Extreme Ultraviolet Lithography (EUVL):

Development of a Next-Generation Lithography Approach

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Overview

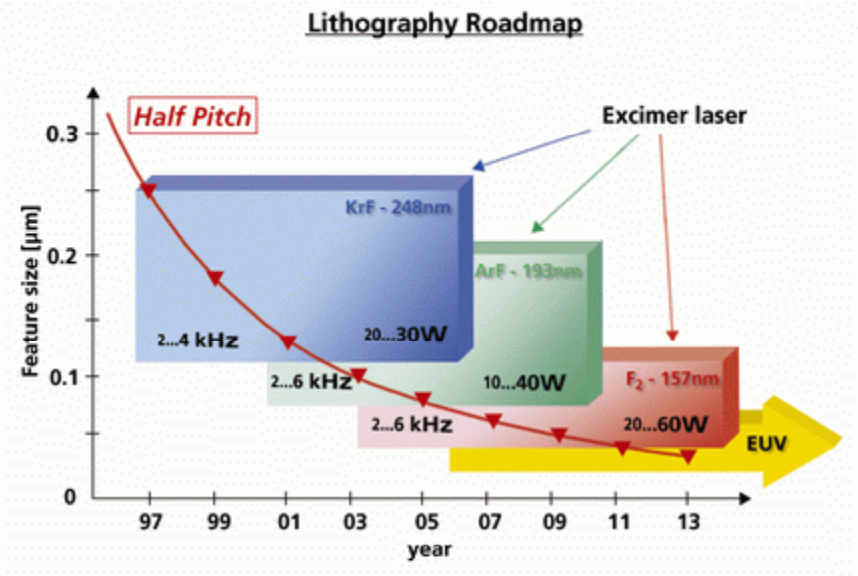
- Introduction/description
- EUVL development challenges:
  - Sources
  - Optics
  - Masks and photoresists
- Commercial utility/viability
- Conclusions

Introduction and Description

- Projection imaging
- Extension of optical lithography

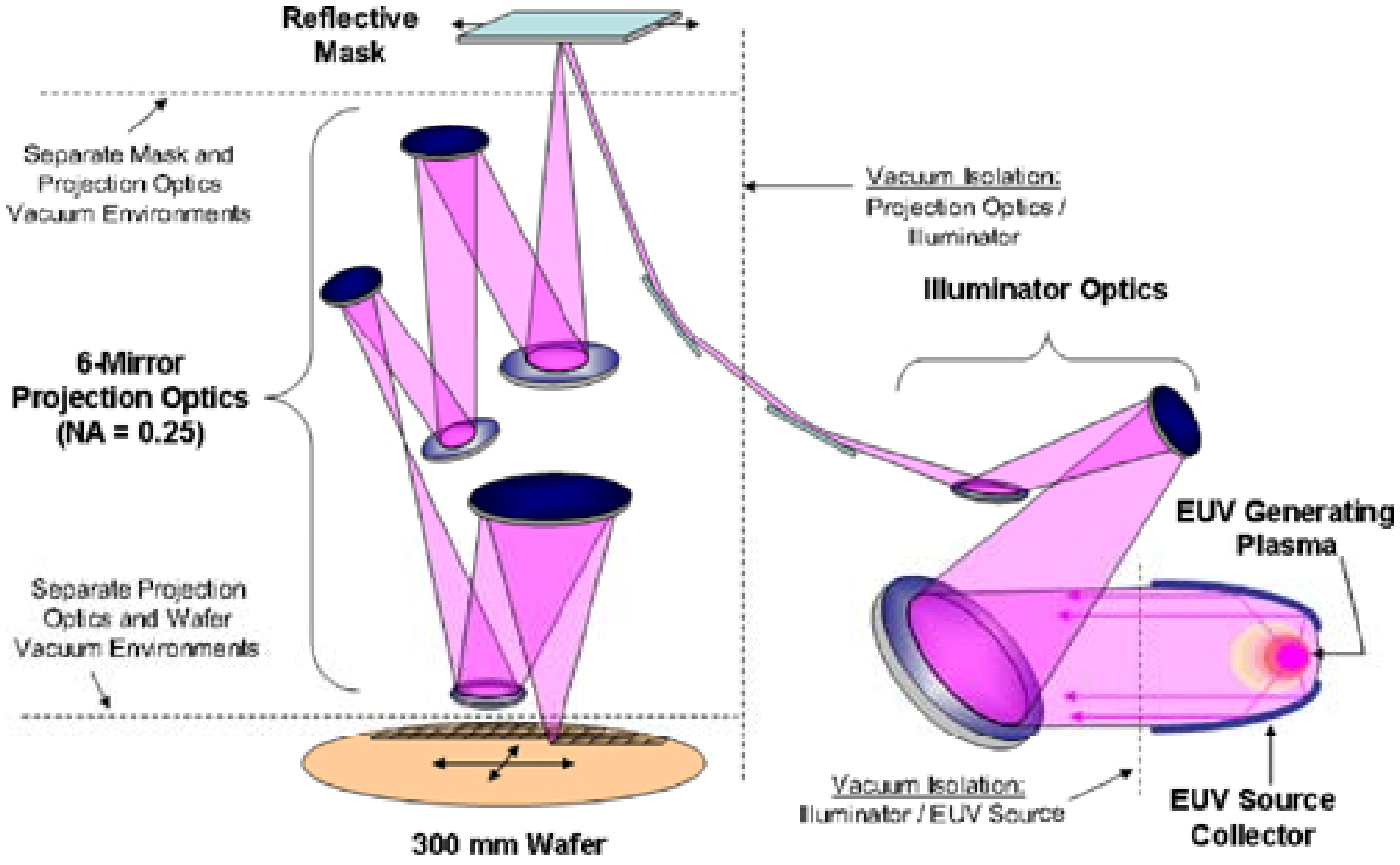
$$R = \frac{k\lambda}{NA} \Rightarrow \lambda \downarrow, R \downarrow$$

