Cleaning Surfaces from Nanoparticles with Polymer Film: Impact of the Polymer Stripping

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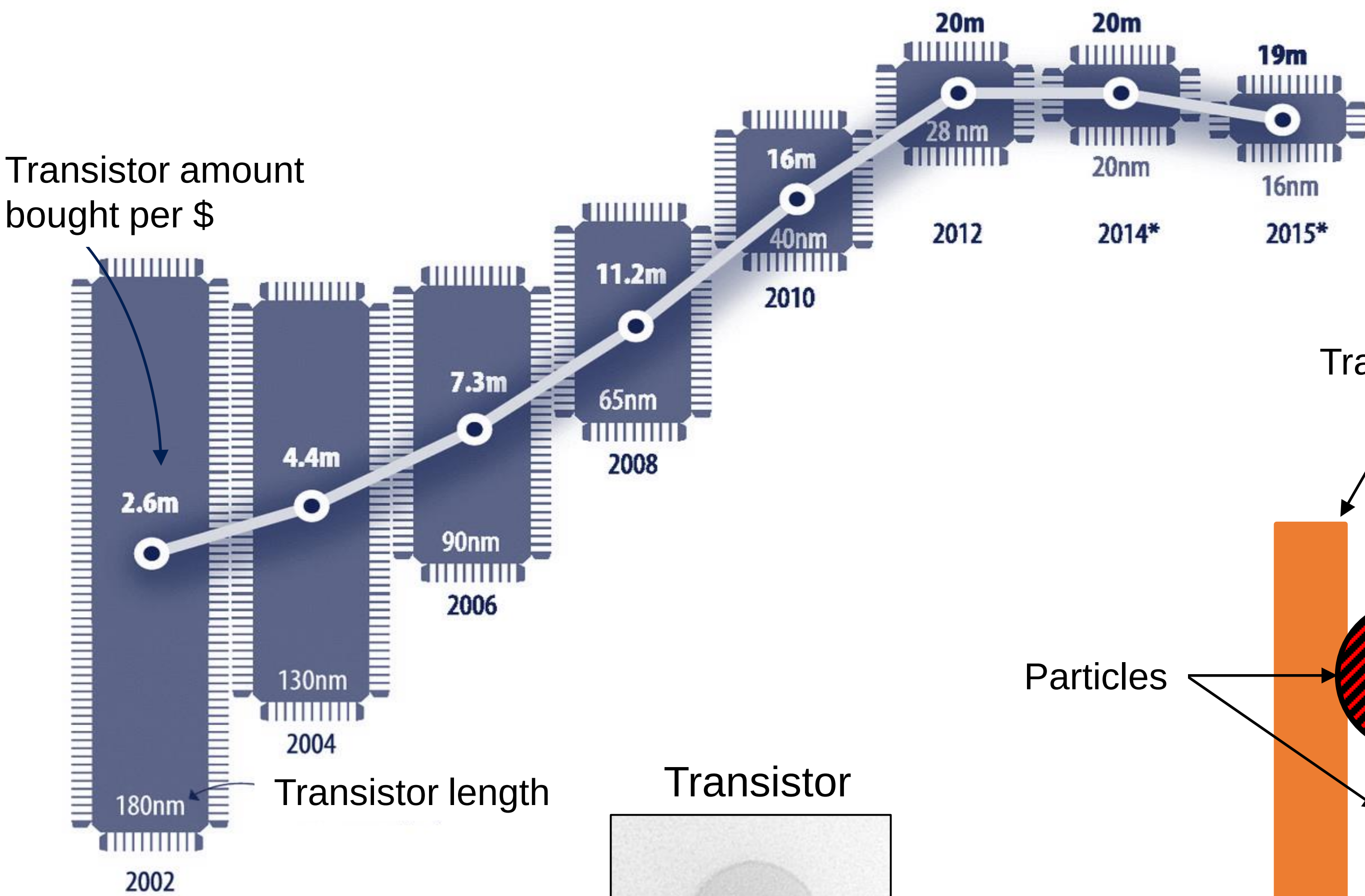
Laboratoire interdisciplinaire de Physique

DE LA RECHERCHE À L'INDUSTRIE

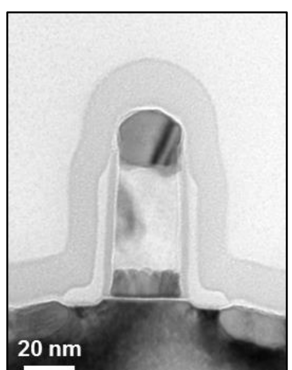
Outline

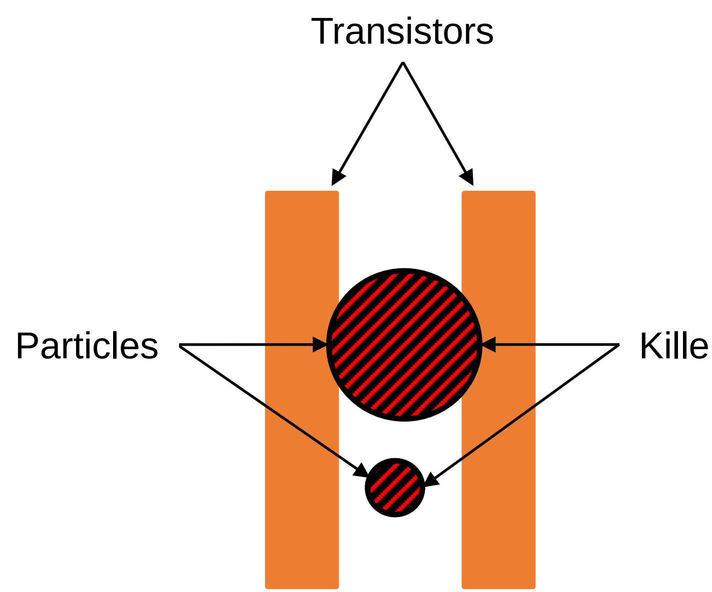
- Motivations
- Experimental setup
- Results
- Hypothesis
- Conclusion

