# I Need More "E" BEAMS, Scotty!

**Towards an e-beam cluster tool for wafer manufacturing**

# Agenda

- How to realize a cost effective manufacturing solution with e-beams
- How much power / current is required and where are we today ?
- Towards a 100 wph e-beam direct write cluster

MAPPER lithography

## Three requirements need to be met for HVM for 20 nm node and beyond

1. CD, CDu and overlay requirements following ITRS roadmap
   - CD < 25 nm
   - CDu < 2.5 nm
   - Overlay < 7 nm (no double patterning)

2. Throughput per unit Investment (wph/M€)
   - 2 wph / M€, following 125 wph and 65 M€ quoted for EUV
   - 10 wph / 5 M€ units -> clustering

3. Throughput per unit Foot Print (wph/m2)
   - In line with today’s immersion tools: ~ 15 $m^2$

# Two machines shipped for infrastructure development

- Systems have 110 beams and automatic 300 mm wafer handling
- Systems are used to verify imaging performance, resist development and PEC correction

# Resolution of pCAR-C – C/H & L/S

- Resist thickness: 45nm / BARC / Si
- 25-nm spot size & stationery writing
- Stage scanning writing (less stripes for dose split) has resolved 32nm HP, further exposures to be done.

| | HP 30 | HP 28 | HP 26 | HP 24 | HP 22 | HP 20 |
|---|---|---|---|---|---|---|
| Mag 250Kx | | | | | | |
| Mag 200Kx | | | | | | |



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# Beam to beam CD uniformity

- Scanning exposures at 32-nm half pitch

| | C/H | L/S_V | L/S_H |
|---|---|---|---|
| Number of beams | 105 | 102 | 102 |
| Mean (nm) | 32.5 | 28.1 | 27.1 |
| $3\sigma$ (nm) | 1.9 | 2.3 | 3.3 |
| Max (nm) | 34 | 29.8 | 30.2 |
| Min (nm) | 31.2 | 25.2 | 23.0 |

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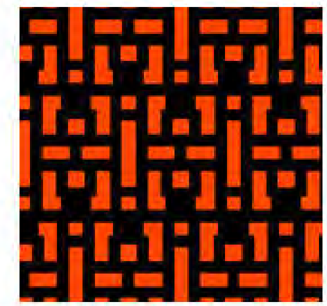
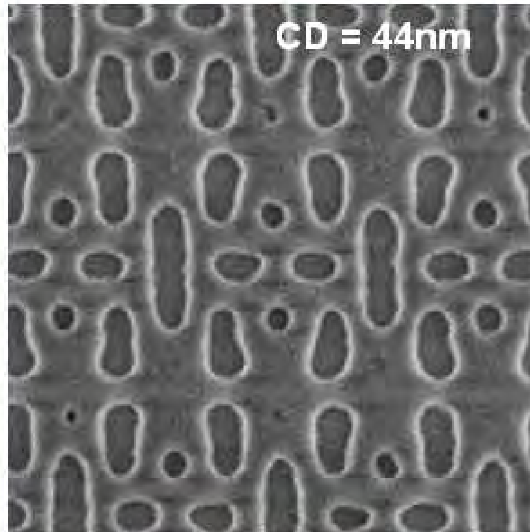
aselta NANOGRAPHICS

# SRAM M1 (22nm node design)
## (CDdesign = 46nm pitch = 90nm)

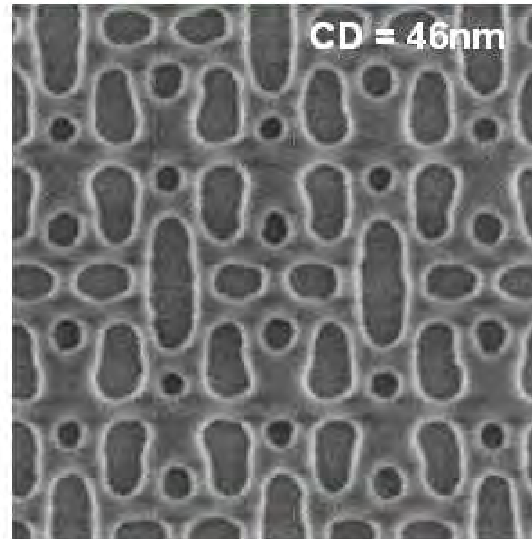


**No correction**



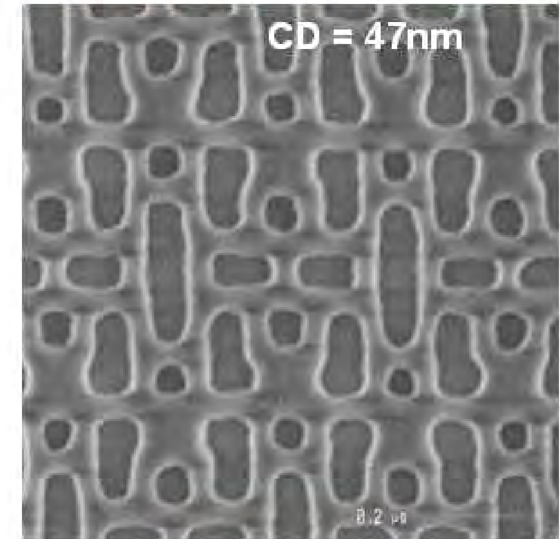

D =12µC/cm²

**Dose Modulation**




D=13.6µC/cm²

**Dose Mod * Geometry**




D=14µC/cm²

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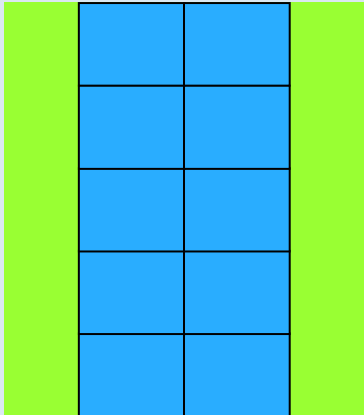
# Footprint overview

