Surfaces and Textures

Nov 2010

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D. Dalmas, J. Teisseire, S. Grachev,
E. Sondergard, E. Barthel

Silicate glasses are exceptional materials

- transparent
- stiff, hard
- experience… a glass transition

- mildly reactive surface

Saint-Jérôme
Albrecht Dürer

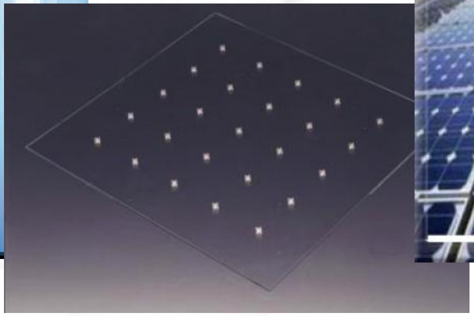
Surface Modification – why ?

Functionalization

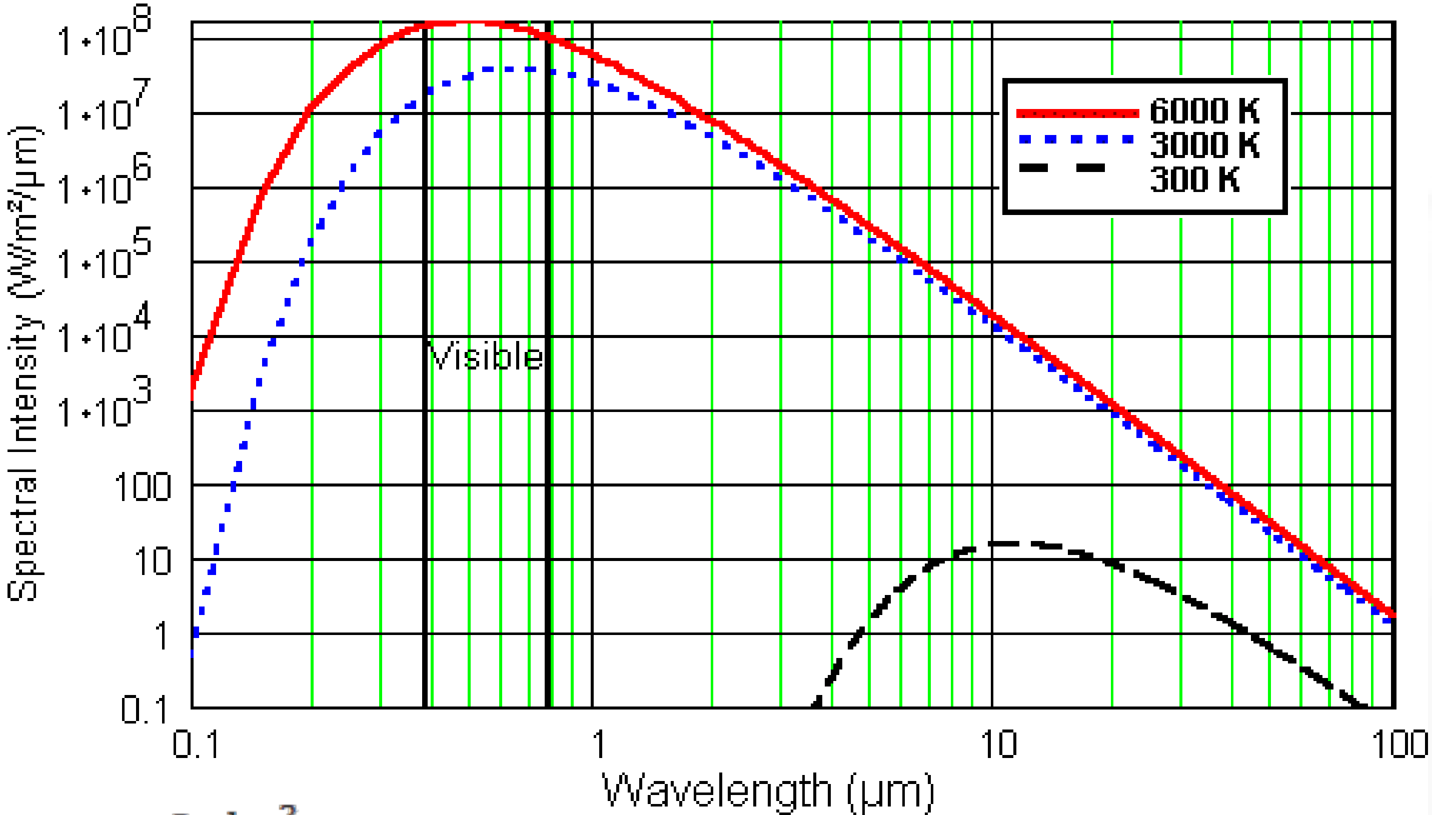
- *optics*
- *wetting, contact, adhesion*







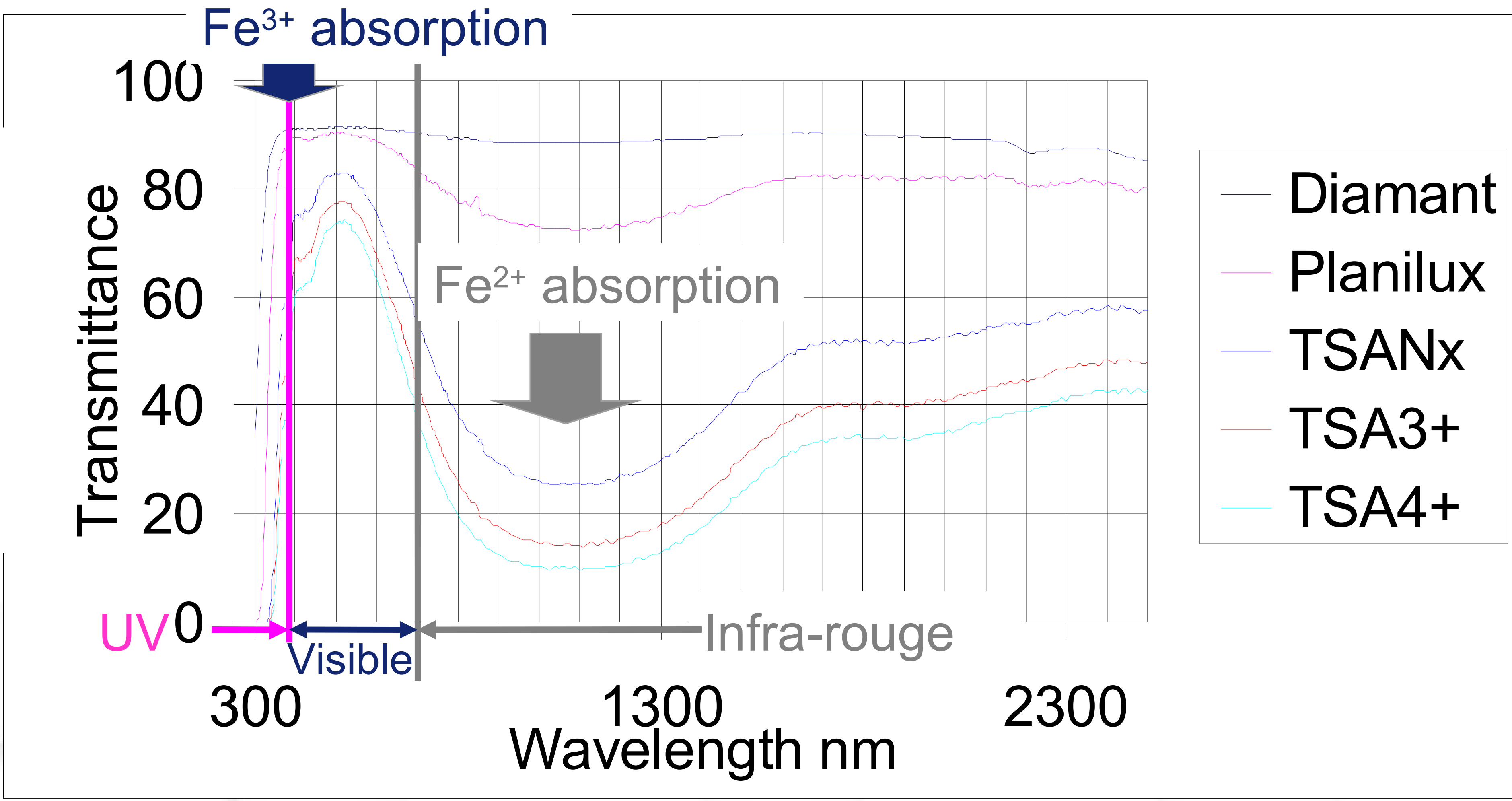
Blackbody radiation



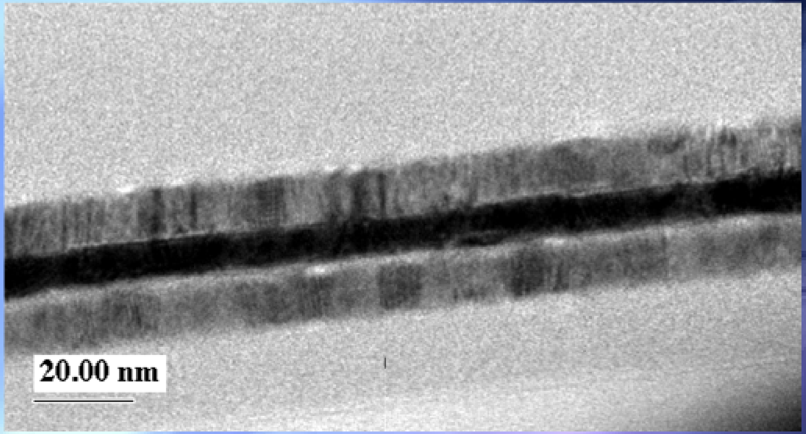
$$F(\lambda) = \frac{2\pi hc^2}{\lambda^5\left(\exp\left(\frac{hc}{k\lambda T}\right)-1\right)}$$

www.pvcdrom.pveducation.org

Adjustment of the optical properties and of the solar energy transmission of the glass

