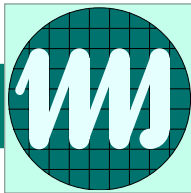


Projection Mask-Less nano-Lithography (PML2) and nano-Patterning (PMLP) for Nanoelectronics

Hans Loeschner and Elmar Platzgummer



IMS Nanofabrication

Contents

2

- IMS Nanofabrication AG**
- Why Mask Less ?
- PML2 principles
- PML2 proof-of-concept
- PMLP principles
- PMLP proof-of-concept
- Summary



IMS Nanofabrication AG is a Vienna based Nanotec company with focus on Projection Mask-Less Lithography (PML2) and Projection Mask-Less Patterning (PMLP)

- 31 coworkers (23 engineers and physicists, 5 technicians)



Gerhard Gross
CEO



Elmar Platzgummer
COO



Karin Schuster
CFO



Hans Loeschner
CTO / Marketing



IMS Nanofabrication is Coordinator of two European Projects:

- **CHARPAN** (Charged Particle Nanotech)
FP6-NMP Integrated Project, started April 2005 / 4 years
www.charpan.com

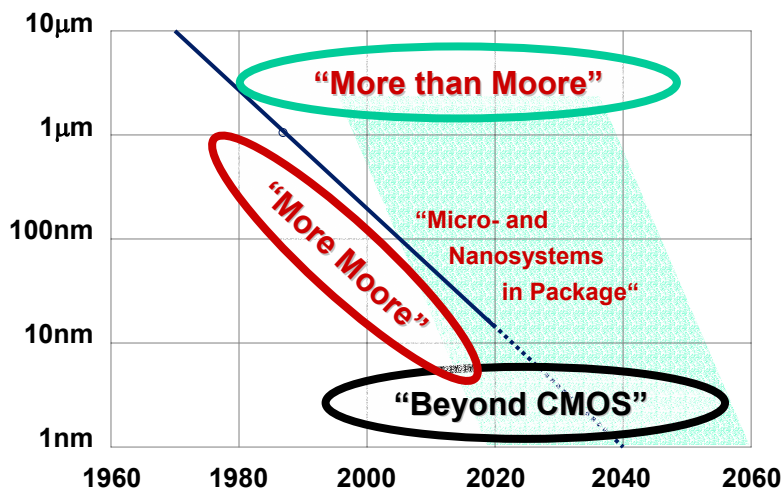
- **RIMANA** (Radical Innovation Maskless Nanolithography)
FP6-IST&NMP STREP, started Oct 2005 / 3 years
www.rimana.org



- IMS Nanofabrication AG
- Why Mask Less ?**
- PML2 principles
- PML2 proof-of-concept
- PMLP principles
- PMLP proof-of-concept
- Summary



