Evaluation of Resist Performance for 22 nm Half-Pitch and Beyond Using EUV Interference Lithography

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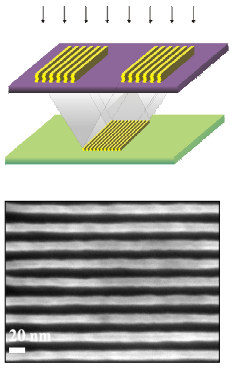
Introduction

The aim of this work is to benchmark the resolution of EUV photoresists by printing dense L/S features in resist and analyze them with top down SEM imaging. The EUV Interference Lithography (EUV-IL) beamline installed at the Swiss Light Source which uses an undulator as light source is applied as exposure tool [1]. The patterns are exposed by coherent illumination of e-beam written masks. For the sample preparation a fully equipped cleanroom capable of 8" wafer processing is available at the beamline.



11 nm hp lines exposed in HSQ [2]

The aerial image of an interference-based exposure tool is sinusoidally shaped:

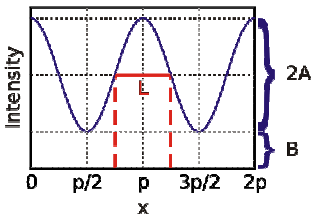
$$I(x) = A(\cos(kx) + 1) + B$$

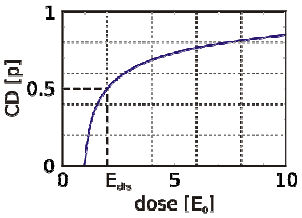
A measure for the image contrast is the normalized image log-slope (NILS):

$$NILS = L\frac{\partial \ln I}{\partial x} = \frac{A}{A+B} = \mu\pi$$

In a background-free interference image NILS is equal to π [3]. When printing dense L/S patterns through dose in an ideal resist the aerial image can be transferred into the resist. Experimentally it can be analyzed via an analytically derived fit:

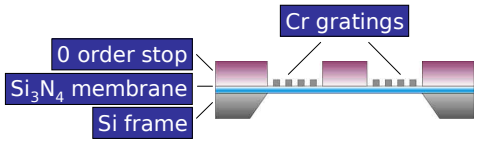
$$CD = \frac{p}{\pi}\arccos\left[\frac{E_{dts}-dose}{\mu \cdot dose}\right]$$

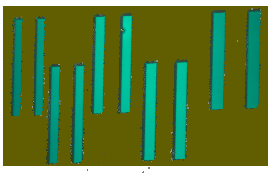




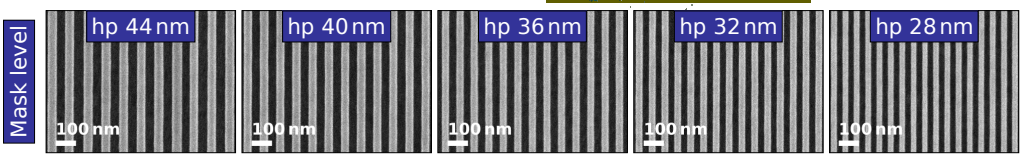
Mask Fabrication & Reference Exposure in HSQ

The mask used for resist testing consists of Cr gratings on a Si_3N_4 membrane supported by a Si frame. In comparison to earlier versions the 1st order diffraction efficiency of the gratings was doubled by increased metal thickness and optimized duty cycle. In order to suppress the direct (non-diffracted) light a several micrometer thick polymer is applied as a zero order stop. The five pitches on the mask range from 88 nm to 56 nm which print patterns of half the pitch of the parental gratings into resist.

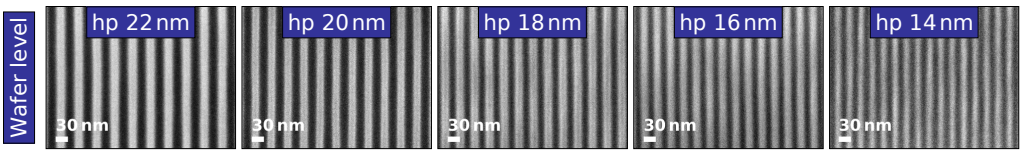




Optical microscope image of the fabricated mask

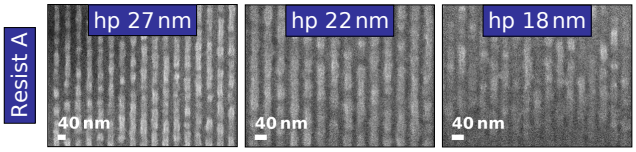


$$p_{wafer} = p_{mask}/2$$

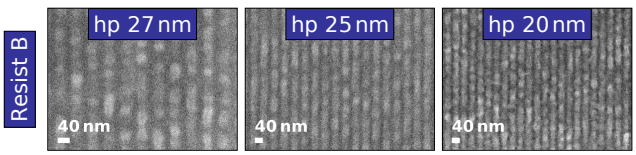


A variable dose exposure in Hydrogen Silsesquioxane (HSQ) developed in NaOH serves as reference exposure. All L/S patterns down to 14 nm hp have been resolved. The resolution limit of the beamline was experimentally determined to be 12.5 nm hp.

Exposures in Chemically Amplified Resists



SEM images of the patterned resists



- For chemically amplified resists (CARs) dense L/S patterns down to 18 nm hp could be resolved
- Compared to the HSQ exposure the lower achievable resolution of CARs can be mainly assigned to acid diffusion
- So far only the resolution limit of the CARs was tested; a detailed analysis of the pitch-dependent exposure latitude will be done in future
- Simulations of the EUV source performance combined with calculations of the beamline optics revealed a pattern overlaying background of 11% in energy limiting the maximum achievable resolution. The origin of this background are the higher harmonics generated by the undulator EUV source.
- Beside the exposure itself optimization of the resist processing (e.g. film thickness, development procedure) will increase pattern quality and resolution

Conclusions

The new EUV-IL exposure tool has proven to have the ability to print down to 14 nm hp patterns in HSQ and 18 nm hp patterns in CARs despite that the exposures still suffer from background radiation. Further tool upgrades in the near future are expected to resolve this limitation and thus even higher resolution of the tested CARs can be expected.

References

[1] H. H. Solak, J. Phys. D 39, R171-R188 (2006).
[2] V. Auzelyte et al., J. Micro/Nanolith. MEMS MOEMS 8, 021204 (2009).
[3] A. Langner et al., Proc. SPIE 7636, 76362X (2010).

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