Etch challenges for DSA implementation in CMOS via patterning

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Outline

- Via patterning by DSA
  - Contact hole shrink & multiplication
  - Etch challenges
- PMMA removal
- Block Copolymer transfer
- Conclusion

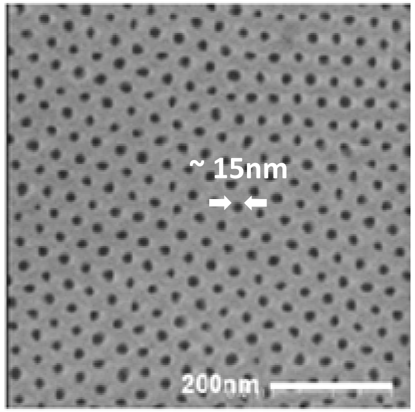
Via patterning by DSA

DSA of Block Copolymers

Guiding templates by lithography

Self Aligned Features

ARKEMA



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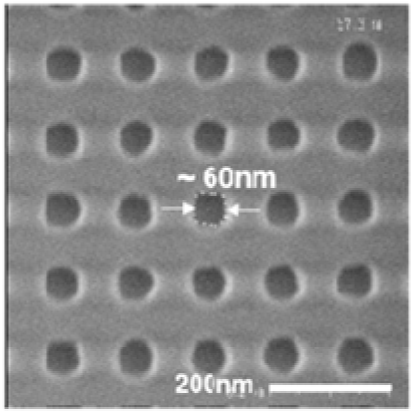

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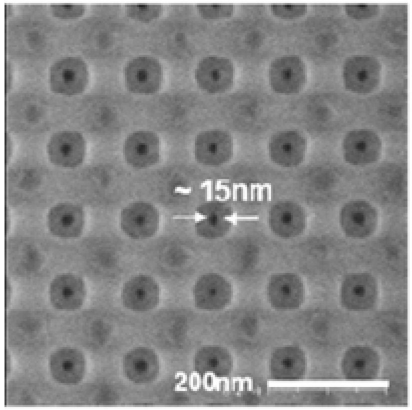
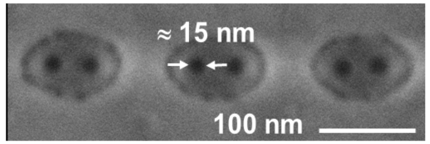
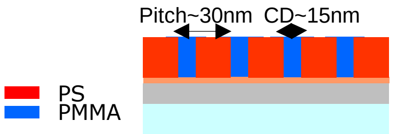
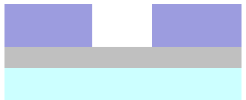
Contact hole shrink

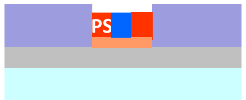


Contact multiplication









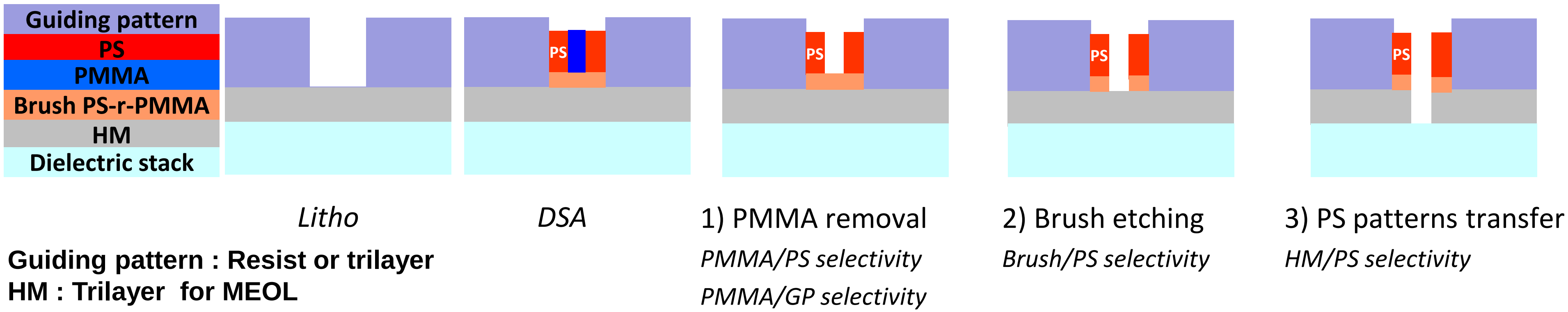
Simple & compatible CMOS process for contact/via applications

Gain in resolution & density

The potential of BCP's DSA for contact hole shrink and contact multiplication, R. Tiron et al., SPIE 2013

Etch challenges

Contact -hole shrink with cylindrical PS-b-PMMA BCP



Guiding pattern : Resist or trilayer
HM : Trilayer for MEOL
HM : Metal layer for BEOL

1. PMMA removal -> selective removal over PS and GP
2. Brush etching -> CD control and pattern fidelity
3. Hardmask etching -> selectivity over thin PS layer