Nanoelectronics and Nanotechnology Roadmap

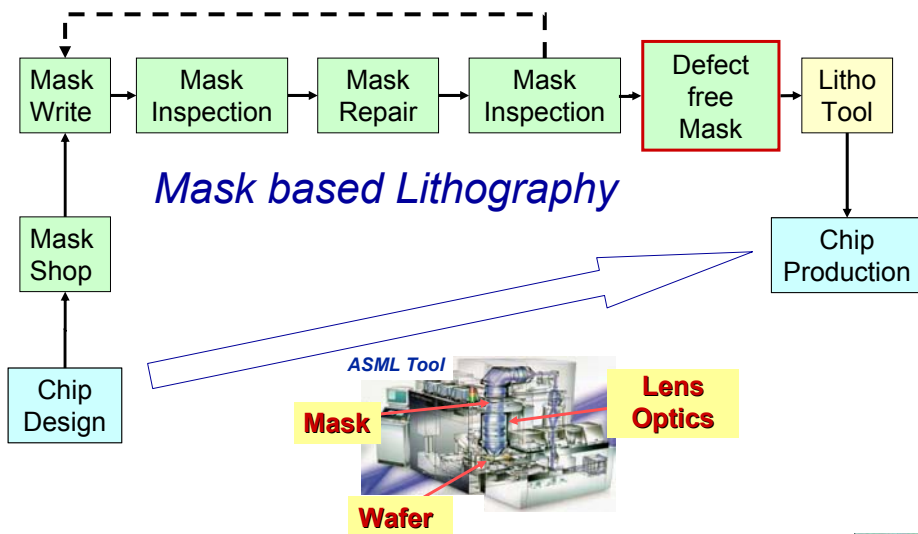


adapted from:
ETP Nanoelectronics, Fred van Roosmalen, Vienna, May 5, 2006



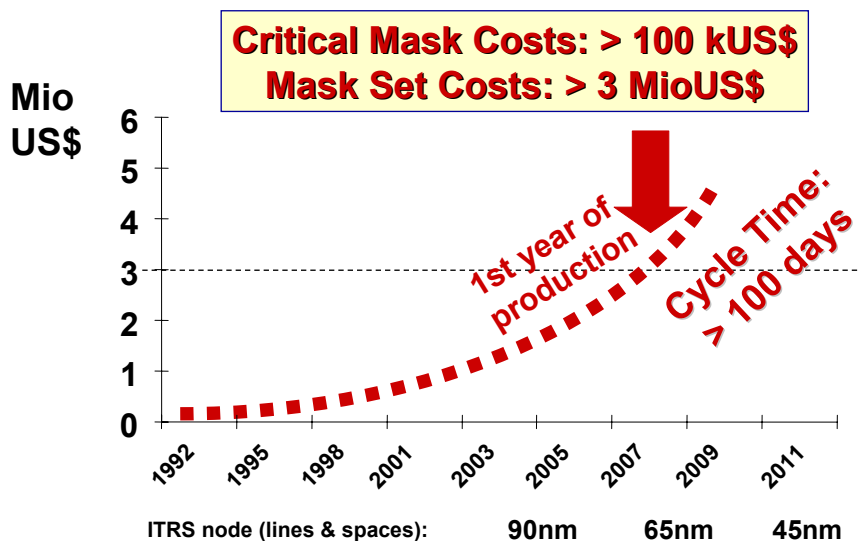
Semiconductor Chip Design ⇔ Production

7



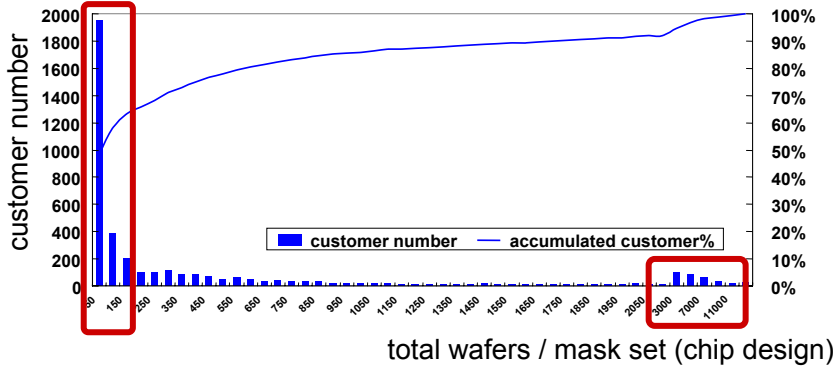
Mask Set Costs and Cycle Times

8



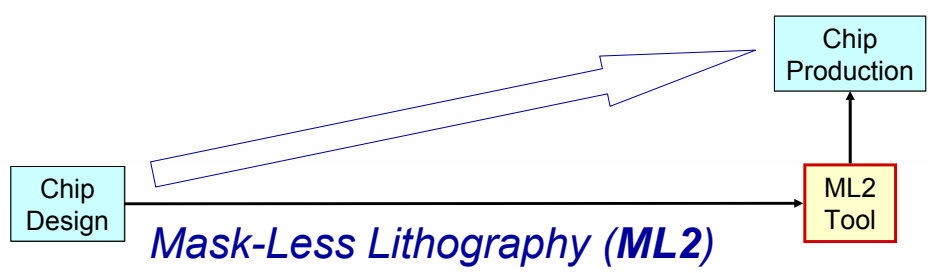


Why is cost awareness so critical?

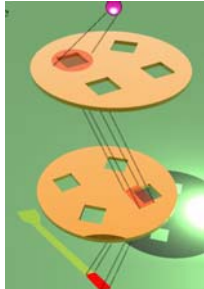


for 65% of the customers: < 200 wafers / chip design

Mask-Less Lithography (ML2)



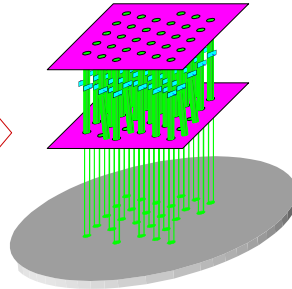
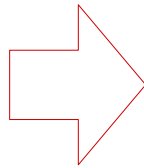
many Hours per Wafer
per 300mm wafer



Source:
Daniel Henry
ST, plenary
MNE 2005

**Electron Beam
Direct Write (EBDW)**

Wafers per Hour
per 300 mm wafer



Mask-Less Lithography (ML2)

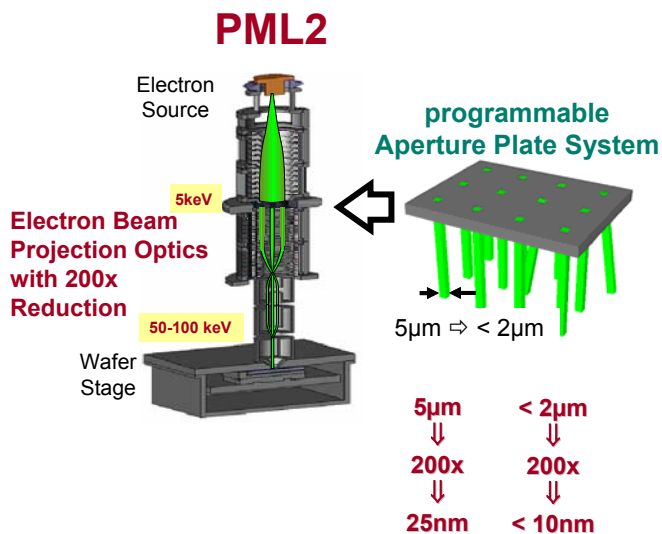
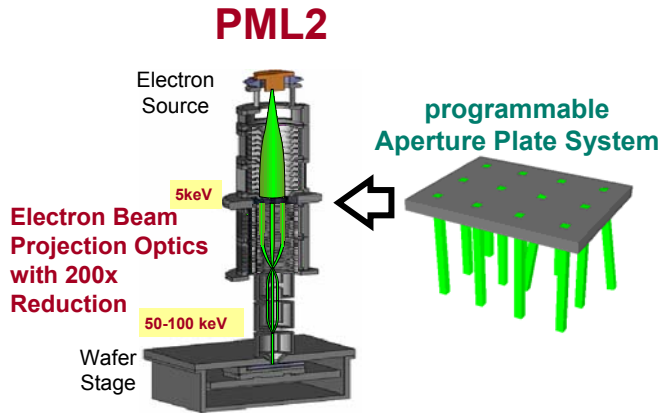
**for rapid chip development & prototyping
low & medium volume production**



