innovation
for industry

IDeAL program : DSA activity at LETI

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MINATEC CAMPUS

Outline

- The IDeAL progam
- Graphoepitaxy of BCP
- Contact hole application
- 300 mm pilot line in LETI
- Conclusion

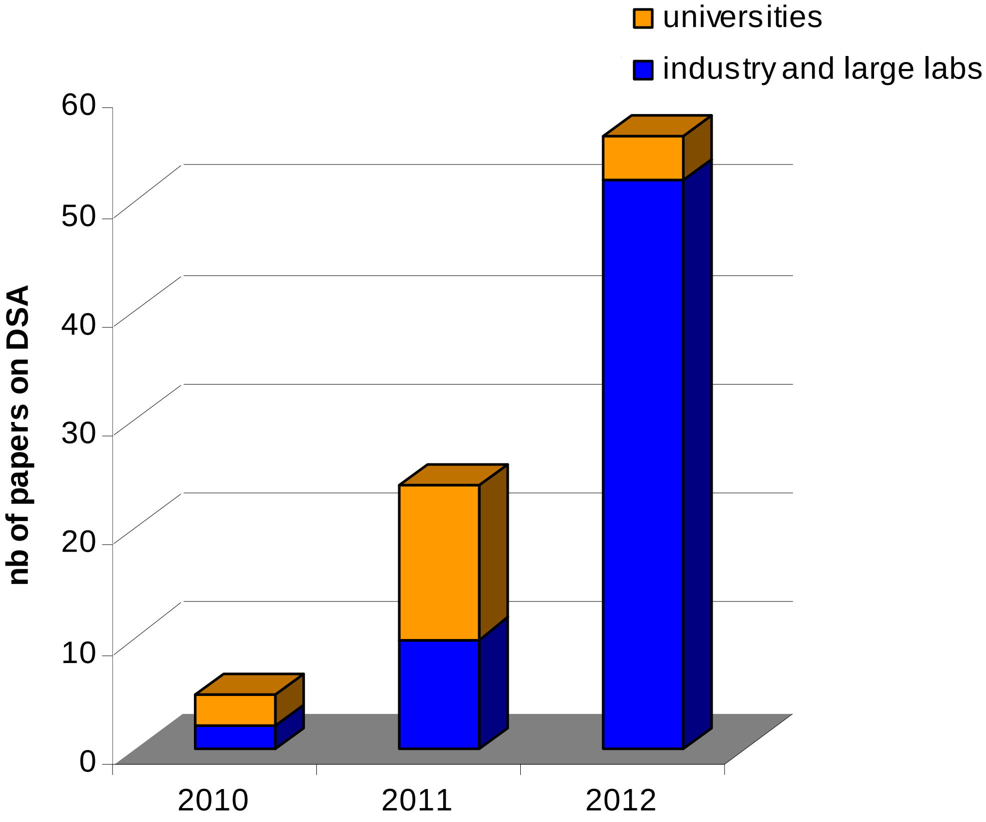
Why DSA for Microelectronics ?

- Block copolymers self assembly capabilities
  - Very high resolution
  - Low intrinsic Line Edge Roughness
  - Easy process
  - Low cost

- C-MOS Lithography constraints
  - Control the domain orientations (1D - 2D)
  - Alignment control with respect to a preview level
  - Integration capabilities
  - Low defectivity
  - Respect of design rules

Why DSA for Microelectronics ?

Advanced lithography SPIE conferences



DSA a complementary lithography techniques that could get inserted as early as the 14nm node

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LETI DSA open program

Insertion of Directed self Assembly Lithography

Directed Self Assembly : the iDEAL lithography?

- Objectives
  - A new open program to develop a full DSA solution
  - Joint work in LETI environment on material, processes, demonstration & integration
  - A cluster open to materials and equipments' suppliers, IDM, EDA
- Partnership status – July 2012
  - DSA material development
    - Copolymer material worldwide leader : ARKEMA
    - Collaboration with academic laboratories LTM LABORATOIRE DES TECHNOLOGIES DE LA MICROÉLECTRONIQUE LCPO
    - resist partners : under progress
  - Equipment suppliers
    - 2 industrial partners SOKUDO TEL
  - End users
    - Bilateral work with ST

iDEAL

Arkema in a few points

- Worldwide player in specialties chemistry
- Ranging from 1st to 3rd position in product lines insuring 80% of the company revenue.
- 2010 revenue : 5,9 Md€
- R&D : > 120M€ / 8 R&D center WW (US, Japan, France)
- Annual Capex : 293 M€
- 80 industrial sites
- 15 000 employees

ARKEMA
The world is our inspiration

ARKEMA strength :
- Worldwide polymer manufacturer
- Strong know-how on block copolymer
- Ability to quickly ramp-up from R&D to industrial scale

missions ?

