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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 50 μC/cm^2 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 variably shaped rectangular beam was estimated by considering limitations due to space charge aberration. The results are shown in Fig. 1(4), where τ 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 0.1 μm can be up to 40nA, 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 F_{XY} 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 125mmϕ wafers per hour. Both SR2 and MR1 have a resolusion of 1 μm, and automatic alignment capability within 0.3 μm. 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 (3 μm) 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 experiments(12). First, oxygen was diffused into FZ wafers with various carbon contents at 1300°C in dry O_2 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 O_2 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.

References: (1) M. Sumi et al; Proc. of the 10th CSSD, p.303 (1978). (2) E. Goto et al; 14th Symp. on Electron, Ion and Photon Beam Tech., May, 1977. (3) T. Funayama et al; 1979 National Conv. Rec. of the IECE Japan No.496 (J). (4) K. Hoh et al; to be published in IEEE Trans. on Electron Dev. (5) M. Ichihashi; to be presented at 40th Meeting of the Japan Soc. of Appl. Phys. (J)。 (6) N. Sugiyama et al; IEEE Trans. ED-26, April, 1979. (7) T. Tada. Extended Abstract of 154th ECS Meeting 78-2, p.475 (1978). (8) T. Shinozaki et al; to be published elsewhere. (9) S. Iwamatsu et al; ditto. (10) T. Asai et al; ditto. (11) K. Hideshima et al; Tech. Digest of 26th Joint Conf. of Appl. Phys. (J). (12) S. Kishino el al; to be published in Appl. Phys. Lett. (13) H. Otsuka et al; to be presented at the 156th Meeting of the ECS, Los Angeles (1979).

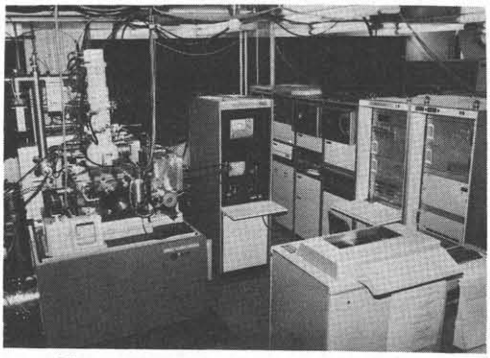

Photo. 1. Variable shape EB system VL-S1

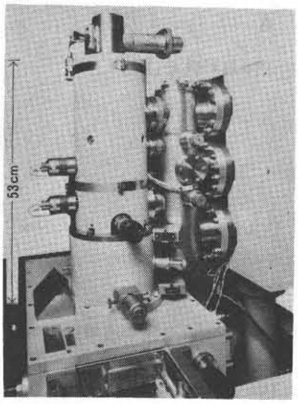

Photo. 2.
EB system VL-F1 with
high current FE gun

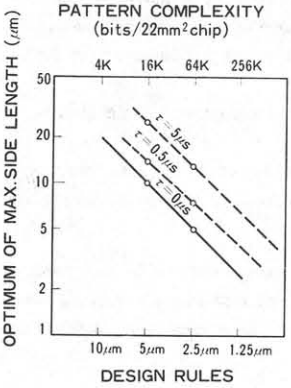

Fig. 1.
Optimum value of
the maximum dimension
of the variably shaped
rectangular beam

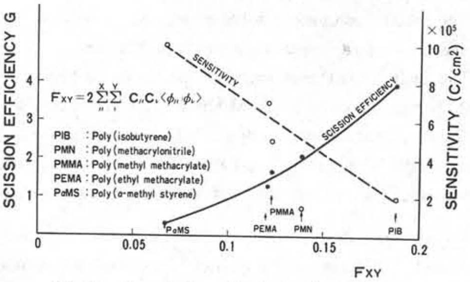

Fig. 2. Correlation of calculated overlap population of E.B. resist F_{XY} with scission efficiency and sensitivity

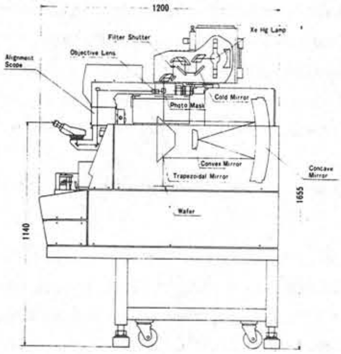

Fig. 3.
Cutaway view of
deep UV scanning
projection system
VL-MR-1

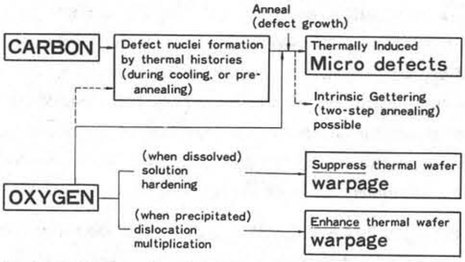

Fig. 4. Major results of the research on crystal technology

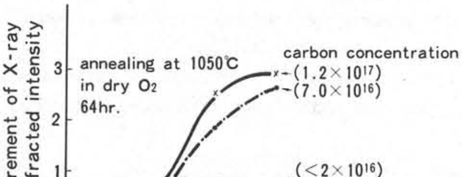

Fig. 5. X-ray diffracted intensity increment by annealing at 1050°C as a function of preannealing time at 800°C in dry O_2

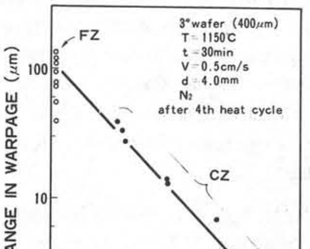

Fig. 6. Dissolved oxygen concentration vs. warpage in 3 inch wafers heated cyclically