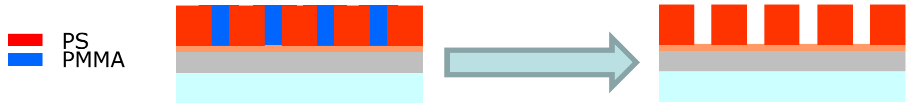
Outline

- DSA for via patterning
- PMMA removal
  - Different paths to remove PMMA
  - Investigation of dry PMMA removal
  - PMMA removal : status
- Contact shrink transfer
- Conclusion

Different paths to remove PMMA

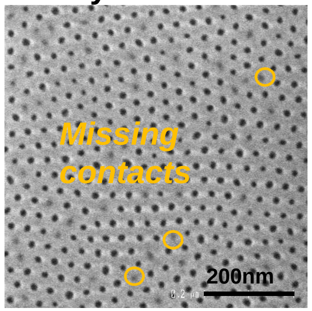
PMMA removal by wet in Acetic Acid :

Before PMMA removal **After PMMA removal**

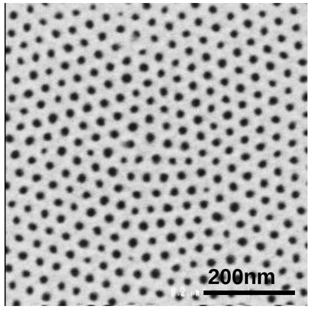


Need of an additional exposure

Only wet in AA

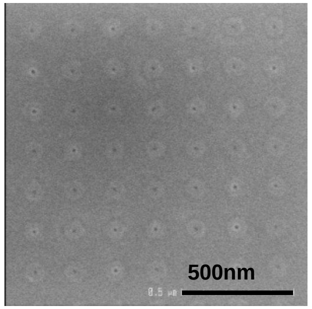


UV + wet dev (AA)

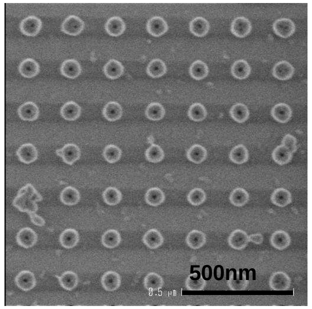


Not compatible with DSA on resists

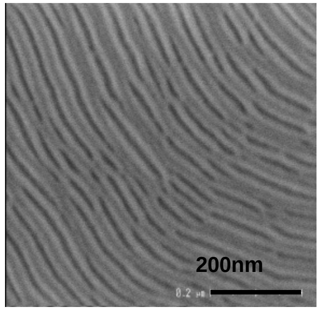
After soft dry etch



After acetic acid dev.



Collapse issues for lines



Solutions under investigations:

To improve UV + wet

Dry PMMA removal

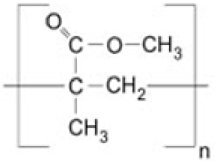
- compatible with DSA on resist
- no collapse issues for lines
- less steps

Selectivity ? → **Study on PMMA & PS homopolymers blankets**

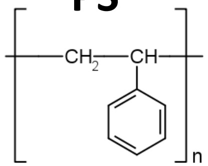
Efficiency ? → **Study on block copolymers films**

