Phase behavior through pitch and duty cycle and its impact on process window

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ABSTRACT

Lithography has moved into 45nm node and will soon go into 32nm node. Alternating Phase shifting masks (PSM) are one of the most effective ways to enhance resolution. However there are two major challenges: intensity balancing and quartz dry etch process. The dry etch process requires not only an uniform quartz etch but also good linearity over a wide range of feature sizes to ensure a 180° phase shift through pitch and duty cycle. Phase errors lead to an image placement error, which becomes even worse through focus. As feature sizes shrink imaging effects and rigorous 3D mask effects impact the phase shift and phase shift measurement becomes extremely critical.

In this paper we report on phase shift measurements through pitch and duty cycle and compare them to rigorous 3D simulations. Furthermore we correlate the phase shift measurements to process window data such as maximum exposure latitude and Image Placement Error (IPE).

An alt. PSM from IMEC was used containing a variety of different line width and pitches to investigate the phase behaviour through pitch and duty cycle. Rigorous 3D simulations have been executed using the simulator EM-suite of Panoramic Technology Inc., which is based on the Finite-Difference Time-Domain method. The phase shift measurements have been performed on the newly developed phase metrology system Phame®, applying coherent 193nm illumination. AIMS45-193i measurements were used to investigate the correlation between phase shift and process window data such as maximum exposure latitude and IPE.

As seen in Figure 1 for small pitches below 180nm at wafer the phase shift drops significantly below 180° which will lead to an image placement error during printing. Furthermore a strong correlation between phase shift and maximum exposure latitude is shown. Figure 2 demonstrates that largest maximum exposure latitude is achieved for phase shift close to 180°. The through pitch investigation shows that the phase shift is significantly impacted by mask topography effects.

This work shows the importance of phase shift measurement especially in the critical features. There is a strong correlation between phase shift and process window. Phame® enables optical phase shift measurement in critical production features providing the opportunity to optimize the quartz dry etch process in terms of signature and linearity. This will help to optimize phase shift of critical features on alternating PSM for largest process window and hence increase end of line yields for reducing overall chip manufacturing costs.

Keywords: Phame, PSM, Phase Metrology, Phase

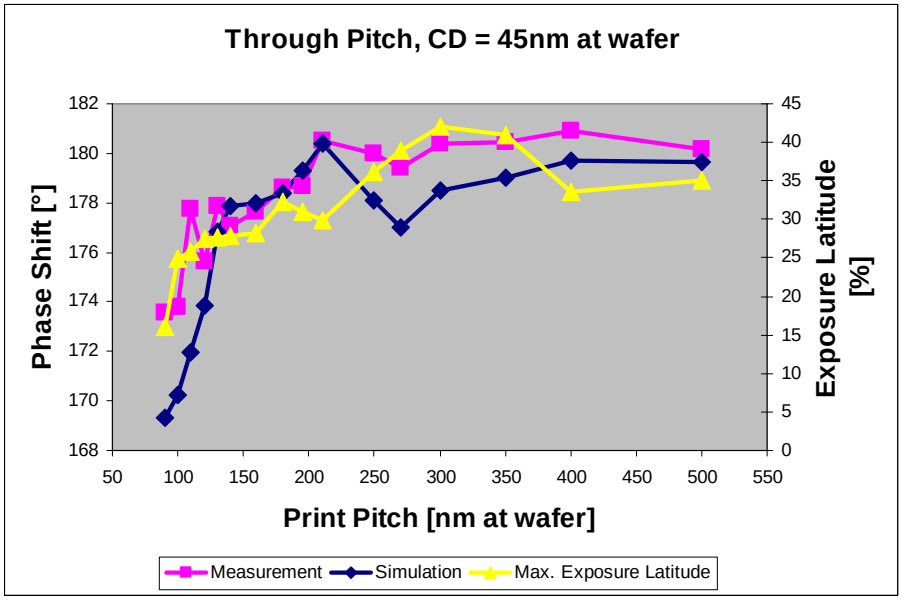

Figure 1: Through pitch investigation for 45nm CD: Comparison between Phame® phase shift measurement and rigorous simulation and its correlation to exposure latitude

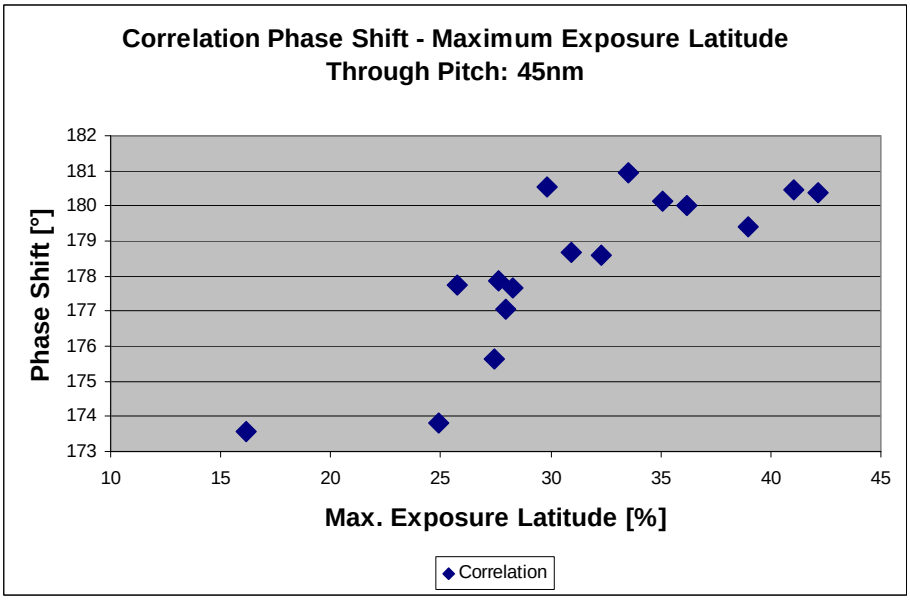

Figure 2: Correlation between phase shift and maximum exposure latitude