A Study of the Critical Dimension variation in a wide exposure field (50 × 50) with a novel beamline

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An intense illumination and a wide exposure field are necessary for the manufacturing of the next-generation ULSI devices using synchrotron-based x-ray lithography. To fulfill this need Sumitomo Heavy Industries (SHI) has developed a compact synchrotron, Aurora-2S, which yields intense x-ray[1]. SHI has also proposed a novel beamline design to illuminate the wide exposure field. The combination of a special motion of a single scanning mirror with a curved shape of the beryllium window foil delivers dose uniformity within ±2 % over 50 × 50 mm exposure field[2]. Since the beam trace along the beam center axis and traces reaching corners of the exposure field are different, the mirror reflection angle and the optical thickness of the beryllium foil are different for of each ray. Thus, the difference of spectra for each exposure point may affect photoresist patterning; this is generally true, to a varying degree, for any optical system in the X-ray.

SHI and University of Wisconsin (UW) studied pattern resolution affected by the difference of spectra of a wide exposure field. In lithography, the main factor concerning the pattern resolution is the controllability of the pattern Critical Dimension (CD). In this poster presentation, we concentrate on CD-variation since we are estimating overall factors, which affect to the blur especially about thermal mask-distortion during scanning. SHI's Aurora-2S and their 7-m beamline were used as the study object; UW undertook the calculation for the CD-variation using with their 'CXrL ToolSet'[3]. The calculation has been done for nine points on a 50 x 50 mm exposure field for features of various dimensions (80-150nm), including both one and two-dimensional features. The beamline optical properties were analyzed using SHADOW and the spectrum, beam shape and blur computed at each field location. After this, the diffraction image from the mask (assuming a .4 µm Ta_9Ge absorber) was computed for 10 and 15 µm gaps, using Shipley UV-II resist for which experimental dissolution rate data were available. The dose image was then transferred to resist exposure and development tool that yielded the developed image. For the purpose of the study, the CD was measured at the foot of the resist. Sensitivity studies were performed by changing the exposure time +/- 10%, and changing the development time by +/- 10s. The modeling effort generated a large number of “experimental points”, corresponding to the various combinations of gap, features, CD and field locations. The CD extracted from the resist images were tabulated, and their distribution analyzed using statistical methods.

In order to separate the effect of spectrum, bias and dose variation we ran the calculations assuming an uniform exposure dose, i.e., we normalized the spectra at the field locations to 100mW/cm^2. Hence, the only difference from site to site must be generated by the variations in the spectrum and in the blur. The effect of non-uniformity can be easily introduced later, after

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[1] T. Hori and T. Takayama, Proc. ICSRS-AFSR'95, Pohang, Korea (1995)
[2] E. Toyota, to be published in J. Vac. Sci. Technol (1998)
[3] S. Bollepalli, M. Khan, F. Cerrina, XEL 98

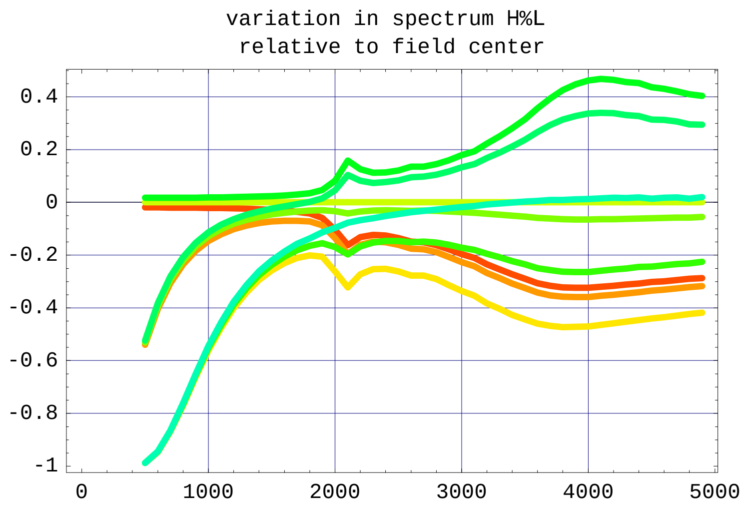
the exposure latitude has been computed: the exposure latitude was obtained by changing the exposure time +/- 10%, and computing the corresponding d(CD)/d(Dose). Finally, we note that the masks were not optimized in terms of bias and thickness, and no external blur was assumed; it is well known that bias and thickness optimization is necessary to obtain uniform CDs and increased dose latitude. The lack of external bias is equivalent to exposure with a high degree of spatial coherence, thus enhancing the effects of the optical system imperfection on the imaging process.

