Fraunhofer IISB

Fraunhofer-Institut für Integrierte Systeme und Bauelemente-technologie IISB

Lithography and optics simulation now and in future

Peter Evanschitzky
IISB Annual Symposium 2023
October 12, 2023, Fraunhofer IISB, Erlangen, Germany

Dr. LiTHO
Lithography Simulation

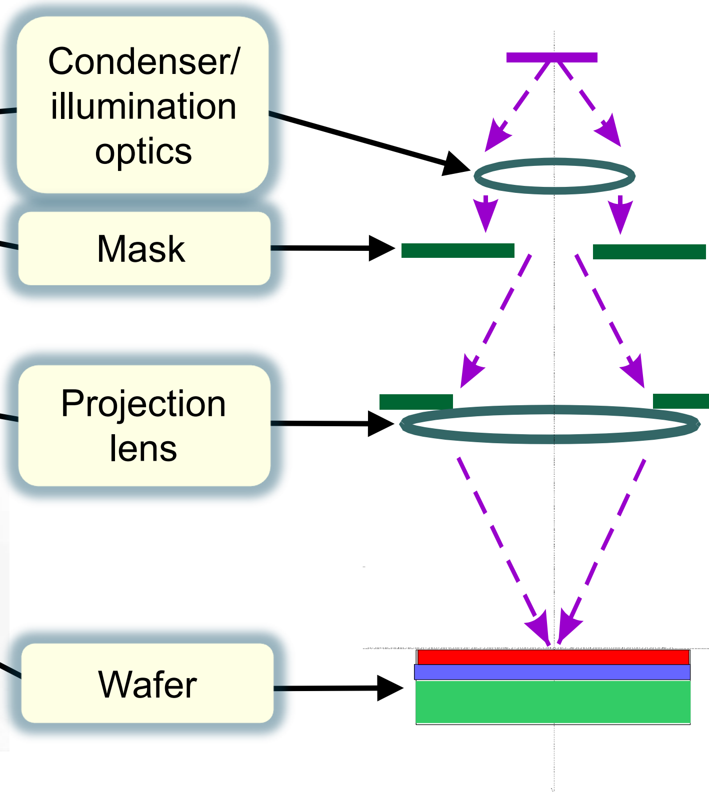
Contents

1. What is lithography simulation
2. Selected applications from projects of the litho group
3. First steps towards future application fields beyond lithography
4. Conclusions

Lithography simulation

What is it all about

Picture from ASML



Modelling of lithography systems to simulate, investigate and optimize lithographic processes and components

Lithography scanner @ 193 nm immersion

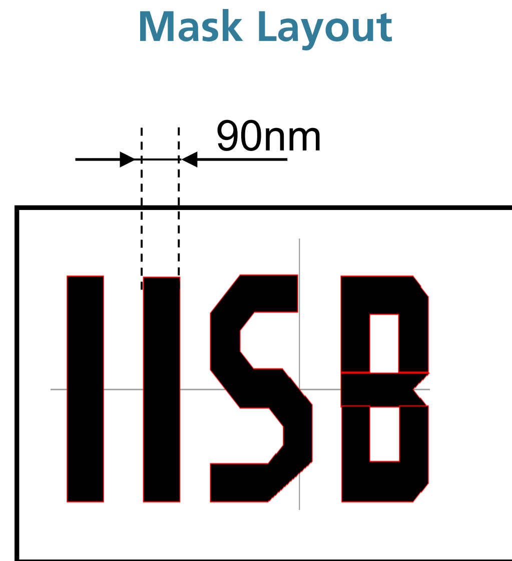
Simulation model

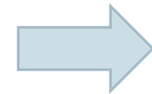
Lithography simulation

How to make smaller and smaller structures

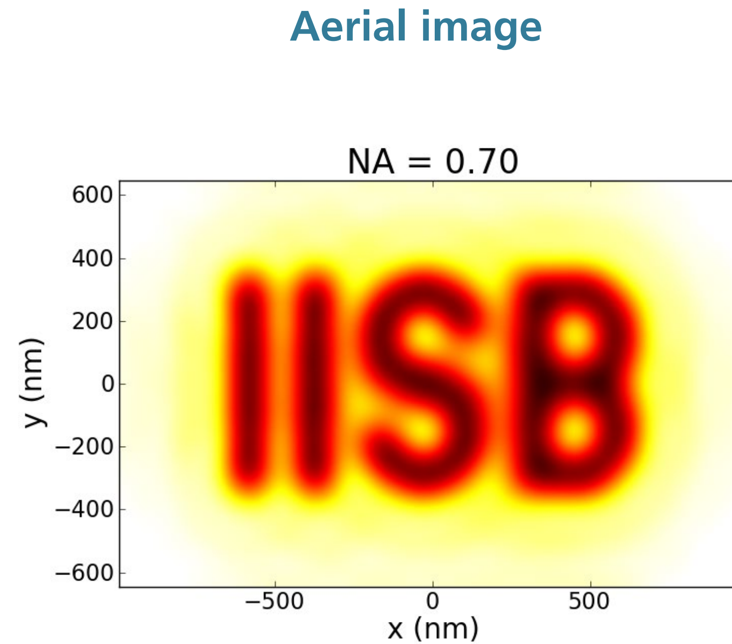
$$x_{min} = CD = k_1 \frac{\lambda}{NA}$$