A selective dry PMMA removal

PMMA



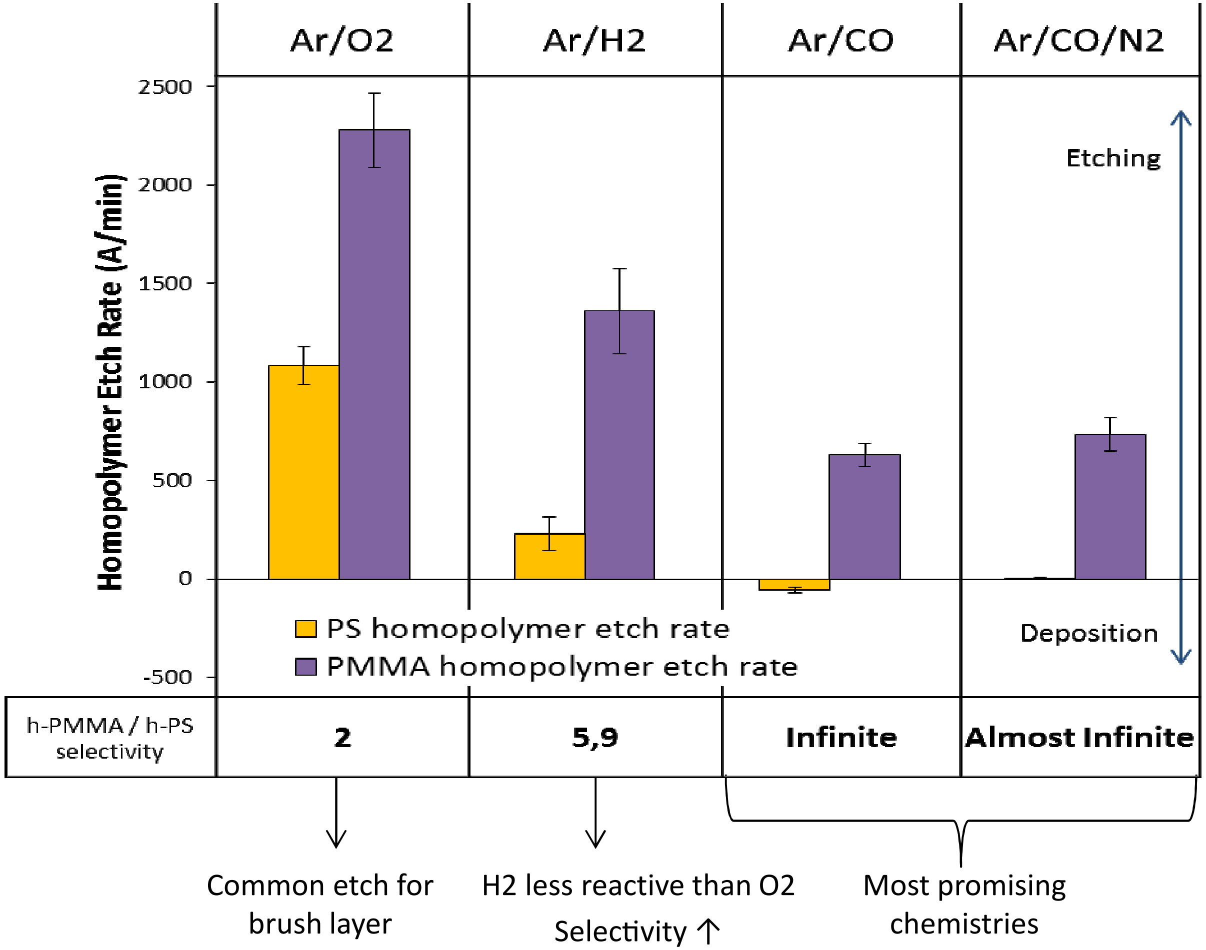
PS



CCP Etching Chamber

(Capacitive Coupled Plasma)

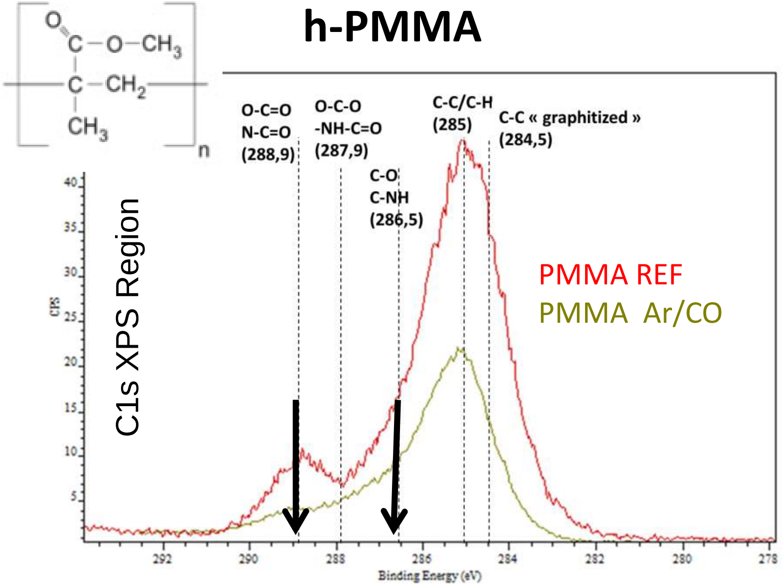
h-PMMA/h-PS etch selectivity evaluation on blankets



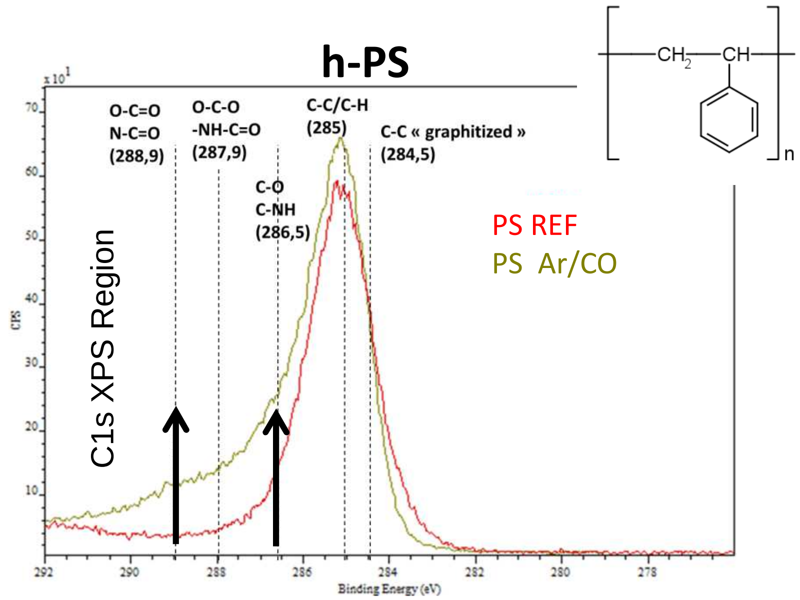
CO based chemistries for a selective dry PMMA removal over PS.

