Patterning with 193nm Resists

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At present, the semiconductor industry plans to use 193nm technology for patterning in 130 to 100 nm node. Patterning with 193 technology has several challenges in the litho and etch areas. At Advanced Tool Development Facility (ATDF) of International SEMATECH, we have benchmarked various 193 nm resists for their patterning capabilities (litho and etch) in order to provide this data to our member companies. We have also developed production worthy 193 nm patterning processes to provide small contacts and trenches to support various internal development projects.

ATDF has demonstrated the ability to print small contacts in oxide with and without a hard mask, using Sumitomo PAR-722, 193 nm resist. With 0.6 NA Micrascan 193 scanner, by using a conventional illumination (0.3 sigma) and a 6% attenuated phase shift mask, we were able to print 140 nm contacts. For contacts the substrate was 10 K of PVD Oxide over 1.5 K Nitride over 5 K Thermal Oxide. An organic BARC (600 A of ARC25 of Brewer) was used to dampen the standing waves. A mask set with contacts of various size and density (spacing of 1:1 to 1:4 and contact sizes from 500nm to 100 nm) was used. Contacts printed smaller than design size on the mask set. 180 nm contacts with 2:1 spacing (pitch of 540 nm) printed as 140 nm with approximately 3:1 spacing, with a 0.6 micron depth of focus. Figure (1) shows the Resist CD profile SEM cross-section and figure (2) shows the top down CD SEM for contacts. Resist CD showed 3-sigma deviation of 15%, for two lots.

Our next challenge was to etch the printed 140 nm contacts. 193 nm resists characterized by lower etch resistance and less than 50% of thickness, as compared to 248nm resists, present a formidable challenge for plasma etch. It was initially believed that 193 nm patterning could not be achieved without hard mask. Therefore BARC etch and hard mask etch were developed as the first step on a TEL DRM etcher. Next, in order to generate the benchmarking data for resist performance and to develop the etch process, etch rate and selectivity and resist breakdown was estimated by running a simple DOE for few selected recipes. Sumitomo PAR 722 resist yielded the etch rate of 4100 A/min and selectivity of PR to Oxide was approximately 4, allowing us to etch the 130 contacts in 10K Oxide (aspect ratio of 7.7) without the hard mask. Final CD was less than Resist CD for our process. Figure 3 and 4 show the etch results. Some tapering of the contact holes is observed at the bottom and we are in the process of improving the profile. Final CD showed, over two lots, the 3 sigma deviation of 13 nm, which is higher than ITRS requirement of 11 nm (3 sigma variation) for 130 nm contacts.

We were also able to etch 130 nm contacts with the hard mask which was not used any further for the sake of process integration simplicity. However, we would like to point out that with the hard mask lithographic performance was improved and we were able to print 130 nm contacts with 2: 1 pitch. These contacts etched as 100 nm contacts, although we have not yet investigated the quality of this size of contacts on multiple lots.

Acknowledgement: We would like to thank from International SEMATECH: Harold Stemper, Arnie Ford, Spencer Pearson, Patrick Holland, FA lab and from TEL: David Wang for their contribution.

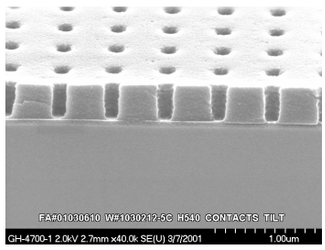

Figure 1: SEM cross-section of Resist CD for 140 nm Contacts with 540 nm Pitch

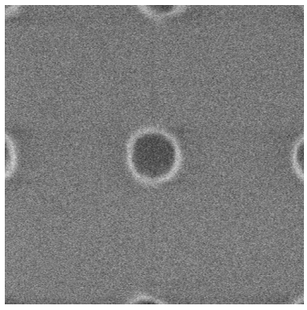

Figure 2: Top down SEM view of Resist CD

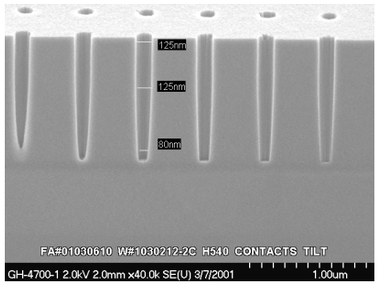

Figure 3: SEM cross-section of Final CD for 130 nm Contacts

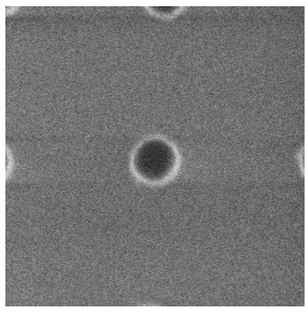

Figure 4: Top down SEM view of Final CD