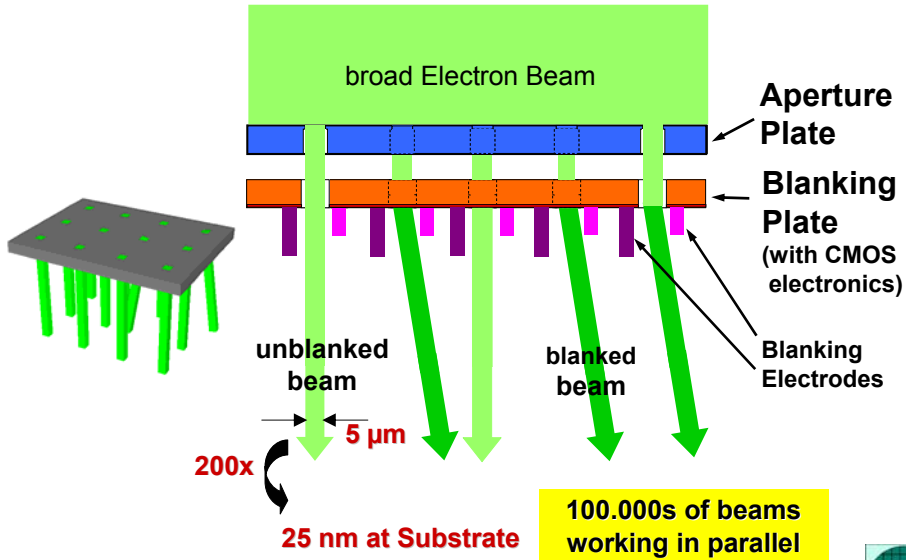
Contents

- IMS Nanofabrication AG
- Why Mask Less ?
- PML2 principles**
- PML2 proof-of-concept
- PMLP principles
- PMLP proof-of-concept
- Summary

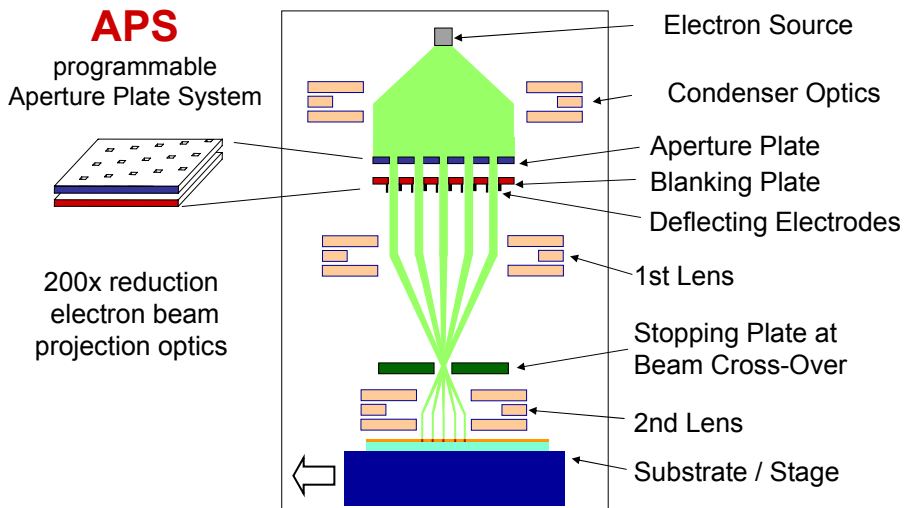


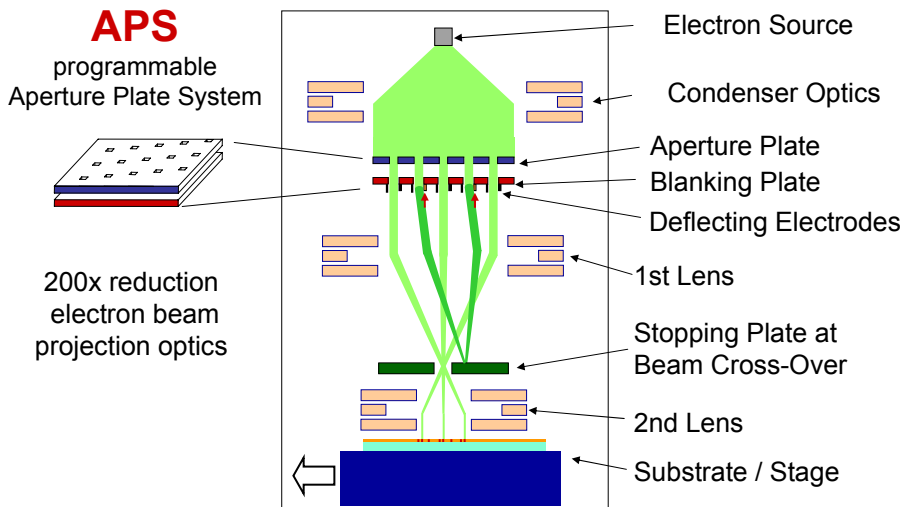
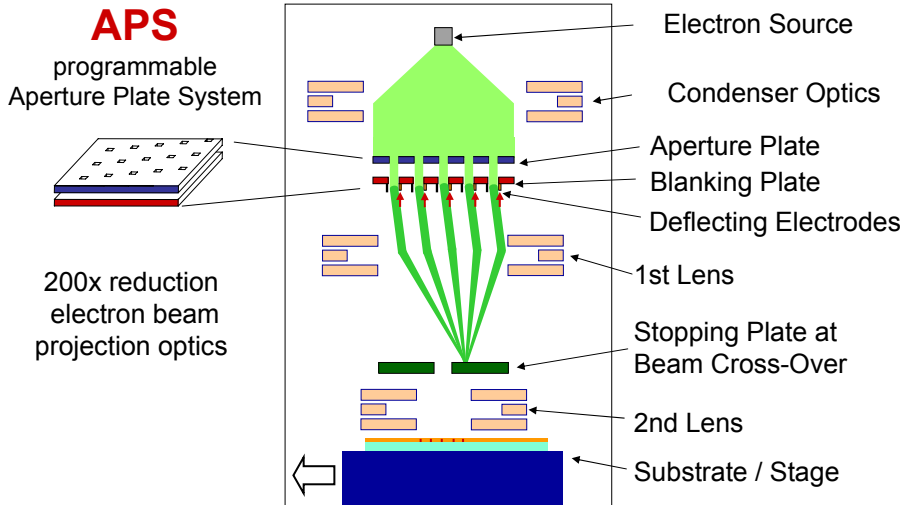