Miniaturization & particle impact on yield



Transistor

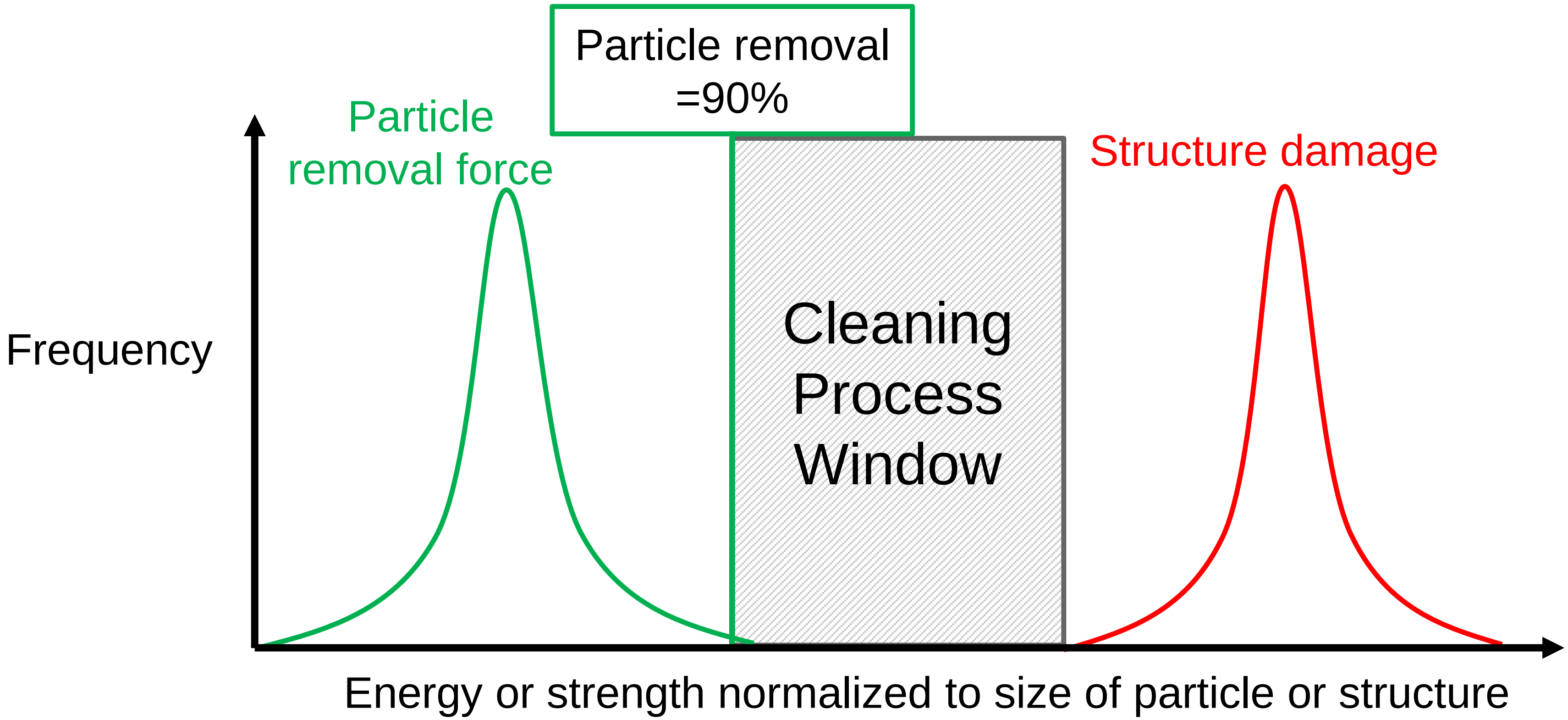


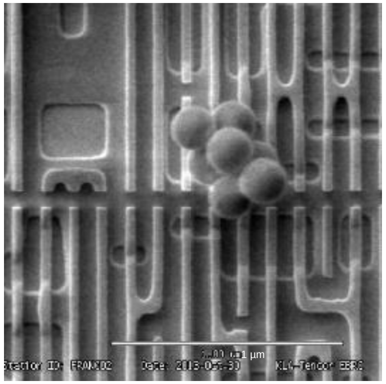


Miniaturization ➔ Critical particle size decrease

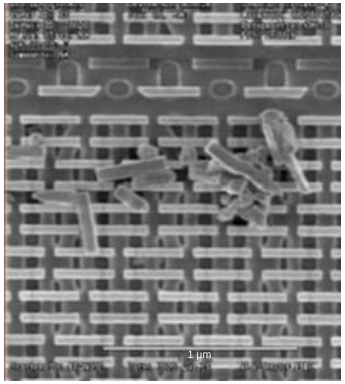
www.economist.com/news

Challenge: Particle removal / No damage





Particles on transistors



Structure damage

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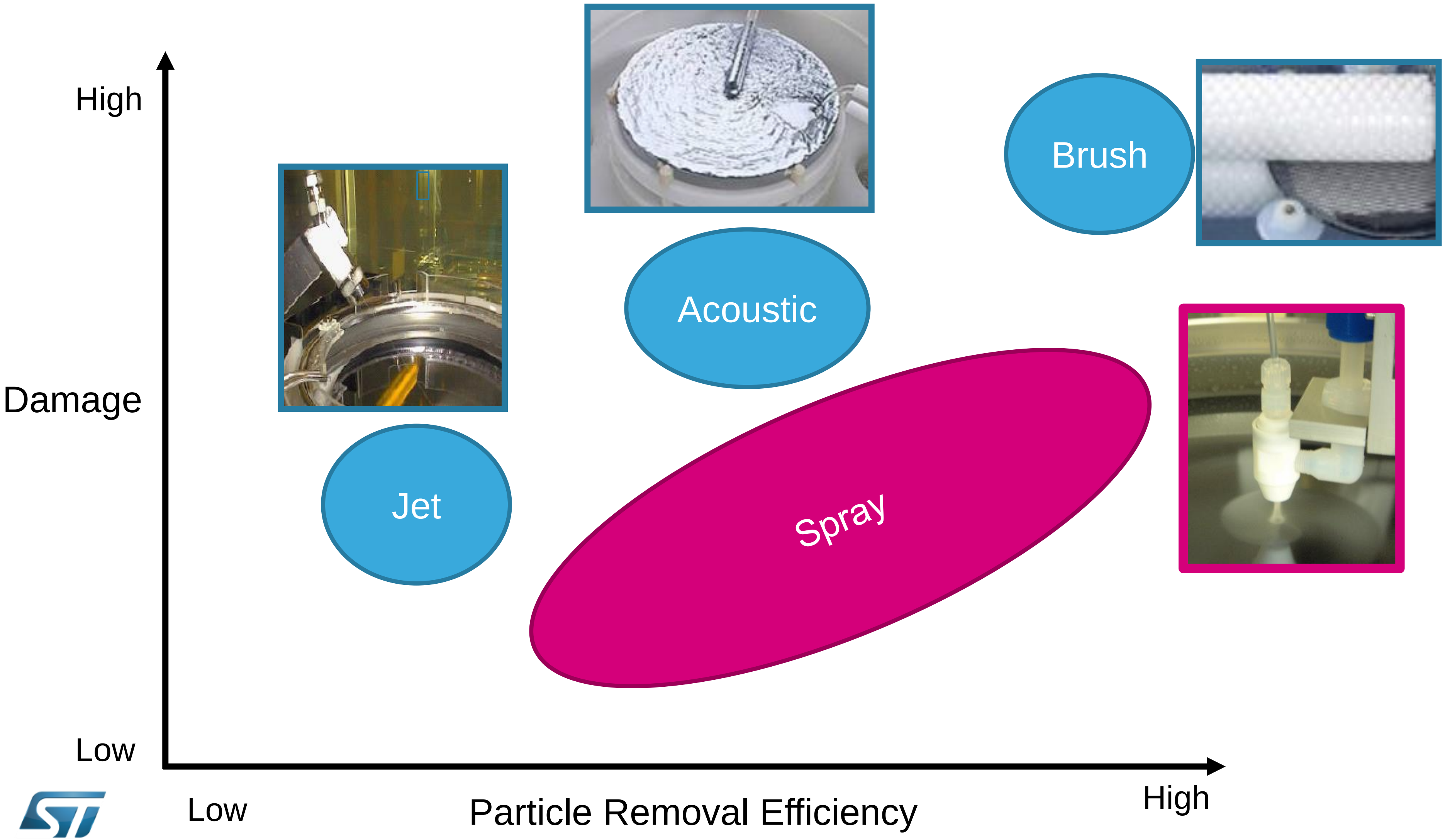
Challenge: Particle Removal / No Damage



