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Plasma-Assisted CD Shrink and Overlay Metrology Techniques for Double Patterning - Reza Sadjadi

Helen Zhu, Peter Cirigliano, Elizabeth Pavel, Amulya Athayde, Cornel Bozdog [†], Michael Sendler [†], Danny Mor [†]
reza.sadjadi@lamrc.com
Lam Research Corporation, 4650 Cushing Parkway, Fremont, CA 94538 U.S.A.
[†] Nova Measuring Instruments LTD, Weizmann Science Park, Bldg 22, Rehovot, 76100, Israel
Phone: +1-510-572- 2831 Fax: +1-510-572-8129

Delays in the availability of high-index immersion and EUV lithography will require the semiconductor industry to turn to innovative patterning solutions for manufacturing devices at the 32 nm technology node. One approach to overcome the problem of printing at very small pitches is double patterning lithography, where two cycles of lithography and etch are used to print the design. By splitting the pattern into two printing steps, the lithography can be printed at twice the desired final pitch, removing some of the process limitations. The process window can be further improved by initially printing features at larger than the target size, followed by a post-lithography shrink, which improves critical dimension (CD) control.

One of the weaknesses of double patterning is that overlay errors between the two litho steps translate directly into CD errors in the final pattern. A very tight overlay tolerance will be required to make double patterning a production-worthy process. Here we present the use of scatterometry to measure the controlled registration shift in a double patterning scheme, combined with a novel plasma-assisted CD shrink technique to reduce the feature size after each litho exposure, resulting in pitch and CD shrink.

Scatterometry has gained market acceptance as production-worthy measurement method of linewidth CD and sidewall angle for etch and lithography patterning applications. In addition to line/space profile measurements, scatterometry combined with current modeling innovations can be used to measure virtually any periodic geometry repeated in one or two dimensions in the plane of the wafer. This technique can be used to verify overlay, as well as provide a process control method to allow for rework (removal and re-patterning of the second pattern).

To produce very small holes and trenches with large lithography process latitudes, a new plasma-assisted CD shrink method has been developed. This method, using the Lam Research 2300® Motif™ patterning system, covers the top and sidewalls of the patterned resist with a plasma-generated polymeric coating. The coating has high etch resistance and can be removed with a standard strip process. The amount of CD reduction can be controlled through the number of shrink process cycles applied, and features as small as ~20 nm have been obtained. Representative trench results showing a CD shrink of 45 nm are presented in Fig. 1.

In this study, a single mask containing a 100 nm line/space pattern at 200 nm pitch was used, with a target final line/space pattern of 50 nm at 100 nm pitch. Following the first lithography step (Fig. 2A), the Lam 2300 Motif shrink process was applied to reduce the trench CD from ~100 nm to ~50 nm (Fig. 2B). After completion of the first etch and strip (Fig. 2C-D), a second litho exposure was carried out with an intentional 100 nm overlay registration shift relative to the first exposure (Fig. 2E). The CD shrink process was again applied (Fig. 2F), followed by the second etch and strip (Fig. 2G-H).

The key for successful double exposure/double patterning is the second mask alignment during lithography. The combination of Nova's NovaScan® 3090CD with Nova's NovaMARS™ scatterometry overlay algorithms, which dramatically enhance the sensitivity for the detection of shifts down to the nanometer level, were used to verify that the second pattern is printed at an offset of precisely half the pattern pitch. This measurement sensitivity is demonstrated through a series of experiments in which the second litho step had variable displacement shift on each row of fields.

The reference structure used to generate the scatterometry model for the targeted results is shown in Fig. 3. The 50 nm trenches at 200 nm pitch resulting from the first half of the double patterning process flow are shown in Fig. 4A. On top of these trenches are the photoresist lines from the second lithography step, where the overlay alignment has been optimized using the scatterometry algorithms. After the second litho/shrink/etch/strip sequence, the final pattern with 50 nm line/space features at 100 nm pitch was achieved (Fig. 4B).

In conclusion, we have shown that well-controlled plasma-assisted CD shrink combined with scatterometry-based overlay metrology methods can enable successful double patterning lithography for pitch and CD reduction, alleviating some of the litho process requirements for device scaling.