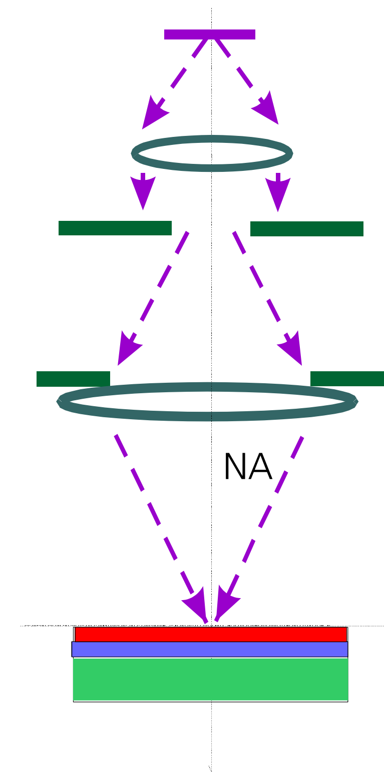
Mask Layout





Aerial image





Imaging with a stepper/scanner @ 193 nm

Simulation model

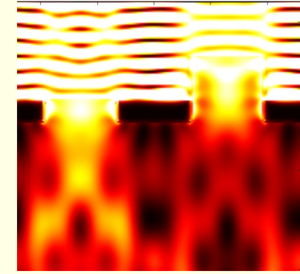
Lithography Simulation
Fraunhofer IISB

Computational lithography and optics group

What are we doing

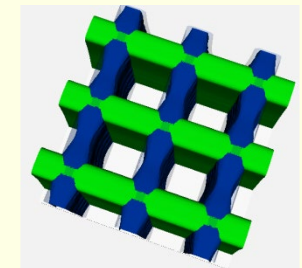
- Simulation and optimization of lithographic processes for optical and EUV lithography, Mask-Aligner and alternative exposures
- Rigorous simulation of light diffraction and imaging of nanostructures (highly accurate physical models, Maxwell equations, Fourier optics)
- Optimization of optical components and processes (genetic optimizer and others)
- Application of AI algorithms in lithography and optics
- Modeling of physical and chemical phenomena in photoresists
- Main research tool: Dr.LiTHO

Light diffraction from phase masks



Imaging using high numerical apertures

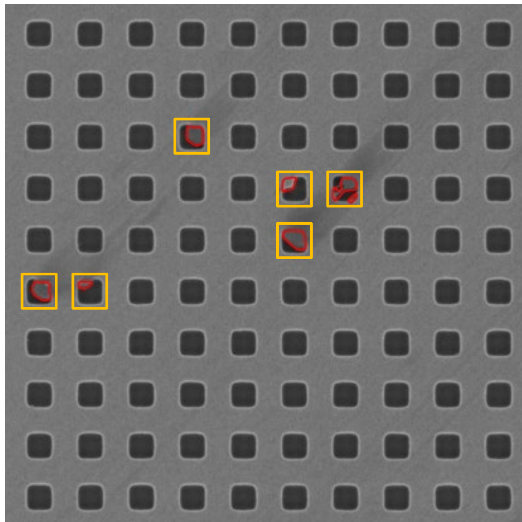
Processing of advanced photoresists

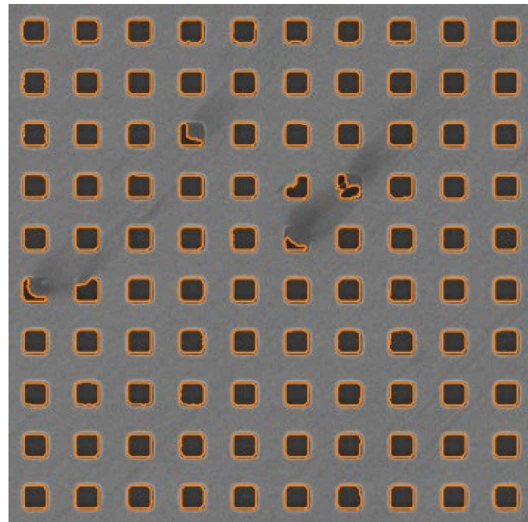


Mask defect and repair assessment for next generation EUV lithography

Physical lithography simulations + AI methods to deal with big and strongly varying data

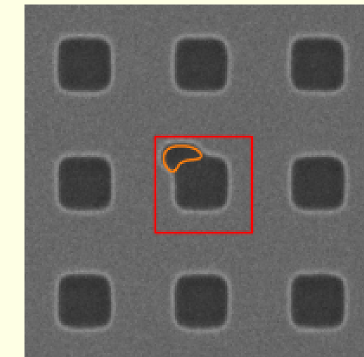
SEM images from Zeiss in the framework of the PIn3S project