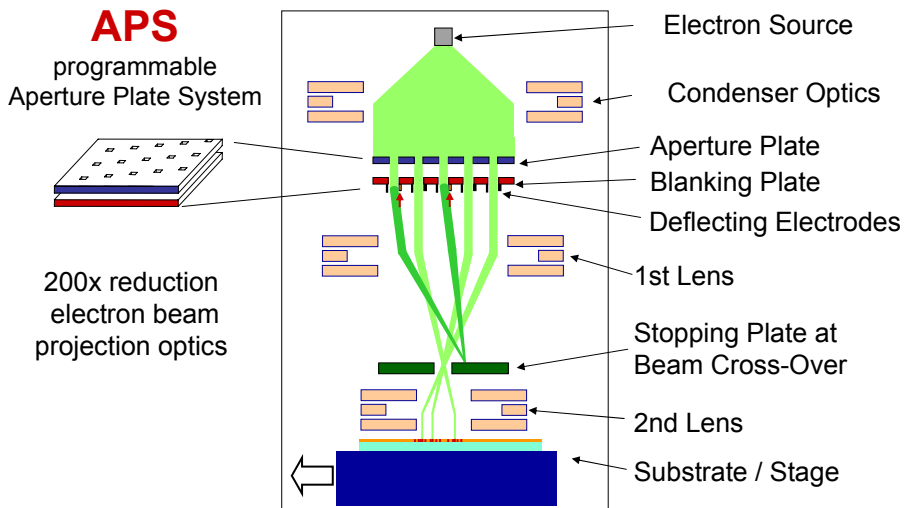
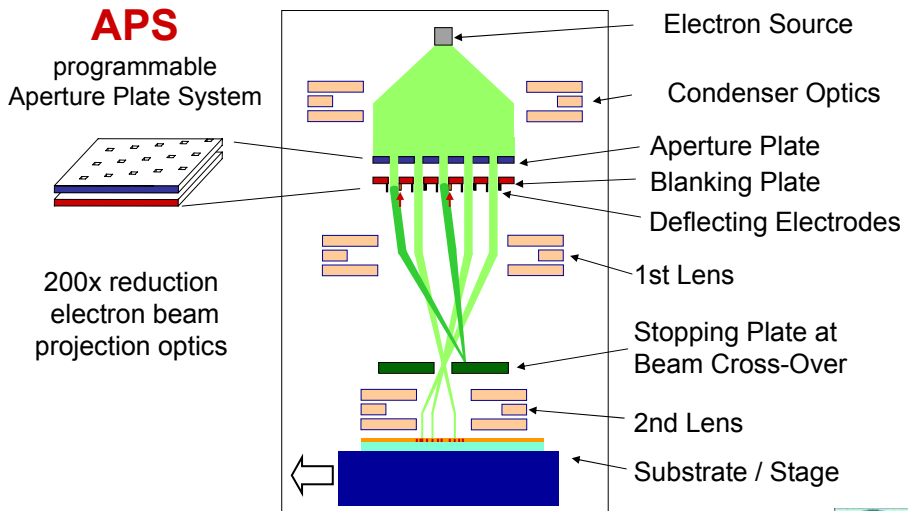
Programmable Aperture Plate System (APS)

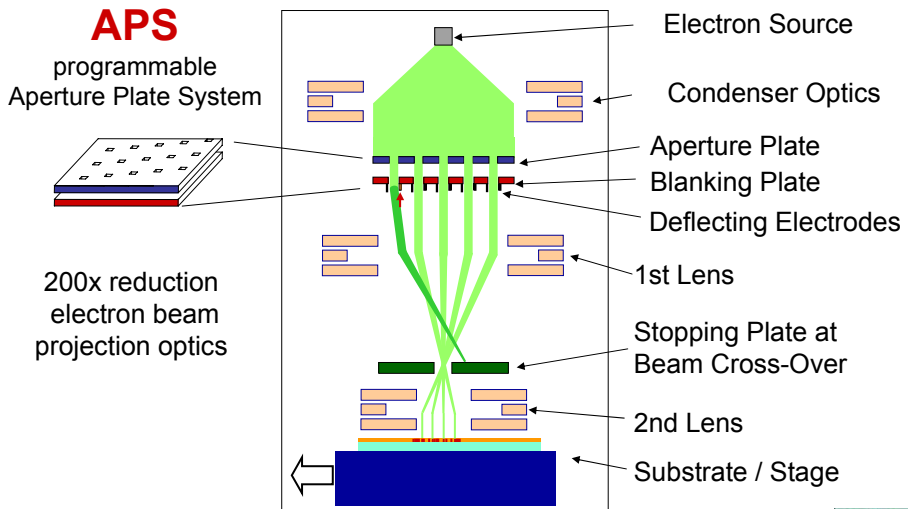


PML2 (Projection Mask-Less Lithography) Principles

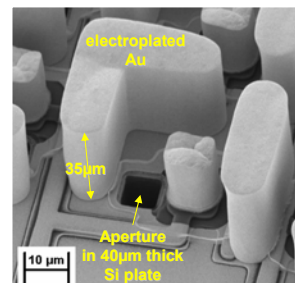
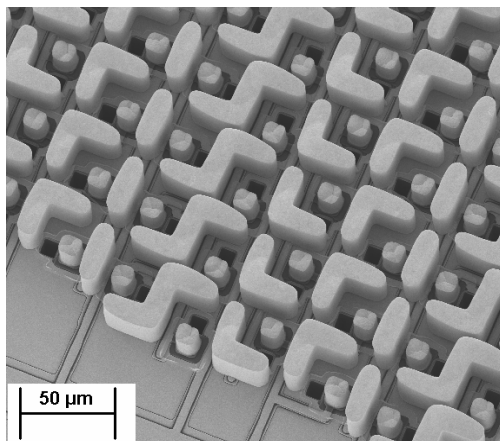