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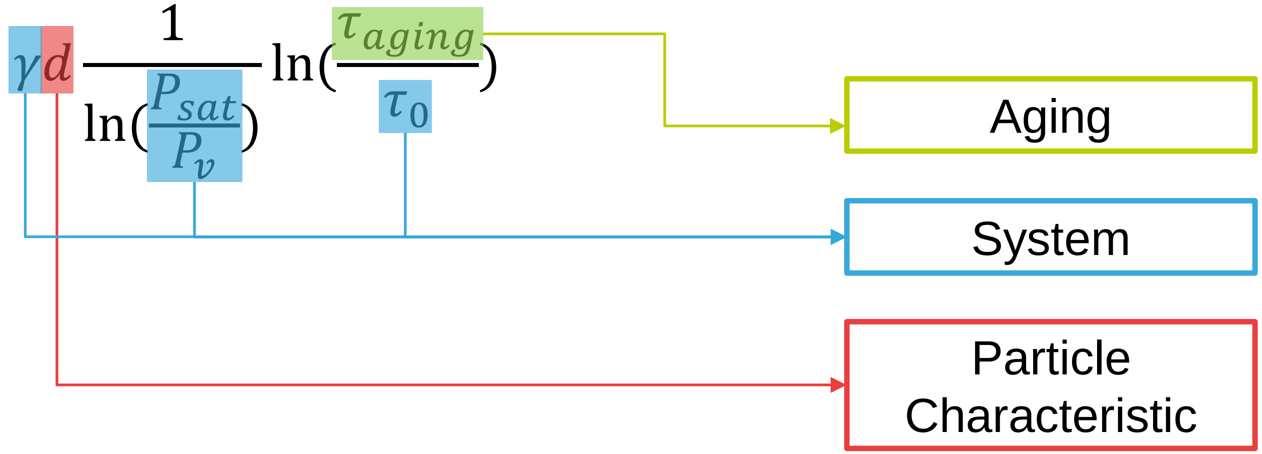
Particle Removal Condition

$$F_{adhesion} < F_{external}$$

Parameters influencing $F_{adhesion}$:

$$F_{adhesion}(\tau_{aging}) = \gamma d \frac{1}{\ln(\frac{P_{sat}}{P_v})} \ln(\frac{\tau_{aging}}{\tau_0})$$



γ liquid surface tension
d distance taking into acount the geometrical characteristics of the contact
P_{sat} saturated water pressure
P_v vapour pressure
τ_{aging} time since contamination
τ_0 time needed to condense one liquid layer

Bocquet, L., *& al*, Nature (1998)

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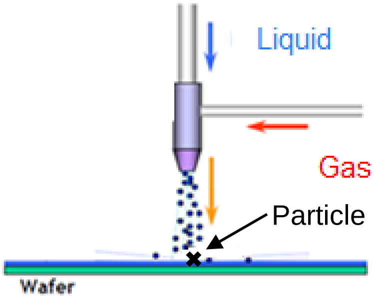
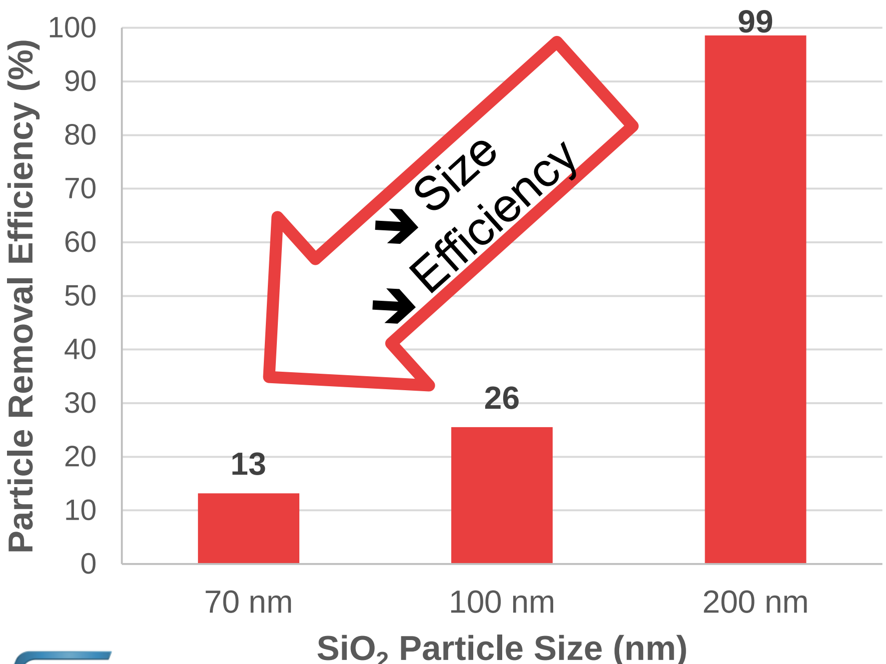
Spray still efficient enough ?

$$F_{adhesion}(\tau_{aging}) = \gamma d \frac{1}{\ln(\frac{P_{sat}}{P_v})} \ln(\frac{\tau_{aging}}{\tau_0})$$

Bocquet, L., & *al*, Nature (1998)

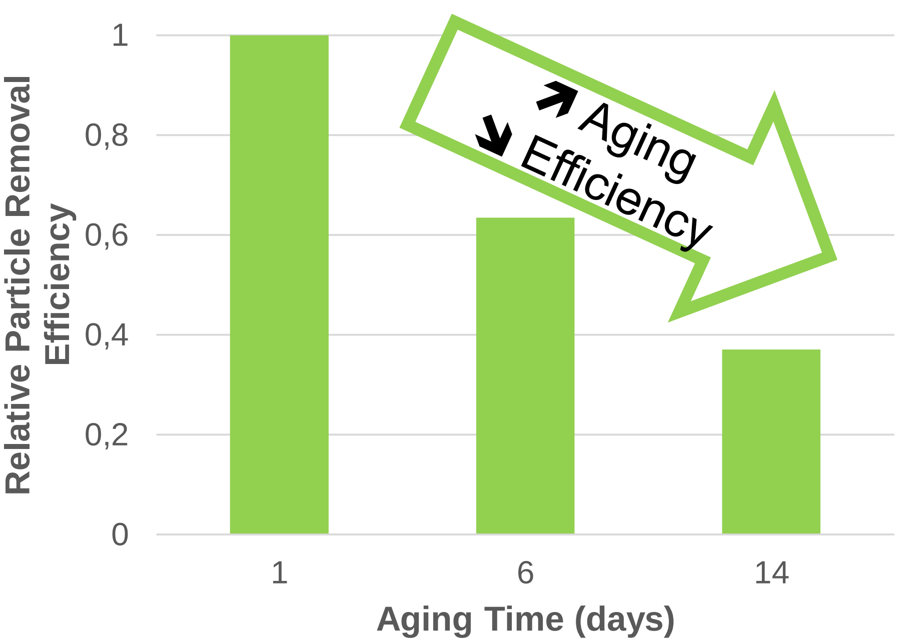


Spray cleaning efficiency on silicon wafer depending on particle size



Aibara, M., & *al*, ECS conf. (2017)

