Joint Activities for Semiconductor Research in Japan

In 1996, the Japanese government founded a new research consortium for advanced electronics named the Association of Super-Advanced Electronics Technologies (ASET). More than half of the research programs in ASET are in the semiconductor area. The rest are in the areas of liquid crystal display and magnetic hard disk technology. Approximately U.S. $400M has been appropriated by the government for ASET this year. More than 30 Japanese companies, and a handful of foreign companies, have joined this consortium. The joint R&D activities for semiconductor research in ASET are summarized here.

The head office of ASET is located in the bay area of Tokyo. The main research center is located at a facility of the Nippon Telegraph and Telephone (NTT) Laboratory in Atsugi where projects on proximity X-ray lithography (PXL) and extremely-ultraviolet lithography (EUV) are under development. Direct electron beam lithography (EBDW) was developed at three different facilities of Toshiba, Hitachi, and Advantest, and was completed last year. The electron beam lithography project was reorganized to focus on mask writing technology at the Hitachi Central Research Laboratory in Tokyo. For the first two years, the optical lithography project evaluated photoresists suitable to the ArF excimer laser. System integration began in 1999 at another NTT Laboratory in Musashino to find a new LSI chip packing technology. Other projects included the analysis of plasma etching, the search for a cleaning process to remove particles smaller than 30 nm, the characterization of very thin silicon dioxide films, and finding environmentally benign interconnect processes. Most of the projects are scheduled to end in 2000 or 2001. Thirty-three satellite laboratories are collaborating with the three research centers in order to meet the deadlines. There were more than 300 researchers involved in ASET projects.

In this report, we give a sampling of some of the typical achievements in lithography at ASET. There are many candidates for the next generation of lithography with a 100 nm node such as the ArF excimer with a wavelength of 193 nm, a fluorine excimer with a 157 nm wavelength, EUV, EBDW, electron beam projection lithography (EPL), PXL, and ion beam projection lithography (IPL). In each of these cases, the lithography is reported to have a resolution of less than 100 nm. Except for EBDW, a residual common issue is mask technology. This requires electron beam mask writing equipment, mask membranes, mask process, and defect inspection and correction. Mask pattern accuracy is fundamental to critical dimension, position, and overlay accuracy.

The ArF excimer lithography team at ASET has achieved resolution capability of less than 100 nm using top surface imaging techniques, although the single resist process has achieved a resolution as narrow as 140 nm, with a dimension accuracy of 30 nm. The EBDW team has already developed equipment to produce patterns less than 150 nm with an overlay accuracy of 50 nm. To solve the main issue of its throughput, the twin column system was developed. EBDW is now used in Japan as a tool of mix-and-match lithography for small-scale production of LSIs as well as for test device fabrication.

The key issue in PXL technology is the mask writer. The EB mask writer for the PXL mask was developed with the cooperation of NTT researchers and features a minimum pattern size of 50 nm and a placement accuracy of 15 nm ($\pm 3\sigma$). The system resulted in the stable operation of an electron gun for over half a year and the beam vibration was reduced to 2 nm. By using the mask writer, the ASET program of PXL was accelerated to produce a critical dimension (CD) of 100 nm and extendibility to the next generation of 70 nm nodes. The controllability of CD was 7.9 nm ($\pm 3\sigma$). The PXL stepper was also developed. An optical heterodyne alignment system with two wavelengths was used to ensure accurate alignment for various processed wafers. The repeatability was less than 20 nm. The PXL technology is useful for making wafers with 100 nm patterns that are used for process and equipment development for the next generation of LSIs.

Japan has a wide range of activities in the development of the next generation of lithography technologies. ArF excimer laser lithography and EBDW are now in the competitive phase and are being developed at various companies. Non-competitive activities on PXL, EUV, and EB mask writing have resulted because of the ASET program's status as an industrial consortium. Lithography is a key technology for microelectronics but its technological barriers are getting higher and higher. Collaboration among companies is inevitable for further advancement in sharing risk, resources, and knowledge. Global collaboration and information exchange in this area is expected among various consortia such as ASET and SELETE of Japan, International SEMATECH and SRC of USA, IMEC and MEDEA of Europe, and others. ■

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