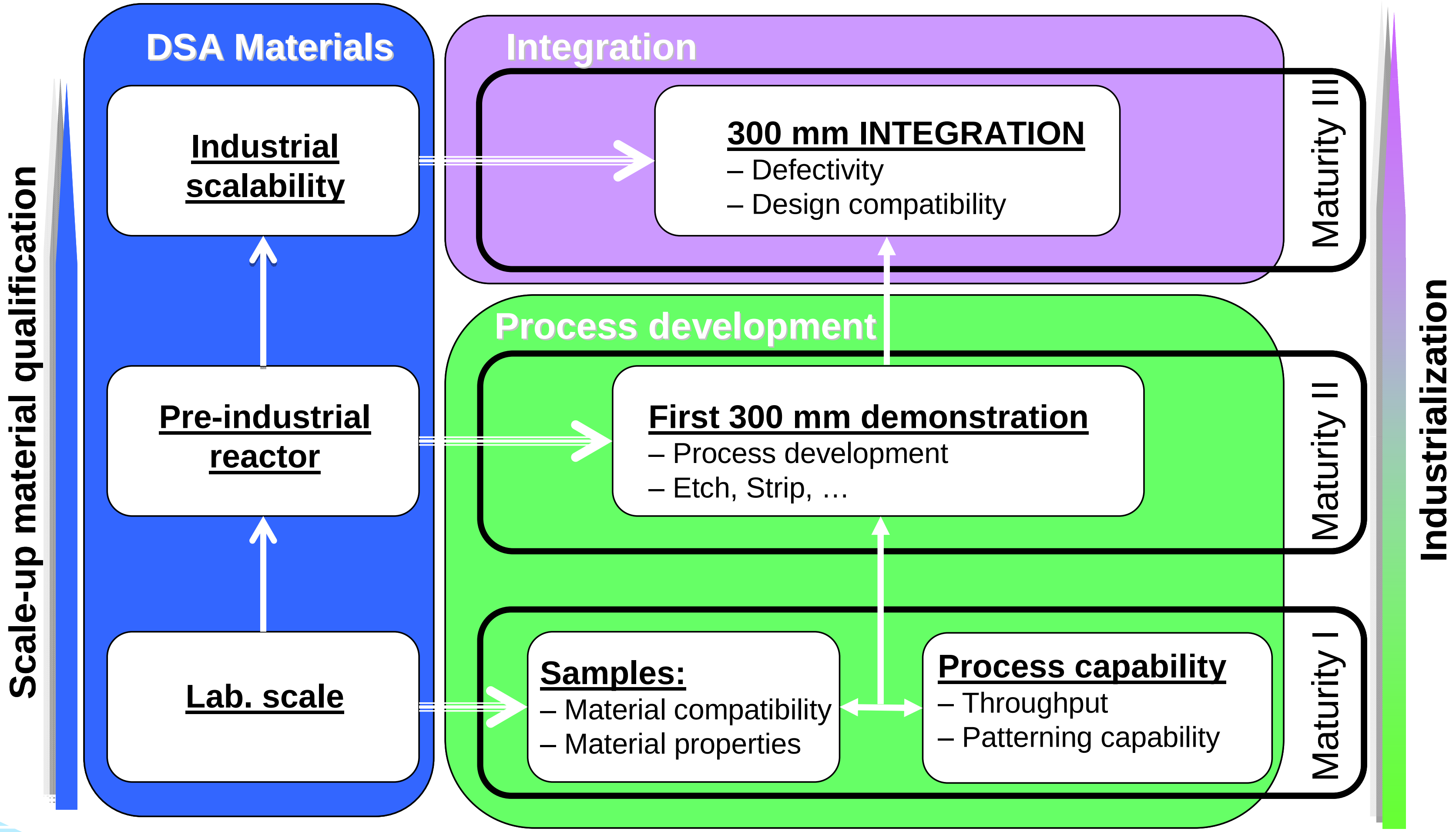
- Push material platforms to maturity
  - From lab scale to industry
  - Evaluate advanced copolymer platform

- Develop 300mm patterning solutions
  - Certify material compatibility with clean room standard
  - Screen DSA material performances
  - Verify transfer capabilities

- Scale-up DSA processes to production level
  - Compatibility with design rules
  - Respect of ITRS standard : defectivity, throughput…

How to go from R&D to industrial ?

A production-oriented consortium



Scale-up material qualification

DSA Materials

Lab. scale

Pre-industrial reactor

Industrial scalability

Process development

Maturity I

Samples:
– Material compatibility
– Material properties

Process capability
– Throughput
– Patterning capability

Maturity II

First 300 mm demonstration
– Process development
– Etch, Strip, …

Integration

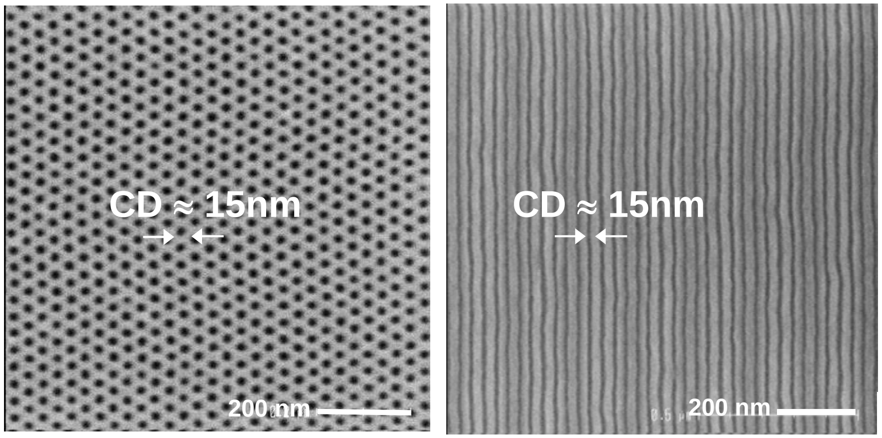
Maturity III

300 mm INTEGRATION
– Defectivity
– Design compatibility

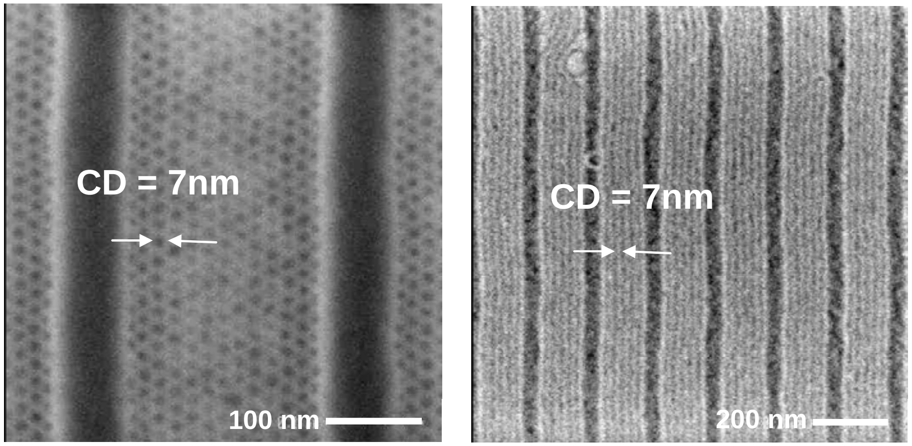
Industrialization

ARKEMA – LETI partnership : materials path

- Efficient neutralization layer
- Several materials under screening
    - PS-PMMA platform
    - High χ platform



