Introduction to Aberration Monitors

Modeling interactions between defects and features is important for two applications. One is determining the degree to which the presence of aberrations increases the tendency of defects on the order of 1/5 to 1/3 of a feature size to cause linewidth variation or bridging. The second is the possibility of using super-sized programmed defects on the order of 2/3 of a 0.6 λ/NA feature size to build aberration sensitive targets to quantitatively measure the presence of aberrations in an optical system. While the former is well deserving of study, the surprising success with a few defect-probe based targets lead to considering only the later in this paper.

The impact of aberrations on lithography is an increasing concern in extending the limits of optical lithography. Brunner has given an excellent overview of the subject [1] and the large number of photoresist based techniques were recently classified by Kirk [2]. Work particularly relevant to the present paper includes focus monitors based on shifts of phase-edge line positions with focus [3], measurements of localized pupil tilt based translation of large features projected from a special aperture restricting mask by Litel [4], SEM’s of shapes of images of λ/2 phase-dots by Dirksen et al. [5,6], and measurements of exposure sensitivity of side-lobe artifacts on halftone mask edges by Hayano, Fukuda and Imai [7-9]. The strategy in this paper is similar to that of the latter in which the exposure sensitivity of an artifact in the vicinity of an exposed area is utilized. Here, super-sized defects are used to interact with the side-lobe spillover from the exposed area instead of the transmission by the halftone area. Since this spillover is often opposite in phase to the feature, this technique works well for strong phase shifting masks where opposite phasing is available. The approach also has some similarities to the work of Dirksen et al. [5] in that the target simultaneously stimulates response from nearly the entire pupil. The work here also draws on the observation of Dirksen et al. [6] and Fukuda et al. [8] that there is a nearly linear relationship of contributions of various Zernike aberration terms to the perturbation of the image in response to the presence of aberrations.

The understanding as to how super-sized defects interact with aberrations is based on the perturbation model for defect-feature interactions [10-12], in which the electric fields (rather than intensities) are added for the defect and feature. This assumes these signals are highly coherent, which is the case when the partial coherence factor σ is small (0.3). The images which will be shown here simulated with SPLAT [13]. The inputs to SPLAT were normalized such that a 0.1 λ of a Zernike aberration corresponded to a peak-to-peak optical path difference across the pupil of 0.2 λ. Since in the Zernike representation all terms are orthogonal, aberrations such as coma are naturally balanced (i.e. have tilt removed, etc.). The simulations are normalized using λ = 0.5 μm and NA = 0.5 so that 1

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µm in the figures equals 1 \( \lambda/NA \). Remote simulations of images for arbitrary \( \lambda \) and NA are available using the ‘Pattern Aberration Interaction’ applet under applications in LAVA [14] at http://cuervo.eecs.berkeley.edu/Volcano/.