programmable Aperture Plate System: Viability proven



Result of MEDEA+ Project T409
supported by

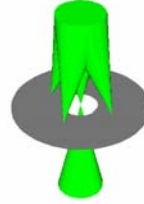
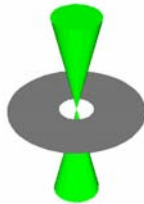
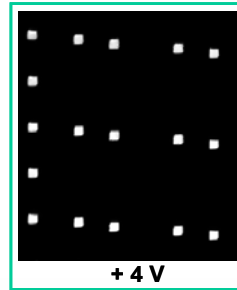
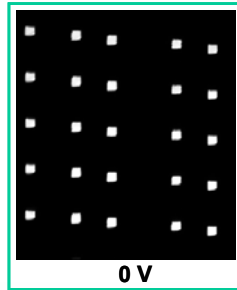


Austria



BMBF
Germany





PML2 Proof-of-Concept

RIMANA

(Radical Innovation Maskless Nanolithography)
FP6-IST&NMP specific targeted research project:
started October 2005 / 3 years

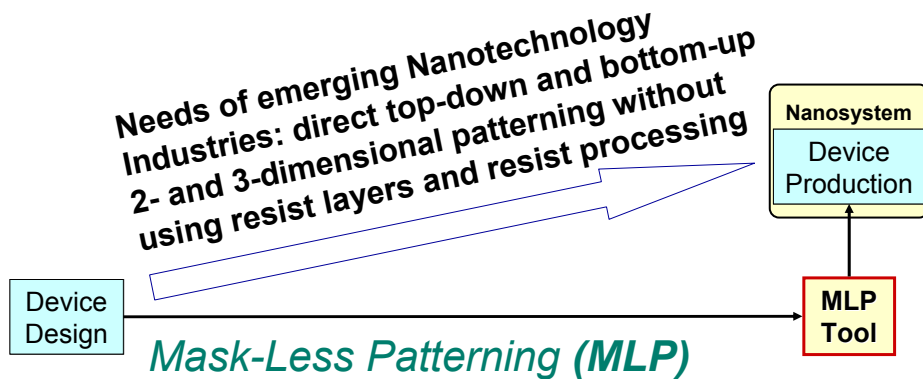
www.rimana.org



- ❑ IMS Nanofabrication AG
- ❑ Why Mask Less ?
- ❑ PML2 principles
- ❑ PML2 proof-of-concept
- ❑ **PMLP principles**
- ❑ PMLP proof-of-concept
- ❑ Summary



Mask-Less Patterning (MLP) for Nanomanufacturing



"Dip-Pen" Manipulation of Molecules

27



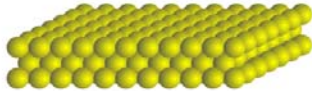
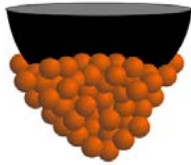
The Nobel Prize in Physics 1986



Gerd Binnig

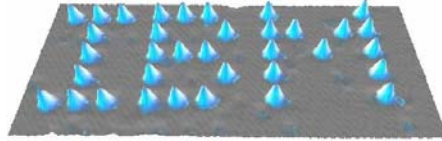


Heinrich Rohrer



Source: Basic Nanotechnology, 2003 by Glenn Fishbine

IBM - 1985



Outstanding research results, but:
Industrial Production needs acceptable Working Distance



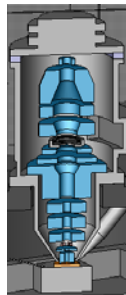
IMS Innovation: Projection Mask-Less Patterning

28

PMLP

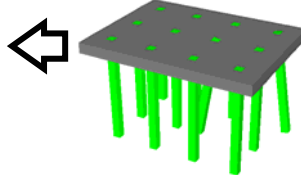
Ion Source
Condenser

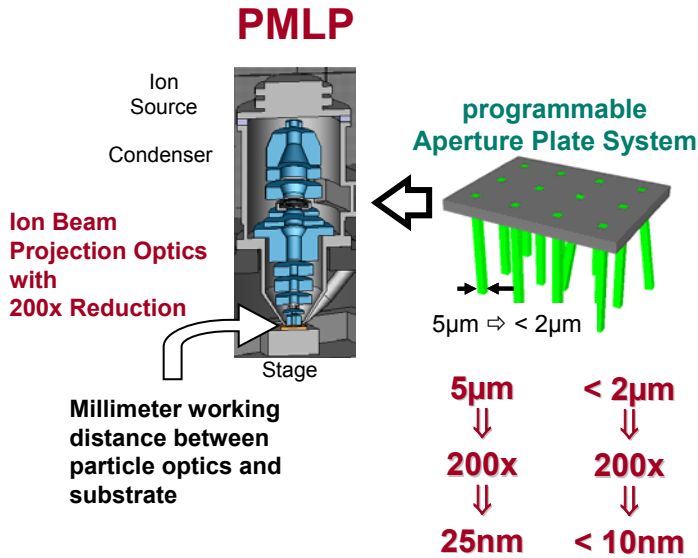
**Ion Beam
Projection Optics
with
200x Reduction**



