Ultra Low voltage SEM for high accuracy measurements of CD/LWR/LER

G. Mozdzen[1], F. Rüdenauer[1], W. Costin[1], P. Sattler[1]. P. Hudek[2]

1. Austrian Research Centers GmbH – Institute of Advanced Materials and Aerospace Technology, 2444 Seibersdorf, Austria
2. Vorarlberg University of Applied Sciences, Research Center for Microtechnologies, Dornbirn, Austria

Key words: metrology, low accelerating voltage SEM, CD, LWR, LER

The continuous reduction of the critical size in the lithography process is one of the key problems for the next generation of IC´s. ITRS roadmap has pointed out the most difficult challenges for the next technology nodes (32 nm and beyond) not only for the reduction of the critical dimension (CD) but also in terms of line edge roughness (LER) and line width roughness (LWR). ITRS defines LWR as 3 times the standard deviations (σ) of the line width measurements, performed at equidistant positions in a line section of predetermined length (Fig.1). It is lower than 3 nm for the 90nm node and will become less than 2nm for the next generations [1].

As the pattern roughness in particular has an enormous influence on the characteristic of the corresponding electronic devices it is extremely important to examine the roughness with high accuracy. For the measurement of LER/LWR and CD, CD-SEM, AFM and Scatterometry have been applied; however, neither of these techniques is a standardized method [2,3,4]. Up to now SEM is the most common technique in the field of line metrology. LER/LWR and CD are currently calculated in top-view SEM images [5,6]. Many factors which relate to the type of resist, patterning process and settings of SEM machine used for the imaging contribute to the roughness of the patterned structures. Furthermore, the software and the calculation algorithms can influence the statistical analysis and at least the final results in a decisive way.

In the presented work nano-scale lines patterned in HSQ resist at 30 and 50 keV respectively have been recorded by HRSEM using an Inlens detector and two different accelerating voltages; of 1.0 and 0.3 keV. Besides the accelerating voltage all another SEM processing parameters such as; working distance, aperture, noise reduction, dwell time have been kept constant. The captured lines have been measured with respect to width and edge roughness. For the measurements a “Line Width Measurement”- module of the “Scandium” software package has been adapted. In order to enhance the measurement accuracy specific algorithms for the removal of data outliers and for the correction of the line misadjustment have been developed. The obtained results showed that the lines recorded at 1 kV are characterised by a smaller width compared to the lines captured at 0.3 kV (Fig.2).This observation relates to the slimming effect [7] which becomes pronounced with increasing beam energy. Additionally, much greater LER details are noted at 0.3 kV than at 1 kV. Hence for a given resist the imaging process at 0.3 kV promises a higher accuracy of measurements than those at 1 kV.

G. Kothleitner, M. Leisch (Eds.): MC2009, Vol. 1: Instrumentation and Methodology,
DOI: 10.3217/978-3-85125-062-6-088, © Verlag der TU Graz 2009

References
[1] International Technology Roadmap for Semiconductors – 2005 Edition - Metrology
[2] Mark L. Scattenburg and Henry I. Smith, The critical role of metrology in nanotechnology, Proceedings of the SPIE, Vol 4608, Gaithersburg, Maryland, 5-7 September 2001
[3] Ndubuisi G Orij, Theodore V Vorburger, Joseph Fu at al., “ Line Edge Roughness metrology using atomic force microscope”, Meas.Sci.Technol. 16 (2005) 2147-2154
[4] .H. Jang, W. Zhao, J.W. Bae “Direct measurement of nanoscale sidewall roughness of optical waveguides using an atomic force microscope”, Applied Physics Letters, Vol. 83, No. 20, 17 November 2003
[5] J.S. Villarrubie, Issues in LER & LWR Metrology, NIST, ULSI Metrology conf. 3/16/2005
[6] GP. Patsis, V. Constantoudis, A. Tserepi, “Quantification of line-edge roughness of photoresists. 1. A comparison between off-line and on-line analysis of top-dawn scanning electron microscopy images. J. VAC SCI TECHNOL B 21 (3): 1008-1018 May-Jun 2003
[7] G. Sundaram, N.T Sullivan, T.Mai and C.M.Ke, “Low Impact Resist Metrology: The use of ultra low voltage for high accuracy performance” Soluris Inc., Concord, MA 01742, USA, Taiwan Semiconductor Manufacturing Corporation