Infinite selectivity with CO plasmas : mechanism

XPS Surface Analysis

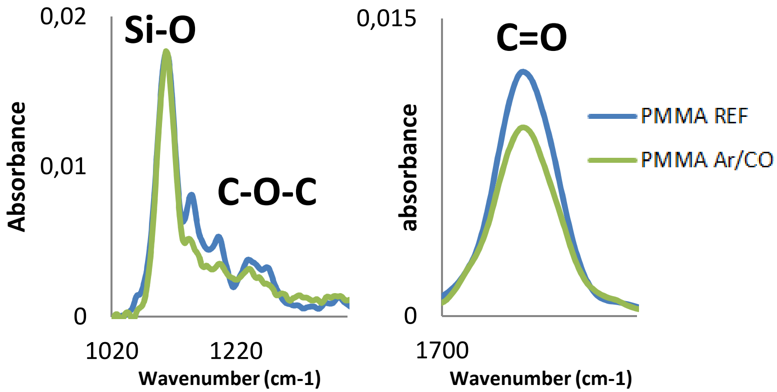


CO bonds loss at PMMA surface

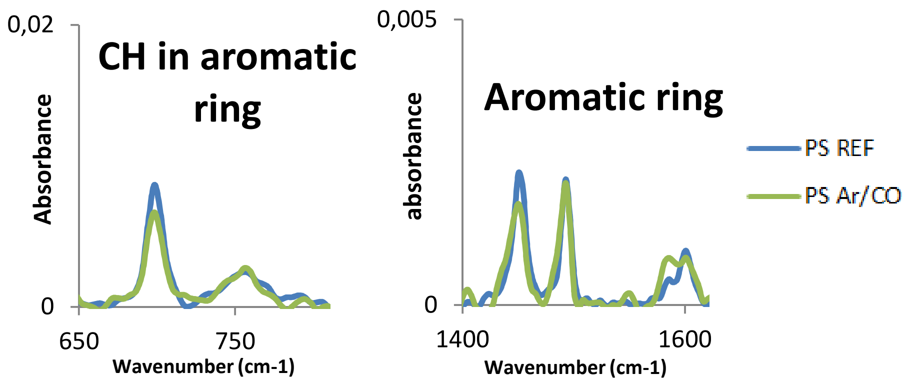


CO bonds at PS surface -> polymer deposition

FTIR Bulk Analysis



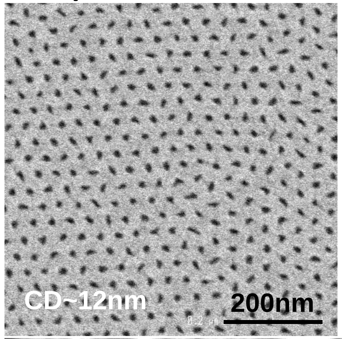
CO bonds loss in PMMA bulk

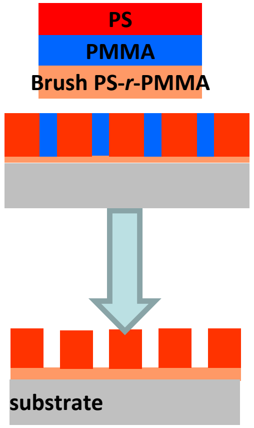


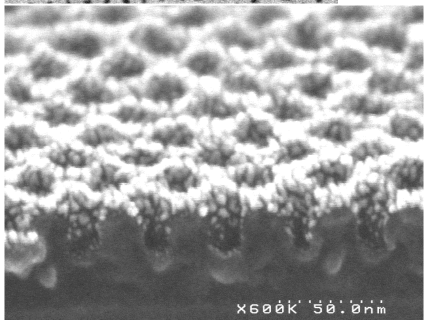
No additional CO peak for PS bulk
Low modification in PS bulk

Removal efficiency on BCP film

Ar/CO



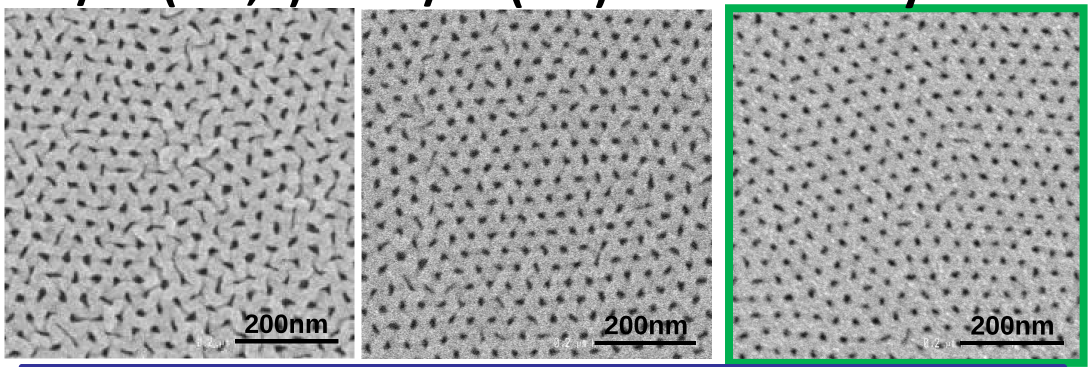




For CO based plasma :