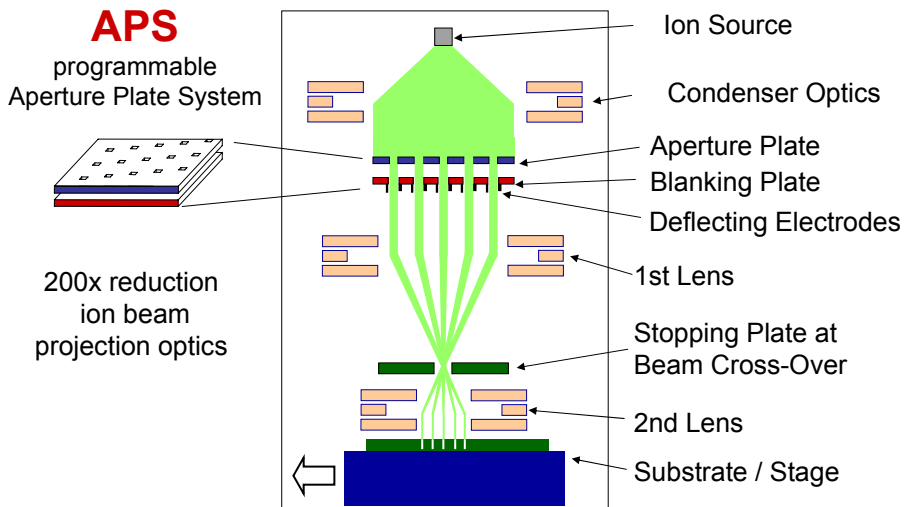
Stage

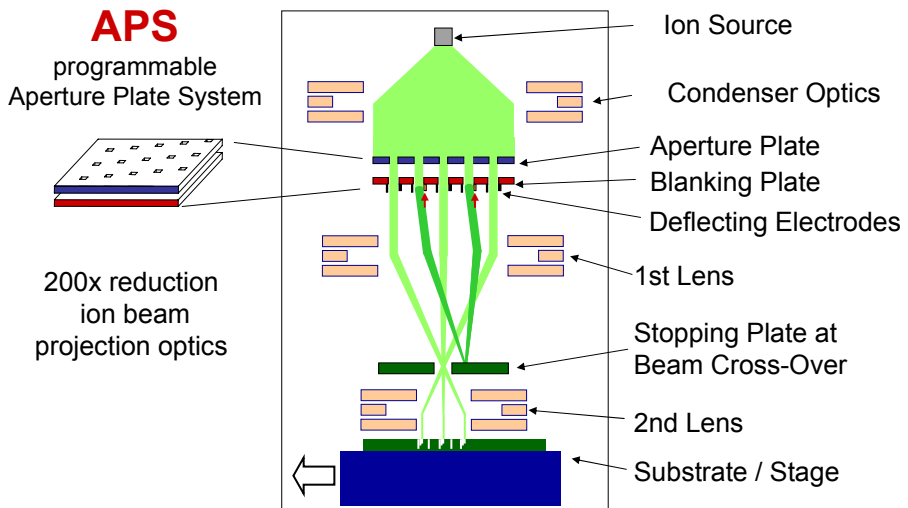
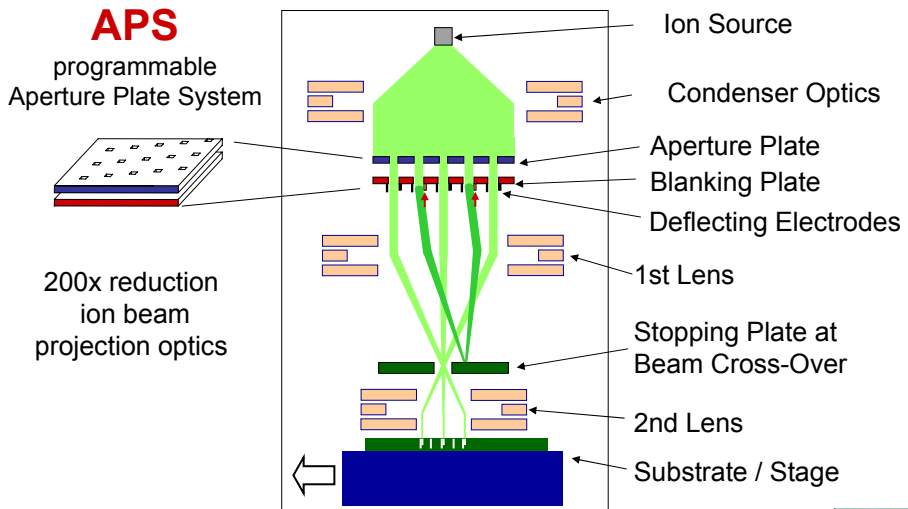
programmable
Aperture Plate System