- Seen as long-term solution for feature reduction



Lithography Roadmap, Coherent Inc.

EUVL System Diagram



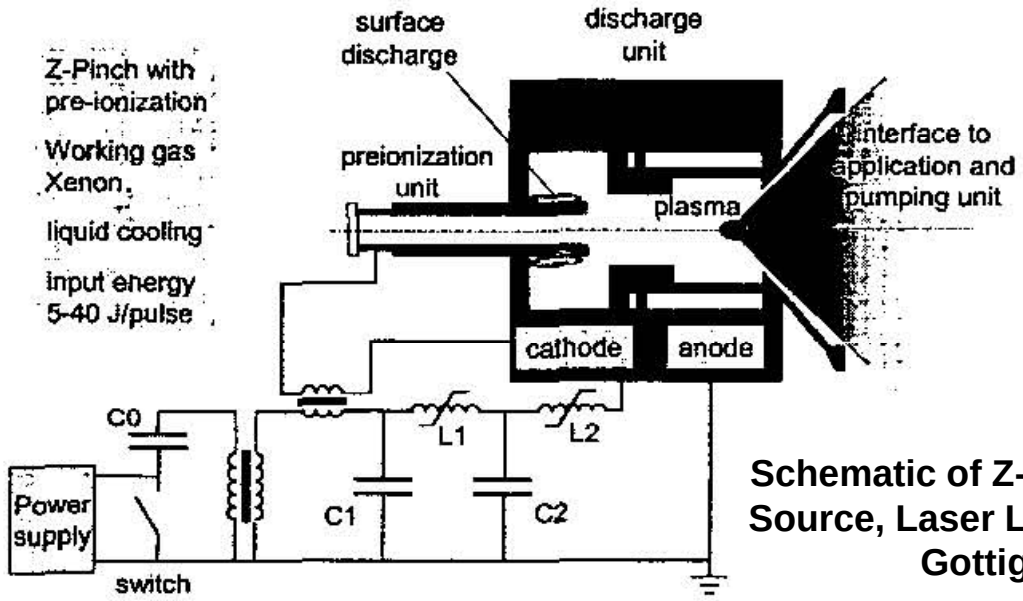
EUVL System Diagram, SEMATECH Lithography Department

EUVL Sources

- Some desired qualities:
  - 12-14 nm wavelength
  - 80-120 wafer/hr throughput
  - Average power output of 50-200 W
  - Low cost
- Plasma EUV Sources
  - Gas discharge-produced plasmas (GDPP)
  - Laser-produced plasmas (LPP)

GDPP Sources

- Emission mechanism:
  - Electrical discharge → plasma
  - Magnetic field compresses plasma radially ("pinching")
- Typical plasma: few 100 μm in diameter, several mm in length



Schematic of Z-Pinch GDPP Source, Laser Laboratorium Gottigen

GDPP Sources (cont'd.)