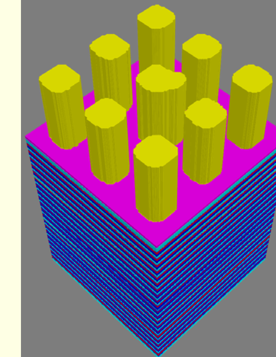


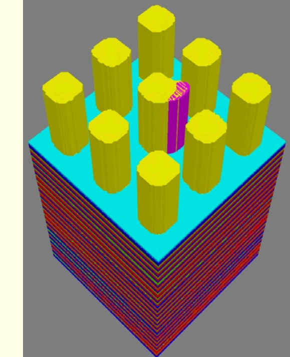
- Defect detection from SEM images with CNN
- Defect shape determination (CNN + analytical method)

- Accurate contour extraction from SEM images (CNN + analytical method)

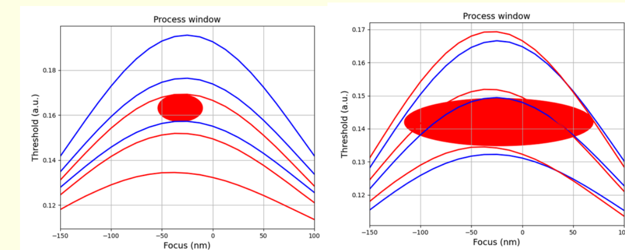


Defect shape and contours





3D mask with/without repair



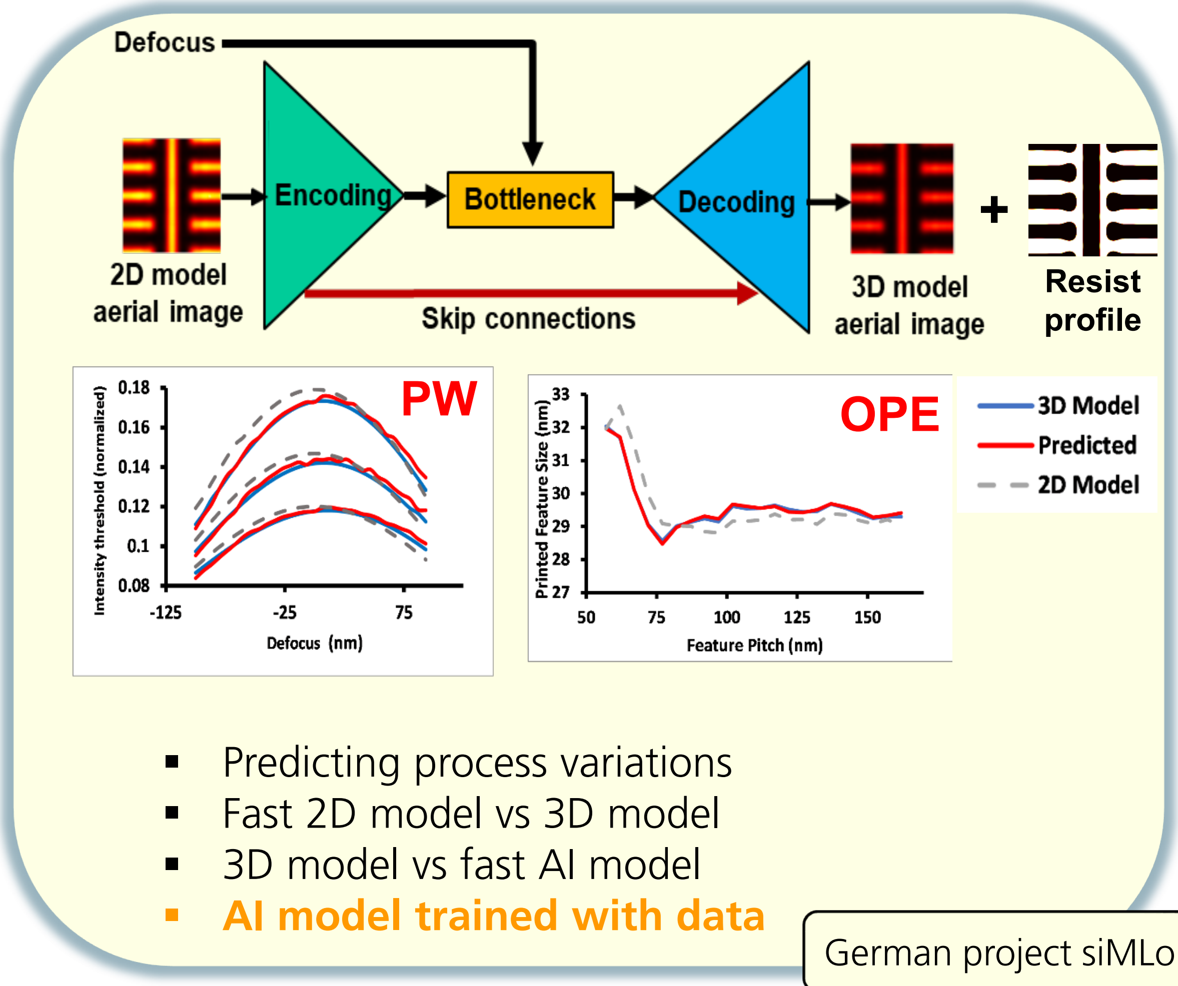
Lithographic assessment of the mask

- Transformation of SEM contours into 3D lithography mask
- Application of repair
- Lithographic assessment of defect and repair with highly accurate Dr.LiTHO simulations

