Abstract

Since the late 90-ties, extensive simulations were performed to explore the imaging characteristics of EUV-masks. Several important imaging artifacts such as orientation dependent placement errors, telecentricity errors, and asymmetric Bossung curves were observed. It is important to note that these imaging artifacts result from the specific geometry of EUV mask features. They occur even for aberration free-projection systems. This contribution presents specific simulations for real and idealized mask geometries that reveal the physical origin of the observed effects. Possible strategies to reduce the magnitude of the unwanted artifacts will be discussed.

Light Diffraction from Optical and EUV Masks

- **EUV-Masks Induced Imaging Artifacts - Observations**
  - imaging blur between features on dark and bright field masks
  - orientation dependence of pattern placement, line-width...
  - angular independent
  - focus dependent placement errors (telecentricity errors)

Krautkraut 2001

- shift, asymmetric Bossung curves
- What is the reason for these artifacts?
- How do off-axis illumination, "thick" absorber, and multilayer reflectivity contribute to these artifacts?
- How to reduce the artifacts?

Peculiarities of EUV Masks

- off-axis illumination: 4-6°
- absorber thickness large compared to the wavelength: 10-8 μm
- multilayer reflectivity

Amplitude and phase of reflected light depend on angle of incidence θ

EUV-Mask-induced imaging artifacts: near fields

Simulation Study for Idealized Mask Properties

**Mask/Illumination Geometries**

- THIN
  - thin absorber
  - angular independent reflectivity of ML

- RAPM
  - real absorber
  - angular independent reflectivity of ML

- PARM
  - thin strong absorber
  - real ML

Default Simulation Parameters

- mask: 30nm isolated lines, absorber: 80nm chromium, multilayer: 40 layers of MoSi, resist: simplified DUV-CAR model, λ=13.4nm, NA=0.3, s=0.5, TE-polarization

Near Fields

- off-axis illumination and absorber cause "intensity imbalancing"
- multilayer and absorber modify phase

Aerial Images

- both absorber and ML contribute to placement error
- absorber causes larger contribution to placement and telecentricity errors

Placement Error versus Focus

- small impact of ML reflectivity on shape of process window
- "thick" absorber is main contributor to deformation of process windows

Process Windows

Simulations for different Absorber Materials

- Some of the observed imaging artifacts seem to be dominated by phase deformation inside the "thick" absorber

Possible Alternatives (from simulation point of view only)

- Cr: n=0.9333, k=-0.0388
- TaCe: n=0.9741, k=-0.0298
- Al: n=1.0030, k=-0.0297

Summary and Conclusions

- off-axis illumination (OAI), "thick" absorbers (TA), and real multilayer reflectivities (ML) contribute to imaging artifacts in EUV lithography
- the placement error depends strongly on OAI
- TA and ML contribute to the placement error. TA contribution to placement and telecentricity error is dominating
- deformation of process windows (tilt, shift) is mainly due to TA, absorber with real parts of refractive indices closer to 1 will show reduced imaging artifacts
- similar observation were made for dense lines and contact holes

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Literature


Fraunhofer Institute of Integrated Systems and Device Technology (IISB), Schottkystrasse 10, D-91058 Erlangen, Germany

SIGMA-C, Thomas-Dehler-Strasse 9, D-81737 Munich, Germany