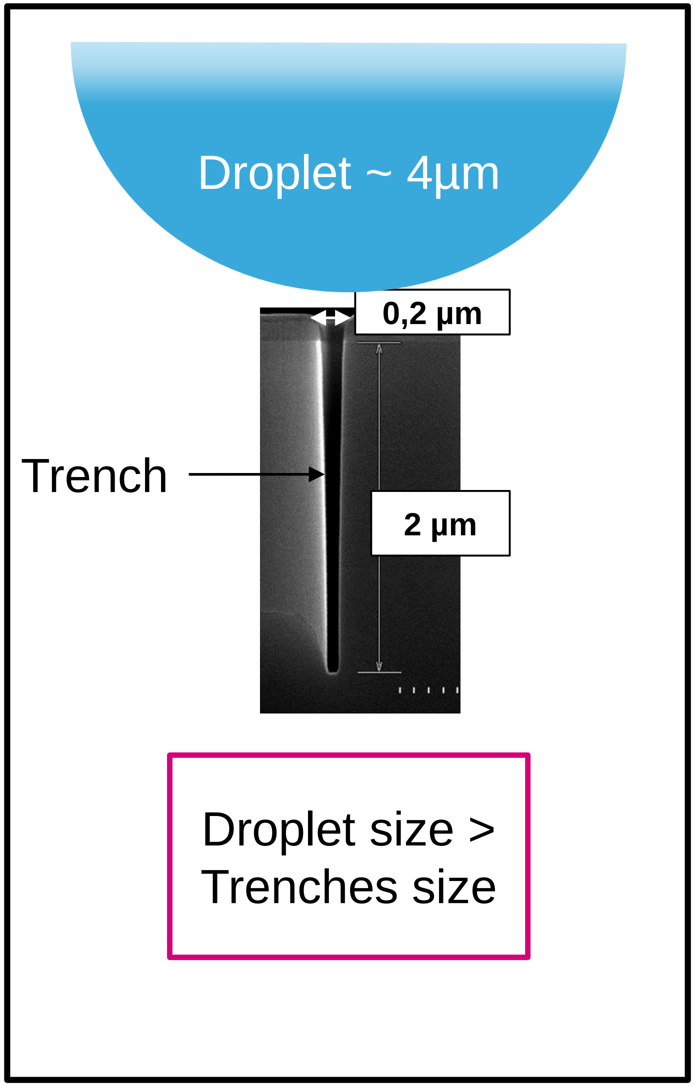
Spray cleaning efficiency on silicon wafer depending on aging time



Spray still efficient enough ?

- Strong particle size dependence on removal efficiency
- Strong aging time dependence on removal efficiency
- Droplet size limitation

→ New solution required



Motivations

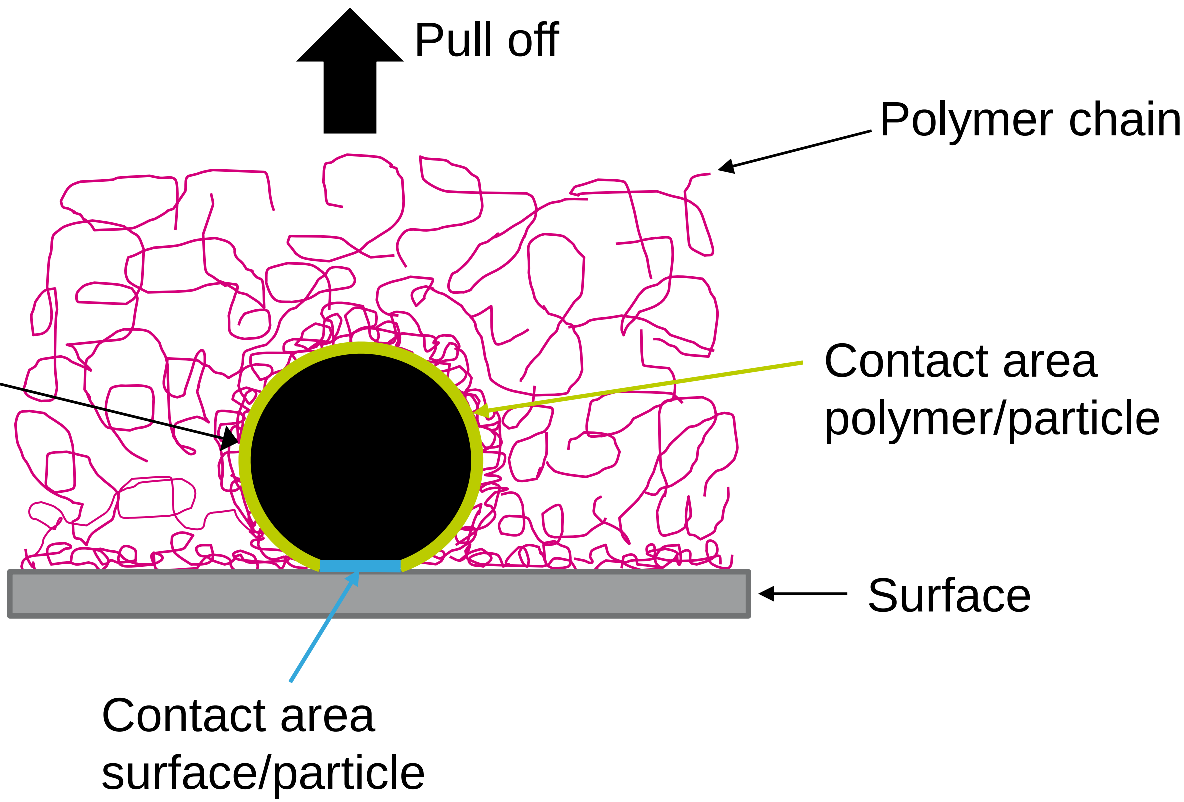
Find a new method to remove nanoparticles :