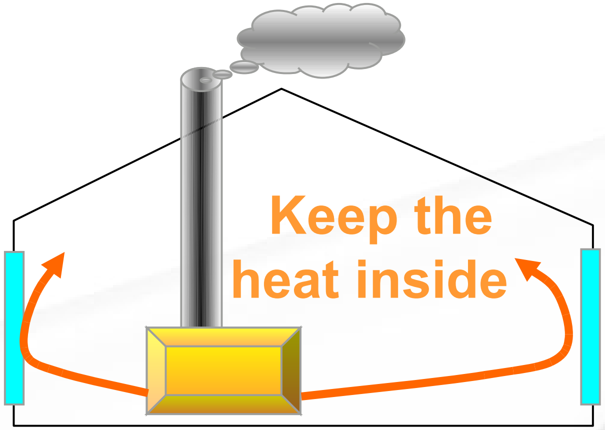


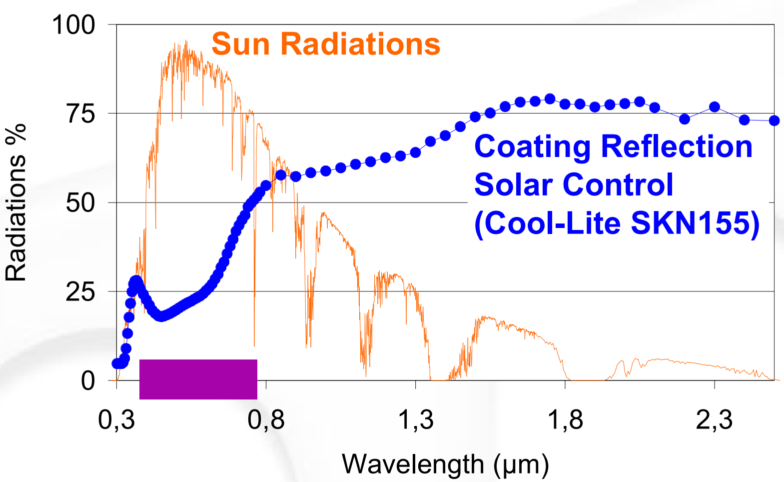
M.-H. Chopinet

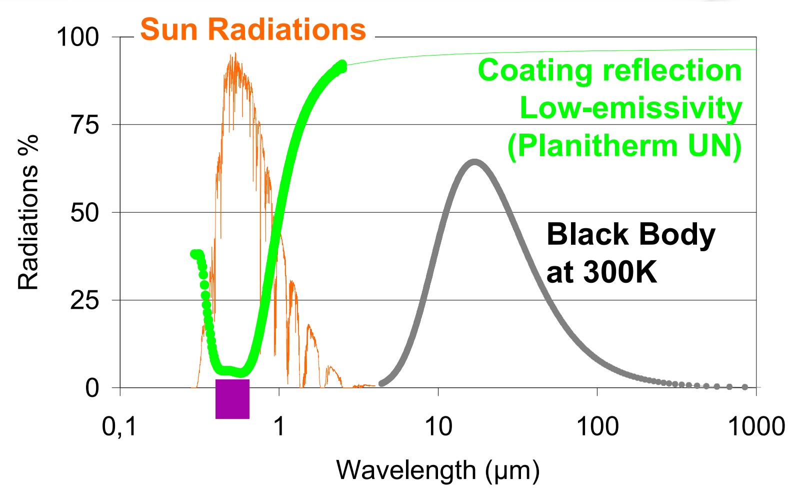

20.00 nm

Solar Control

- Two functions to reduce heat transfer due to radiations
  - Solar Control
  - Low Emissivity