European project PIn3S

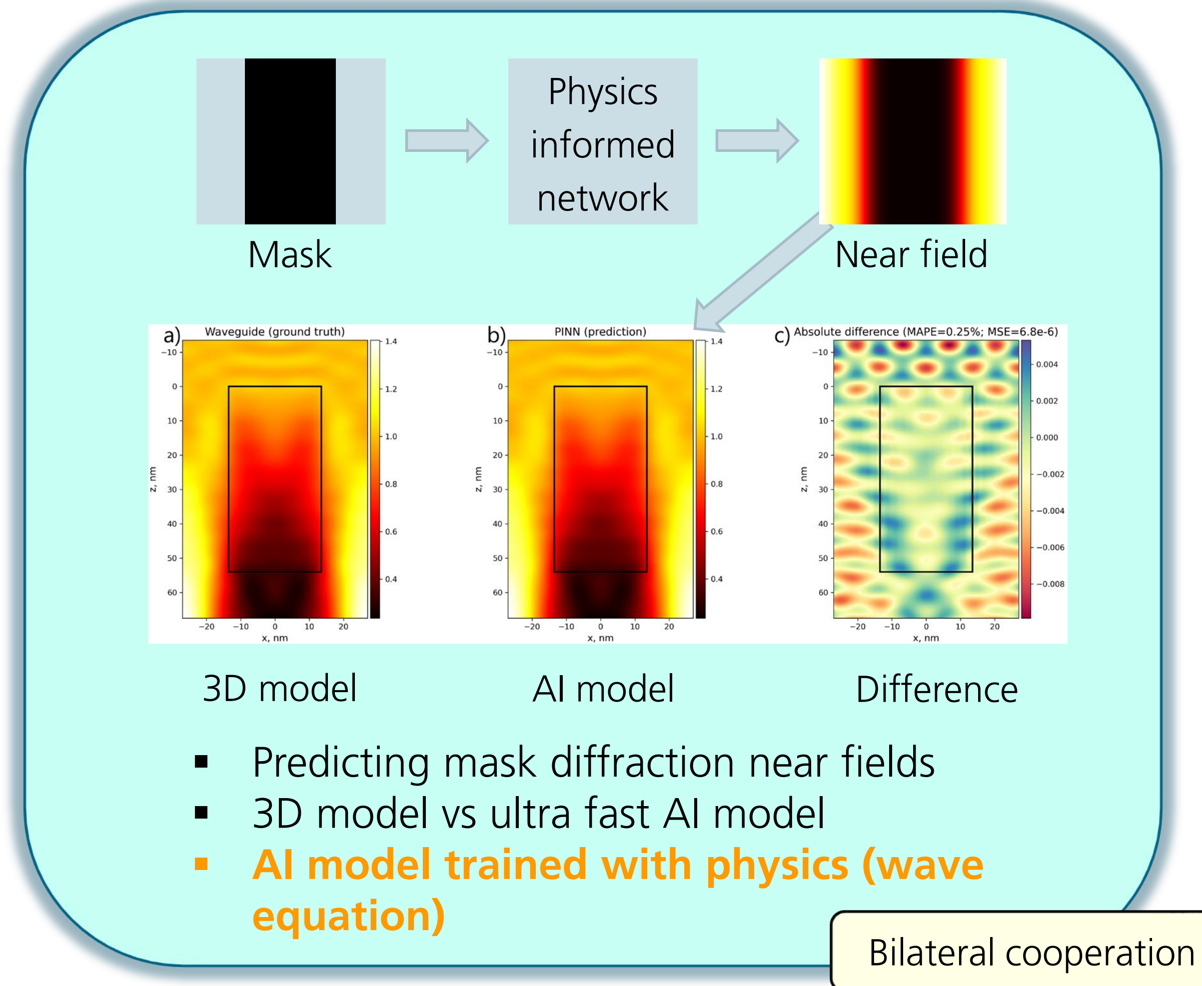
Mask simulation with data driven and physics informed AI methods

To tackle the more and more severe simulation time issue of physical mask simulations



- Predicting process variations
- Fast 2D model vs 3D model
- 3D model vs fast AI model
- **AI model trained with data**

German project siMLopt



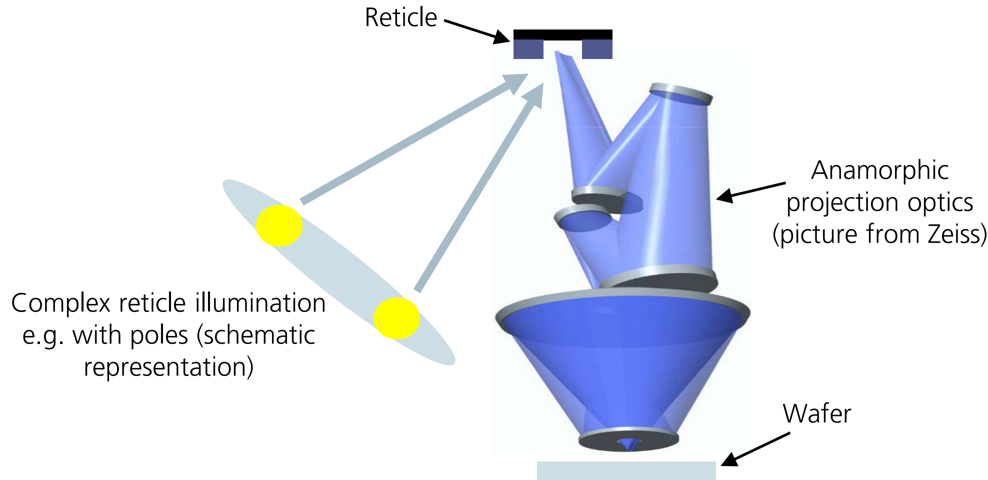
- Predicting mask diffraction near fields
- 3D model vs ultra fast AI model
- **AI model trained with physics (wave equation)**