The calculation results show that the variation across the field in CD is less than 3%. This indicates that the spectral changes have indeed an effect on the CD. The reason is due to the fact that a spectrum change will modify the absorbed dose, even when the aerial image remains constant. Thus we believe that it will possible to compensate for the spectral changes by modifying slightly the delivered dose, i.e., by requiring the *absorbed dose* to be uniform, rather than the intensity. Further work remains to be done to fully clarify the interplay of these factors.

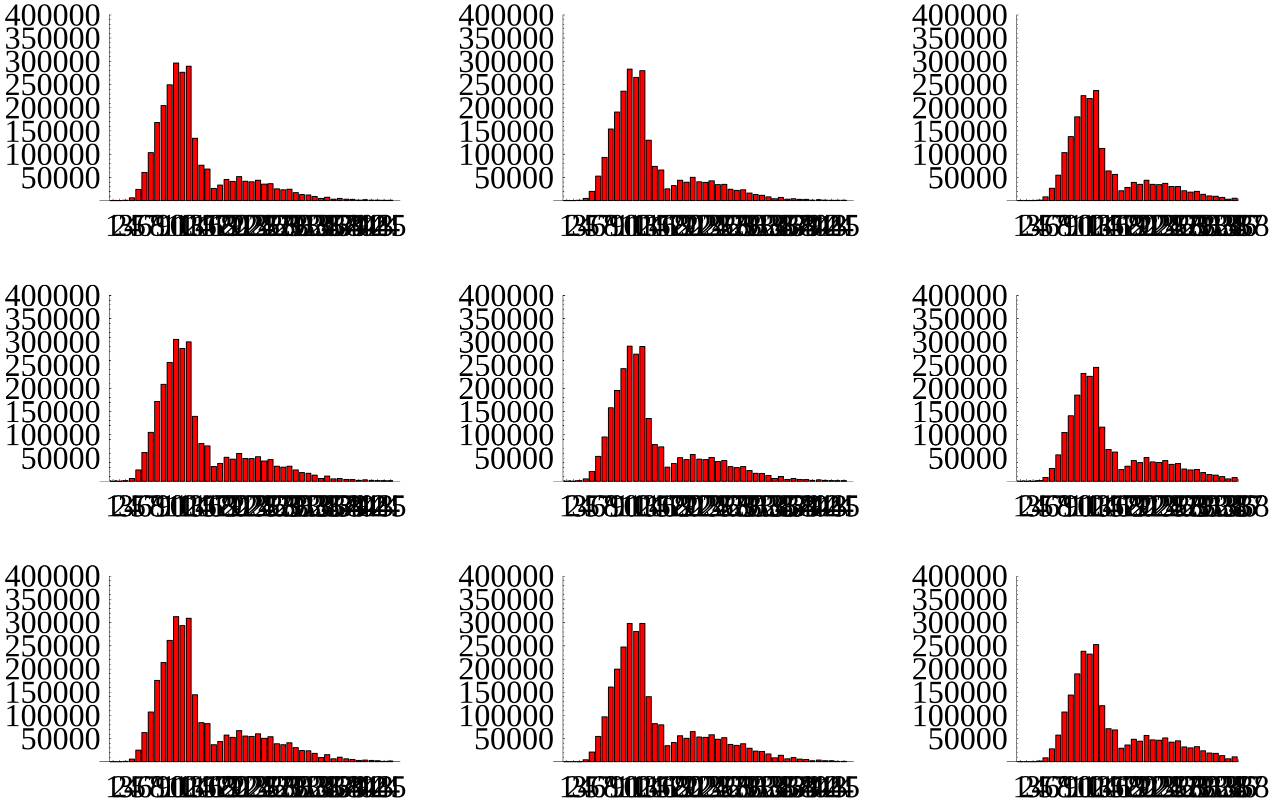
An additional change was observed with gaps of 10 and 15 µm, the former yielding consistently better results, as expected from the large Fresnel number.

In conclusion, the study shows that spectral effect are small but not negligible, particularly for smaller dimensions. These effects are common to all beamlines based on mirror optics, because of the variation of the angle of incidence with field position. We expect that the optimization of bias and blur will further decrease the already small intrafield variation to level exceeding the requirements of the SIA Roadmap.