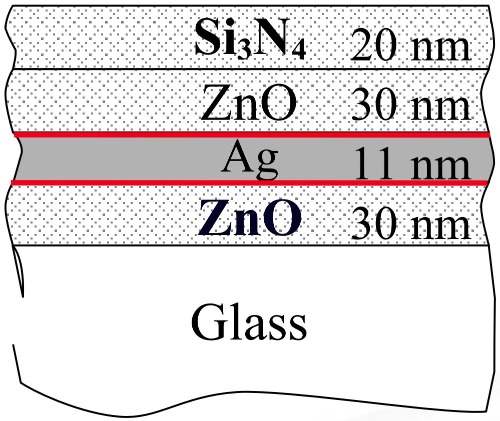




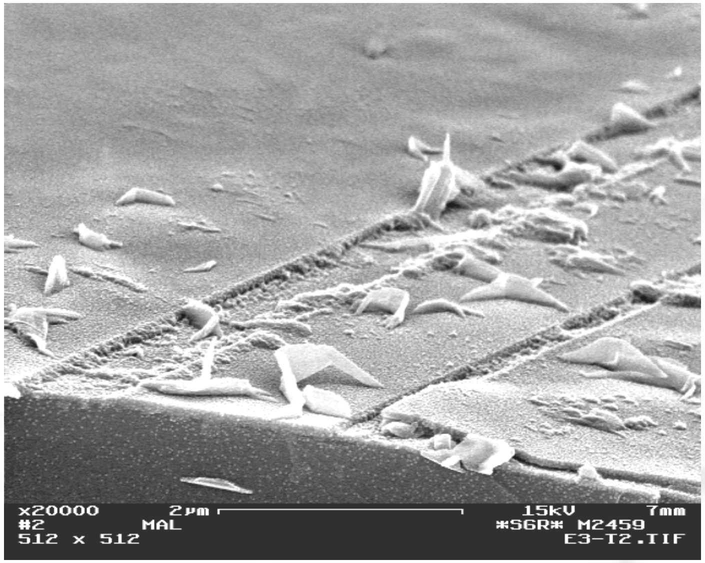
Multilayers and scratch resistance

Weak adhesion

$1 \sim 2$ J/m^2



Scratch

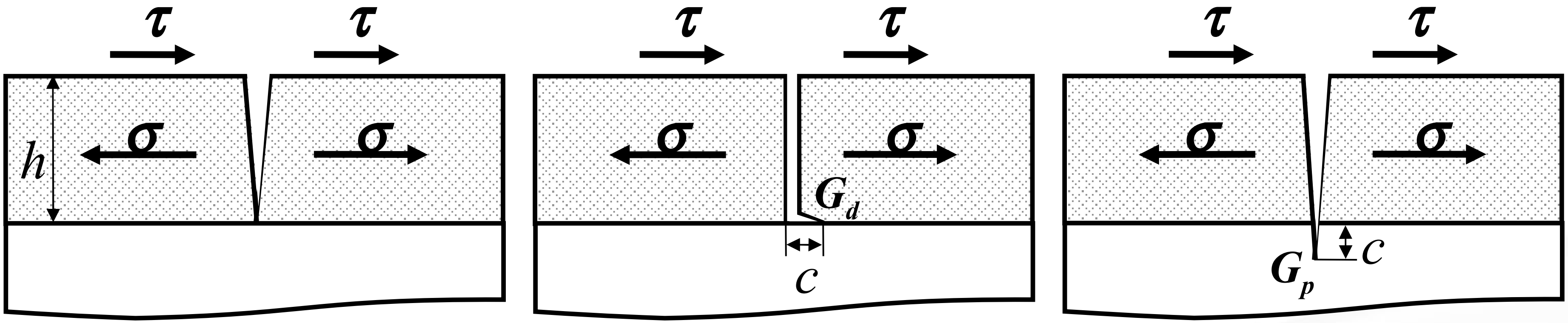


G. Duisit, S. Pelletier (TMM, SGR)

Friction

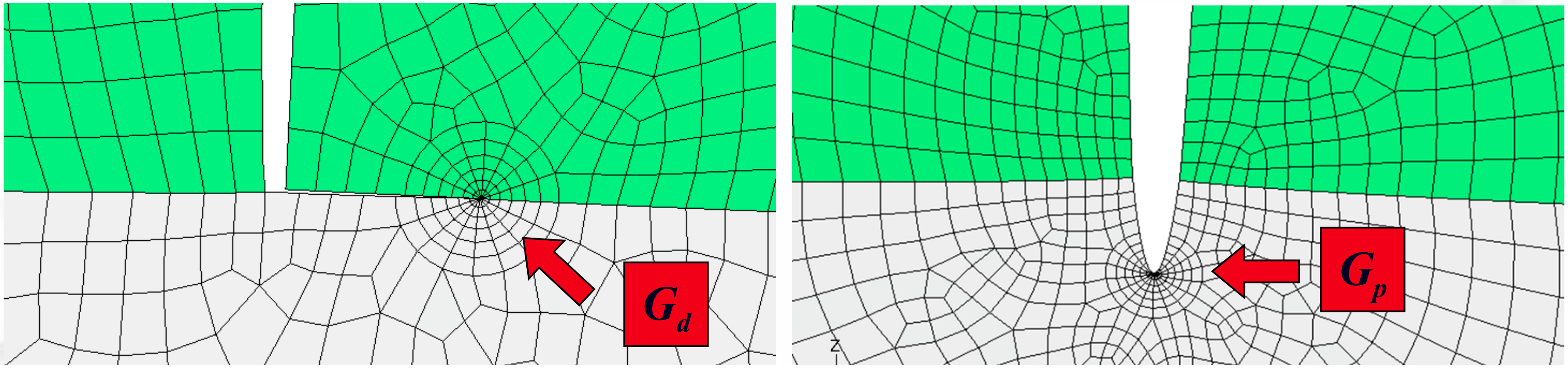
Steel/$\mathbf{Si_3N_4}$: **μ = 0.9**

Crack deflection



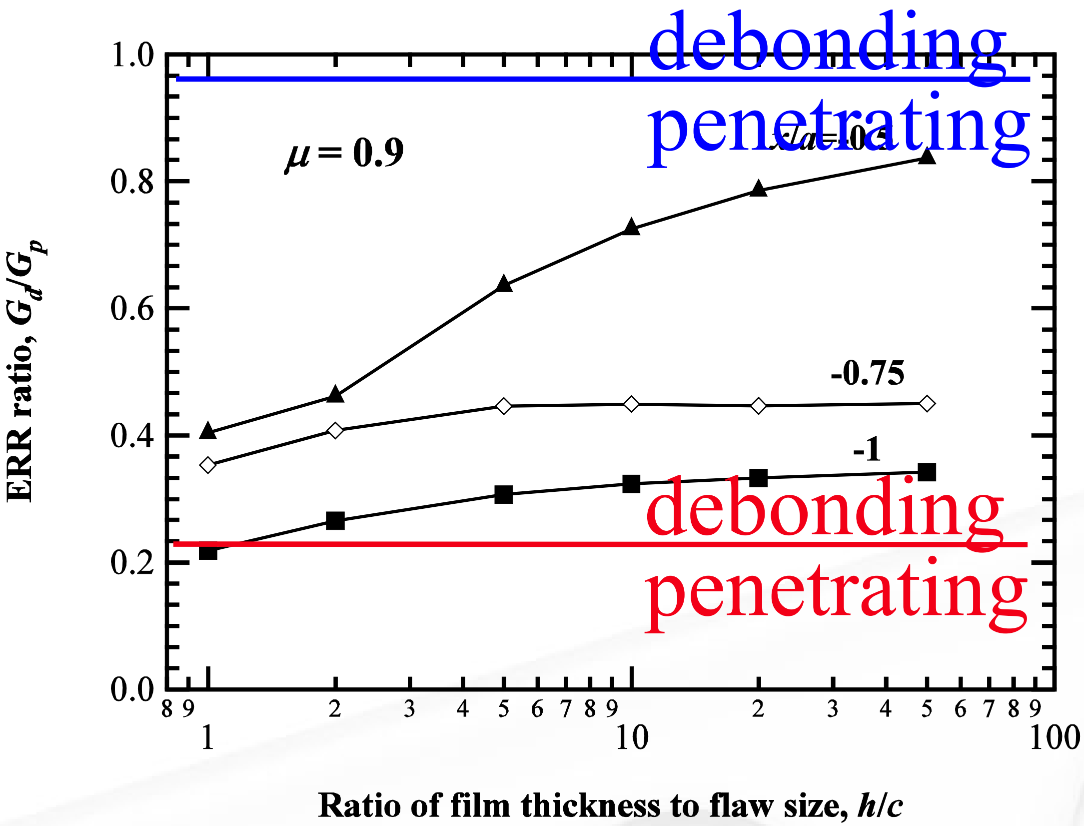
G_d: driving force for debonding along the interface

G_p: driving force for penetration into the substrate



Finite element analysis (X. Geng, Z. Zhang)

Crack deflection and adhesion



$\Gamma_{interface} \geq 8\ \mathrm{J/m^2}$

Si_3N_4 monolayer

Multilayer coatings

$\Gamma_{interface} \approx 1 \sim 2\ \mathrm{J/m^2}$

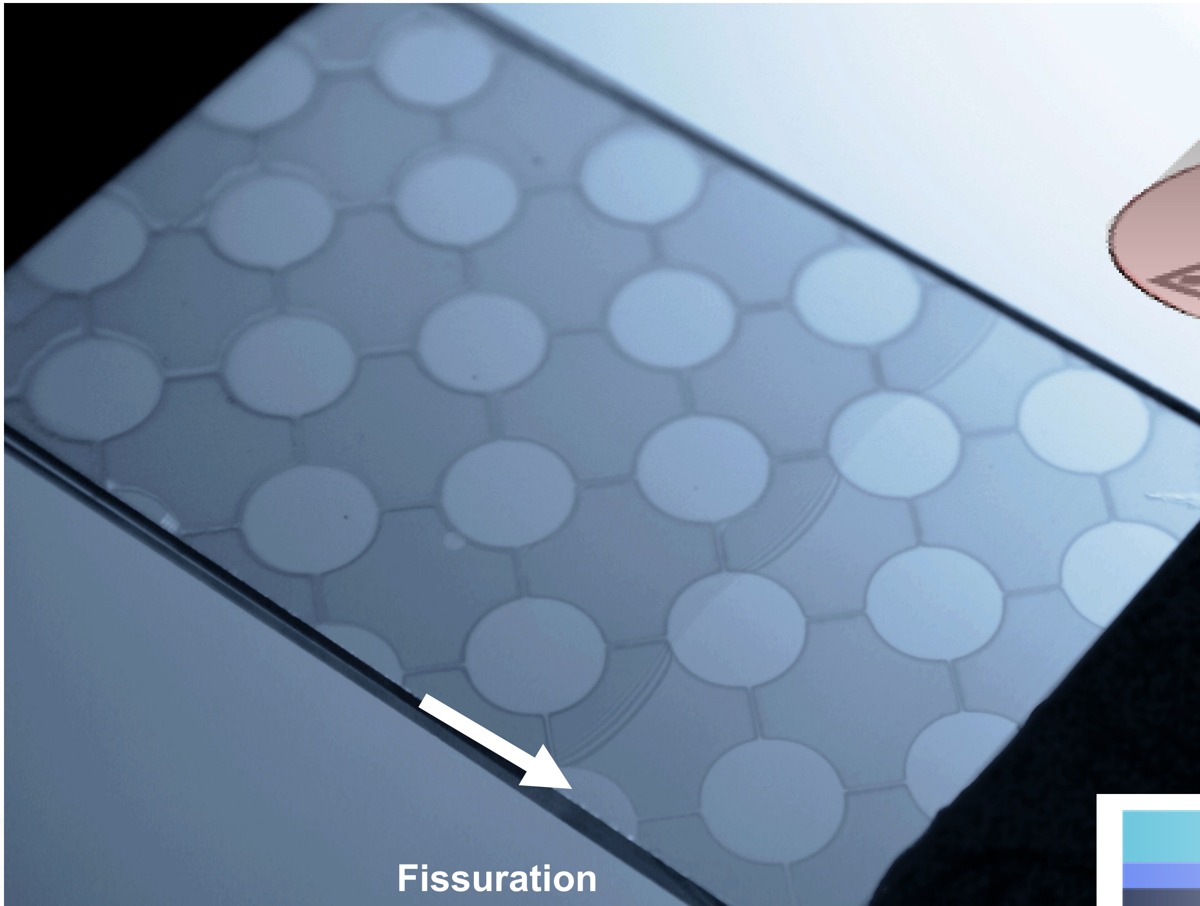
Criterion for penetrating:

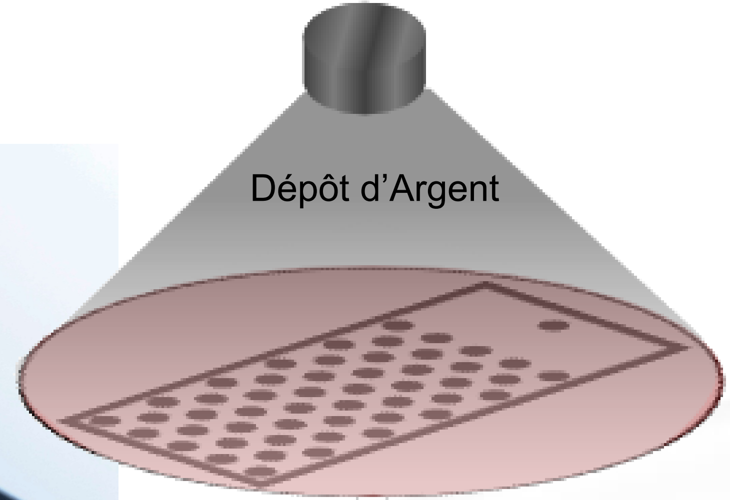
$$\frac{G_d}{\Gamma_{interface}} < \frac{G_p}{\Gamma_{glass}}$$