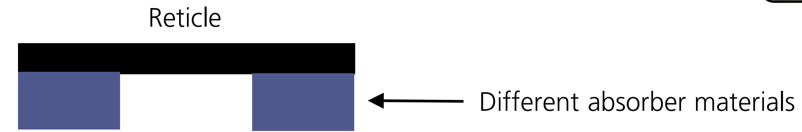
Bilateral cooperation

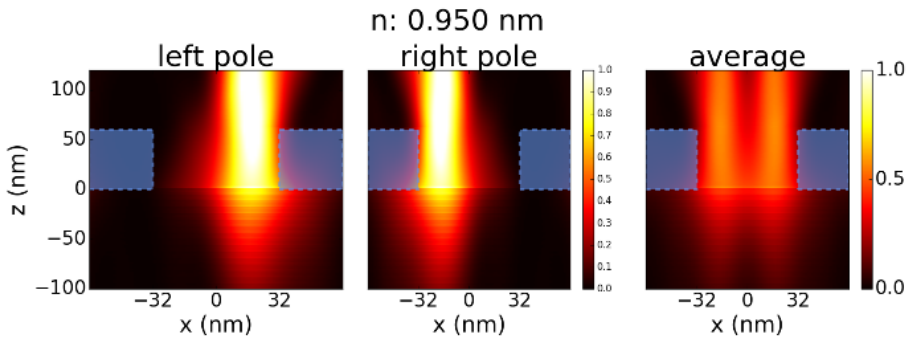
Optimization of EUV system components

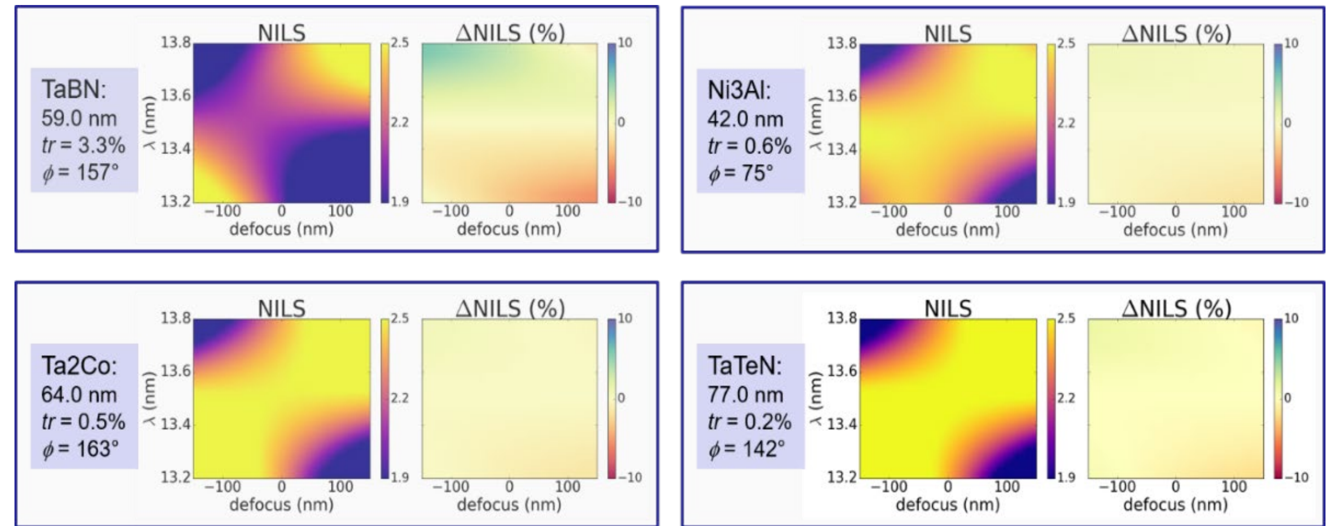
Highly accurate lithography simulations and optimizations for next generation systems

European TAPES3 project









Modeling imaging performance of the anamorphic scanner optics, support of Zeiss SMT in optical systems design

Modeling, characterization and optimization of novel absorber materials for EUV masks, cooperation with imec and Zeiss SMS