PS-b-PMMA BCP



High χ BCP

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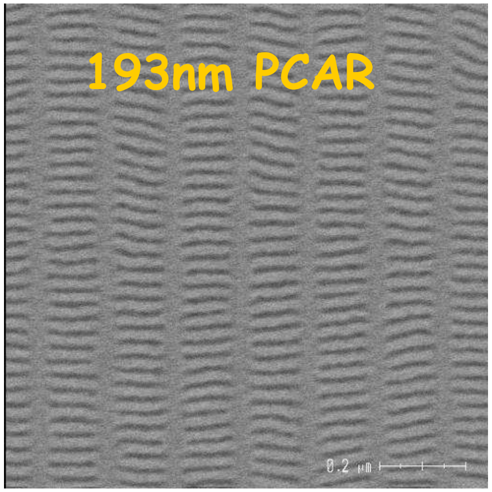
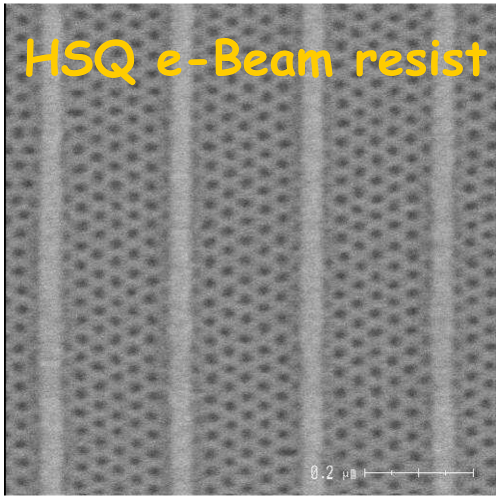
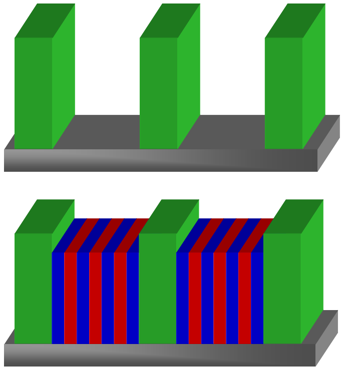
Why grapho-epitaxy preference ?
A versatile process
LETI demonstration