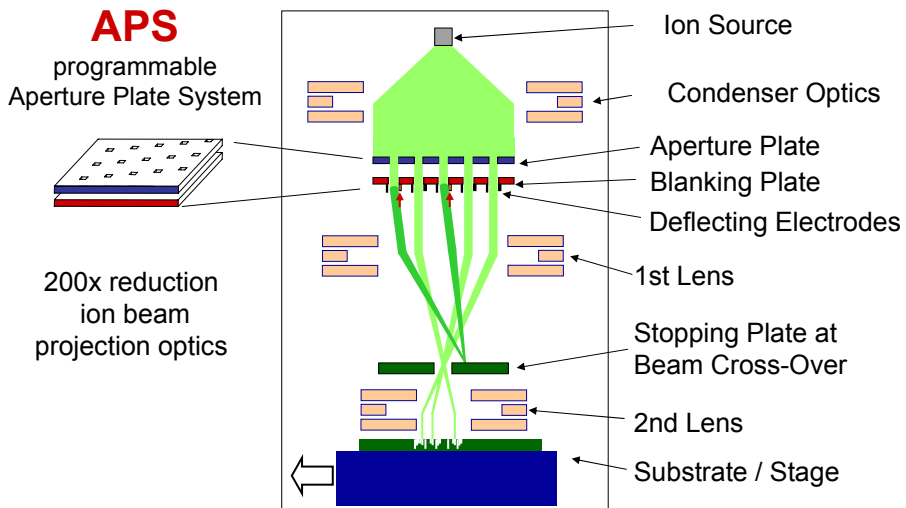
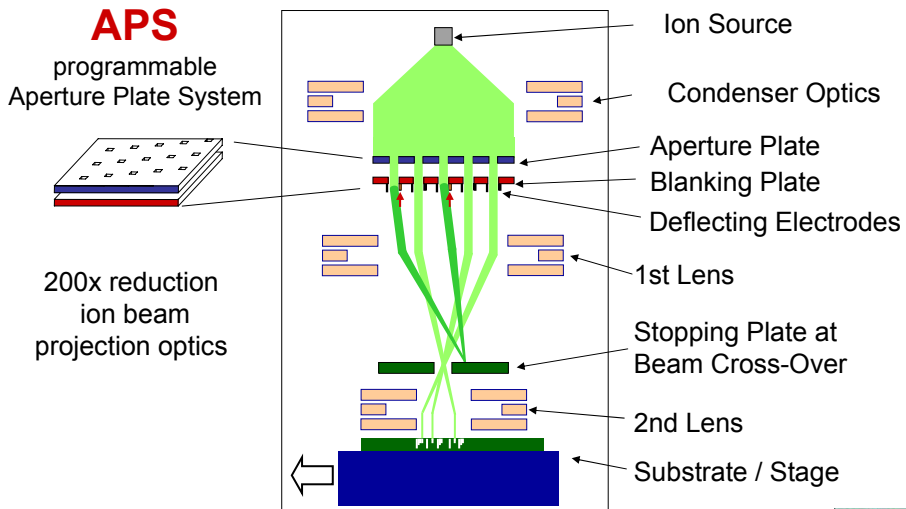


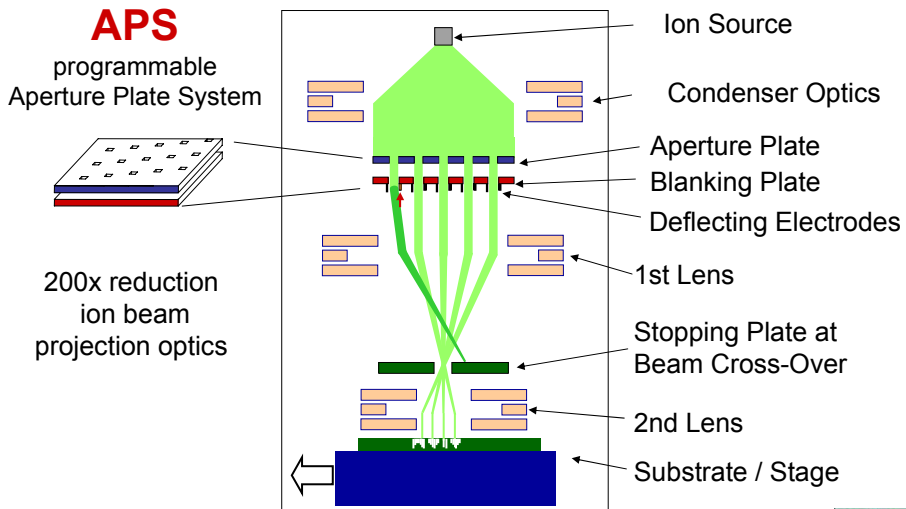


PMLP Principles









PMLP Proof-of-Concept

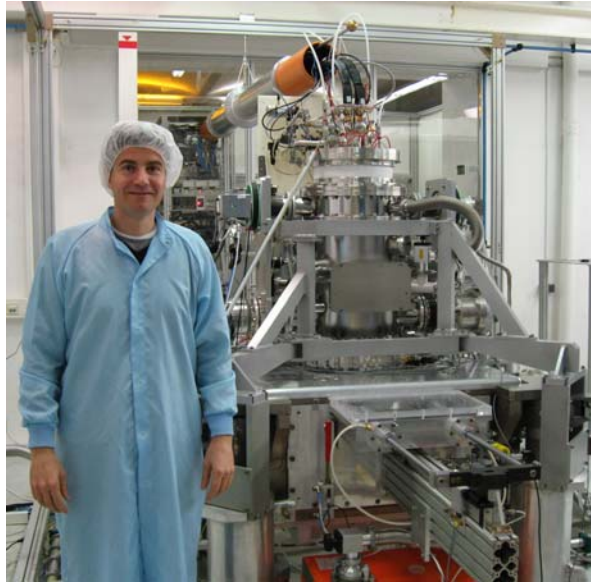
CHARPAN

(Charged Particle Nanotech)

integrated FP6-NMP project: started April 2005 / 4 years

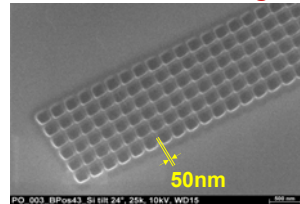
www.charpan.com





Targets:
40.000 ion beams
working in parallel with
< 20nm resolution

Feb 2007: “Beam-On“
first ion beam projection
optics with 200x reduction
realized and working !