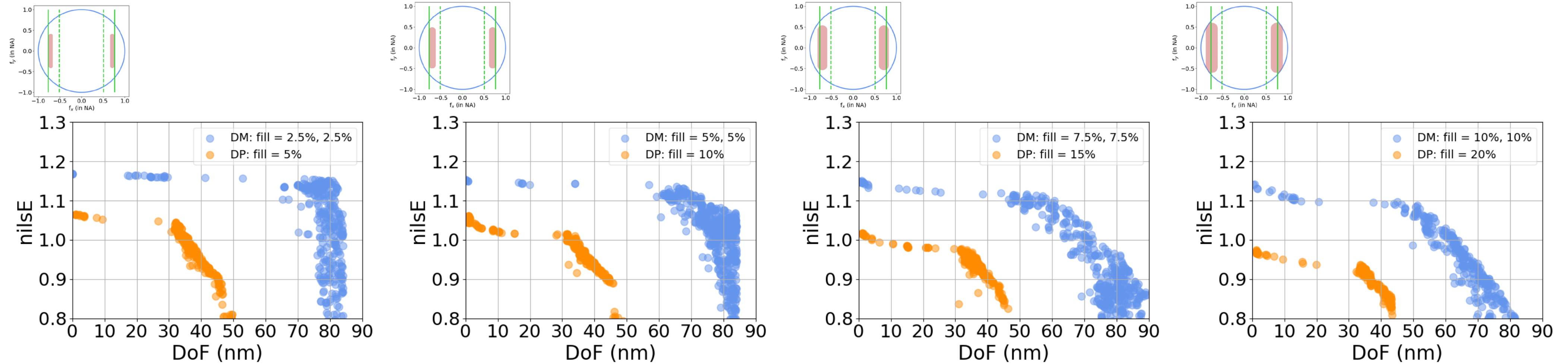
Public

Lithography Simulation
Fraunhofer IISB

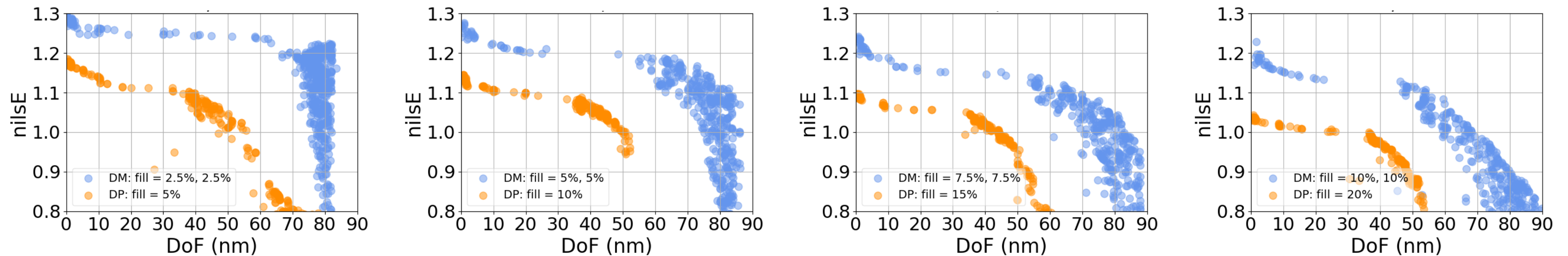
Multi-objective optimization for next generation high NA EUV lithography

Combination of highly accurate litho simulations with multi-objective genetic optimizer

TaBN



Low-n, low-k

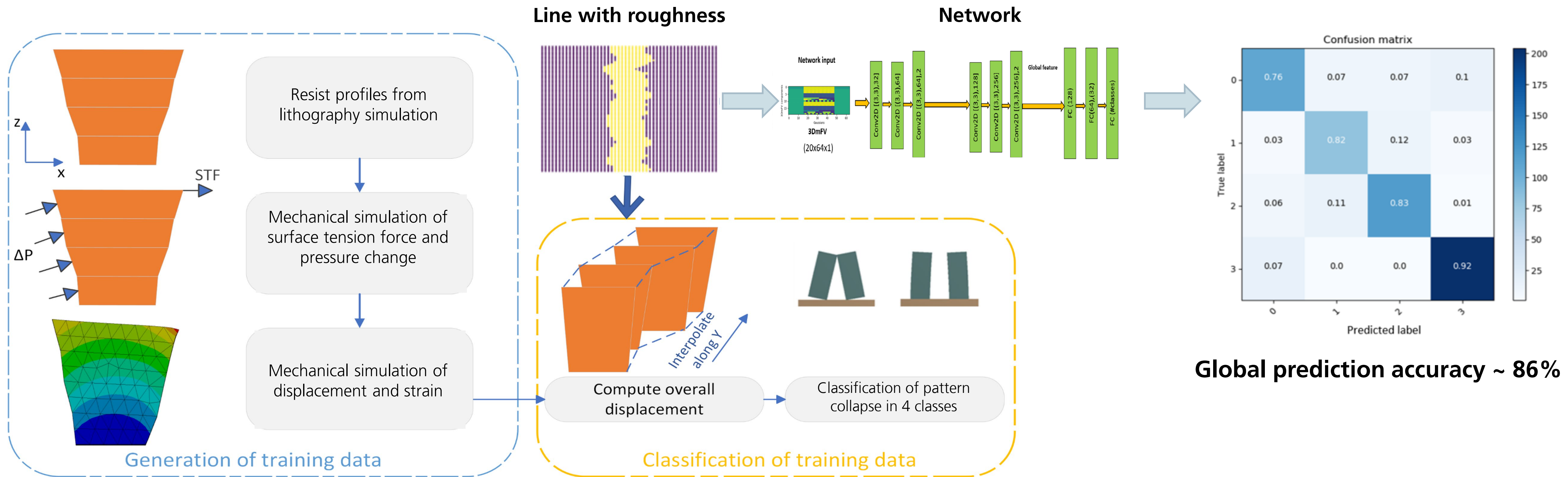


Cooperation with ASML

Multiple system parameter solutions (mask absorber, illumination and more) to optimize imaging performance with multiple quality measures (nilsE, DoF and more)