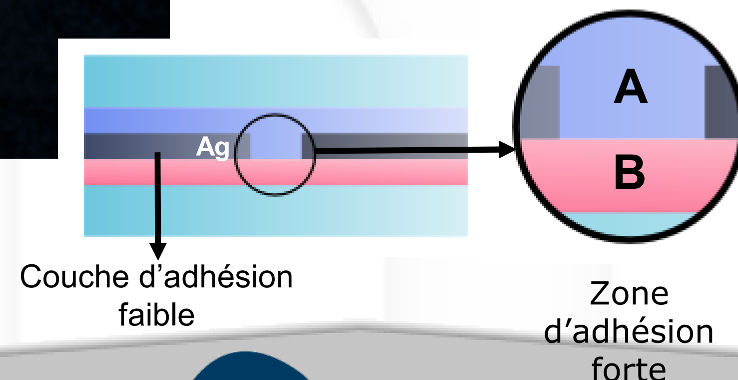
(X. Geng, Z. Zhang)

CNRS SAINT-GOBAIN

Au delà des couches minces ?







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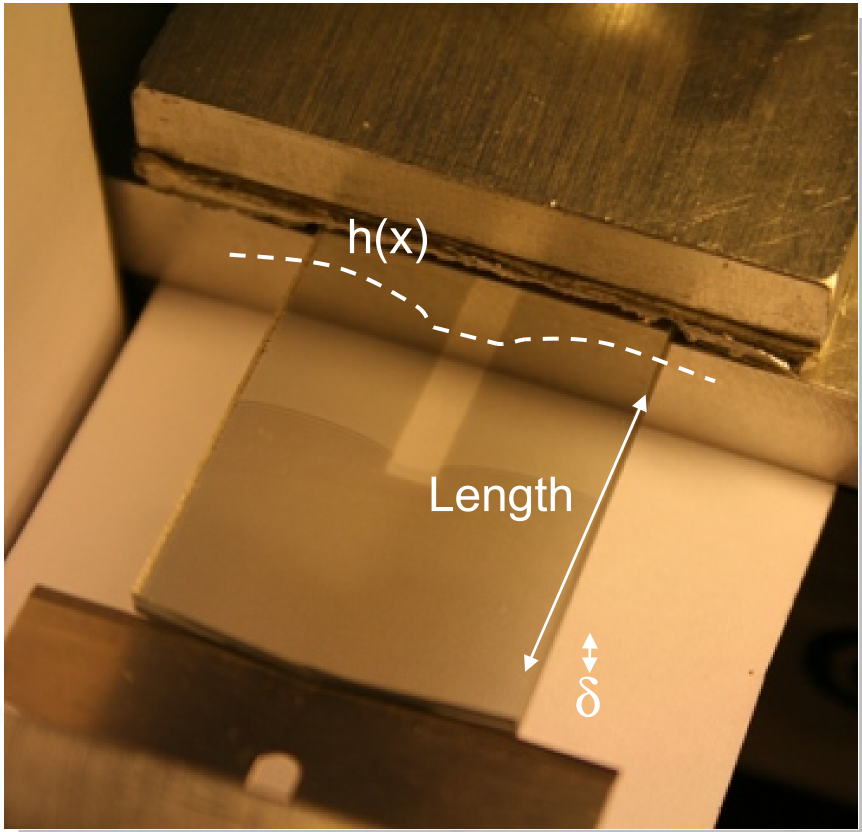
Exploitation of cleavage test



Information from cleavage test:

Global: L=Length

δ=opening

Local: Shape of the front h(x)

Which is the link between δ and L and **global** adhesion?

Energy of Adhesion

$$G = -\frac{\partial U_E}{b\partial L} \propto \frac{Eh^3\delta^2}{L^4}$$

E=Young Modulus, h=Glass thickness

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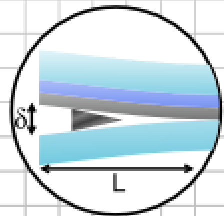
Effective adhesion energy of the composite interface

Global approach G = f (δ,L)

Model of Kanninen



$$G = \frac{3Eh^3}{16} \frac{\delta^2}{(L+0.64h)^4}$$

Constant

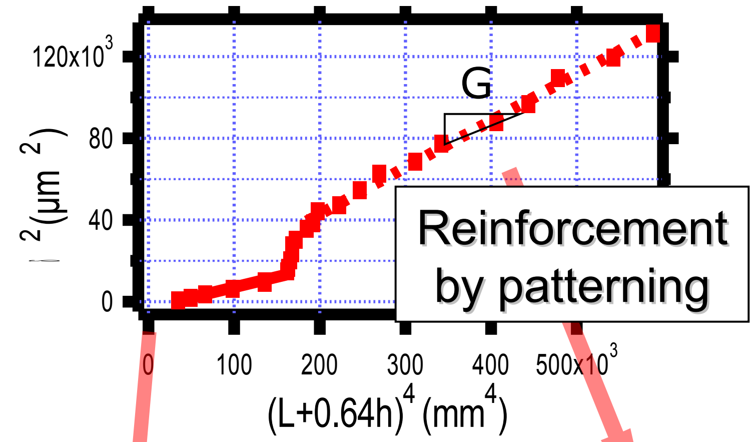
G= Energy release rate
E= Young Modulus
h= Glass Thickness
δ= Crack opening
L= Crack Length

For plane stress

$$K = \sqrt{G \cdot E}$$

K= Stress intensity factor

Energy of adhesion (J/m²)



G_{homo}=0.52 J/m²

G_0=1.17 J/m²

Lina Alzate

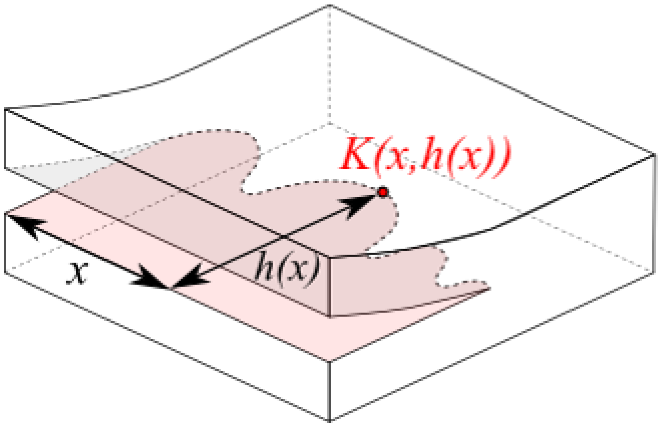
Can we determine the energy of adhesion of the masked zone?

Shape of the crack front

Local approach K = f (h(x))

Gao et Rice, J. Appl. Mech. 56, 828 (1989)

By using a perturbative analysis, Gao and Rice propose a local expression of K (or G) at a point (x,h(x)) of the front in function of the front roughness for a purely 2D crack :



Pinning Model

Local toughness

$$K(x,h(x)) = K_0\left(1 + \frac{1}{2\pi}\int_{-\infty}^{+\infty}\frac{h(x)-h(x')}{(x-x')^2}dx'\right) \geq K_C(x,h(x))$$

Where K_0 is the macroscopic toughness and h(x) the in-plane front roughness

Can we validate and use this theory in an experimental way?

Validation of pinning theory

Local approach K = f (h(x))

H.Gao, J.R. Rice, J. Appl. Mech 56 (1989) 828-836

Pinning Model (Gao and Rice)

$$K(x,h(x)) = K_0\left(1+\frac{1}{2\pi}\int_{-\inf}^{+\inf}\frac{h(x)-h(x')}{(x-x')^2}\,dx'\right)$$

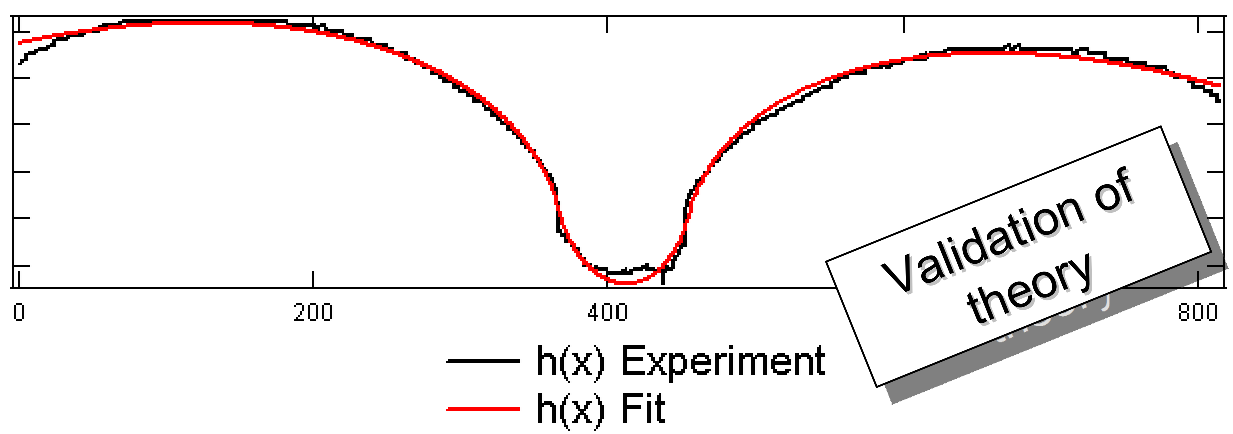
$$h(x) = \frac{1}{\pi^2}\frac{\Delta K}{K_0}\{log(\|x\|)*a(x)\}$$

Term to fit

$a(x) = 0$ Outside of the masked zone

$a(x) = 1$ Inside of the masked zone

$h(x) =$ Crack Tip



Can we determine the value K of the masked zone ?

