Metrology Solution for Double Patterning Processing

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Scatterometry has gained market acceptance as production-worthy measurement method of linewidth critical dimension (CD) and sidewall angle (SWA) for patterning applications (etch and lithography). Compared to the traditional electron microscopy (CD-SEM) method for linewidth measurements, scatterometry has higher throughput, order-of-magnitude better repeatability of measurement, and significantly lower cost of ownership.

Today scatterometry is no longer limited to line-space profile measurements. Modeling innovations allow measurement of practically any periodical geometry, be it repeated in one or two dimensions in the plane of the wafer. Subsequent process steps have always required near perfect alignment of the new pattern relative to existing patterns on the wafer. This requirement is even more stringent for the emerging double patterning pitch-shrinking methods.

Here we present the use of scatterometry to measure the controlled registration shift in a double exposure/double patterning (litho-etch-litho-etch) application. In this study, a single mask containing a line/space pattern with a 200 nm pitch was used to create a final line/space pattern with a 100 nm pitch. After the first litho exposure, the Lam Research 2300® Motif™ patterning system was used to shrink the trench CD from 100 nm to 50 nm before etch. After completion of the first etch, a second litho exposure was carried with an intentional 100 nm overlay registration shift relative to the first exposure. The 2300 Motif shrink process was again applied, followed by the second etch, resulting in the final line/space pattern with 100 nm pitch.

The key for a successful result is the second mask alignment during lithography. Here, a reliable overlay technique is required to verify that the second pattern is printed precisely at an offset of half the pattern pitch. The process control scheme can then provide for rework (removal and repatterning of the second pattern) for wafers found to deviate from the control limits.

In this paper, we show how under normal circumstances the measurement of half-pitch shifts is non-trivial. A study of scatterometry sensitivity to detection of small pattern alignment shifts indicated very low sensitivity of the measurement as the minimum detectable shifts were on the order of few nanometers or more, making it impractical for control of this application. We will also show how using Nova's patented scatterometry overlay algorithms dramatically enhanced the sensitivity for the detection of small shifts (Figures 1 and 2). With this, we show that the limit of detectable shifts decreased below nanometer level. This analysis was done using the NovaMARS™ application development software. Additionally, we performed measurements on NovaScan 3090 CD tool. An experiment was performed where the second litho step had variable displacement shift on each row of fields in order to demonstrate the displacement shift measurement. We also measured an "on-target" wafer and confirmed the findings. A nanometer level sensitivity to overlay shift was shown.

In conclusion, scatterometry-based overlay methods are easily applicable to double patterning shift measurements. This capability is an enabler for integrated process control schemes for the litho-etch module.

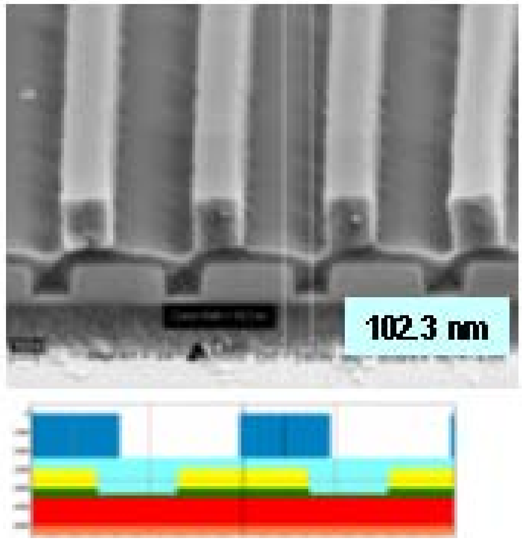

Figure 1. SEM cross-section (top) of the test structure after the second lithography step used to generate the scatterometry model (bottom).

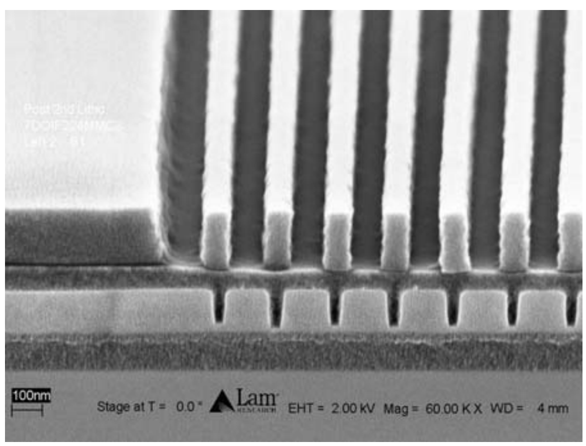

Figure 2. SEM cross-section of the final structure after the second lithography step, demonstrating optimized overlay between the first and second exposures.