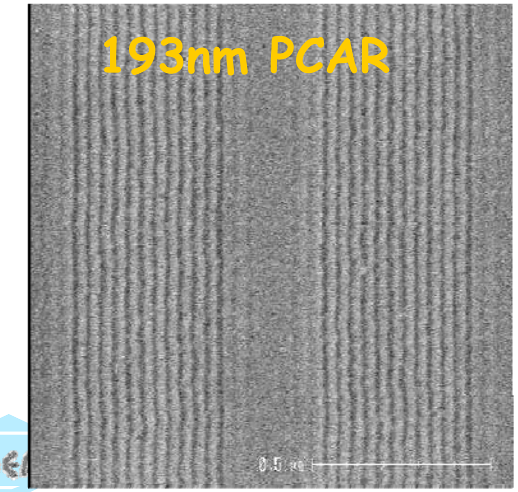


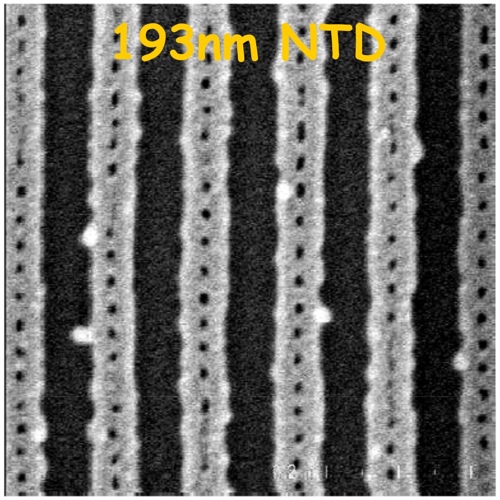


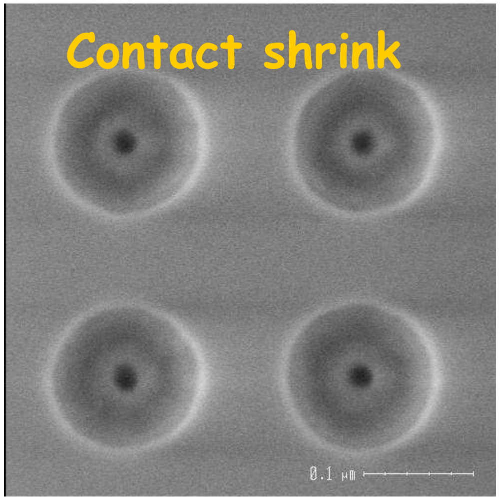
Graphoepitaxy



Leti approach

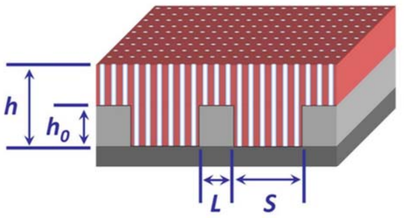


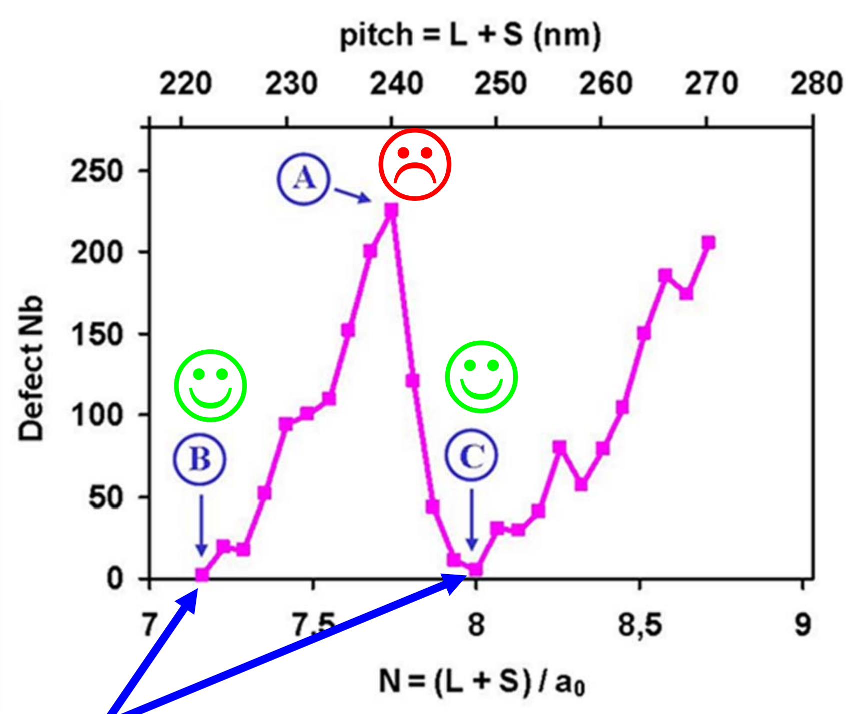


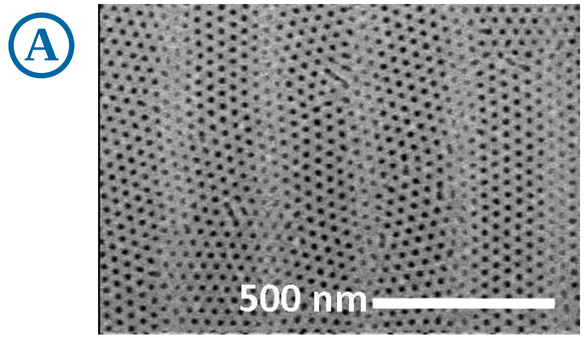


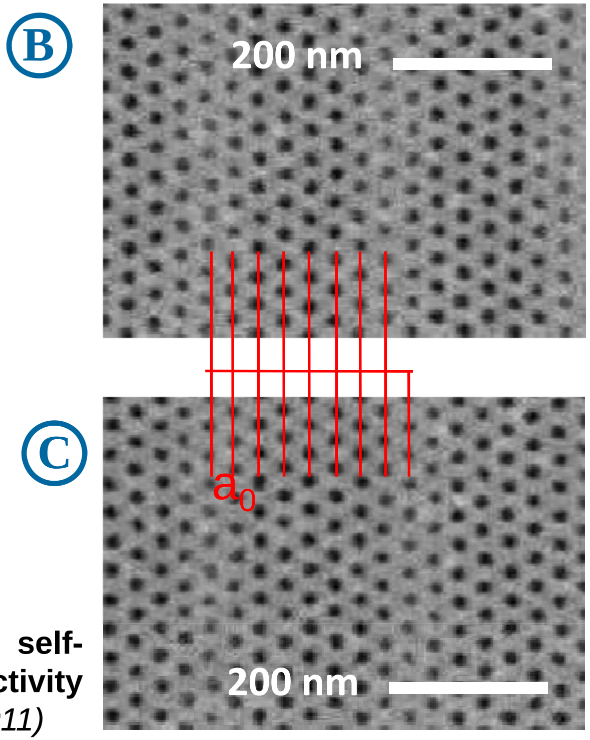
How to find optimum guiding litho process ?

=> Influence of Litho1 design rules & BCP material







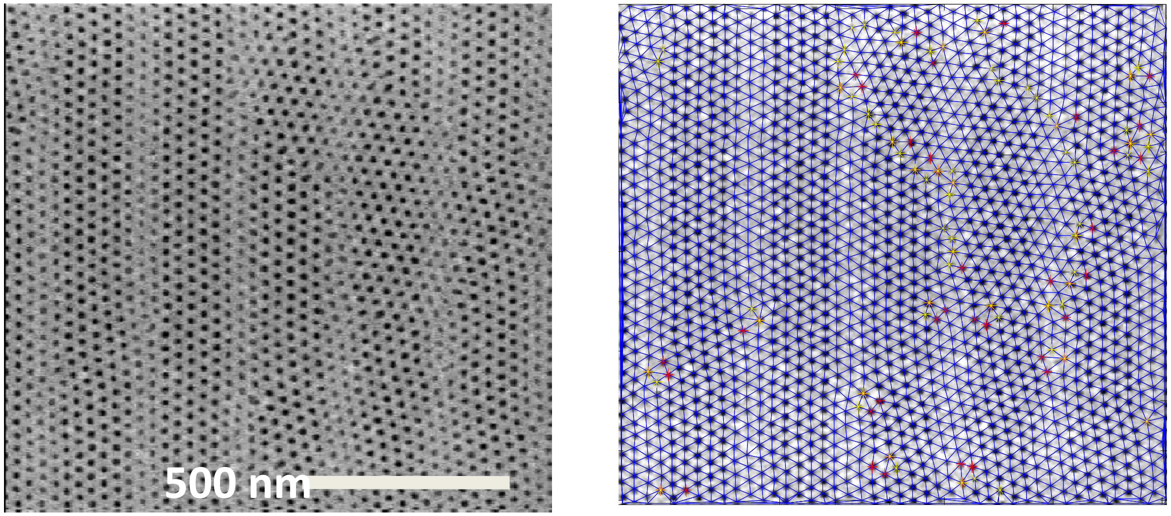


Design rule compatibility

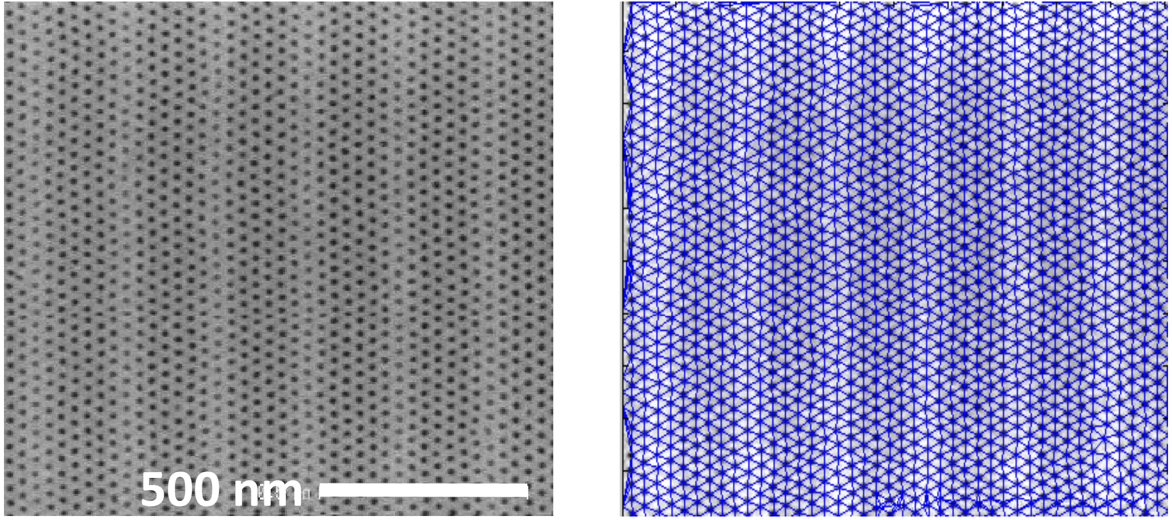
"Optimization of block copolymer self-assembly through graphoepitaxy: A defectivity study" *R.Tiron et al., JVST B29 06F206 (2011)*

