Digest of Tech. Papers The 11th Conf. (1979 International) on Solid State Devices, Tokyo

A—1—2
(Invited)

X-Ray Lithography

Shin'ichi YAMAZAKI and Toa HAYASAKA

Musashino Electrical Communication Laboratory, N.T.T.

Musashino, Tokyo 180, Japan

Although electron beam lithography is best for mask making, throughput for direct wafer exposure is still a problem. As to fine pattern replication, x-ray lithography has great potential in its short turn around time. In addition, x-ray step and repeat exposure is applicable, since the exposure time per unit area is kept constant under certain assumptions. Thus, x-ray lithography is advantageous in filling the need for larger size wafer and finer patterns. As a first step, a high speed x-ray lithographic system was developed with 0.2 μm resolution, less than ±0.2 μm alignment accuracy and less than 1 minute exposure time(5 mJ/cm^2) for 3" wafers as shown in Fig.1.

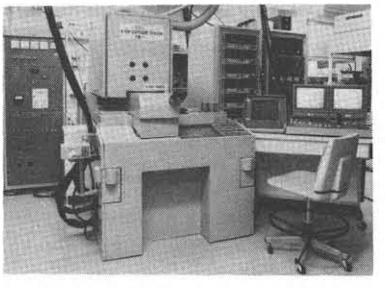

Fig.1 X-ray lithographic system

X-ray wavelength was optimized with respect to x-ray transmission loss, resist sensitivity and thermal properties of target materials. As a result silicon K x-ray was chosen. To realize silicon K radiation, a silicon layer was formed by a plasma deposition method on the surface of a water cooled rotating target. Using this target, input power can exceed 20 kW, as shown in Fig.2, with long life time.

For precision aligning, a vibration method has been used which is applicable to both optically transparent and opaque x-ray mask. For a transparent mask, mark image from wafer mark, shown in Fig.3, is vibrated and detected through a reference slit. By analyzing the detected signal frequency, displacement can be measured within

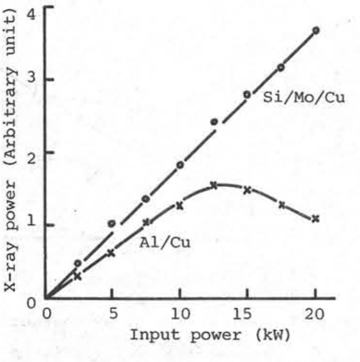

Fig.2 X-ray radiation characteristics of Si and Al targets

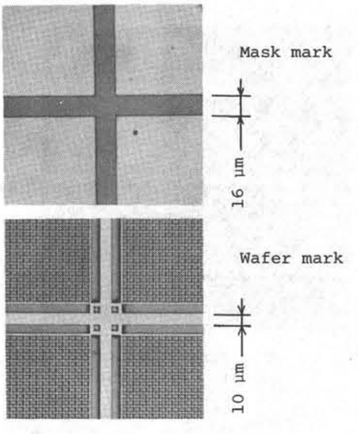

Fig.3 Mask mark and wafer mark

0.1 μm resolution. For an opaque mask, a light beam passing through a mark perforated on the wafer is used as a detecting light. In this case, the wafer is rotationally vibrated, instead of vibrating the mark image. By employing the vibration method, a fully automatic aligner has been developed which includes a position adjusting mechanism consisting of elastically supported stages and electrodynamic drivers.

For x-ray mask, a Si_3N_4 and SiO_2 composite membrane has been developed. This is sufficiently rugged and transparent. An absorption pattern formation process, including lift-off steps, has also been developed to form sharp pattern edges as shown in Fig.4, where pattern width and thickness are 1.5 μm and 0.8 μm respectively.

Highly sensitive resists are, generally, weak in regard to dry etching because of their low softening points. So, specimen cooling method in plasma reactive sputter etching has been investigated. By using a heat sink method, specimen temperature during etching could be limited below 50^0C.

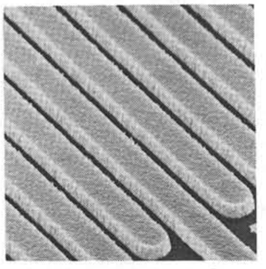

Fig.4 Gold absorption pattern

Typical performances of the x-ray lithographic system are less than 6 minutes exposure time for FBM resist (50 mJ/cm^2) and less than 0.2 μm total aligning accuracy.

This system has been used in the fabrication of solid state devices. Fig.5 shows patterns for a magnetic bubble device. Fig.6* shows MOS transistors with less than 1 μm effective channel length. Propagation delay and power-delay product of the devices are shown in Fig.7*. Further improvements in throughput, exposure area and accuracy are being researched.

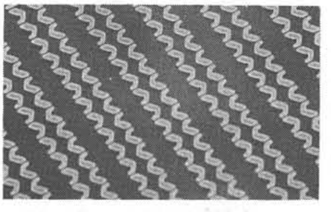

Fig.5 Bubble device patterns

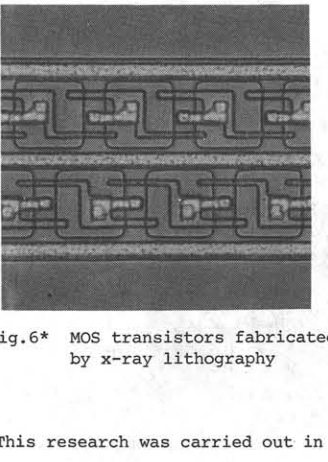

Fig.6* MOS transistors fabricated by x-ray lithography

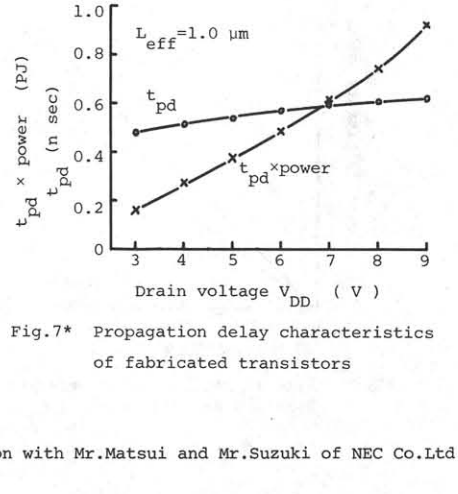

Fig.7* Propagation delay characteristics of fabricated transistors

*This research was carried out in cooperation with Mr.Matsui and Mr.Suzuki of NEC Co.Ltd..