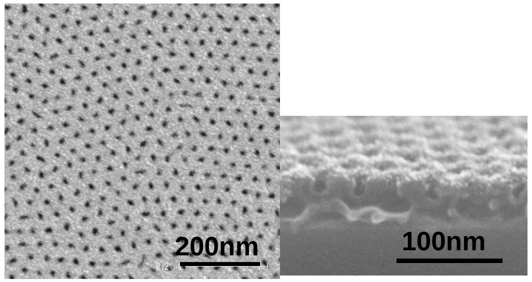
- Straight profile
- Hole deformation
- Holes not totally opened

CO/Ar (1:2,5) | CO/Ar (1:1) | CO only

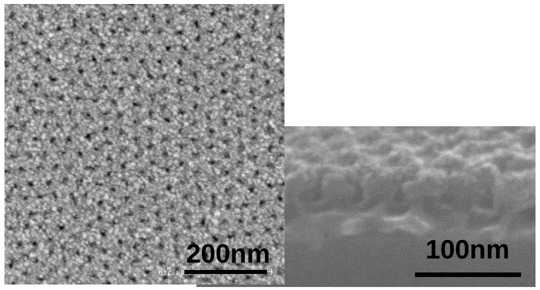


Hole deformation caused by Ar ion

ER on brush (PS-*r*-PMMA) blankets < 1A/min



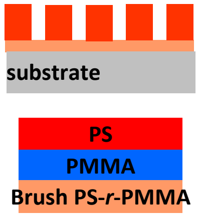
CO 85s



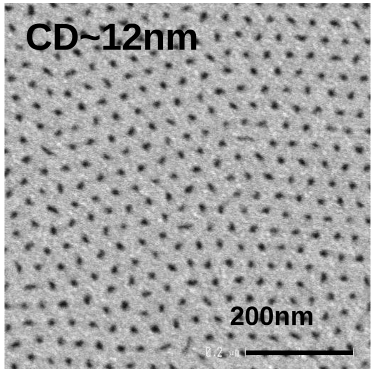
CO 200s

Etch stop on brush layer with CO only

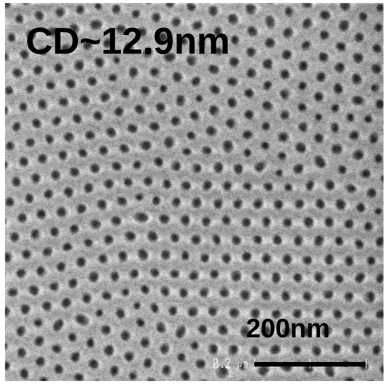
PMMA removal : status



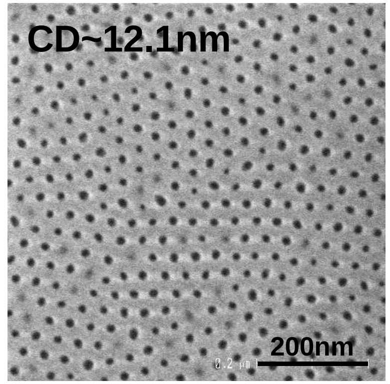
CO dry removal



UV + wet (AA)



Wet (Acid Acetic)



	CO dry removal	*UV + wet (AA)*	*Wet (Acid Acetic)*
Highs	**+ Compatible with DSA on resist** **+ No collapse issues for lines**	**+ Efficiency**	**+ Less steps**
Lows	- **CD Control after litho**	- **Compatibility issues with resist** - **Collapse issues for lamellar BCP** - **More steps**	**- CD Control after litho.** **- Compatibility issues with resist** **- Collapse issues for lamellar BCP**

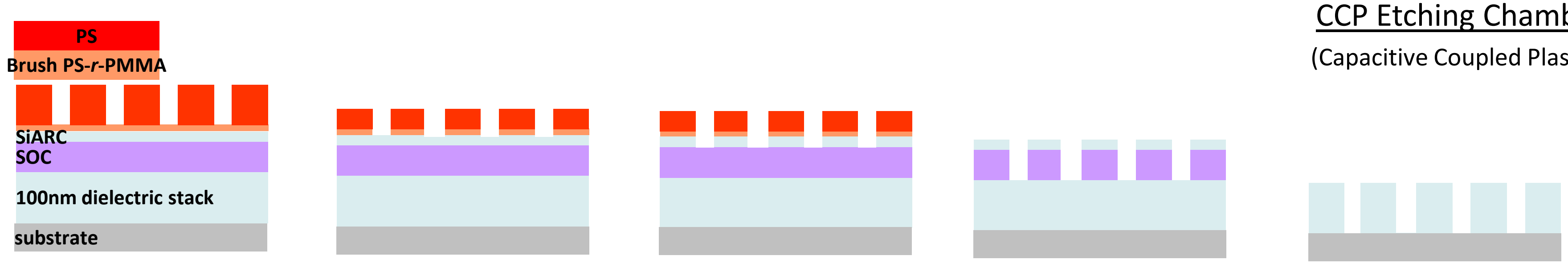
Needs further investigations (CO dry removal)

Wet approach used for the next studies (UV + wet (AA), Wet (Acid Acetic))