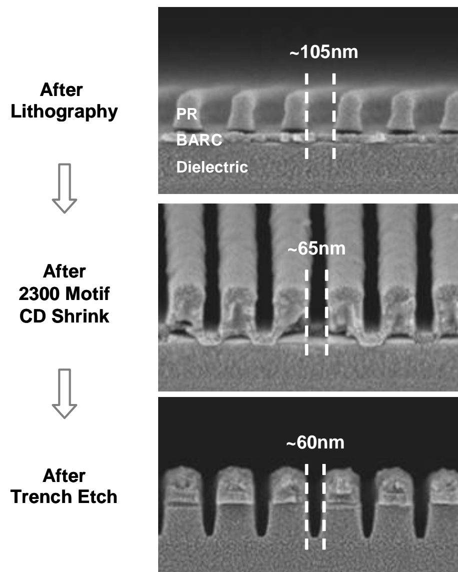
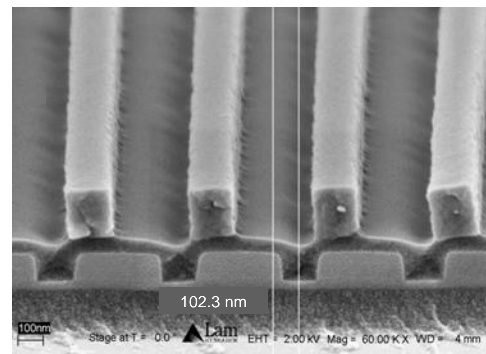


Figure 1: Representative trench CD reduction using the 2300 Motif plasma-assisted shrink process.



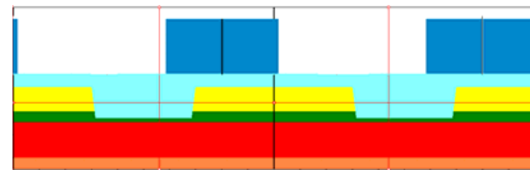


Figure 3. Reference structure (top) used to generate the scatterometry model (bottom): 500 nm pitch with ~100 nm overlay offset between first and second lithography exposures.

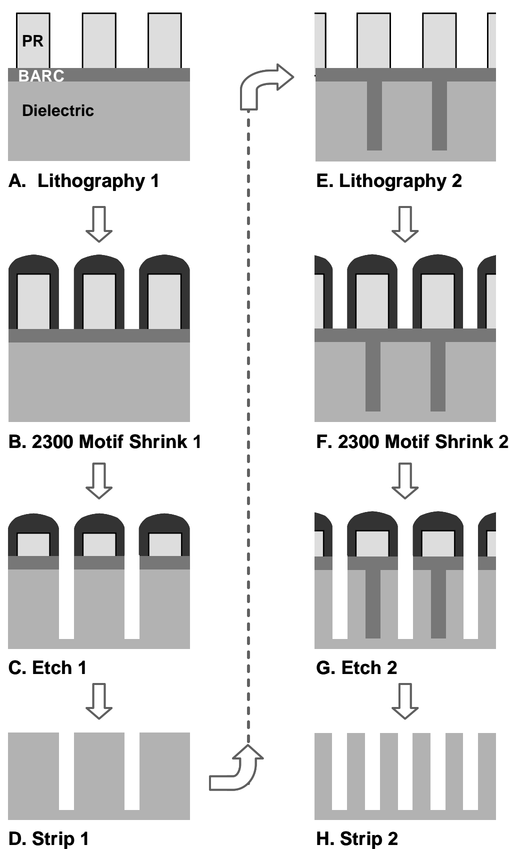
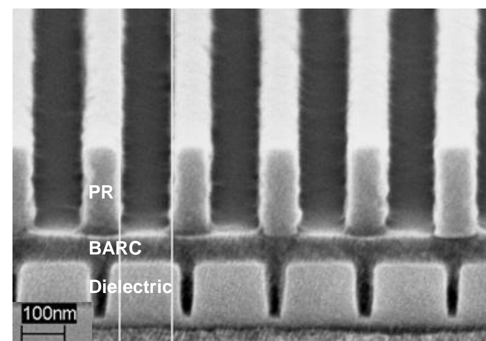


Figure 2: Double patterning scheme using 2300 Motif CD shrink after each lithography exposure. (Steps A, B, and C are represented in Fig. 1.)



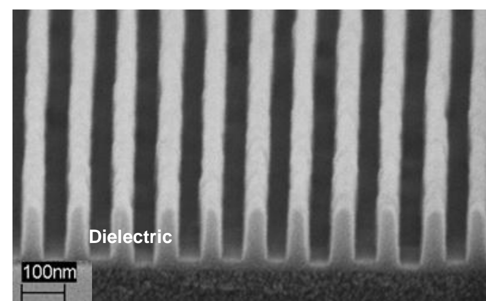


Figure 4. Final structures with optimized overlay between the two litho exposures. Top: 100 nm resist lines at 200 nm pitch after second litho step (corresponding to Fig. 2E). Bottom: final 50 nm features at 100 nm pitch (corresponding to Fig. 2H).