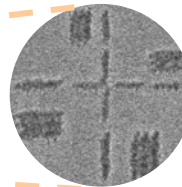
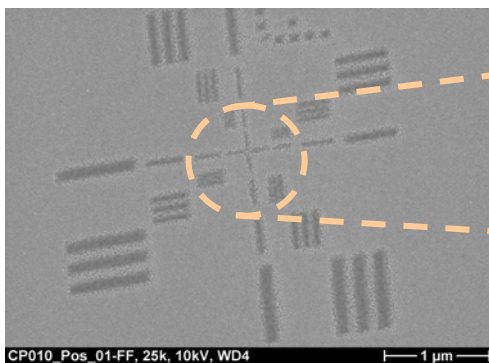


Argon ion multi-beam
patterning of Si surface

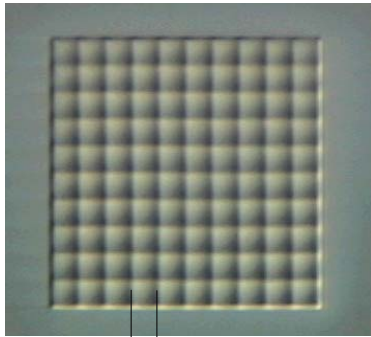


fine adjustment ongoing

16nm
lines & spaces

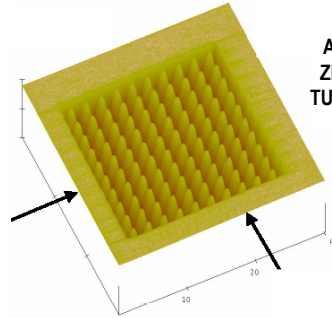


10 x 10 Microlenses

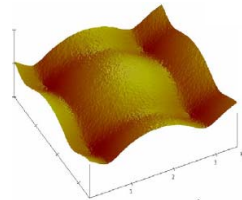


→ ← 2.2 μm

**14 March 2007:
first PMLP
3D Nanopatterning**



AFM:
ZMNS
TU Wien



x, y = 1 μm
z = 80 nm



PMLP Markets

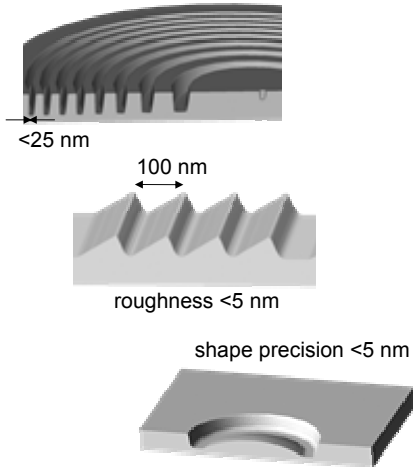
existing Market

ion multi-beam
nanopatterning for

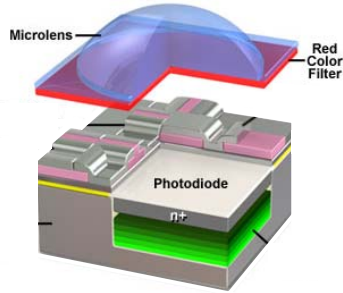
- Leading Edge
Complex Masks
- 2D and 3D
Nanoimprint Templates
- Nano-Photonics
- Nano-Magnetics
- Nano-Biotechnology
-



Fabrication of 2D and 3D Nanoimprint Templates



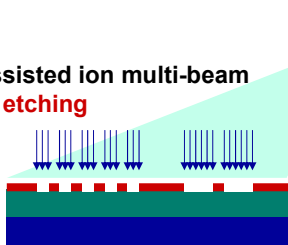
PMLP fabrication of 3D templates for "Above-IC" Nanoimprinting of many 100thousands of **Microlenses with nanometer surface precision**, e.g. for mobile phone imager chips



PMLP: Resist-Less Nanopatterning

for Leading Edge Complex Masks

Gas assisted ion multi-beam
in-situ etching



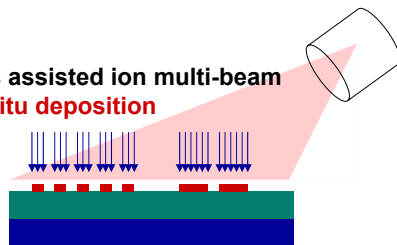
Pattern transfer



Hard Mask removal



Gas assisted ion multi-beam
in-situ deposition

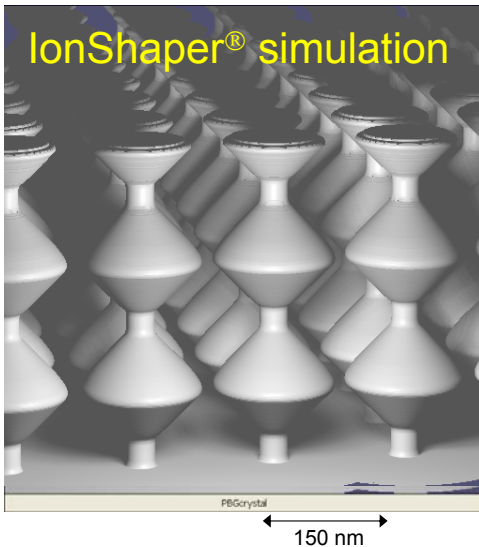


Pattern transfer



Hard Mask removal





Ion Multi Beam
Bottom – Up
 Nanotechnology
 for
 NanoPhotonics,
 NanoMagnetics,
 NanoBiotechnology,



FIB (single Focused Ion Beam) / PMLP comparison

at 10nm resolution:

	FIB	PMLP	
Ion Beam Species	Ga ⁺	H ⁺ , He ⁺ , Ar ⁺ , Xe ⁺ , C ₆₀ ⁻	
total Ion Beam Current at Substrate	~ pA	1 - 300 nA*	higher productivity by many orders of magnitude

* depending on configuration
 (1nA for CHARPAN POC Tool,
 higher currents for PMLP Prototype,
 Beta and Production Tools)



Projection Mask-Less Lithography (PML2) and Projection Mask-Less Patterning (PMLP)

- Large working distance, meeting industrial production requirements
- Multi-generational: < 10 nm resolution limits
- Maskless \Leftrightarrow from design directly to substrate
- PMLP \Leftrightarrow resistless 3D modification of materials
- Enhanced Throughput \Leftrightarrow 1 Mio beams in parallel

are enabling a flexible high value-added European Nanoelectronics and Nanomanufacturing Industry



PML2 and PMLP