Zero Defect Configuration

Before litho1 optimization

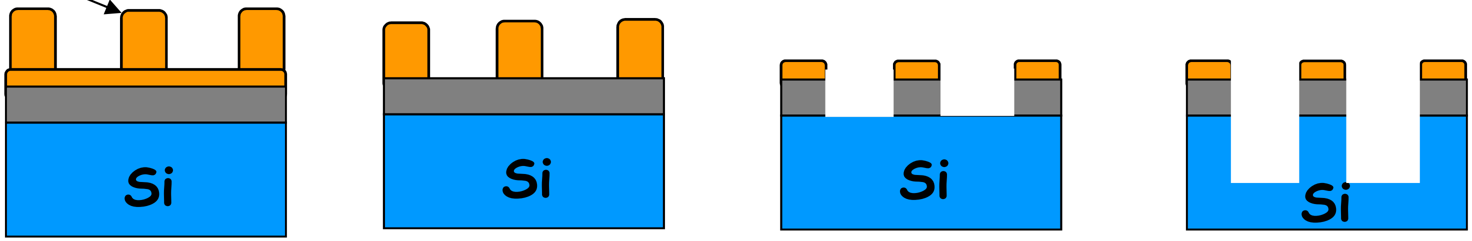


After litho1 optimization



Defectivity measurement enables lithography and process optimization

Silicon Etching with Copolymer Lithography



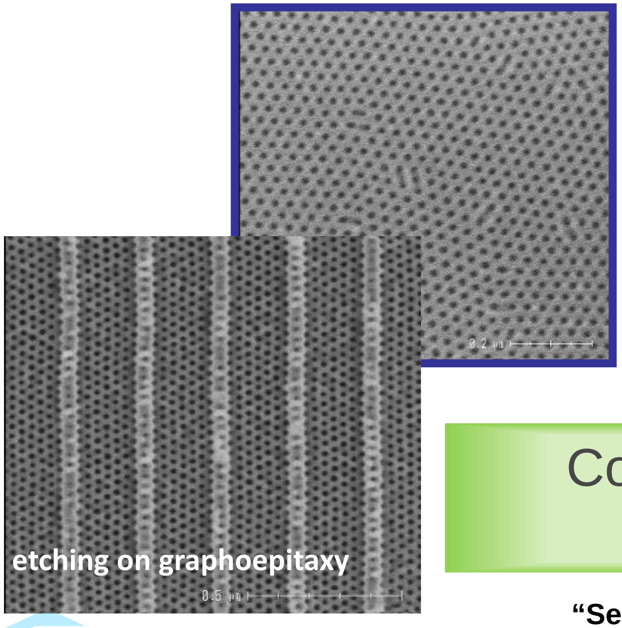
Initial mask (PS)
30 to 100 nm thick

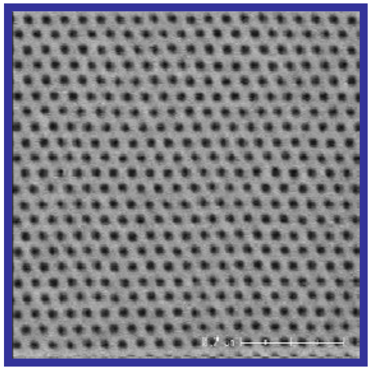
SiO_2 Mask
(10 nm)

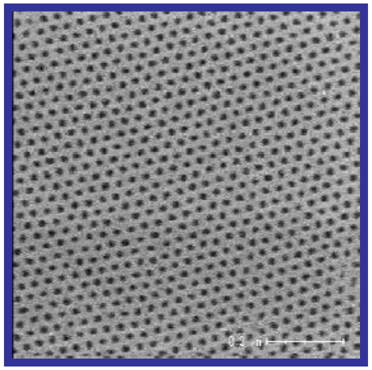
- *Brush opening (Ar/O_2 plasma)*
- *PS plasma treatment*