- Without structure damage
- Environmental friendly

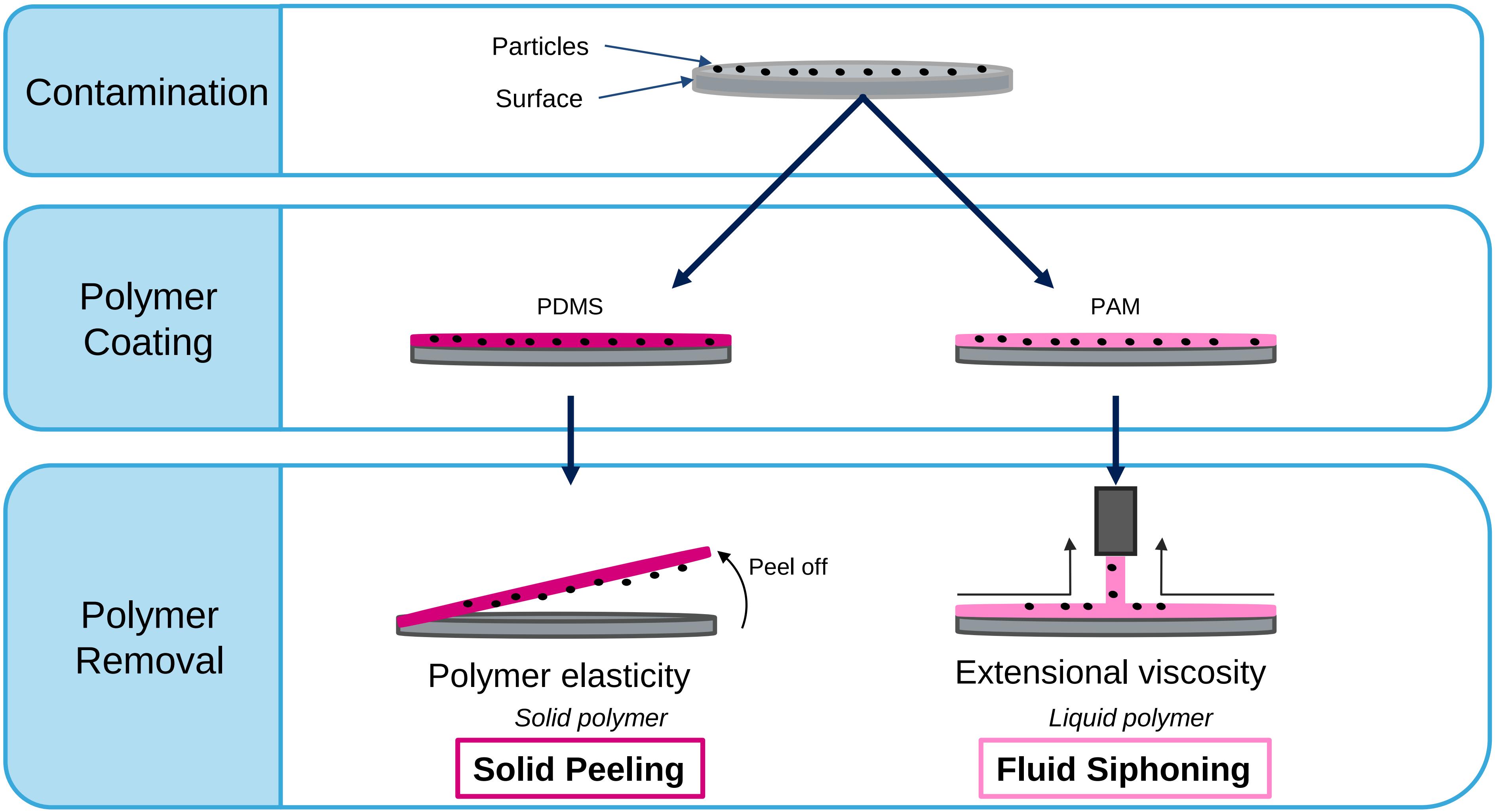
New solution based on polymer removal

$$F_{adhesion}^{\ polymer/particle} > F_{adhesion}^{\ surface/particle}$$

$$\text{Contact area}^{\ polymer/particle} > \text{Contact area}^{\ surface/particle}$$



2 postulated ways to remove the polymer

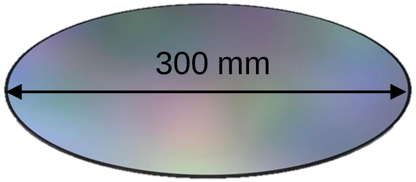


Lin, P., *& al*, Nanotechnology (2013)

Walker, T.W., *& al*, JoR (2014)

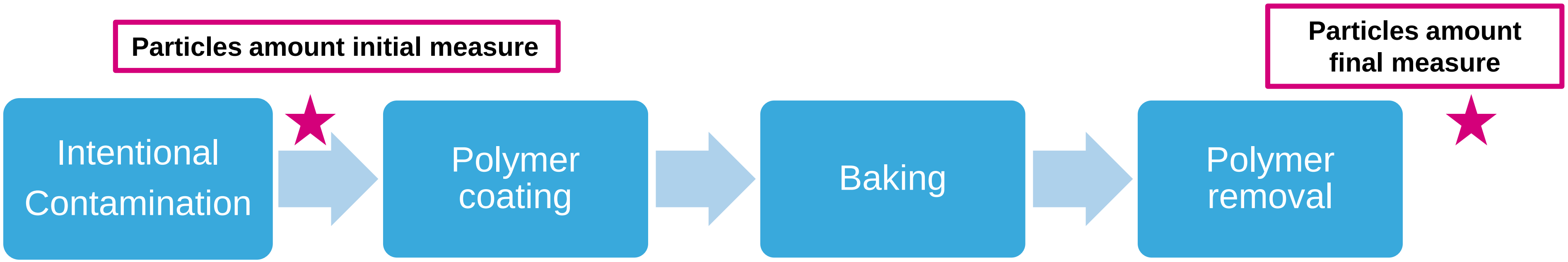
Outline

- Motivations
- Experimental setup
  - Process step
  - Polymer removal
- Results
- Hypothesis
- Conclusion



Silicon wafer

Method - Process Steps



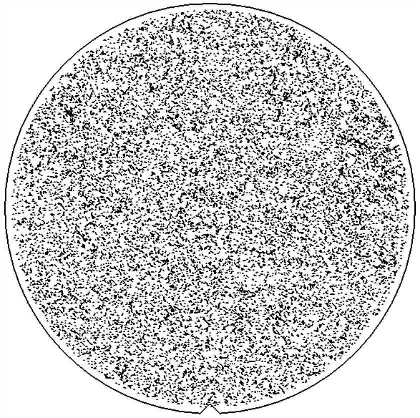
Contamination: Spin dryer / SiO_2 ➔ 60 nm

Polymer coating: Polymer 1,8 µm thickness

Baking: No reticulation (130°C)

Polymer removal: Chemical solution (SPM / SC1)

Measurement: Laser diffraction spectrometer



Wafer defect mapping – Initial contamination

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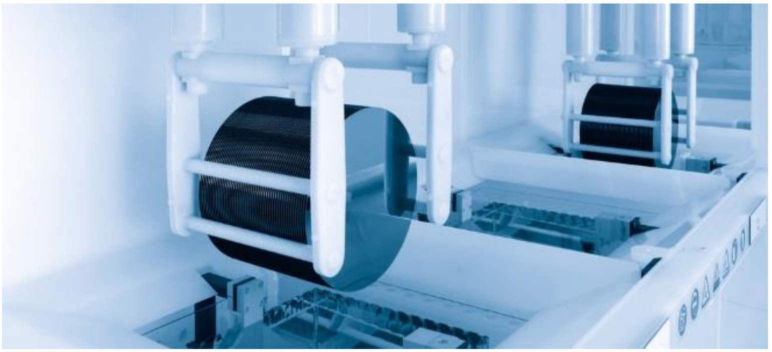
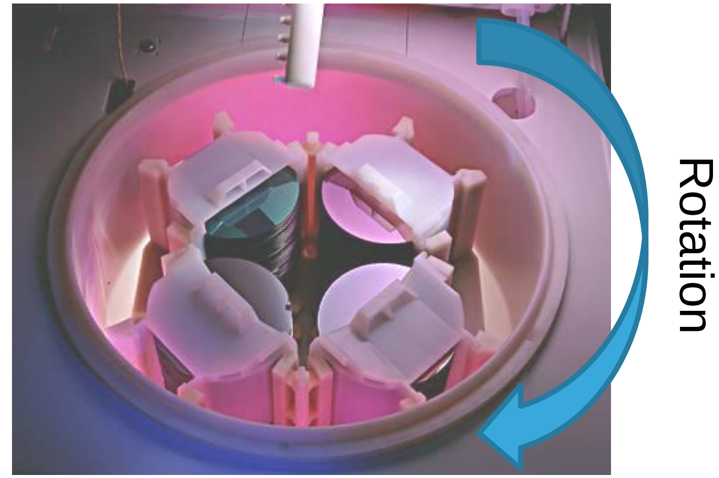
Method – Polymer Removal

