# A-6-5 Monte Carlo Simulation of Alignment Mark Signal for Direct Electron-Beam Writing

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Direct electron-beam writing technique is important for VLSI fabrication, and in the fabrication process VLSI patterns for each level should be aligned within an alignment tolerance less than a few tenths of minimum pattern line width. In order to secure the alignment tolerance, it is necessary that a signal with corresponding precision is obtained, when an alignment mark placed appropriately on the silicon substrate is scanned by an electron beam. For this purpose, the mark profile and dimension should be optimized so that the proper signals are obtained. However, no useful theoretical evaluation method has been available for actual mark fabrication. Wilson et al.[1)] and Friedrich et al.[2)] reported the study of the alignment marks, but their methods are all expectations. This paper reports an evaluation method using Monte Carlo simulation, experimental results of several kinds of alignment marks and a new-type alignment mark evaluated by this method and examined by actual fabrication. The Monte Carlo simulation method is first applied to the electron scattering process around the alignment mark carved on the silicon substrate.

The principle and procedure of the present method are as follows. Angular elastic scattering is calculated with the screened Rutherford expression for cross section. Energy loss between elastic scattering events is calculated under the Bethe's continuous-slowing-down approximation. Step length is given by the mean free path. The applicability of the Monte Carlo mehtod based on this model was investigated in detail by Bishop[3)], and the method was applied by Shimizu and Murata[4)] to the problem of the resolving power and contrast of the SEM, and they obtained a good agreement with experimental results on the escape electrons and the back-scattered electrons. In the present work, back-scattering coefficients for each incident point across the mark are calculated by Monte Carlo simulation based on the above-mentioned model. These back-scattering coefficients do yield a simulated curve for the back-scattered electron signal current obtained by electron-beam scanning across the alignment mark. To save the computing time, the particular programming technique is prepared and used.

Profiles of the marks examined are silicon steps and V-shaped grooves on the silicon substrate. The deposited over-layers effect is evaluated. The energy and angular distributions of the back-scattering electrons are calculated. These distributions are useful for the detector system optimization. Mark dimensions are varied from 0.5 μm to 4 μm. The computer used in this work is the ACOS-700. The results obtained by this method show a good agreement with experimental signal current obtained by the electron-beam exposure system VL-R1, which will be reported in this conference. As an example, simulated signal current obtained by this method and experimental signal current for the V-shaped groove are successfully compared in Figs. 1 (a) and (b). We will further present calculated and experimental results for other kinds of alignment marks, including a new-type alignment mark such as double V-shaped grooves which give the stable and reproducible signal current throughout all silicon wafer processes.

In conclusion, this method has been proved to have a merit that the alignment marks can be evaluated with sufficient accuracy before actual fabrication.

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References

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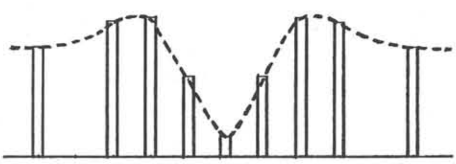

Fig. 1 (a) Simulated signal current for V-shaped groove. ( depth: 2.0 μm, width: 2.8 μm )

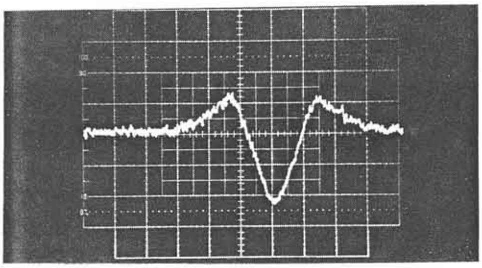

Fig. 1 (b) Experimental signal current for V-shaped groove obtained by the electron-beam exposure system VL-R1. ( depth: 2.3 μm, width: 3.3 μm )