AI based prediction of pattern collapse in resist processes

Combining litho simulations, mechanical simulations and AI methods for more holistic investigations



Global prediction accuracy ~ 86%

Combination of lithography simulation (optical simulation + resist simulation) and mechanical simulation (tension, pressure, displacement) for the generation of AI training data

Bilateral cooperation

Modeling of direct laser writing for nanoscale 3D topography

Extended (litho) simulation models for applications beyond classical lithography

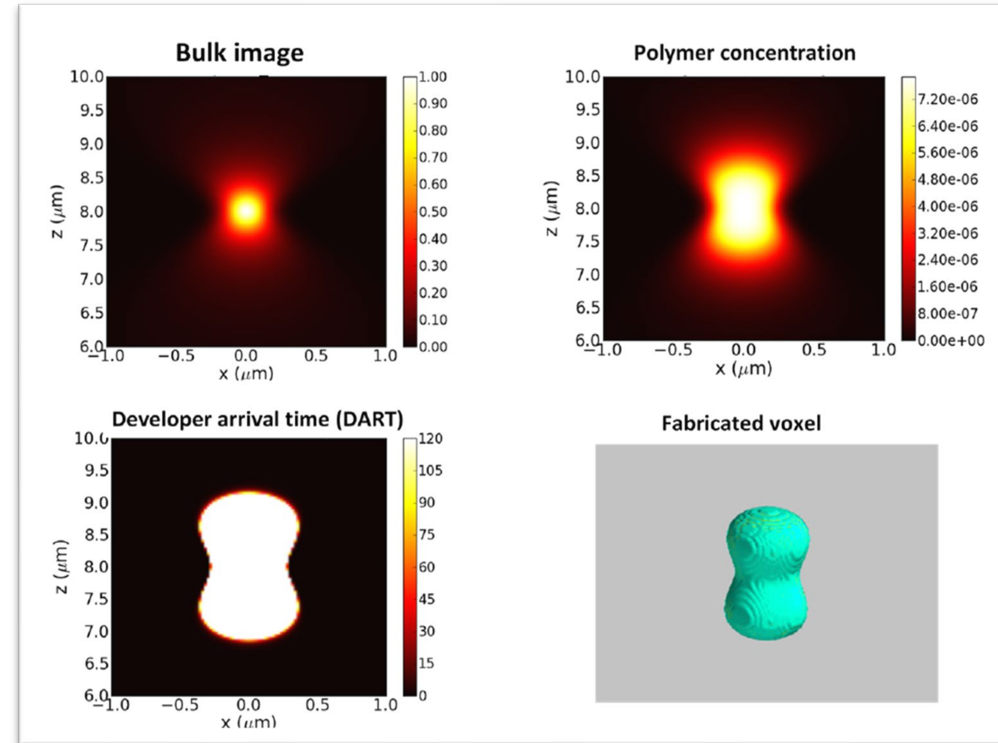
Adapted resist model for ultrasensitive photo resists

Wide area optical system for massively parallelized MPL

Model for micro-scope objectives

Direct laser writing process to fabricate nanoscale 3D structures

Fabricated meta surface

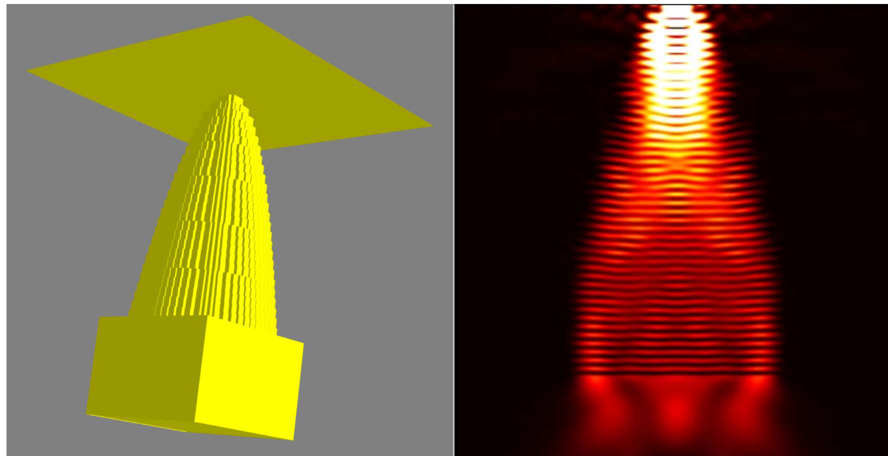


Simulation flow to investigate and optimize the writing process and the generated 3D structures