Wet Bench

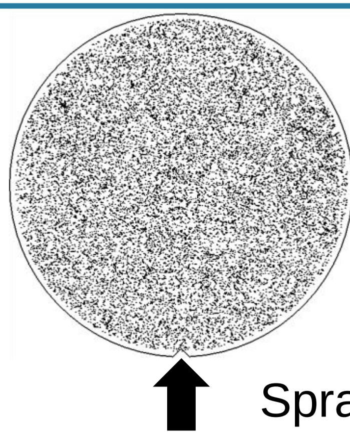


Chemical removal only

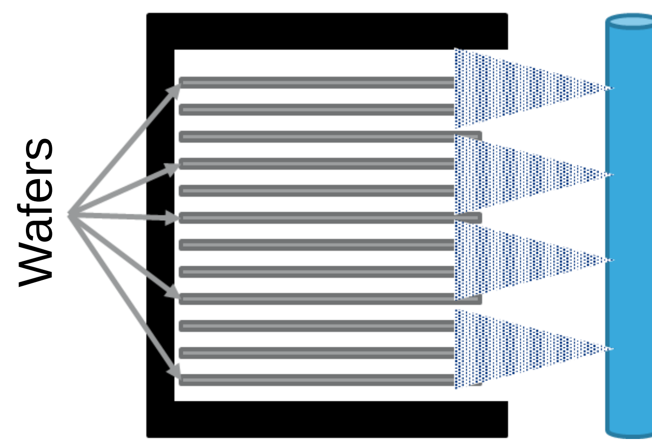
Spray Batch



Chemical & **Physical** removal



Side view



Outline

- Motivations
- Experimental setup
- Results

Polymer removal:
- Wet Bench vs Spray Batch

Polymer coating

Cleaning efficiency

Surface

Contamination:
- Particle Nature (SiO_2, Si_3N_4,…)
- Particle Size
- Aging time

- Hypothesis
- Conclusion

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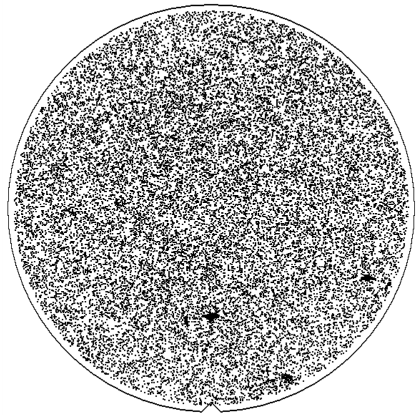
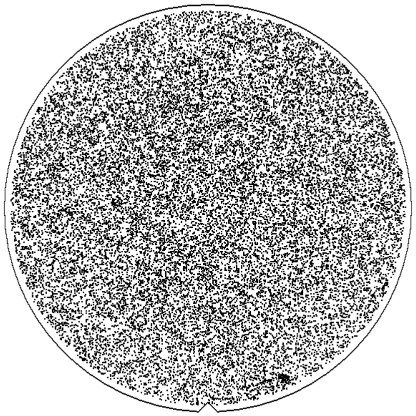
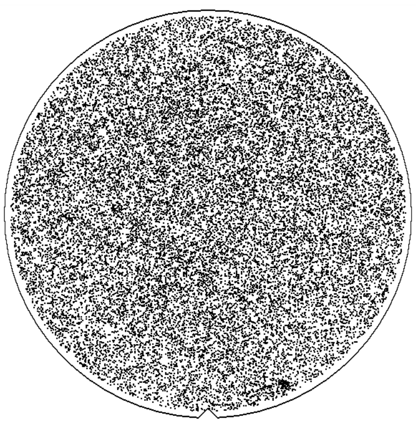
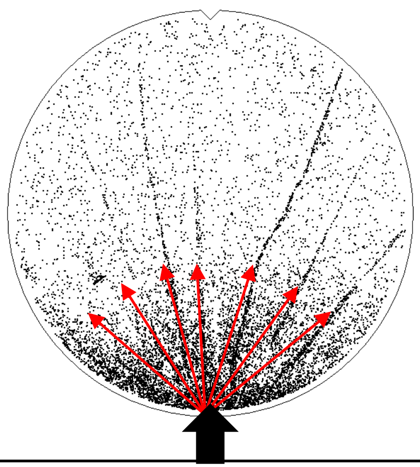
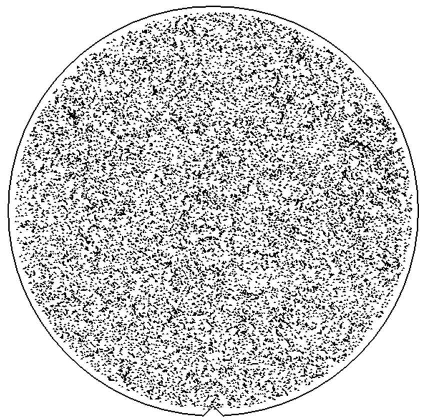
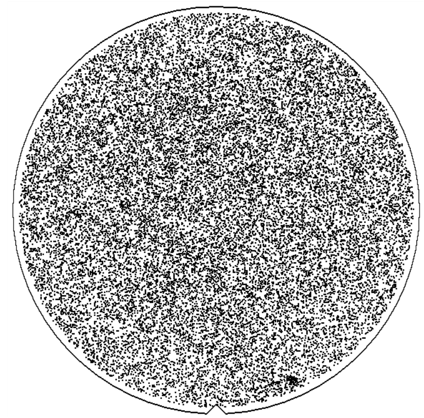
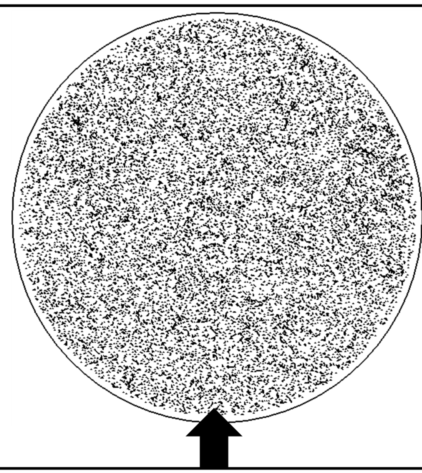
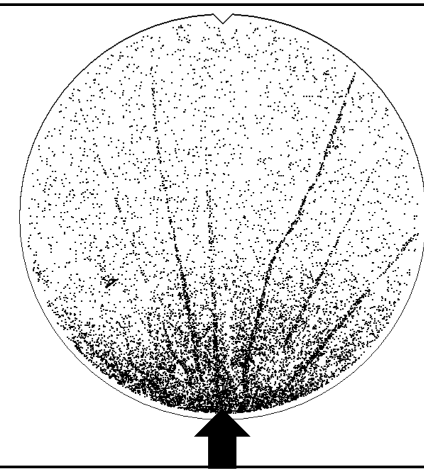
Wet Bench versus Spray Batch

	Polymer	
	Chemical solution (SPM / SC1)	
	Wet Bench	Spray Batch
Initial Particles Mapping		
Final Particles Mapping		
Removal efficiency (%)	0 %	87 %

- Physical action mandatory
- Non uniform removal Particles remain along the spray flow lines