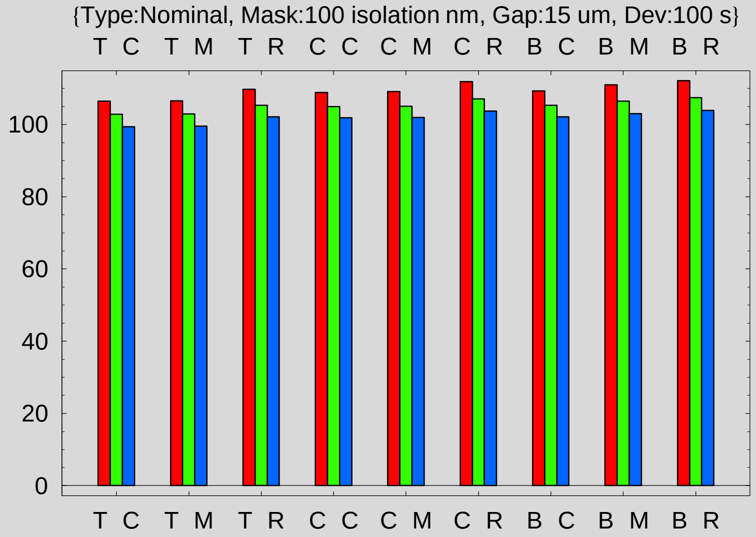
List of Figures.



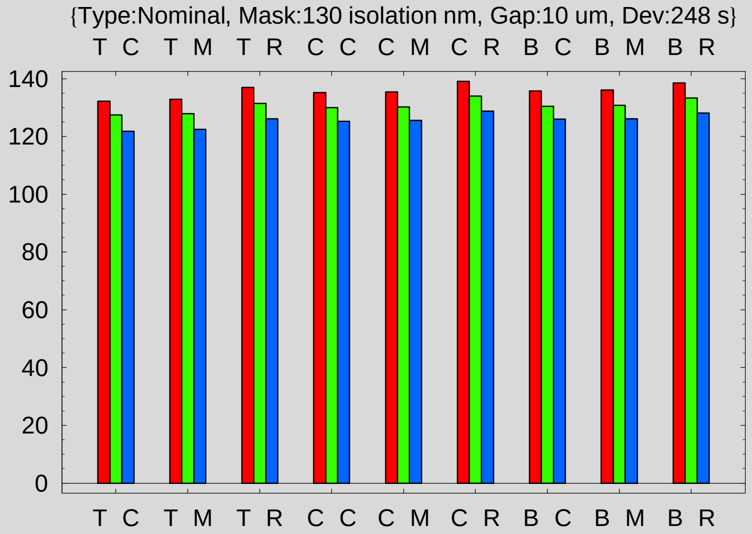
Difference between spectra at the field locations; the spectrum a the center of the field (leftmost in second row below) is taken as reference



Spectra computed at the field locations. First row is top of scan (+25mm), lowest bottom of scan (-25mm). Left column is field center, rightmost is +25mm field position.