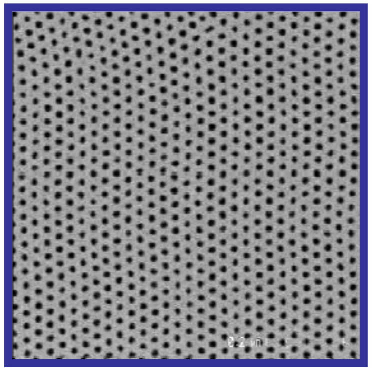
- *Mask etching (CF_4 based plasma)*

- *Silicon etching ($HBr/Cl_2/O_2$ plasma)*


etching on graphoepitaxy



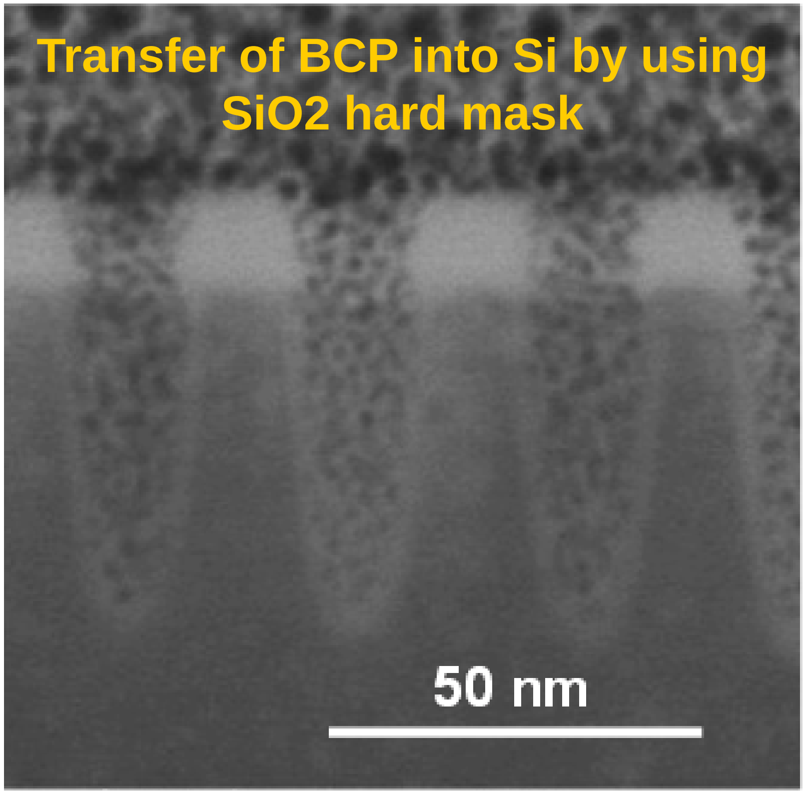


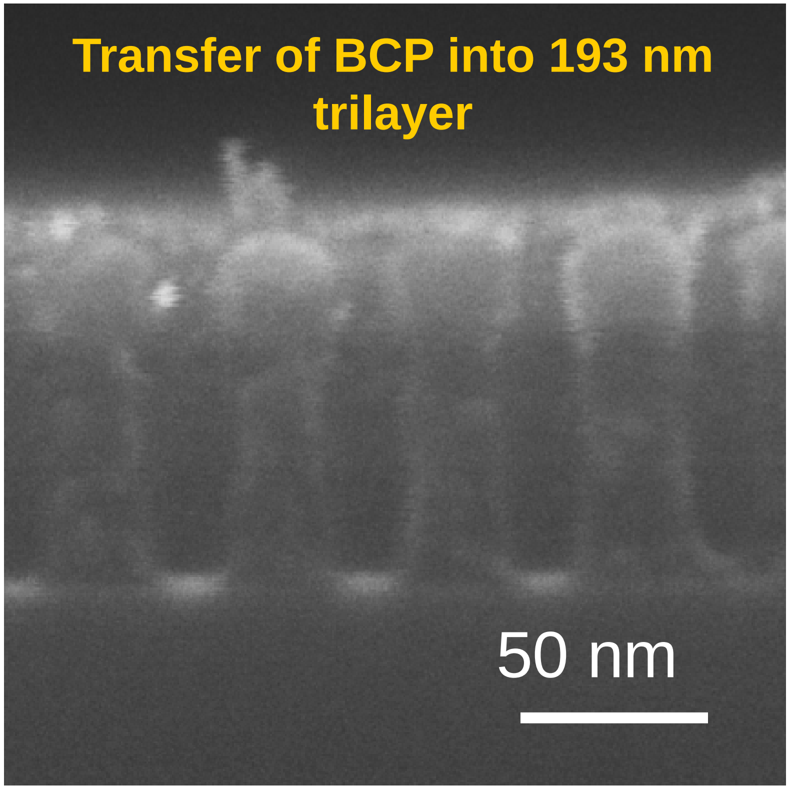


Copolymer etching process fully compatible with CMOS requirements

"Self-assembly patterning using block copolymer for advanced CMOS technology: optimisation of plasma etching process"
Thierry Chevolleau, CNRS (France)- Paper 8328-20, SPIE2012

Silicon Etching with Copolymer Lithography





Copolymer etching process fully compatible with CMOS requirements

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Contact shrink and multiplication using DSA of BCP

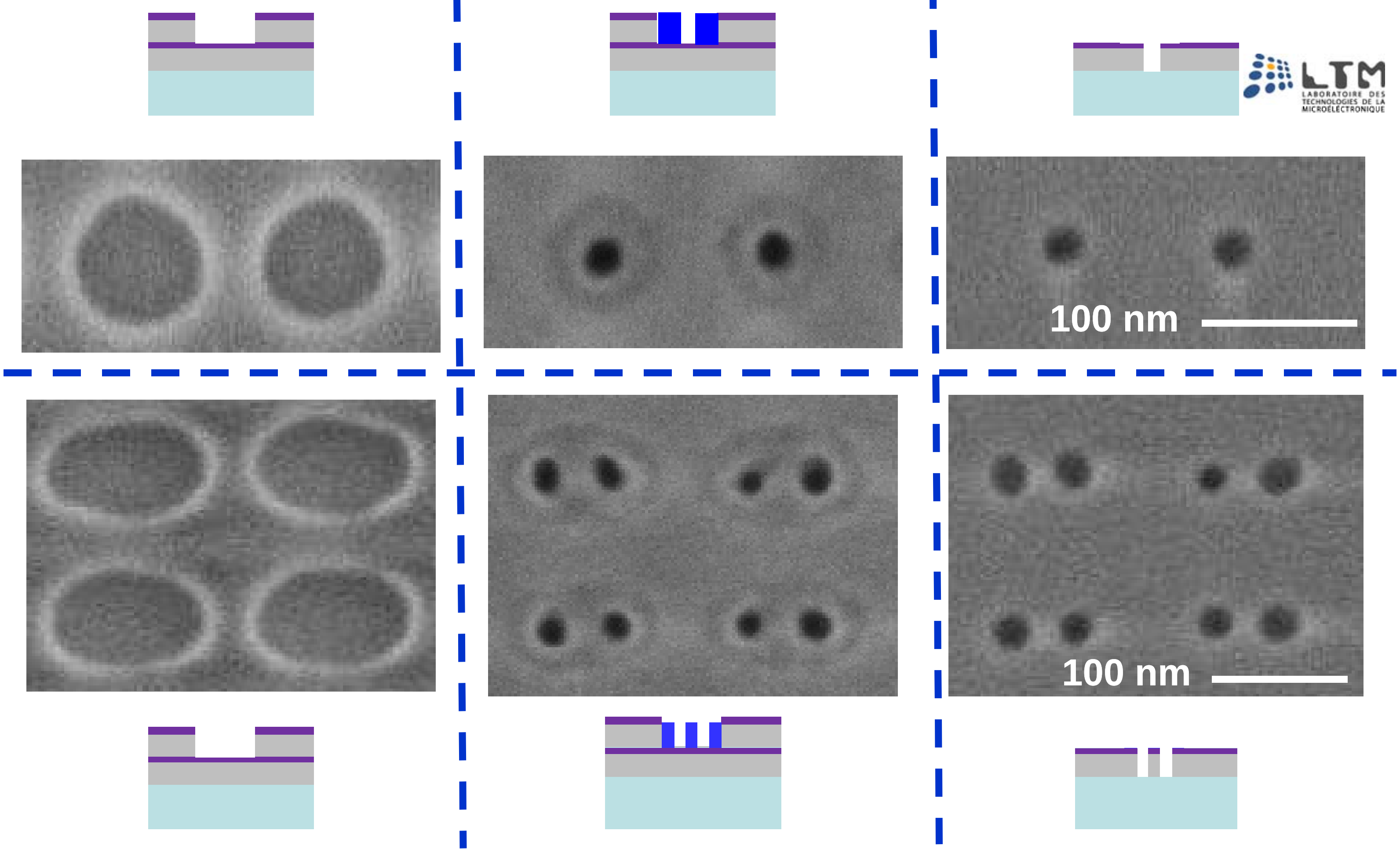
After 193nm litho.