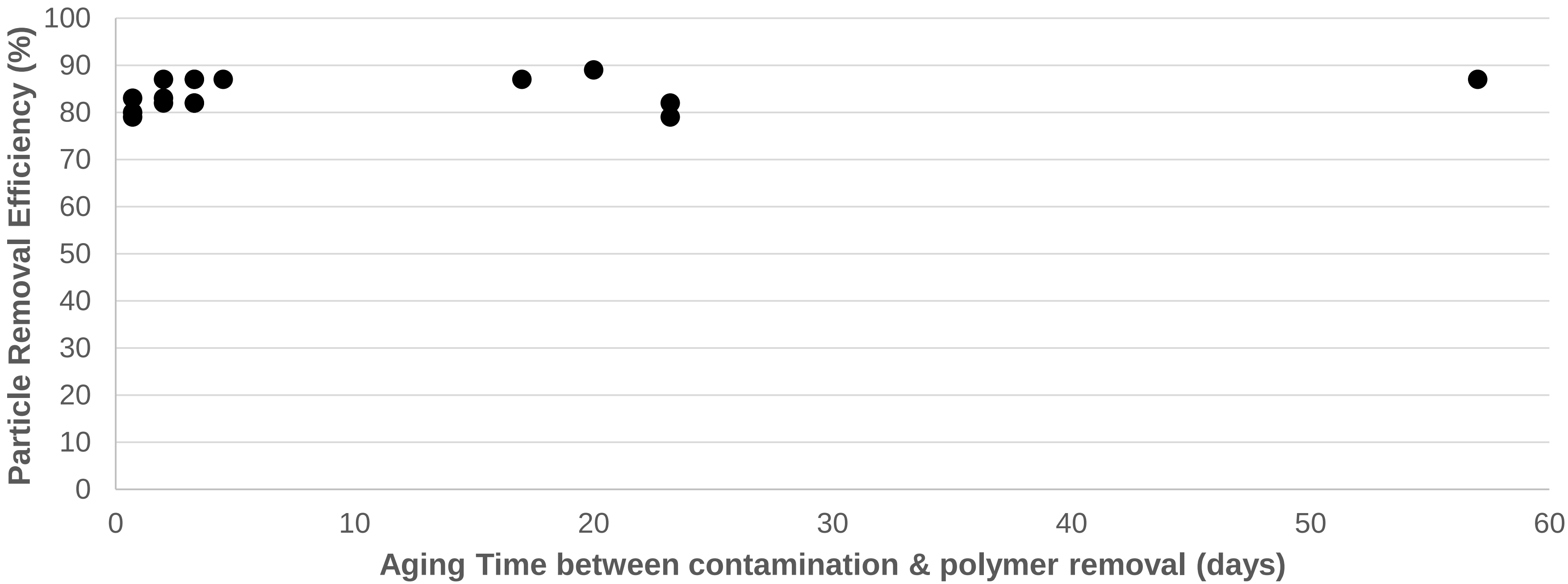
Polymer Presence

	No Polymer	Polymer
	Chemical solution (SPM / SC1) - Spray Batch	
Initial Particles Mapping		
Final Particles Mapping		
Removal efficiency (%)	0 %	87 %

- Polymer needed for particles removal

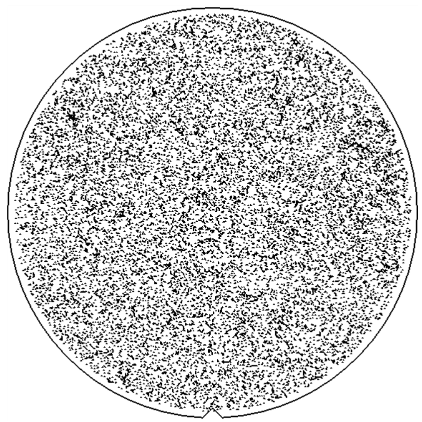
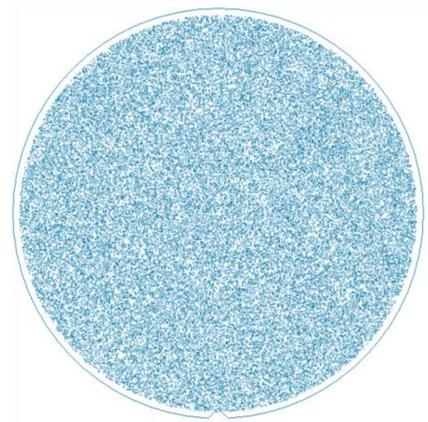
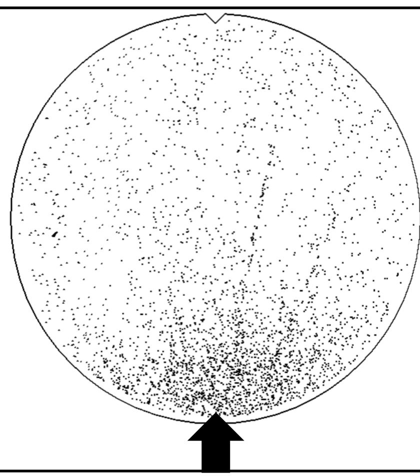
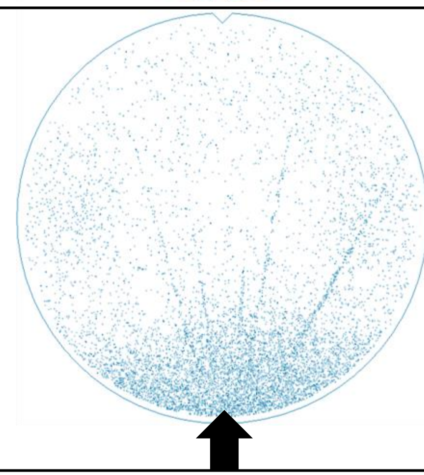
Aging Time

SiO_2 Monodisperse Contamination → Polymer Coating Baking → Polymer Removal Chemical Solution (SPM / SC1) – Spray Batch

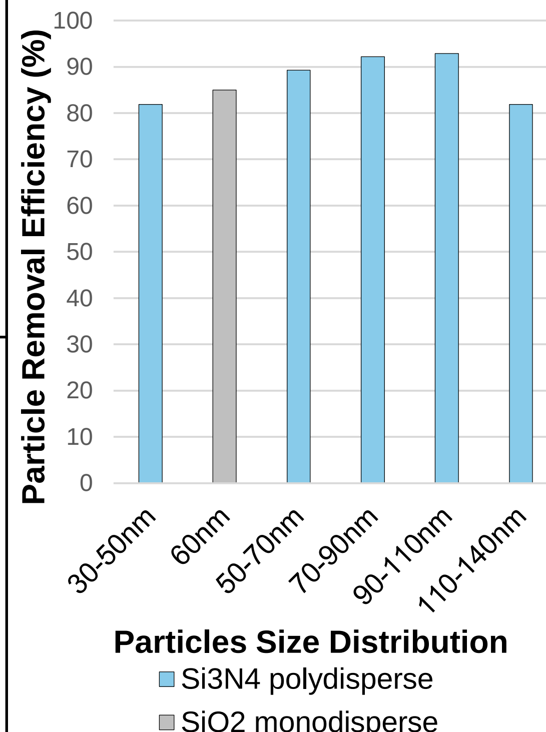


- No aging time dependence on Particle Removal Efficiency

Particles Size & Nature

	SiO_2 monodisperse	Si_3N_4 polydisperse
	Polymer	
	Chemical solution (SPM / SC1) - Spray Batch	
Initial Particles Mapping		
Final Particles Mapping		
Removal efficiency (%)	85 %	85 %

➢ Efficient removal for both particles nature



➢ No size influence on Removal Efficiency

Summary

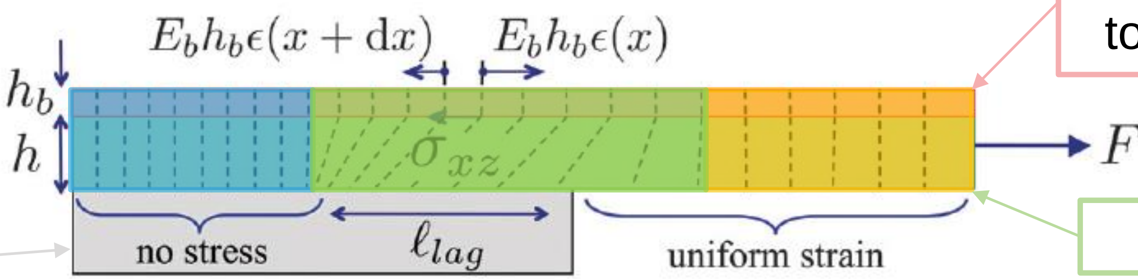
- **No aging time** dependence on removal efficiency
- **No particle nature** dependence on removal efficiency
- **No particle size** dependence on removal efficiency

➔ No influence of the $F_{adhesion}$ ↗ on removal efficiency

- Hypothesis ?

Hypothesis : Peeling Zero Degrees

Shear stress due to expansion ?