- Collection Efficiency (CE)
  - Low etendue → lower CE
  - CE ≈ 2-5x worse than LPP
- Self-absorption problematic
- Cooling required
- Power scaling and reliability
- Sensitive to gas flow



GDPP Source Implemented in EUVL Stepper, EXITECH

LPP Sources

- Emission mechanism:
  - Target (Xe/Li/Sn) in vacuum
  - Pulsed laser-beam excitation
- Large stand-off distance
  - Plasma 3-7 cm from nozzle
  - High volume manufacturing (HVM) – reduced heat loads

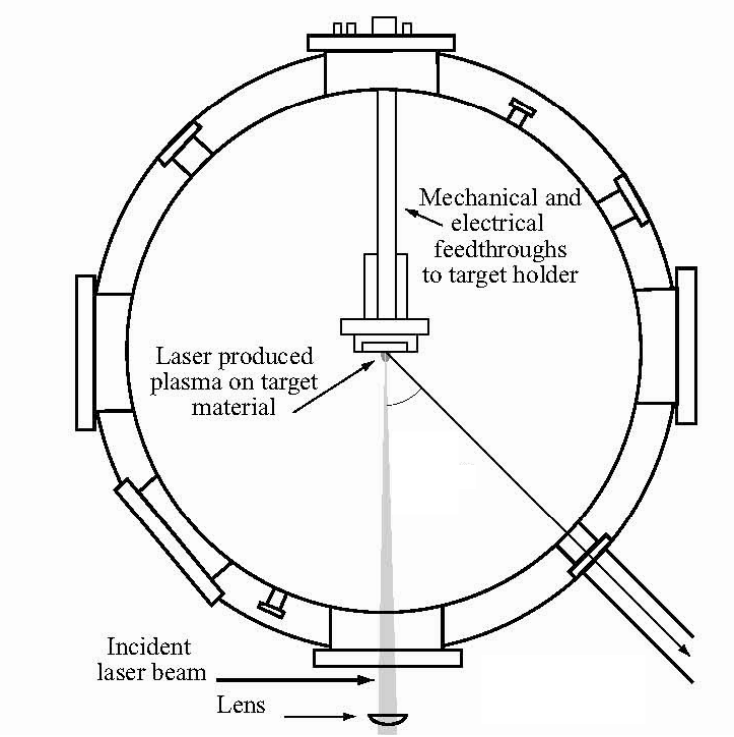
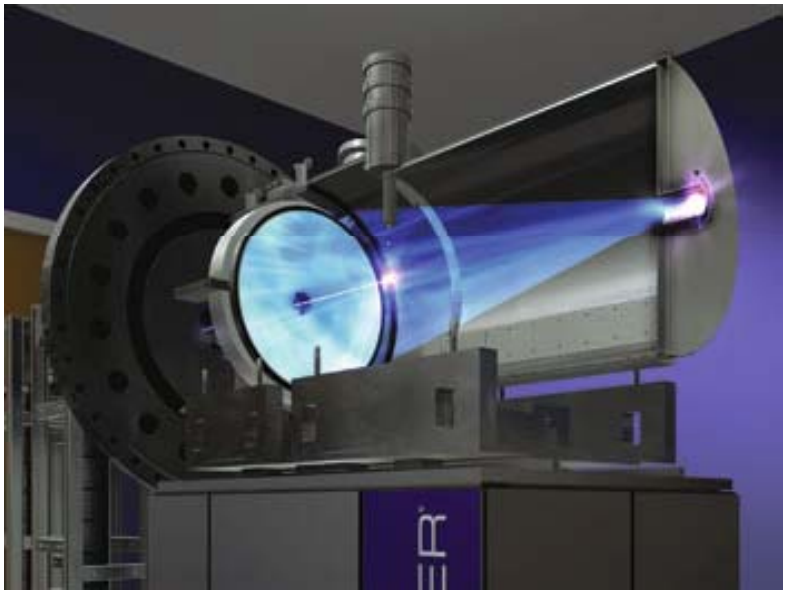


Diagram of LPP Source, University College Dublin

LPP Sources (cont'd.)



3-D Depiction of an LPP Source Using Droplet Targets, Semiconductor International

- CE maximization:
  - Minimize heat dissipation in source
  - Minimize driving power of laser
- Debris mitigation
- Laser
  - .5-10 kW operating at 0.5-10 kHz
  - Expensive