{Type:Nominal, Mask:100 isolation nm, Gap:15 um, Dev:100 s}



{Type:Nominal, Mask:130 isolation nm, Gap:10 um, Dev:248 s}

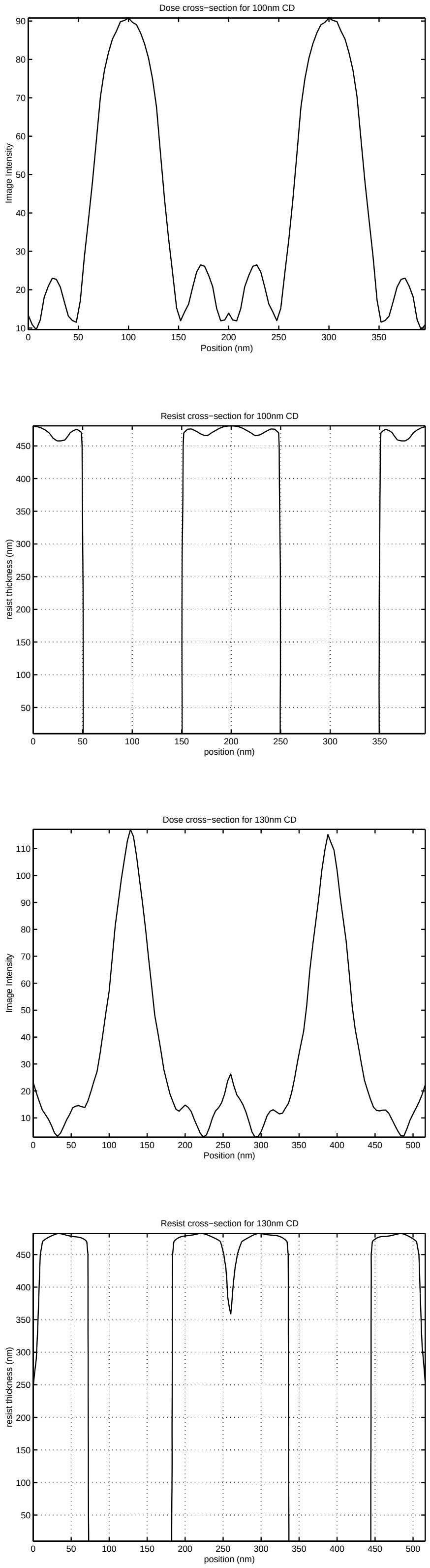
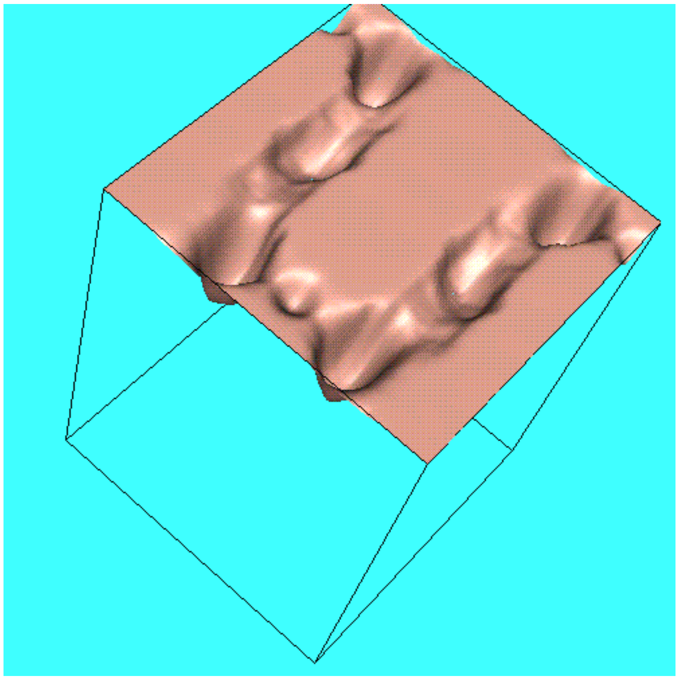
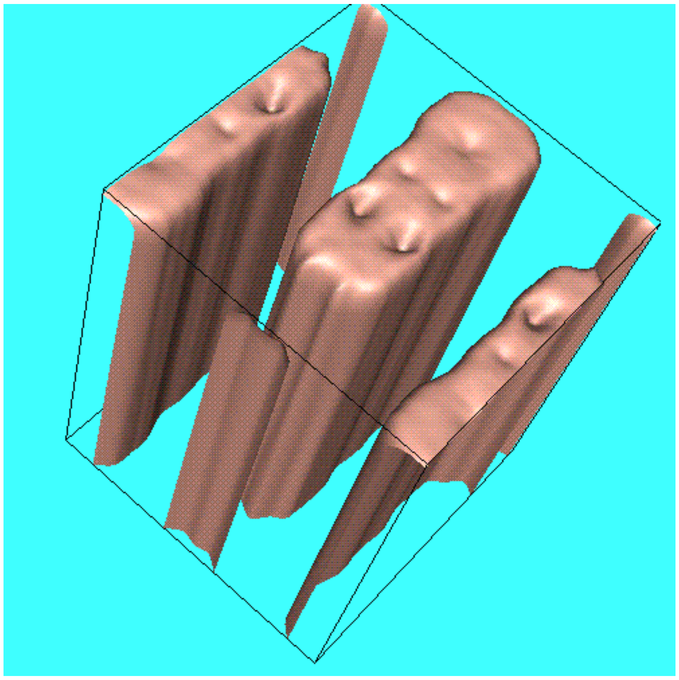


Figure 3: Dose and resist cross-sections



(a) Profile after 0.5 seconds



(b) Profile after 50 seconds

Figure 4: Development profiles