

High throughput AFM metrology for high-NA EUV lithography

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The semiconductor industry has continued its push on scaling with the use of multi-patterning while in parallel introducing 3D transistor architectures and advanced packaging to achieve higher transistor density and performance gains. High-NA EUV lithography machines are expected to provide relief from multi-patterning translating to fewer process steps and increased yield. However, the use of higher numerical aperture has a direct impact with reduced depth of focus among others, requiring process optimization especially for use in high-volume manufacturing (HVM), not limited, but critically on the focus and exposure parameters of the lithography tool [1]. With maturity, the feature sizes are also expected to reduce further especially at the interconnect and contact-hole layers directly above the transistor devices.

CD-SEM has been the industry workhorse, especially in HVM. However, with further scaling, CD-SEM suffers from low-SNR and photo-resist shrinkage, and significant modelling and complementary techniques are required to capture the CDs accurately [2]. While AFM is well-suited to provide fully non-destructive measurements on photo-resist wafers either after exposure or development with the required resolution, they are generally considered slow and are not in large use in HVM environments. In this work, we present our results obtained by using a high-throughput fully automated AFM based metrology tool for wafers processed using high-NA EUV lithography tool at IMEC [3].

The wafer is processed using a focus exposure matrix and consists of contact holes of pitch 40, 36 and 32nm. Shots are measured on the wafer along the focus and exposure change lines, where the first set of measurements targets capture of resist thickness and resist loss information, showing that the former is more stable over dose variation than focus, with the latter having a linear trend with dose variation and being stable over focus. The second set of measurements targets the contact holes of different pitches to capture variation in hole depth, critical dimensions (CD) at various height. The results indicate an increase in both depth and CD with increase in dose, while changes in focus are more closely linked to defectivity. These results show the coming of age of high-throughput AFM for the upcoming semiconductor nodes where high-NA EUV lithography is expected to be used in HVM.

[1] Zahlten, Claus, et al. "High-NA EUV lithography: pushing the limits." 35th European Mask and Lithography Conference (EMLC 2019). Vol. 11177. SPIE, 2019.

[2] Zidan, Mohamed, et al. "Contact hole metrology study: understand the electron beam interaction with photoresist and how to minimize its impact." *Journal of Micro/Nanopatterning, Materials, and Metrology* 24.2 (2025): 024004-024004.

[3] Chin, Hokyun, et al. "AFM metrology for 3D high aspect ratio semiconductor structures." *Metrology, Inspection, and Process Control XXXIX*. Vol. 13426. SPIE, 2025.