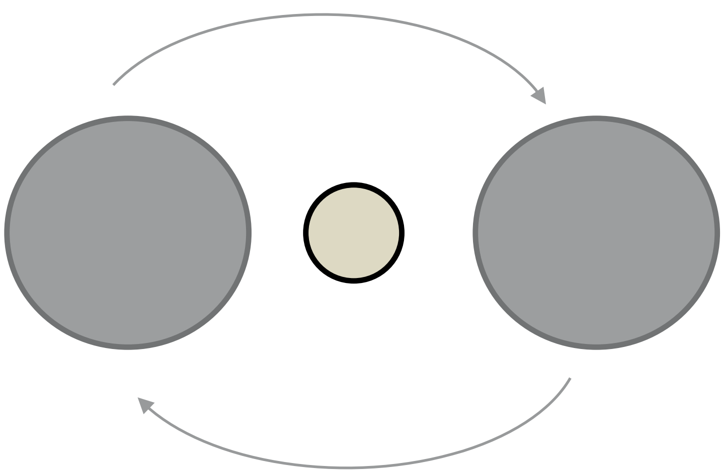


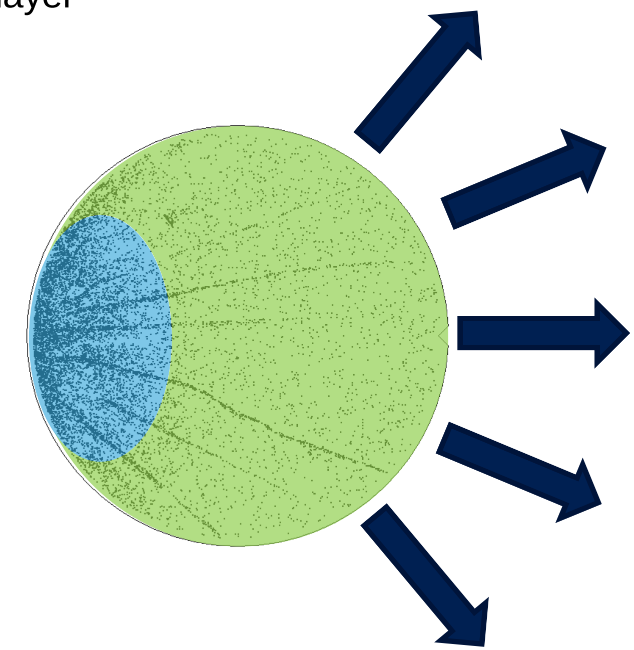
Surface

Bulk polymer

E_b Young Modulus of the hard layer

Spray Batch
Top view



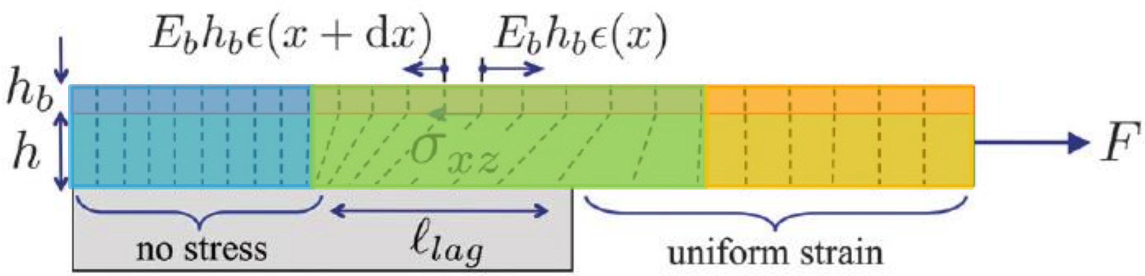


Centrifugal Force

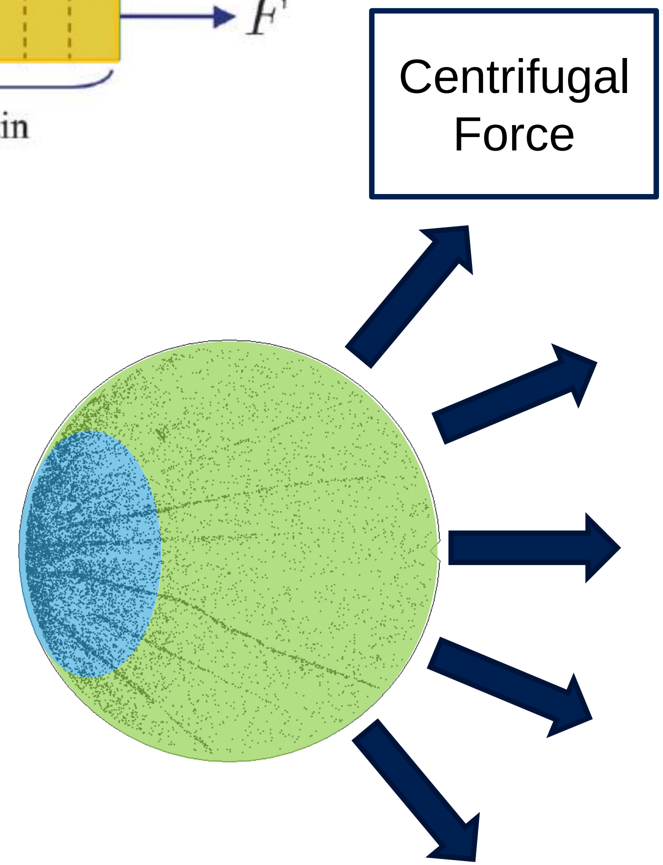
Rotation 80 RPM

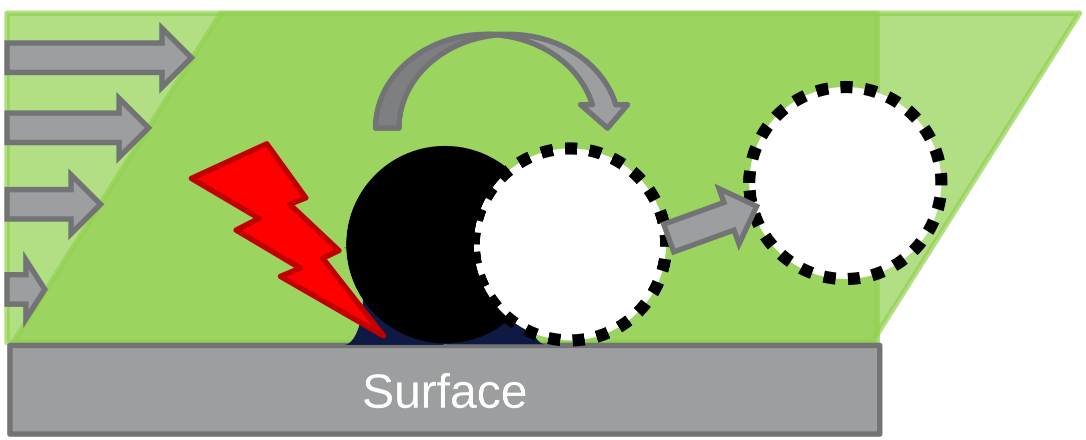
Ponce, S., *& al*, Soft Matter (2015)

Hypothesis : Peeling Zero Degrees



E_b Young Modulus of the hard layer





Ponce, S., *& al*, Soft Matter (2015)

Conclusions & Perspectives

Conclusions

- New solution to remove nanometric particles

→ Aging independent

→ Particle nature/size independent

→ Without pattern damage

Perspectives

- To fully understand the mechanism of polymer removal

- Verify the peeling zero degrees hypothesis

→ Adhesion & rheological studies

Thank you for your attention