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

A—1—5 Electron Beam Mask Fabrication for MOSLSI's with 1 μm - 1.5 μm Design Rules

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Electron beam lithography is rapidly replacing optical systems in making master masks with linewidths of 2 μm or above in production environments. It also provides an excellent means of research in fine line patterning and device technologies.

In this paper, we investigate the feasibility of making electron beam masks for the purpose of evaluating Si devices with minimum linewidths of one micron or less. Two types of masks were made. One includes a 4096 bit n-MOS RAM and ring-oscillators with 1.5 μm design rule and discrete MOSFET's with gate lengths ranging from 0.5 μm to 1.5 μm. The second was identical to the first except for being reduced in size by a factor of 2/3. Electron beam mask making consists of the following steps: resist coating, prebaking, electron beam exposure, vacuum curing (only for the negative resist), developing, postbaking, resist descumming, chromium etching and resist removing. Two types of electron resists are used in this work: PGMA, a negative resist, and P(MMA-AN), being a positive.

Great care had to be taken throughout the processing to realize good linewidth control. The vacuum curing effect of PGMA resist was studied over a wide range of time after exposure. The curing time was adjusted to make the average linewidth of all the patterns within the mask as close to the design value as possible (Fig. 1). The prebaking temperature of PGMA resist had to be controlled within ± 5°C to control the linewidth variation of the resist image within ± 0.05 μm (Fig. 2). The developed P(MMA-AN) resist linewidth was found to vary over ± 0.4 μm for development temperature variations of ± 1°C, so precize temperature control was necessary (Fig. 3). Proximity effects were not corrected in this work, but the exposure dose was adjusted so that the linewidths of isolated lines were within ± 0.1 μm, as shown in Fig. 4.

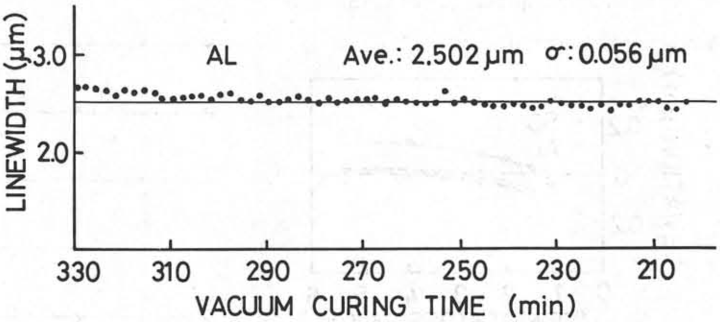

Fig. 1. The effect of vacuum curing on the Cr linewidth in the case of PGMA resist.

These results enabled the linewidths of all the masks in this study to be controlled within ± 0.2 µm.

The step and repeat accuracy of the masks obtained, which is well within ± 0.1 µm, is shown in Fig.5. The typical overlay accuracy of two mask layers, obtained by the least square fitting of the step and repeat data, is within 0.15 µm in terms of standard deviation.

Wafer processing has been carried out using the 1.5 µm rule mask set and the contact printing method. The electrical characteristics of discrete MOSFET's and ring-oscillators have been measured as functions of device dimensions. Some preliminary data has also been obtained on the scaled-down memory devices. The shrunken version of the mask set, representing 1 µm design rule, is now being used to study the feasibility of deep UV lithography.

This shows that the combination of electron beam masks and the contact printing can provide experimental devices with linewidths on the order of one micron, making it possible to make and evaluate scaled-down devices. It also shows that electron beam masks are useful in investigating future printing technology.

The authors wish to thank Dr. G.Tatsuno of Musashino Electrical Communication laboratory, for letting us use the EB52 exposure system. Thanks are also due to Mr. N.Hashimoto, Mr. H.Masuda and Mr. K.Shimohigashi for helpful discussions on wafer processing and device evaluation.

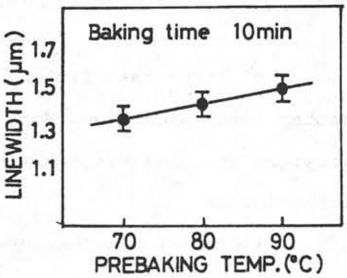

Fig.2. Prebaking temperature dependence of PGMA resist linewidth.

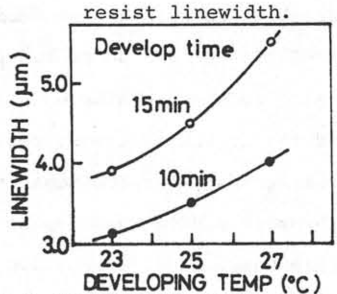

Fig.3. Developing temperature dependence of P(MMA-AN) resist linewidth.

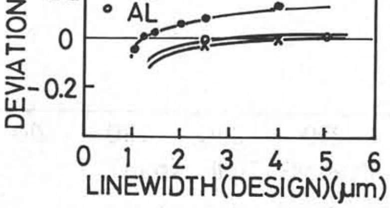

Fig. 4. An example of intra-pattern proximity effect.

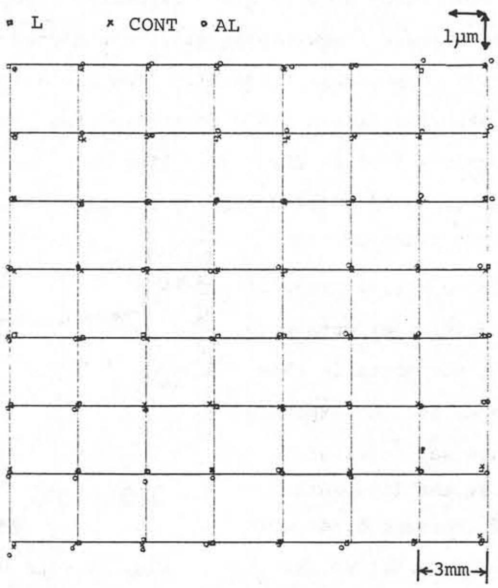

Fig. 5. Step and repeat accuracy.