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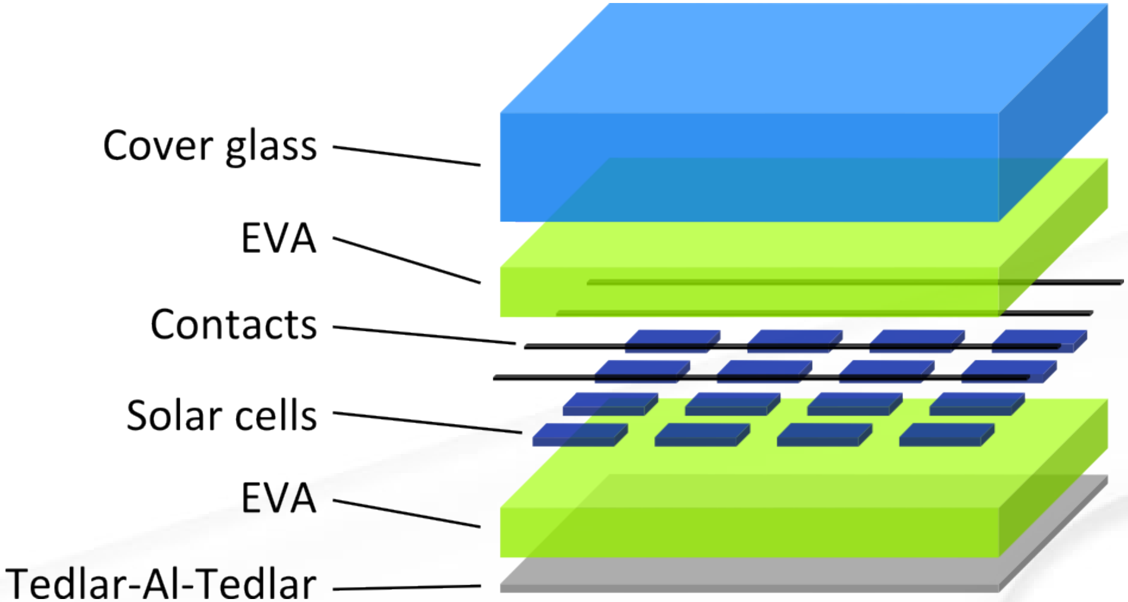
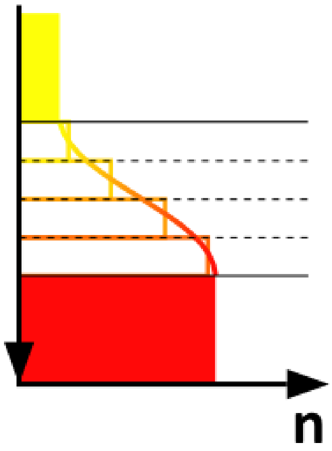
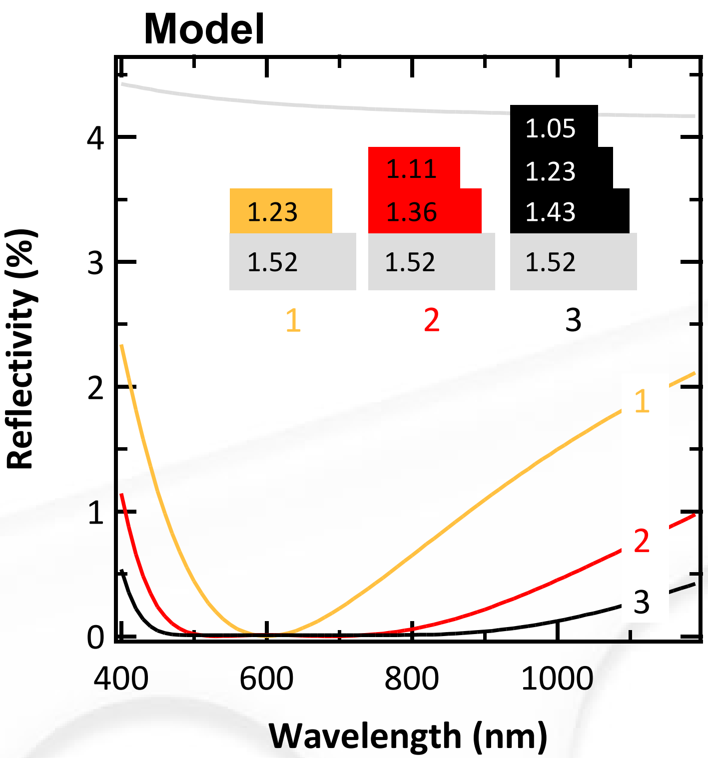
Solar cells encapsulation