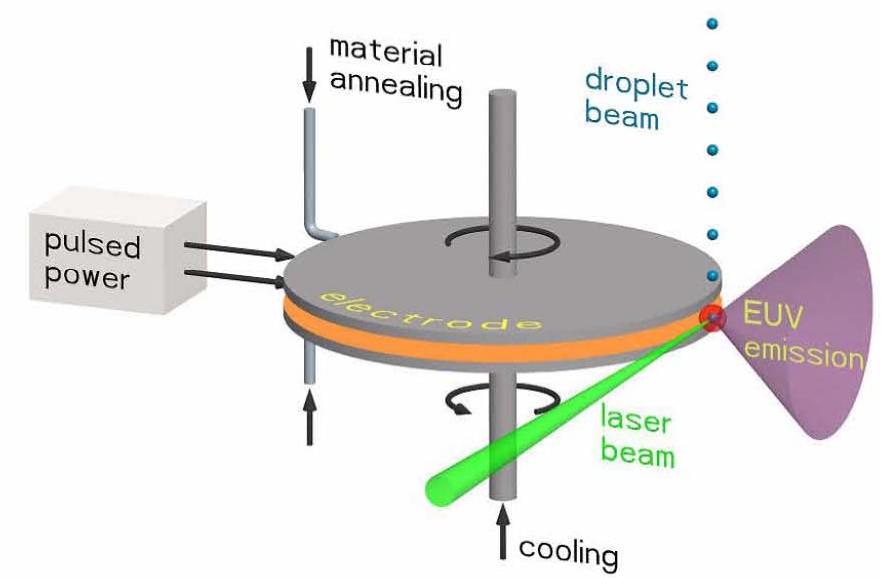
Comparison of GDPP/LPP Sources

Issue	GDPP Sources	LPP Sources
Complexity	✓	✗
Power Output*	✓	✗
Lifetime	✗	✓
Cooling Requirements	✗	✓
Collection Efficiency	✗	✓

* Based on current implementations, not indicative of theoretical limits

Potential Source Improvements

- GDPP Sources
  - Better cooling
  - Higher power
- LPP Sources
  - Higher laser power
  - Different target
- Rotating Disk Electrodes (RDE)



Conceptual Drawing of R.D.E., XTREME Technologies

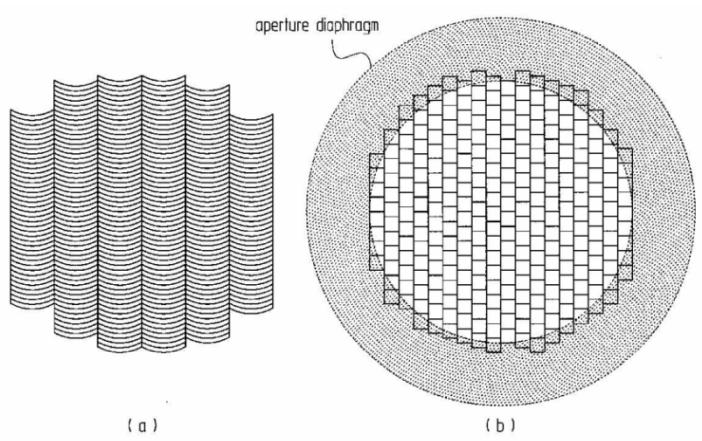
Optics

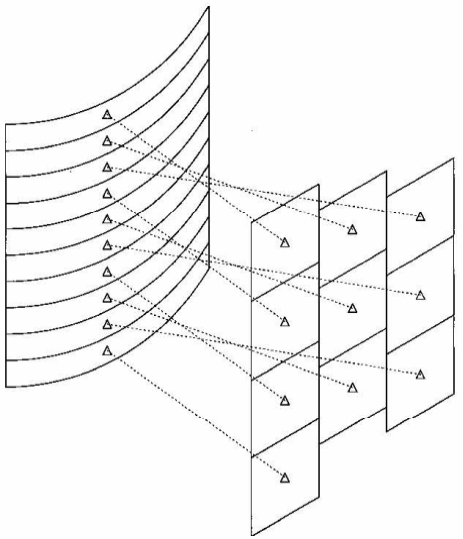
Illuminator optics collect, collimate source light:

1. Fly's-eye mirrors
2. Collimator mirrors

Projection optics take image to wafer

- Metrology, Polishing, and Coating





Fly's-Eye Mirrors and Mirror Configuration, Nikon

Photoresists and Masks

- EUV absorption → need for ultra-thin resists
- EUV-specific resist issues:
  - Photospeed (sensitivity)
  - Outgassing
- Masks – *reflective*, not transmissive

Specifications	2007 Goals	Resist A	Resist B*	Resist C	Resist D
Resolution lines – 1:1 (nm)	32	28	26	30	26
Line Width Roughness (nm, 3σ)	< 2.5	6.0 @ 30 nm	3.6 @ 26 nm	7.5 @ 30 nm	8.2 @ 30 nm
Photospeed, EUV (mJ/cm^2)	10	17.25 @ 30 nm	27.6 @ 26 nm	20.9 @ 30 nm	20.0 @ 30 nm
Outgassing (molecules/cm^2)	6.5e14	Pass	Pass	Pass	Pass

Table 1: EUV Photoresist Results Compared to 2007 Goals (SEMATECH)

Commercial Utility and Viability

- Eventually, EUVL will be a necessity
- On the positive side…
  - Intel is already preparing for EUV HVM in 2009
  - Collaboration among EUV developers are leading to better developments for the technology
- But on the other hand…
  - Affordable, bright sources still present a challenge
  - Throughput is still currently well behind industry demands

Conclusions

- EUVL – extension of optical lithography
- Light sources – obstacles to HVM with EUVL
- Absorption of EUV light in materials causes difficulties in implementations
- Collaborative efforts fostering developments to make EUVL realistic

References

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