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

A—1—4

1:4 Demagnifying Electron Projection System

T. Asai, S. Ito, T. Eto and M. Migitaka
Cooperative Laboratories
VLSI Technology Research Association
4-1-1, Miyazaki, Takatsuku, Kawasaki, 213, Japan

Conventional photolithographic techniques for fabricating LSI are limited in resolution to minimum linewidths of around 2μm. The demagnifying electron projection system[1),2)] which projects a demagnified image of a mask onto a wafer will be successful in future as one of the electron beam lithography systems for submicron patterns. Here we report a new 1:4 demagnifying electron projection system which makes possible to obtain a large field using a relatively small electron optical column and to attain high alignment accuracy.

A schematic of the system functioning in the projection and alignment modes are shown in Fig. 1. In the projection mode, after suitable collimation by the three condenser lenses a small portion of the mask is illuminated by 20KV electron beam from a conventional electron gun and this beam is then magnetically scanned across the whole mask pattern by two sets of deflection coils (upper and lower coils) mounted above the third condenser lens. These coils are so designed that the effective deflection center can be shifted along an optical axis by changing the power of each coils. Electrons passing through the mask openings are imaged by two magnetic projection lenses (symmetric magnetic doublet[1)]) onto the wafer with a 4× reduction in size. In this mode the demagnified image of the electron source is formed at the effective deflection center using the first two condenser lenses. The third condenser lens then acts so as to provide the parallel illumination in the mask plane. However, the illumination angle varies with the distance from the axis mainly due to the spherical aberration of the third condenser lens. This deteriorates the quality of projection images. In order to obtain same illumination angles at any part of the mask without any change of the strength of the third condenser lens, the effective deflection center was shifted by adjusting the power of each set of deflection coils in synchronism with the beam deflection. Then the demagnified image position of the source was also shifted to the deflection center by changing the strength of the second condenser lens. Furthermore, the focusing of projection images of the mask was adjusted by changing the strength of projection lenses synchronizing with the beam deflection. As the results, accurate imaging over a large field was obtained using a relatively small electron optical column.

The alignment mode shown in Fig. 1 was used for registration and focusing procedures. The condenser system is converted into a large field scanning electron microscope. The demagnified source image is focused in the mask plane by means of adjusting the strength of the second condenser lens without changing that of the third condenser lens. The anticipated effect of the variation in the illumination potics on the projection optics was thus eliminated. The probe so focused is then magnetically scanned across the mask plane by the two sets of deflection coils used in the projection mode. The projection optics remain unchanged in this operation. In this mode the effective deflection center was also shifted in the same method as in the projection mode to achieve same illumination angles. Accordingly in this system an illumination angle of the mask in the projection mode agreed precisely with that in the alignment mode and close coincidence between the positions of the images of the mask in these two modes was obtained. As the results high alignment accuracy was achieved. A self-supporting metal foil some 20×20^{mm} in size and about 3μm thick was used as a mask. We chose here a mask which consists of test patterns and which does not have an electron opaque area which is completely surrounded by an electron transparent area. Exposures made through these masks are shown in Fig. 2 and Fig. 3. In case of a mask with patterns which have an electron opaque area completely surrounded by an electron transparent area such as aluminum wiring patterns, some deformation[3),4)] of the mask structure should be made.

We gratefully acknowledge Dr. Y. Tarui and the members of the Cooperative Laboratories for thier support and discussions. We also express our appreciation to the team for electron beam technology in Hitachi Ltd. for their technical contributions.

References

1) M. B. Heritage ; J. Vac. Sci. Technol. 12 (1975) 1135

2) J. Frosien et al ; Proc. of the conf. on microcircuit engineering (1978), Cambridge, G. B.

3) M. B. Heritage et al ; Proc. Symp. Electr. Ion Beam Sci. Technol. (1976) 348

4) A. Meyer et al ; Proc. Symp. Electr. Ion Beam Sci. Technol. (1976) 332

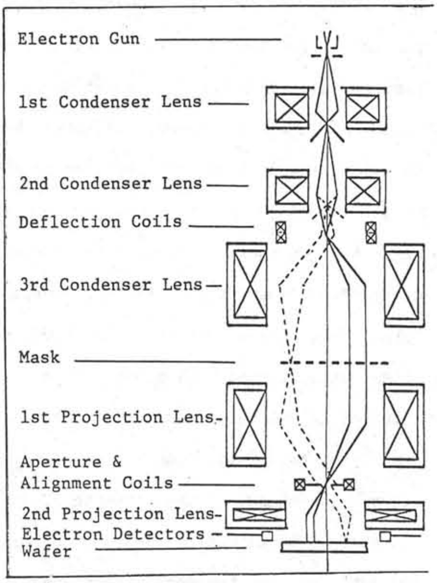

Fig. 1 Schematic of 1:4 demagnifying electron projection system.
solid line : Projection mode
dotted line : Alignment mode

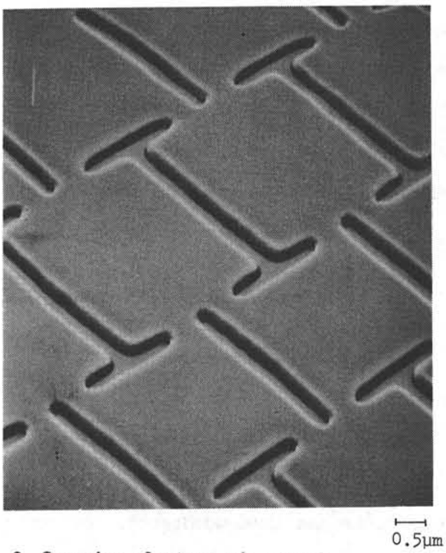

Fig. 2 Scanning electron micrograph of 0.5μm linewidth test patterns exposed in a resist film.

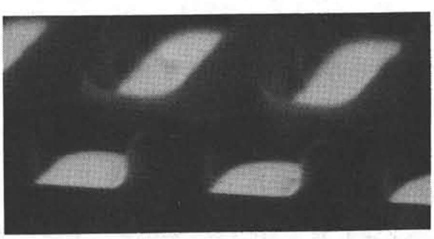

Fig. 3 Scanning electron micrograph of cross section of a 0.5μm linewidth grating pattern exposed in a resist film.