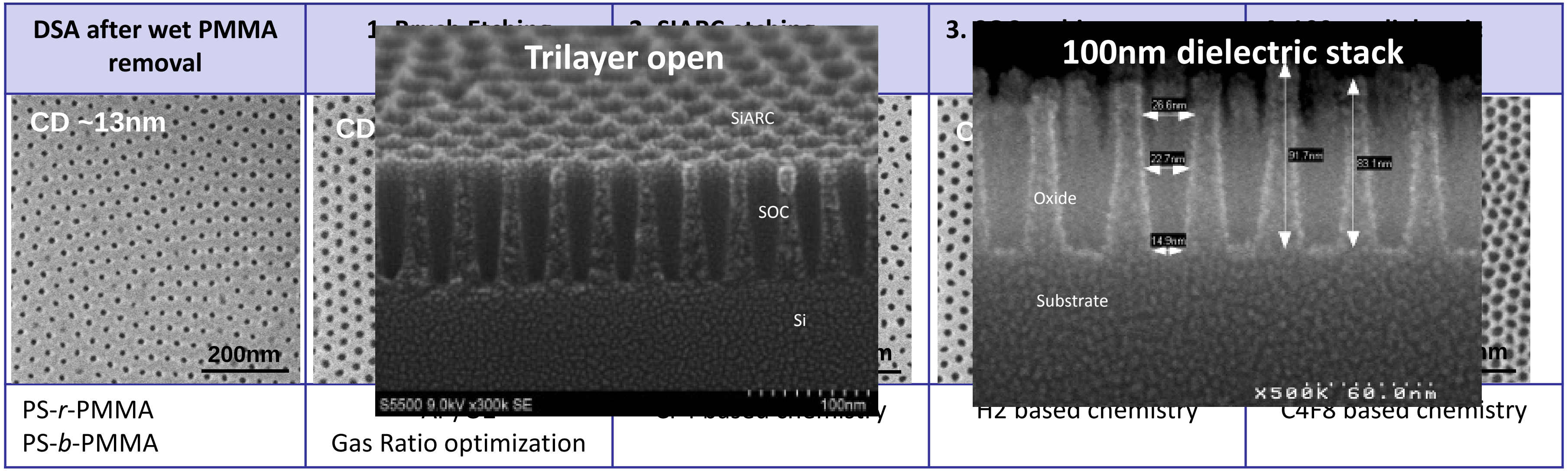
Outline

- Via patterning by DSA
- PMMA removal
- Contact Shrink transfer
  - Transfer into dielectric stack
  - Contact Shrink for MEOL & BEOL
  - CDU
  - Remaining challenges
- Conclusion

Transfer into dielectric stack



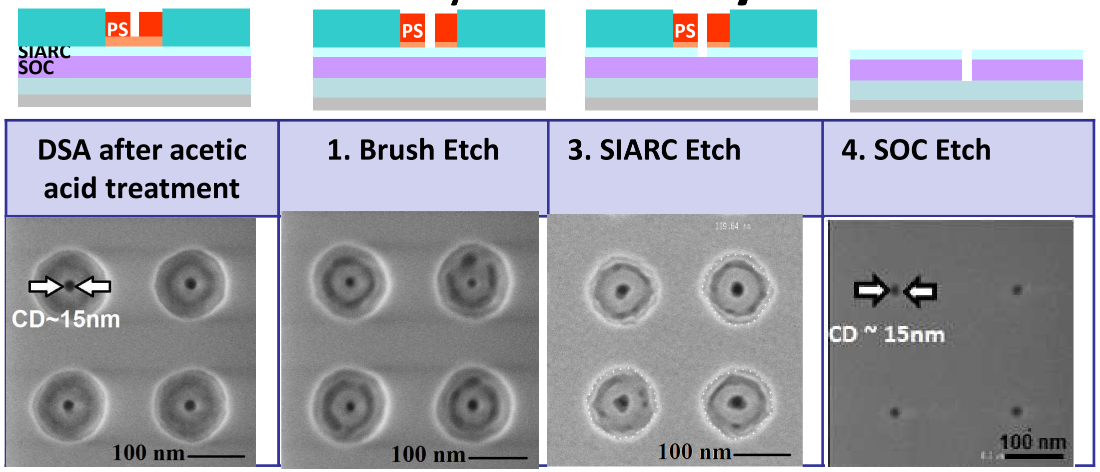
CCP Etching Chamber
(Capacitive Coupled Plasma)



- Key points for CD control & low hole distortion :
  - **Ar/O2 ratio** optimization during brush etching
  - SiARC etching with **almost infinite selectivity to PS**