European project FABulous

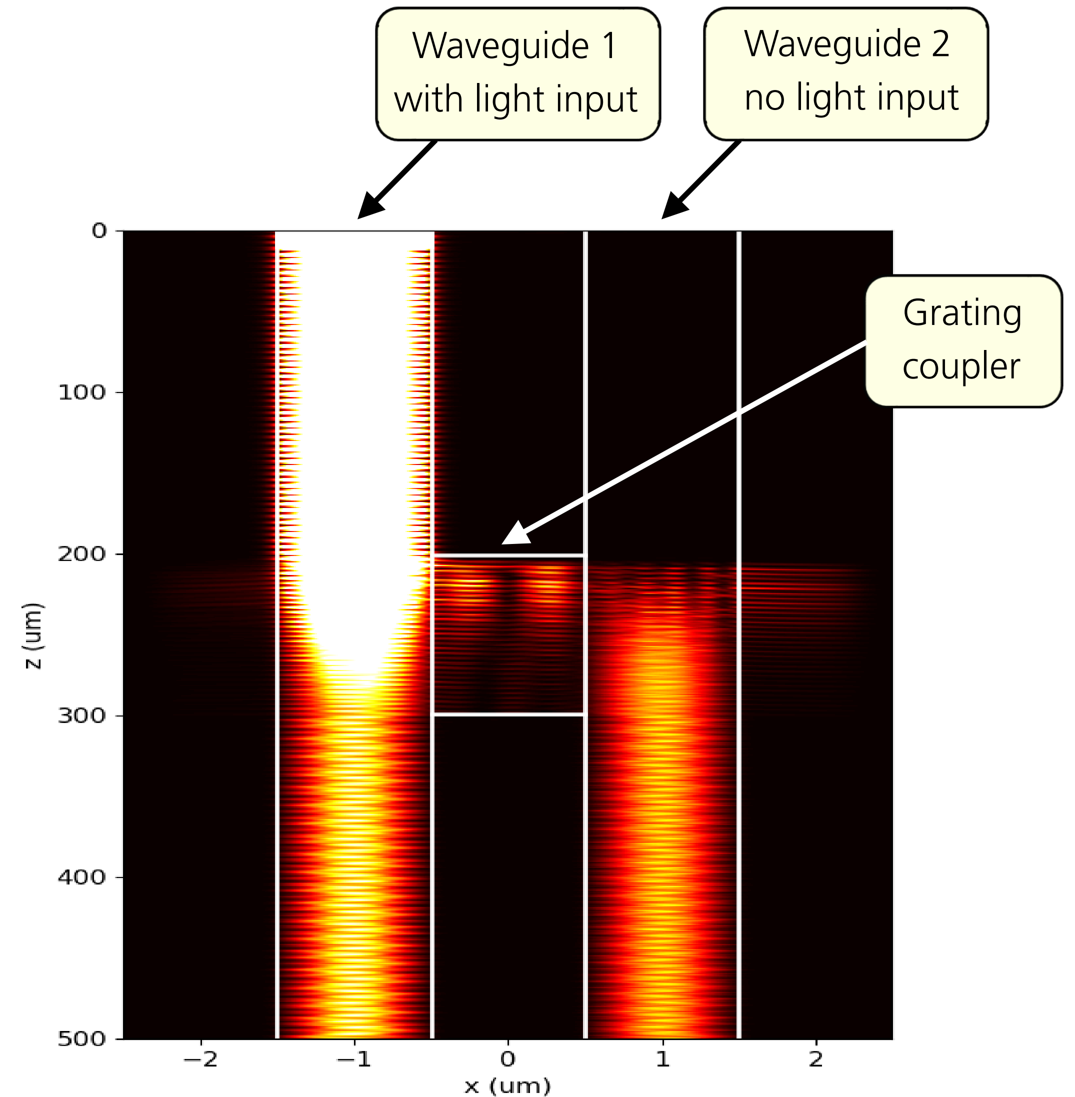
First steps towards future application fields

Adaptation of optical (litho) models to photonic devices



Micro lens geometry | Light propagation inside the lens

Simulation of micro lenses in the small micrometer range for advanced light collection



Simulation and optimization of light propagation in a double waveguide with grating coupler

Conclusions

- Today, the models of the Fraunhofer IISB litho group are used for the simulation, investigation and optimization of next generation EUV lithography components and processes and for applications beyond the classical lithography like direct laser writing
- First adaptations of the models towards the simulation and optimization of photonic devices are available and could be a promising future application field
- Highly accurate physical simulations are still essential for the detailed investigation and optimization of current and future lithography systems
- The combination of physical simulations with AI methods is essential to deal with the growing amount of data and with more and more severe simulation time issues and to allow more comprehensive simulation approaches in the future

Fraunhofer
IISB

Fraunhofer Institute for Integrated Systems and Device Technology IISB

Contact

Peter Evanschitzky
Modeling and Artificial Intelligence / Computational Lithography and Optics
Tel. +49 9131 761 259
peter.evanschitzky@iisb.fraunhofer.de

Dr.LiTHO
Lithography Simulation