After BCP DSA

After BCP etching

Contact Shrink

Contact Multiplication

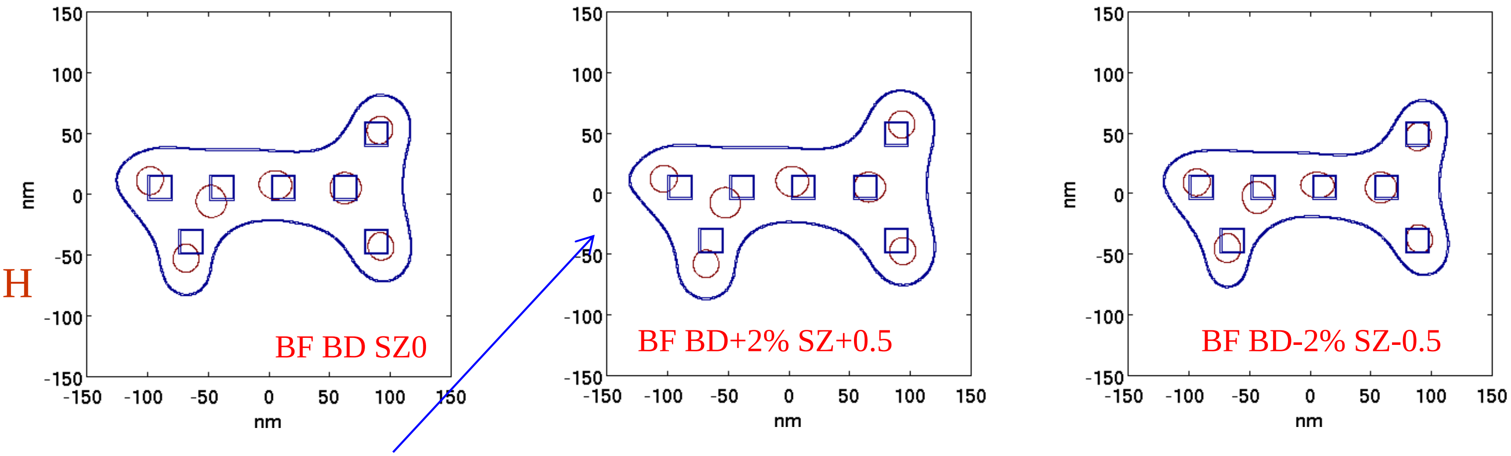


Integration (litho+etch) demonstrated for contact shrink and multiplication

How to define design rules: Example of code

□ Design

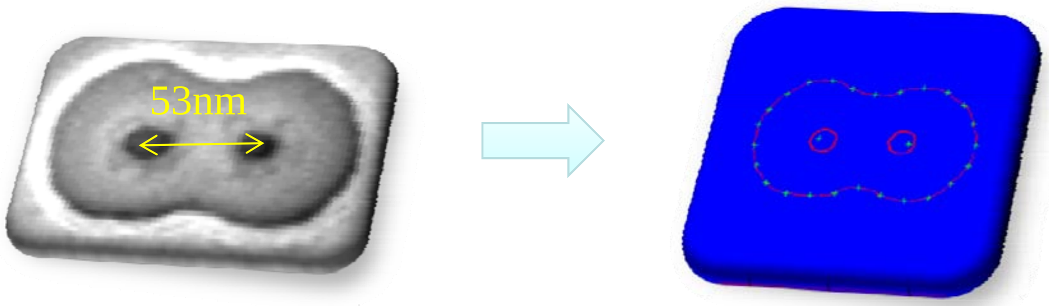
○Calculated CH placement



Simulation contour

Contour variation w.r.t. dose, focus and mask CD error variations

Experimental validation



+ Extracted Contour

+ Calculated CH position

○ CH position on wafer

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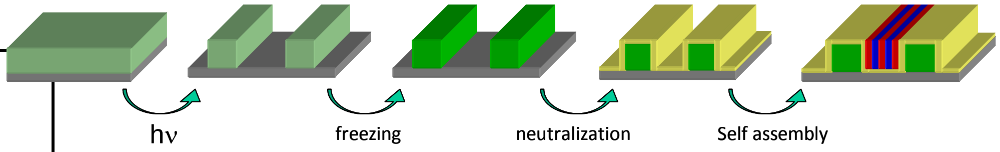
DSA 300 mm infrastructure on SOKUDO RF^3 track



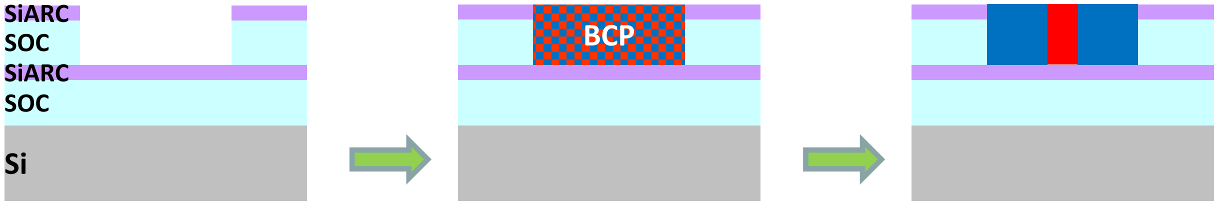
Process steps	CMOS requirements
Guided litho	➢Resist hardness to bake and solvent
PS-r-PMMA spin coat.	➢metal/ ionic contamination ➢ solvent compatibility
Grafting	➢ Bake time and temp.
Rinse	➢solvent compatibility
Copolymer coating	➢ metal/ ionic contamination ➢ solvent compatibility
Self assembly	➢Throughput ➢Defectivity
Etching	➢Transfer capabilities

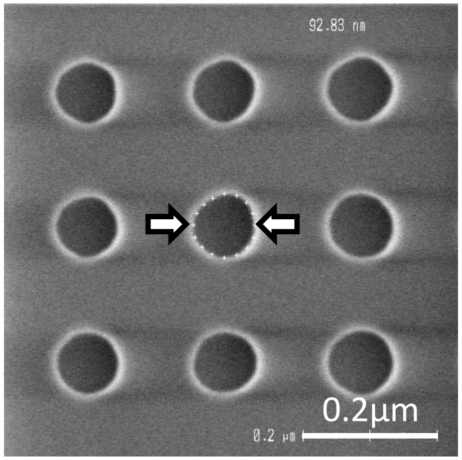
Front-end production
300mm track & scanner

"Pattern density multiplication by direct self-assembly of block copolymers: toward 300mm CMOS requirements" Raluca Tiron et al, CEA-Leti (France) - Paper 8324-23, SPIE2012

