Experimental demonstration of Dark Field Illumination using Contact Hole features

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The use of off-axis illumination in present lithography processes has enabled patterning to push below $k_1 < 0.40$. This continual drive towards printing smaller feature sizes at the 193 nm wavelength has lead to the investigation and successful implementation of a number of new RET approaches. In this work, the application of Dark Field Imaging as a resolution enhancement technique for low-k_1 contact hole features was examined using both simulation and experiment on a standard lithography toolset. Specifically, the lithography performance of contacts through-pitch and various 2-D contact shapes are examined.

Here Dark Field imaging is defined as imaging where a portion of the illumination source is placed outside of the projection optics. This approach is similar to standard off-axis illumination approaches using the familiar two-beam imaging, but at greater incident angle where the 0^{th} diffraction order is not captured within the projection optics. Dark Field image modulation is created by higher order contributions to the diffraction pattern. This approach creates a number of interesting effects with relevance to practical application. We show these for contact hole patterns using an ASML Twinscan modified to operate in Dark Field mode.

We demonstrate the following Dark Field effects for contact holes and a 6% Attenuated Phase Shift (AttPSM) reticle:

1. Mask Error Enhancement Factor (MEEF) < 1.0 for $k_1 < 0.40$.
2. Inverted CD vs. Pitch behavior with isolated pitch features having larger dimensions than dense pitches at constant mask bias.
3. Increased 2-D fidelity for contacts with aspect ratio > 1.0.
4. Increased process window and defocus behavior of Dark Field contacts.
5. Image tone reversal for Alternating Phase Shifting Reticles (AltPSM).
6. Outlook what this implies on CH printing capability (node extension).

Lastly, the advantages of the Dark Field imaging approach over various mainstream RET are discussed in this work.

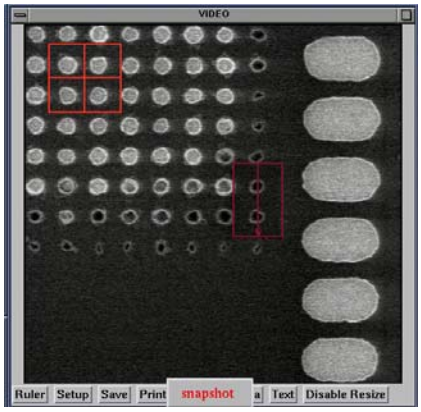

Figure 1:
Edge Effects for Contact Array with Standard Illumination

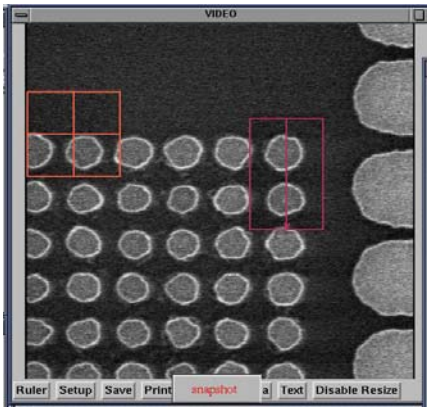

Figure 2:
Edge Effects for Contact Array with Dark Field Illumination