CH integration flow for MEOL & BEOL

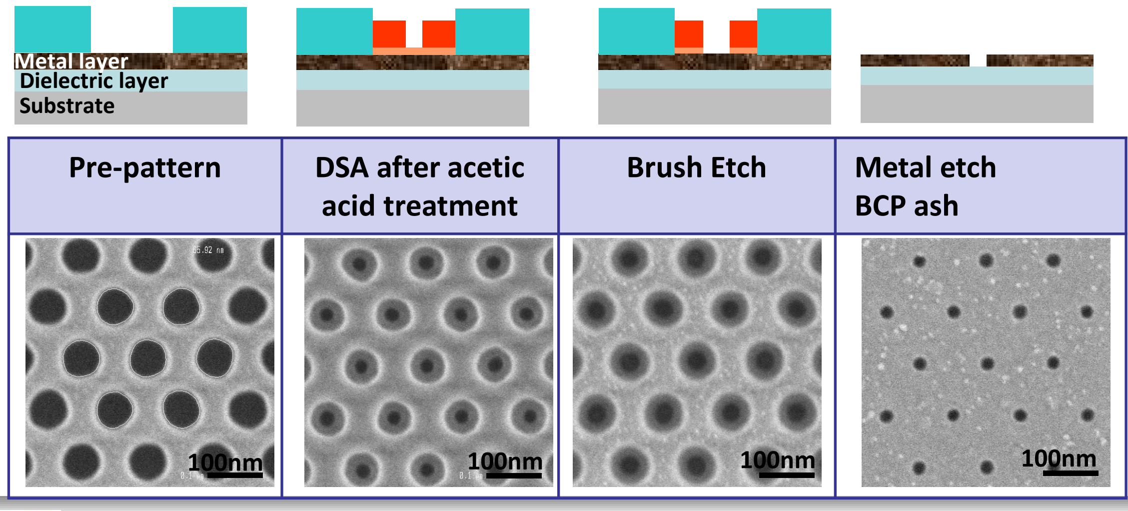
- DSA inside trilayer on **trilayer HM** : **MEOL** applications



CCP Etching Chamber

(Capacitive Coupled Plasma)

- DSA inside trilayer on **metal HM** : **BEOL** applications

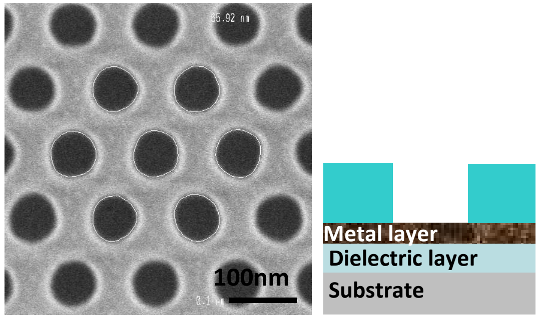


ICP Etching Chamber

(Inductive Coupled Plasma)

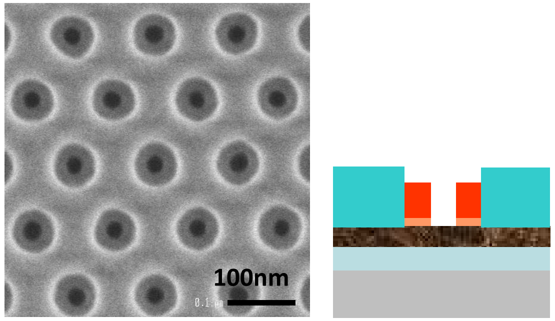
CDU wafer after DSA

Guiding pattern:



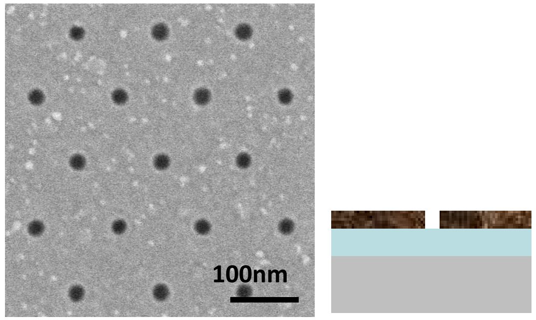
Mean CD = 65nm
3 σ (CDU wafer) = 5.9nm

DSA after brush opening:



Mean CD = 33nm
3σ (CDU wafer) = 2.5 nm

DSA transfer in metal:

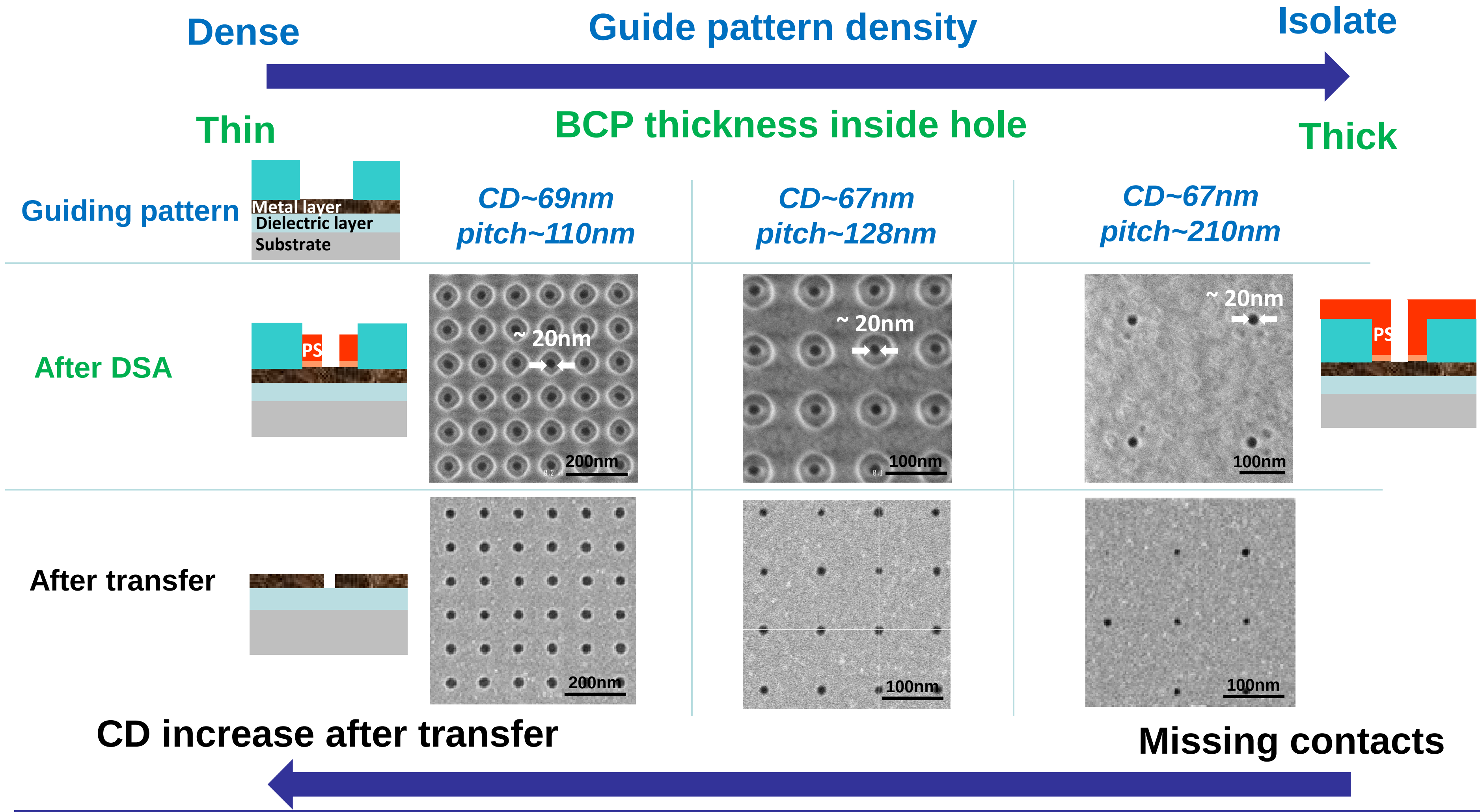


Mean CD = 25nm
3σ (CDU wafer) = 3.4 nm

CD shrink down to 25 nm

CDU improvement after DSA process

DSA process pitch dependence on same wafer



BCP thickness inside holes impacts etching performances
Remaining challenge : to perform several pitch on same wafer

Conclusion

- **CO based chemistry is a promising full dry PMMA removal**
  - Infinite selectivity of h-PMMA over h-PS
  - Etch stop on PS and on brush layer
  - Need of further investigations to better understand the deposition & etch regimes

- **CH hole shrinking by DSA successfully demonstrated for MEOL & BEOL integration :**
  - Transfer into trilayer, metal & dielectric stack demonstrated in ICP and CCP chamber
  - CDU improved by DSA

- **Remaining challenges :**
  - DSA processes' dependence on pre-pattern density

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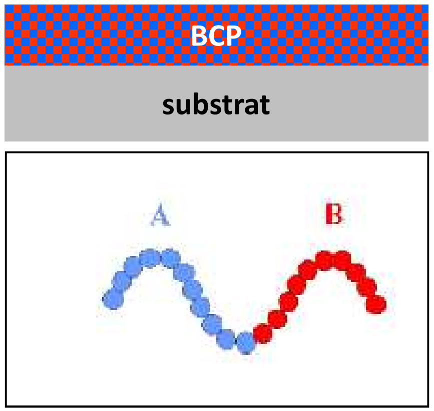
Thank you for your attention

Via patterning by DSA

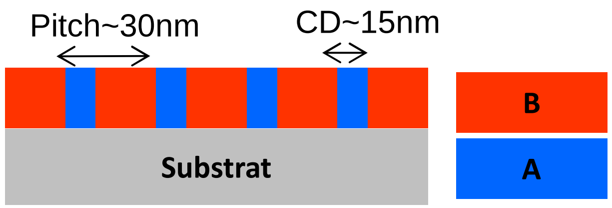
- Block copolymers

disordered

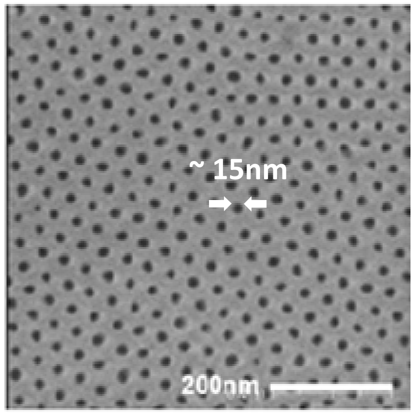


annealing →

Ordered



Cylindrical morphology



1 polymer ↔ 1 morphology ↔ 1 CD ↔ 1 pitch

Possibility to create sub-15nm lines and holes