~4% reflection of solar light on glass surface

Index-gradient anti-reflective coatings

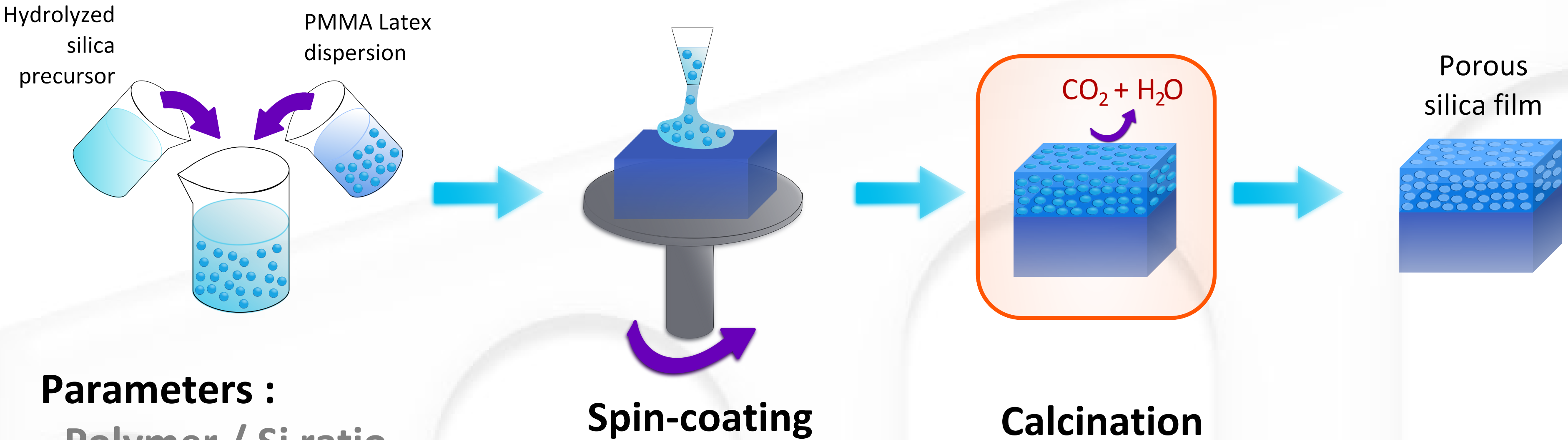




- Low angular variation
- Wide band
- Need for very low refractive index

Latex templated silica films

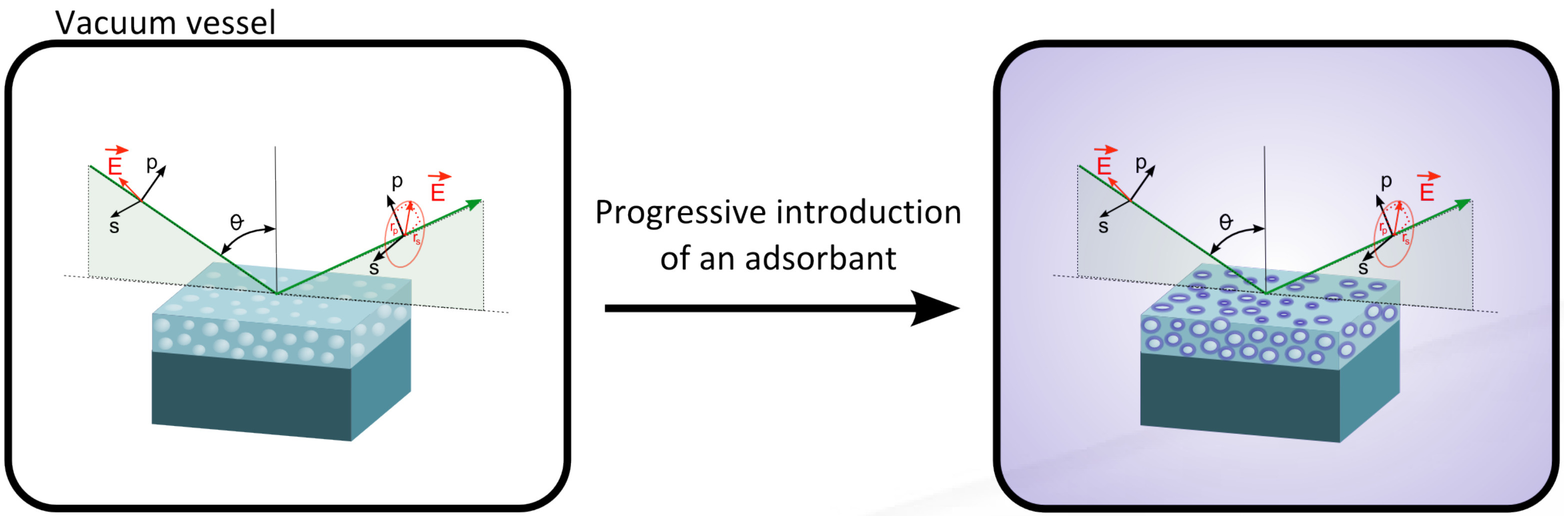
•Organic nanoparticles as sacrificial template



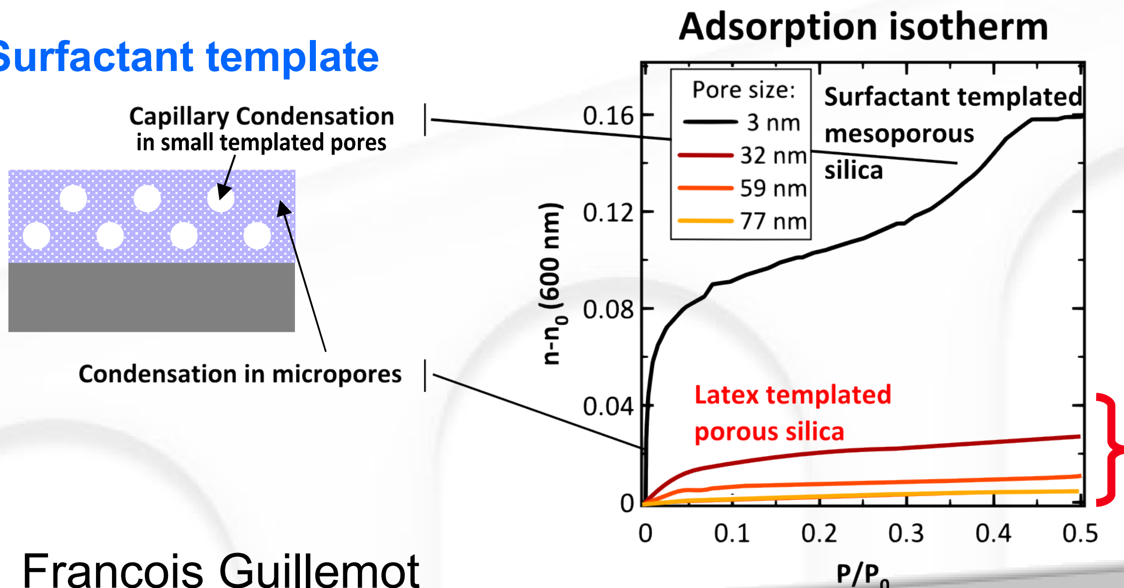
Parameters :

- Polymer / Si ratio
- Nanoparticles size
- Dilution

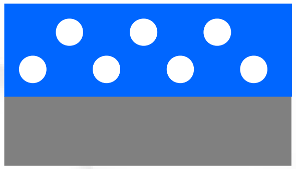
Pore structure : ellipsometry-porosimetry



Surfactant template



Latex template



Pore size >30 nm :