Acknowledgement:

This work was performed as part of the EU funded project RIMANA (Radical Innovation Maskless Nanolithography), administrated by Hans Loeschner, IMS Nanofabrication AG, Vienna. More information about this project is provided at www.rimana.org

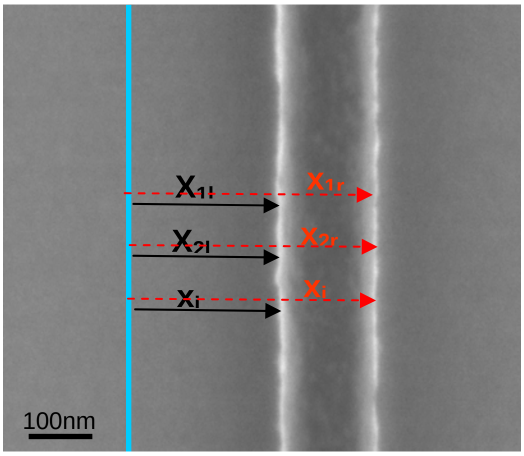


Fig.1. Calculation manner of CD, LWR and LER

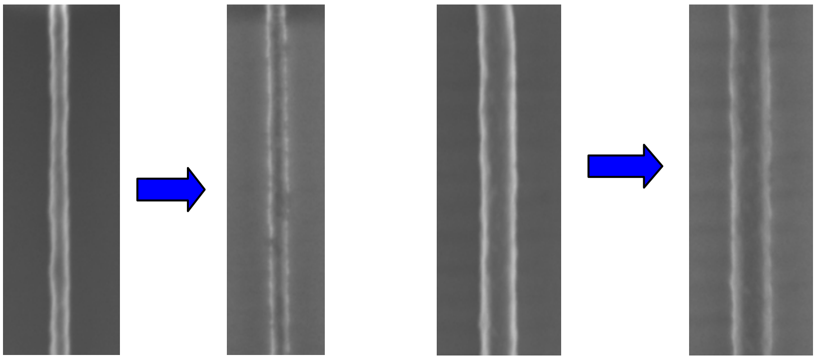
LER_{left} is calculated as 3 σ of the distances between a reference-line and the left edge accordingly **LER_{right}** is calculated as 3 σ of the distances between the same reference-line and the right edge. LER is calculated as average of **LER_{left}** and **LER_{right}**

$$LER_l = 3\sqrt{\frac{\sum_i \left(x_{il} - x_l^{avg}\right)^2}{n-1}} \qquad LER_r = 3\sqrt{\frac{\sum_i \left(x_{ir} - x_r^{avg}\right)^2}{n-1}} \qquad LER = \sqrt{\frac{LER_l^2 + LER_r^2}{2}}$$

LWR is defined as 3 σ of the line widths in each measured image line

$$CD = \frac{1}{n}\sum_i \left(x_{ir} - x_{il}\right)$$

CD is calculated as a difference from distances between a reference-line to the right edge and between a reference-line to the left edge



1 kV
CD = 57.0nm

0.3 kV
CD = 62.5nm

1 kV
CD = 118.7nm

0.3 kV
CD = 129.5nm

Fig.2. Influence of accelerating voltage on the line width and the edge roughness for two different lines.

G. Kothleitner, M. Leisch (Eds.): MC2009, Vol. 1: Instrumentation and Methodology,
DOI: 10.3217/978-3-85125-062-6-088, © Verlag der TU Graz 2009