Footprint of one 10 wph exposure unit:

Today: 1.4 m x 1.4 m

Matrix: 1.1 m x 1.4 m



**MAPPER: 15.4 $m^2$**
**Target TPT: 100 wph**

**Matrix 10.10**
**100 wph cluster**

MAPPER lithography

## 2 wph / M€ leads to a 5 M€ selling price

- Today we know what the main components of our system cost
  - Electron optics cost for 10 wph is similar to today's 110-beam tool cost
  - Wafer stage + interferometer cost is similar to today's 110-beam tool cost
- Main additional cost is in data path. Based on the hardware we have built, we know that we can keep the cost low enough to meet the target

# Three requirements need to be met for HVM for 20 nm node and beyond

| Requirement | Demonstrated |
|---|---|
| 1. CD, CDu and overlay requirements following ITRS roadmap | |
| ▪ CD < 25 nm | 27 nm |
| ▪ CDu < 2.5 nm | 1.9 nm for contacts |
| ▪ Overlay < 7 nm (no double patterning) | |
| 2. Throughput per unit Investment (wph/M€) | |
| ▪ 2 wph / M€, following 125 wph and 65 M€ quoted for EUV | manufacturing cost |
| 3. Throughput per unit Foot Print (wph/m2) | |
| • In line with today's immersion tools: ~ 15 $m^2$ | 15.4 $m^2$ |

# Main requirements to demonstrate

1. 10 wph throughput
2. Overlay

# MAPPER is now designing the Matrix system

**Pre-alpha**

Upgrade to scanning stage
Tool parameter matching to imaging performance

**Matrix 1.1**

< 25 nm resolution
Overlay 10 nm
1 wph @ 30 μC/cm²

**Matrix 10.1**

< 25 nm resolution
Overlay 10 nm
10 wph @ 30 μC/cm2

**Matrix 10.10**

< 25 nm resolution
Overlay 7 nm
100 wph @ 30 μC/cm2

MAPPER lithography

## Agenda

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# How much power / current is required ?

- Agreement with end users: 30 µC / $cm^2$ resist sensitivity required
- For 10 wph, regardless of pattern density, total current required is ~ 170 µA
- With 13,000 beams, 13 nA per beam is required
- Efficiency in optics is about 0.1 % -> 133 mA required from source

# Source status today

| | | spec | actual |
|---|---|---|---|
| √ | Uniformity | < +/- 5% | < +/- 5% |
| √ | Total current | > 133 mA | 195 mA |
| √ | Brightness | > $5.10^5$ $A/m^2SrV$ | $5.10^5$ $A/m^2SrV$ |
| ~ | Lifetime @ DC operation | >> 1000 hrs | 80 hours |

Source cost: $100

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# To get the power on the wafer, the source is available -> we need more beams

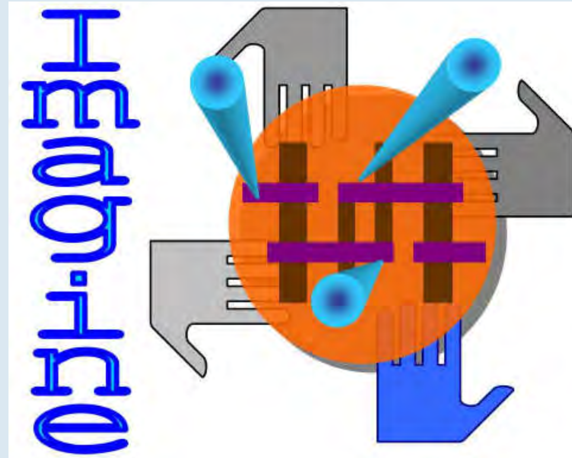
- Today we have demonstrated 110 beams running in parallel, individually switched
- We will introduce in 2012 an optics based on our patterned beam approach with a 1 wph performance
- Total current reaching the wafer is 17 μA for 1 wph
- Then we need to scale the illumination optics to a 26 mm x 26 mm field to reach 10 wph

# Agenda

- How to realize a cost effective manufacturing solution with e-beams
- How much power / current is required and where are we today ?
- Towards a 100 wph e-beam direct write cluster

# Semiconductor companies are invited to join our IMAGINE program @ CEA-Leti

SOKUDO



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## With Sokudo, among others, we are working on realizing this 100 wph cluster

## Conclusions

1. One e-beam column is limited to about 10 wph, therefore MAPPER has demonstrated
   - Low tool cost
   - A small footprint to enable clustering
2. Best resolution demonstrated is 27 nm hp, CDu of 1.9 nm beam-to-beam
3. Currently developing Matrix platform
   - First step: Matrix 1.1, enabling 1 wph with overlay capabilities
   - Second step: Upgrade to Matrix 10.1, enabling 10 wph
   - Third step clustering several modules together

# Thank you