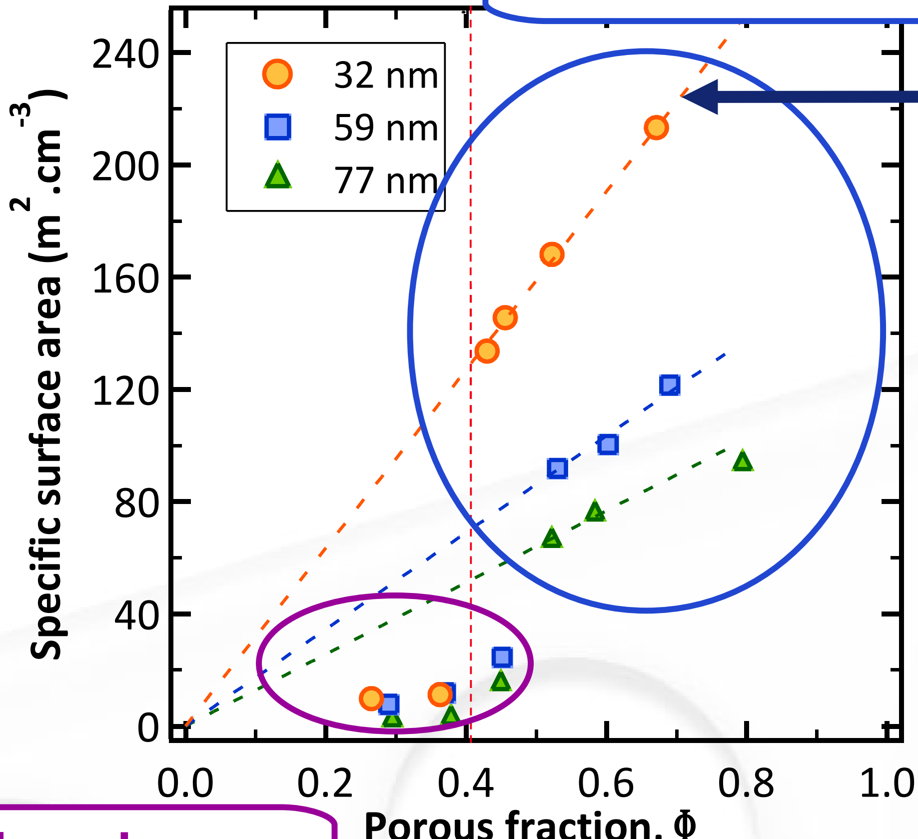
Stable refractive index

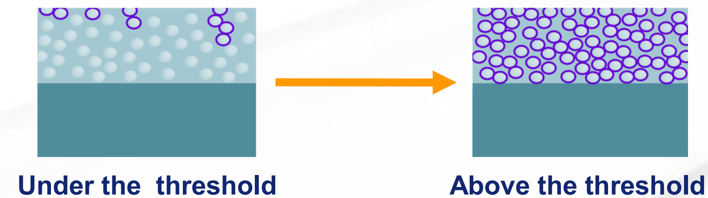
François Guillemot

Pore structure : specific surface area

Open pore structure

Geometry : $S_{spe} \propto \dfrac{\Phi}{d_{pore}}$



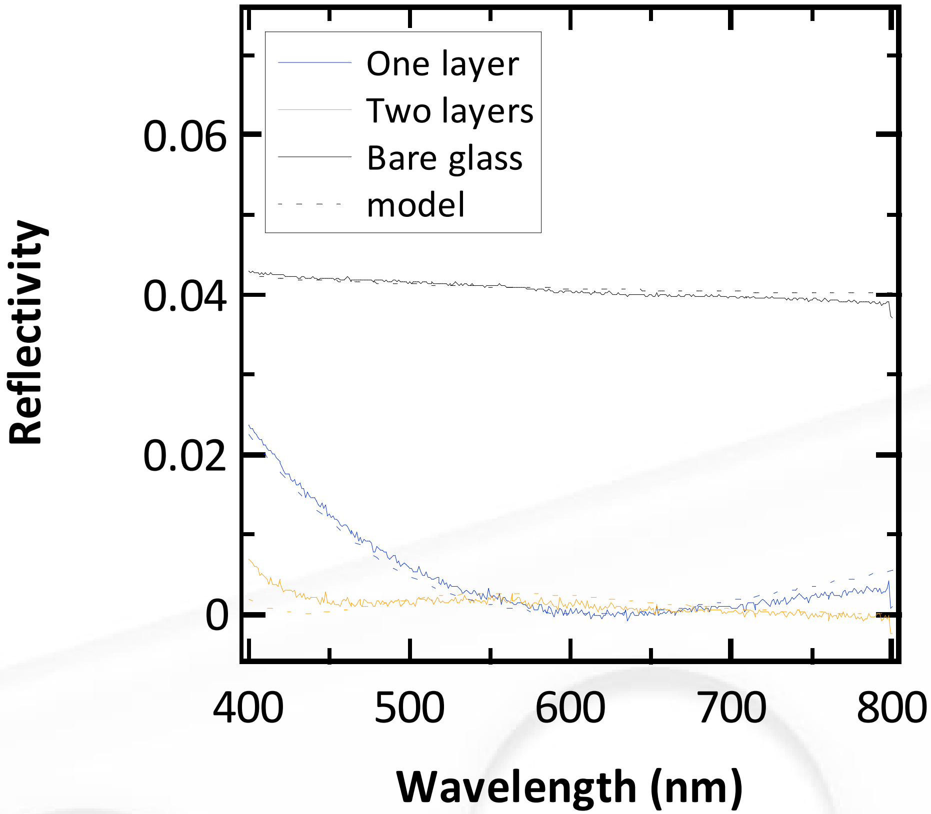


- Percolation transition
  - Scale invariance
  - Threshold around 40%

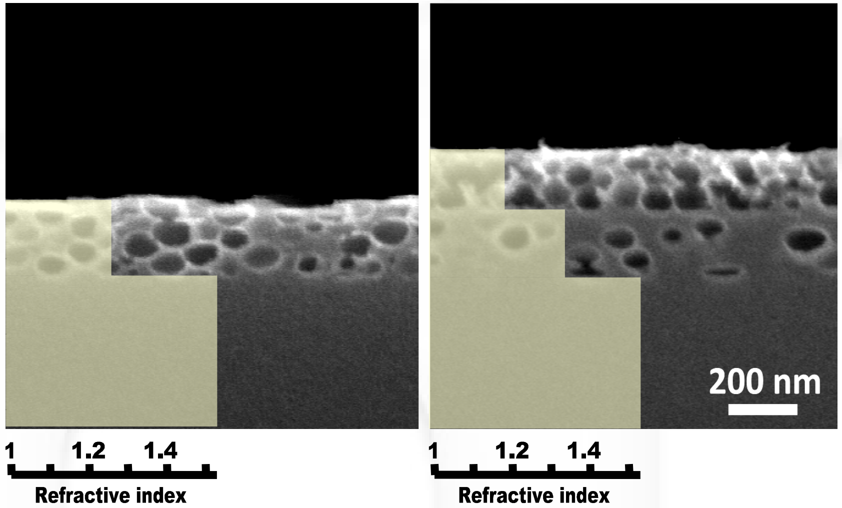
Closed pore structure

François Guillemot

Index gradient antireflective stacks

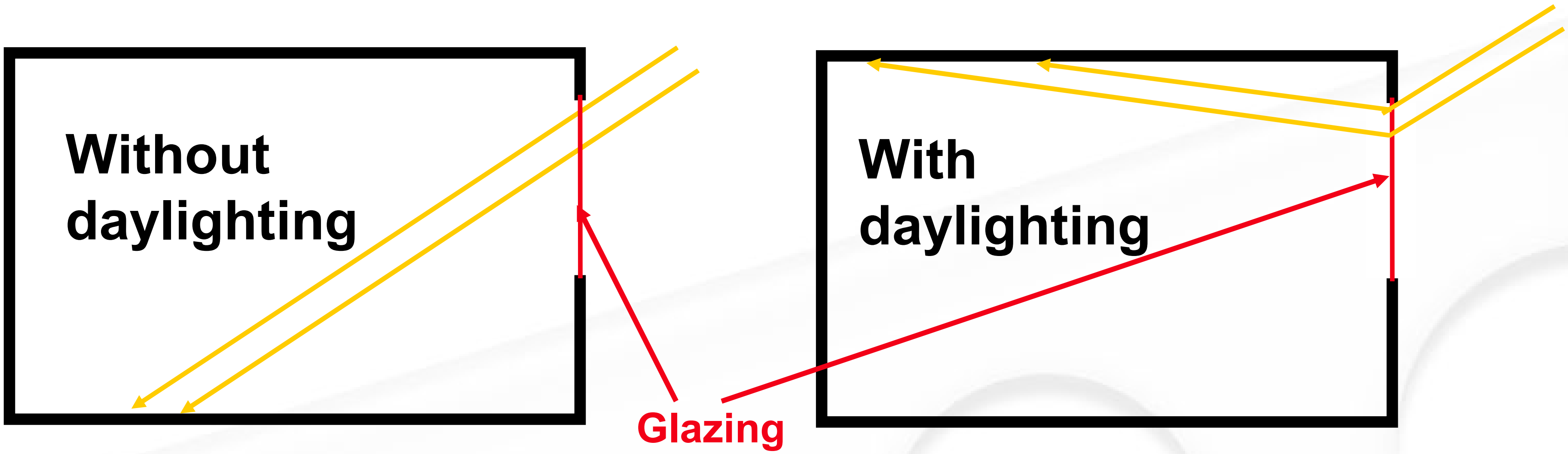


Flatter reflectivity with smoother refractive index gradient



Modeling with CAMFR : ***Peter Bienstman, PhD Thesis, Ghent University, Belgium, 2001*** (http://camfr.sourceforge.net)

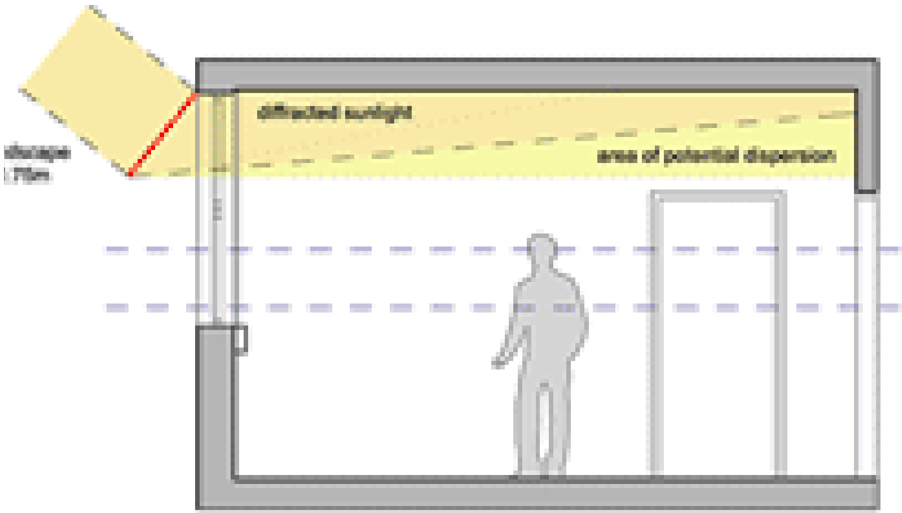
Daylighting – Principle

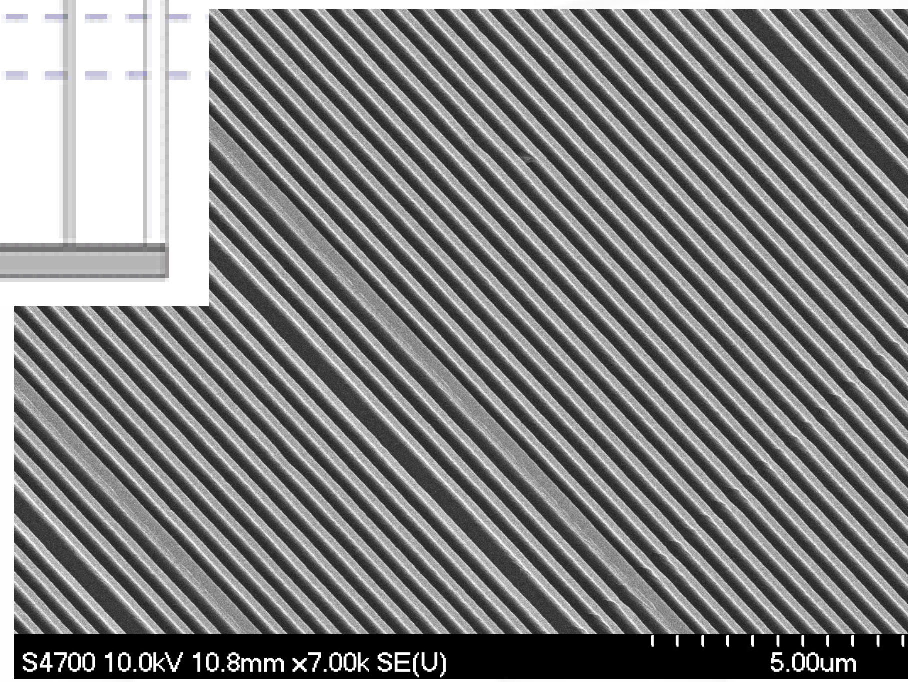


Daylighting – Application

Applications : miscellenaous

- Daylighting glazing

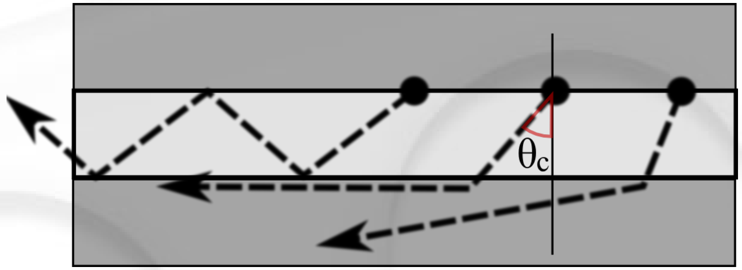




Saint-Gobain Recherche / O2M

Application : LEDs

die	λ (nm)	n_{die}	n_{encaps}	θ_c	$1 - \cos\theta_c$
alumina	589	1.76	1.0	34	0.18
alumina	589	1.76	1.5	60	0.49
GaN	411	2.5	1.0	24	0.08
GaN	411	2.5	1.5	37	0.2
GaAs	589	4.02	1.0	14	0.03
GaAs	589	4.02	1.5	22	0.07



