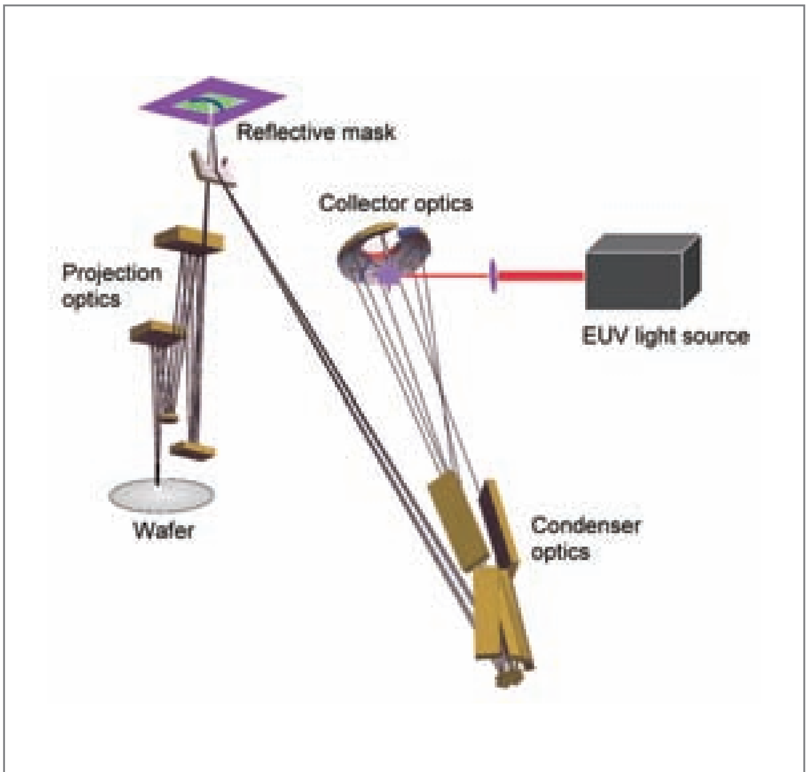

Fig. 1: Schematic diagram of an EUV lithography system. (courtesy of Intel)

Plasma-induced EUV, such as DPP (discharge-produced plasma) and LPP (laser-produced plasma), are candidates for a source of EUV light. These lamps have the potential to provide powerful EUV (~180 W) for mass production of nano devices, but they are not well-developed and are expensive. The bandwidth is also too large for qualitative and quantitative analysis, and the debris generated from the plasma source seriously degrades the performance of the optical components.

Synchrotron radiation (SR) is a clean, tunable and coherent light source. All leading companies have adopted SR EUV to implement their R&D work. Many EUV beamlines with varied functions have been constructed in SR centers worldwide, such as ALS (USA), New Subaru (Japan), BESSY (Germany), SLS (Swiss) and PLS (Korea).

In 2008, we proposed a project to National Program on Nano Technology (NPNT) of NSC, integrating the resources from universities (NCTU, NTU, NCKU, NKU) and national laboratories (NSRRC, NDL), to initiate an EUVL research program in Taiwan. In this three-year project, we established several key end stations and technologies at NSRRC using SR EUV (Fig. 2). The major achievements follow.

(1) Construction of a high-resolution EUV reflectometer for measurements on ultra-thin films or resists. The measurement results attained satisfactory benchmarks with those of other facilities (IMEC and ALS @ Berkeley). This work will benefit domestic companies to use this technology.

(2) Construction of an evaluation system equipped with a quadrupole mass spectrometer (QMS) and double-ion chamber to study resist outgassing.[2] To our knowledge, this study produces the first measurement results of absolute ionic outgassing. We also collaborate internationally with two companies for work on resist outgassing under EUV irradiation.

Fig. 2: Major end stations established at NSRRC: (a) reflectometer, (b) resist evaluation system, and (c) EUV interference system and the generated 1D/2D nano patterns.

(3) Establishment of a technology platform for EUV interference lithography and successive generation of 1D and 2D pattern through a transmission grating mask.[3] This platform is useful for studying the lithography resolution of new resist materials.

(4) Investigation of the effects of EUV radiation damage on nano devices.[4] The results indicate that high-energy EUV photons damage most materials, but the resistance to radiation damage of the nano devices can be greatly improved on optimizing materials and the structural design. This work will benefit the fabrication of nano devices using EUVL technology.

We proposed a NPNT project phase II at the end of 2010; that three-year project was granted with a total budget 30 million NT dollars. A major work therein is to construct a dedicated EUV beamline at NSRRC.

In the project phase I, we used mainly beamlines **08A1** and **21B2** to conduct EUVL research, but the approved beamtime was limited because these two beamlines had been originally designed for research on photon emission and gas-phase reactions. In the project phase II, EUV metrology will be the core work, which is very time-consuming. Domestic companies began to apply beamtime to perform their EUV analysis work since 2010. The EUV beamtime is in high demand in coming years.

We therefore propose to co-construct a dedicated EUV beamline with other parties. NCTU and NSRRC agreed to provide the financial support, and NSRRC committed to a provision of a beamline **19A1** port and its existing vacuum components to construct the EUV beamline.

The new beamline will be designed to provide high-flux EUV light with adequate (< 2 %) bandwidth. The wavelength range covers both 6.7 and 13.5 nm, as BEUV (beyond EUV, @ 6.7 nm) is the next-generation EUVL technology. The light is extracted from a bending magnet at port **19A1**. The design concept and details will be prepared by the beamline group of NSRRC after thorough discussion with the EUVL interest groups. The beamline will be constructed in 2013 and then opened first to the project PIs. Once the beamline is constructed, NSRRC can provide EUV photons with various features of high flux (**19A1**), high resolution (**08A1**), off-band (**04A**) and coherence (**21B2**) to meet the requirements from both the academics and industries.

Coupled with SR EUV, this project has established several important end stations and analytical technologies for EUVL-related research. More than 40 professors and graduate students have joined this project to undertake research related to EUVL. Several international and domestic companies, including TSMC, ASML and Nissan Chemicals, have coupled with this work through a joint development project, commission project or service. In 2011~2012, the income from the commission analysis of semiconductor companies is more than 1.6 million NT dollars. We believe that this project has successively initiated EUVL research in Taiwan.

References

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