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(Invited)

BASIC TECHNOLOGY FOR VLSI

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This paper describes some of the results of work in the fields of microfabrication technology and crystal technology at the VLSI Cooperative Laboratories.

EB PATTERN DELINEATOR. A raster-scan type system, VL-R1 has already been developed(1). Because of the small angle of deflection, a high charge density of 50µC/cm² is possible. And a variable-area shaped beam technique(2) is under development. Photo. 1 shows a recently constructed experimental system, VL-S1(3).

The maximum dimension of the variable shaped rectangular beam was estimated by considering limitations due to space charge aberration. The results are shown in Fig. 1(4), where t is the mean overhead time for one rectangular beam shot. The pattern complexity value is determined using a simple scaling rule, without considering other improvements such as device structure, isolation method, and chip size.

The high current field emission gun shown in Photo. 2(5) has been developed, the exposure current within diameter of 0.1µm can be up to 40mA, with noise current less than 5%. A data processing system(6) has been constructed for delineating patterns down to submicron dimension using EB exposure apparatus. The system is capable of correcting field distortion, wafer warpage, and proximity effect, generating positive/negative polarity data, and eliminating unnecessary overlap exposure.

EB RESIST. The positive electron beam resist sensitivity is a function of scission efficiency G and development characteristics D. Molecular orbital studies(7) provided the guiding principle for the design of a high sensitivity EB resist. As shown in Fig. 2, calculated overlap population PXY correlates well with the scission efficiency. Depending on the development characteristics of D, there may be some discrepancy in sensitivity.

PROJECTION. Electron beam mask delineation and optical projection will be used in the early stages of VLSI's mass production. A pair of step and repeat projection systems VL-SR-1 and VL-SR-2 have been built(8). Fig. 3 shows a cutaway view of VL-MR-1, which is a 1:1 deep UV scanning projection system(9). The system uses a Xe-Hg point light source (λ = 200-260nm), and a reflection optical system for enlargement to a uniform circular arc for optimum focusing. MR-1 is capable of exposing 60 125mm² wafers per hour. Both SR2 and MR1 have a resolution of 1 µm, and automatic alignment capability within 0.3µm. Selection between these two types of systems will be made on the basis of wafer distortion in specified processes, and the alignment accuracy necessary for each chip.

A new method of EB projection using a sweeping EB for high alignment accuracy has been experimented with(10). Also, a new polyimide membrane (3µm) mask structure with grooves has been developed(11).

CRYSTAL TECHNOLOGY. Fig. 4 shows the major results of the crystal technology research. In order to investigate the function of carbon and oxygen in microdefects formation, we carried out the following experiment(12). First, oxygen was diffused into FZ wafers with various carbon contents at 1300°C in dry O₂ for 18.5 h. Second, these wafers and controls without oxygen diffusion were isothermally preannealed at 800°C, and then annealed at 1050°C in dry O₂ for 64 h. Fig. 5 shows the variation in diffracted X-ray intensity (proportional to generated micro defects) by annealing as a function of preannealing time. It is clear that carbon and oxygen must coexist for micro defects formation.

Fig. 6 shows thermal warpage of wafers as a function of dissolved oxygen concentration(13). The dissolved oxygen atoms have the effect of suppressing thermal warpage, possibly by resisting dislocation motion through the so-called solution hardening mechanism.

Photo 1. Variable shape EB system VL-S1

**PATTERN COMPLEXITY**

(πr²/2mm² chip)

![Graph showing the relationship between pattern complexity and variable shape EB system VL-S1.](image)

**Fig. 1.** Optimum value of the maximum dimension of the variably shaped rectangular beam

**DESIGN RULES**

![Diagram showing design rules for the variably shaped EB system VL-S1.](image)

**Fig. 2.** Correlation of calculated overlap population of E.B. resist $F_{XY}$ with scission efficiency and sensitivity

**CARBON**

- Defect nuclei formation by thermal histories (during cooling, or pre-annealing)
- Intrinsic Gettering (two-step annealing) possible

**OXYGEN**

- (when dissolved) solution hardening
- (when precipitated) dislocation multiplication

**Fig. 3.** Cutaway view of deep UV scanning projection system VL-MR-1

**Fig. 4.** Major results of the research on crystal technology

**Fig. 5.** X-ray diffracted intensity increment by annealing at 1050°C as a function of preannealing time at 800°C in dry O₂

- Carbon concentration: $(1.2 \times 10^{17})$, $(7.0 \times 10^{16})$
- Oxygen diffused: $(<2 \times 10^{14})$

**Fig. 6.** Dissolved oxygen concentration vs. warpage in 3 inch wafers heated cyclically