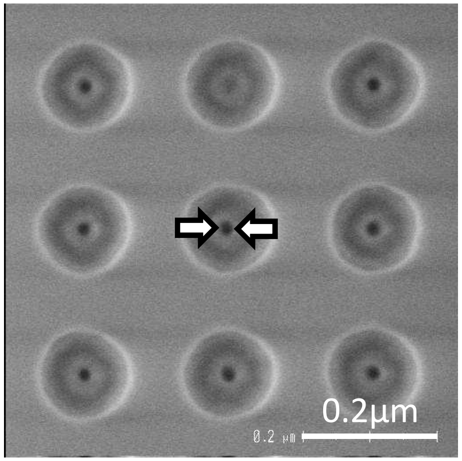
Shrink of contact holes 300mm process

graphoepitaxy with standard lithography 193nm



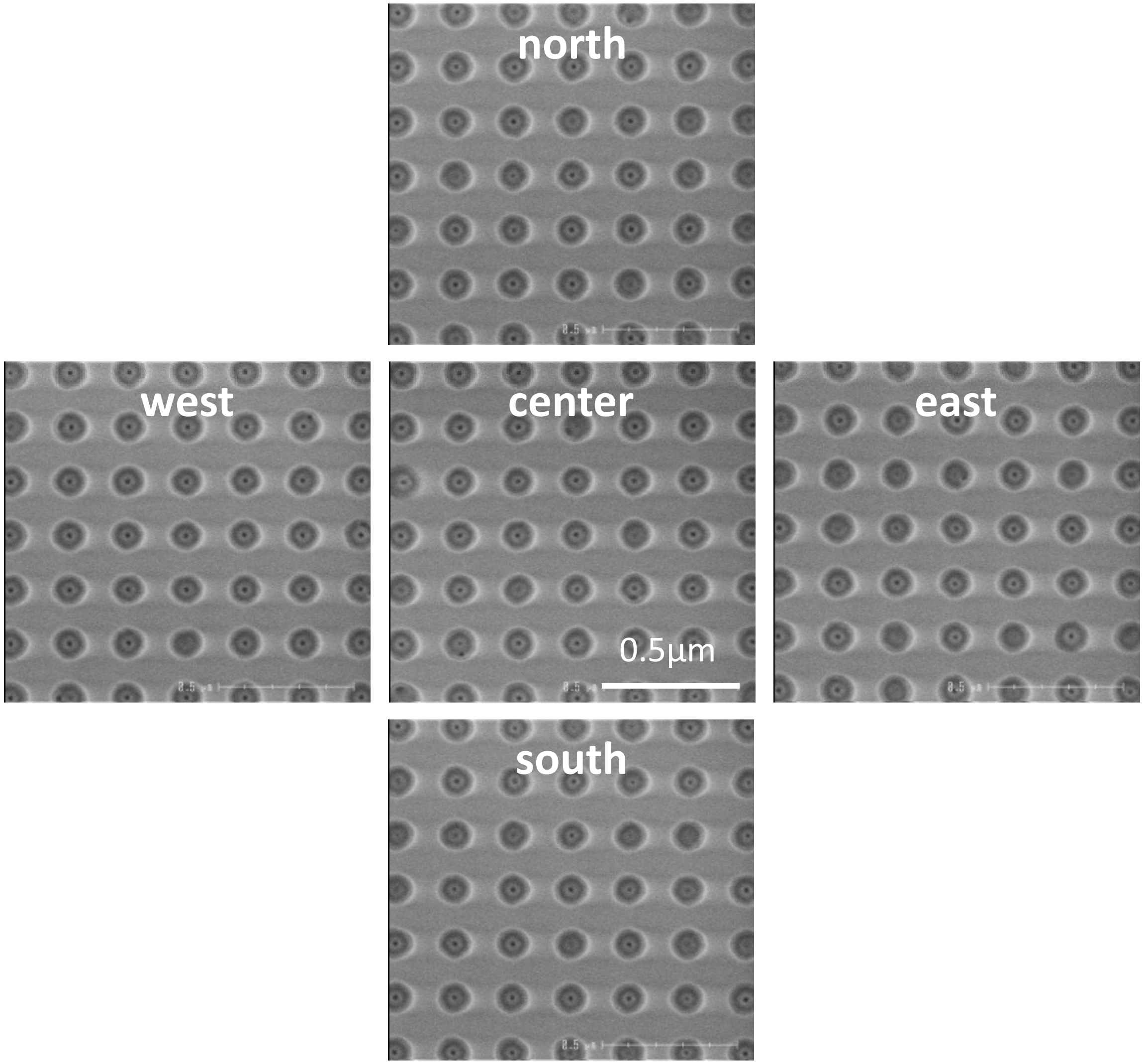


CD ~ 100nm



CD ~ 15nm

Shrink of contact holes 300mm process



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To conclude

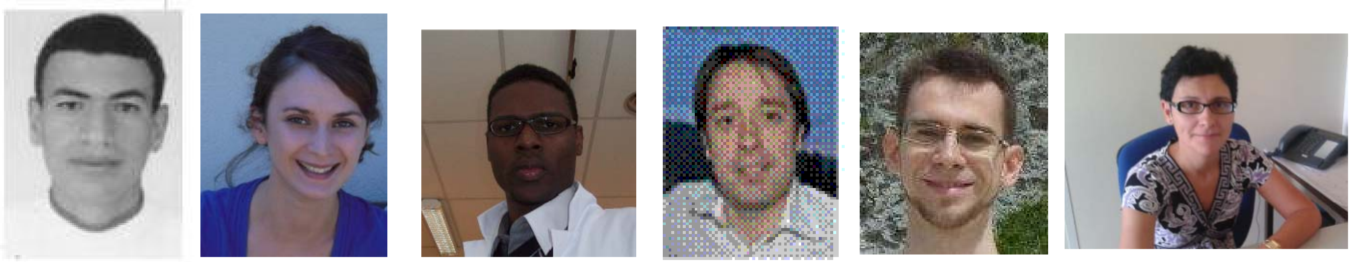
- DSA a complementary lithography technique that could get inserted as early as the 14nm node
  - In a firs step by using PS-b-PMMA like materials
  - In a second step by using high χ materials

- A realistic application: contact hole shrink and doubling

- Defectivity is key

Thanks for SOKUDO involvement and support

All this is possible thanks to:



A.Gharbi, P.Pimenta-Baross, J. Dubray,
S.Barnola, J.Belledent, S.Moulis, R.Tiron *LETI*
X.Chevalier, M.Argoud, C.Navarro *Arkema*
G.Cunge, M.Delalande, T.Chevolleau *LTM*
G.Fleury, G.Hadziioannou, LCPO

But also…

L.Pain, I.Cayrefourcq and LETI peoples involved in the project