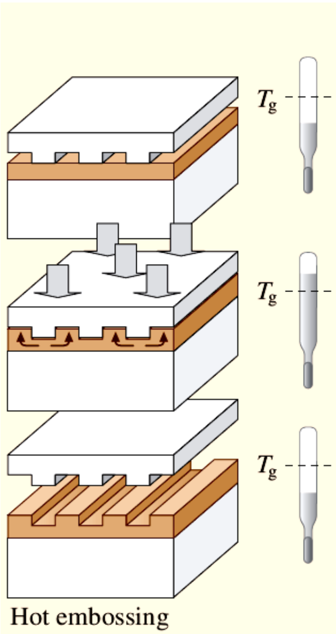
$$\sin\theta_c = \frac{n_{encap}}{n_{die}}$$

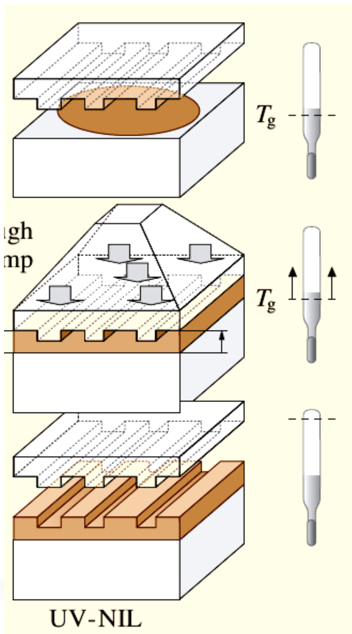
$$X_{tot} = 1 - \cos\theta_c$$

Contexte

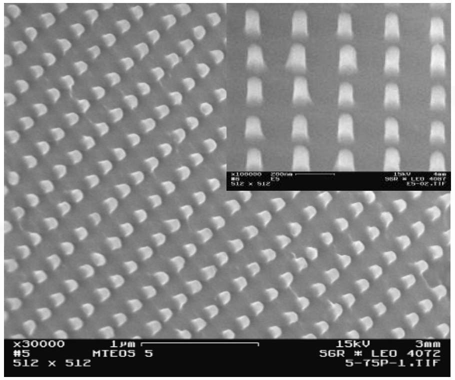
C. Peroz et al., *J Vac Sci Tech B*, **2007**, 25(4) L27
C. Peroz et al., *Advanced Material,* **2009,** 21(5) 555
PCT/FR2008/050594 C.Peroz, E. Sondergard E. Barthel

Procédé d'impression

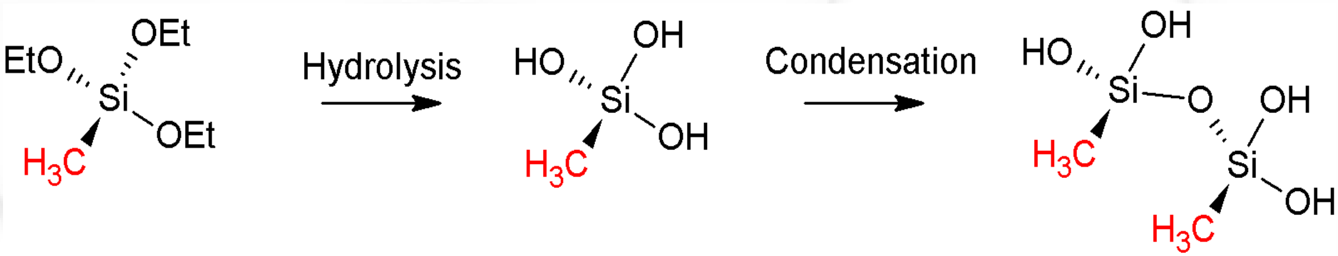




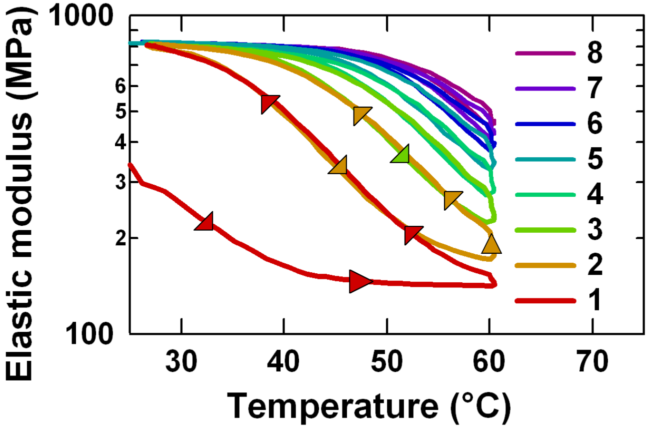
Obtention de structures avec une faible période et des rapports d'aspects >1

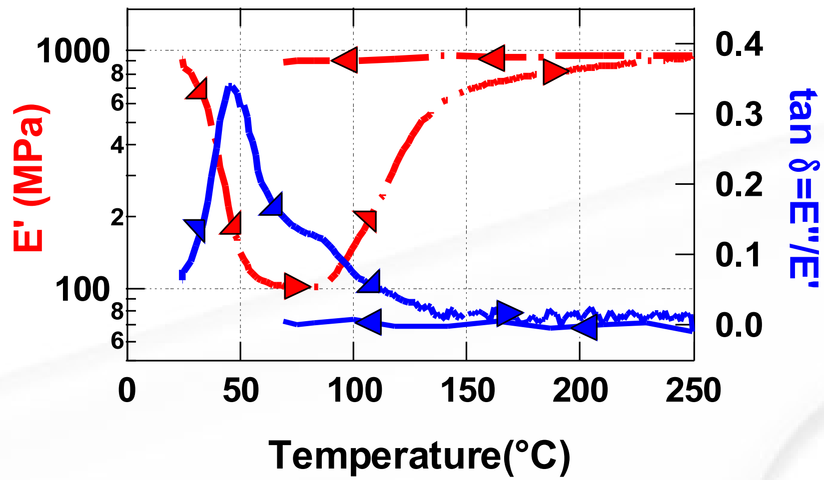


dots (∅=75nm, p=230nm, h=150nm)



DMA: mise en évidence d'une T_g et évolution durant le traitement thermique

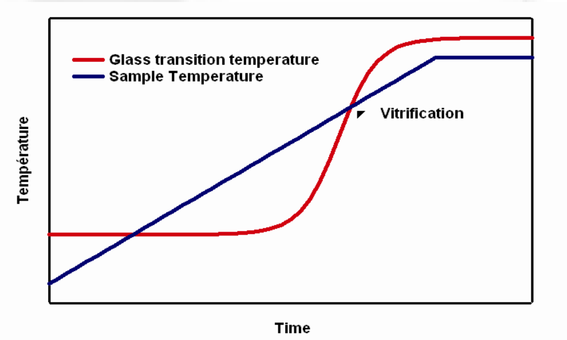




•T_G initial proche de 30°C

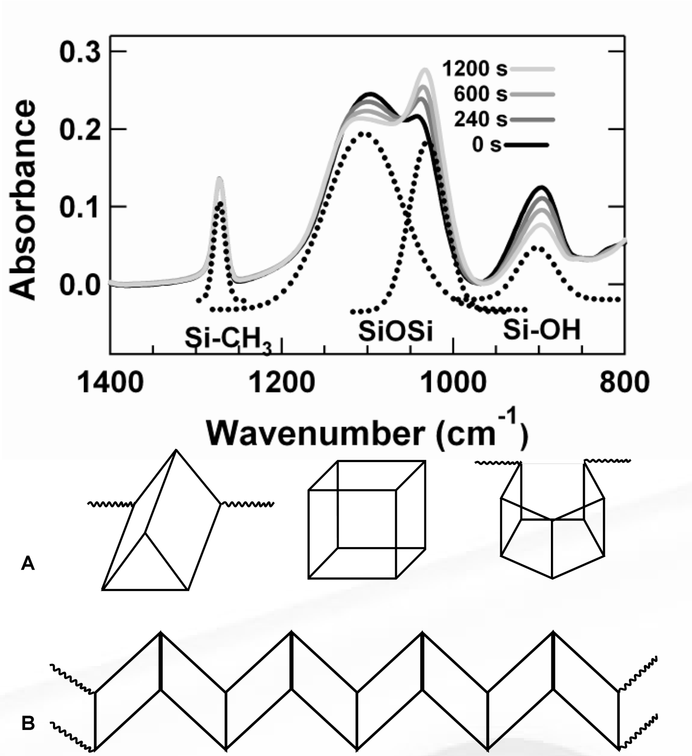
•Augmentation progressive de la T_g avec la condensation

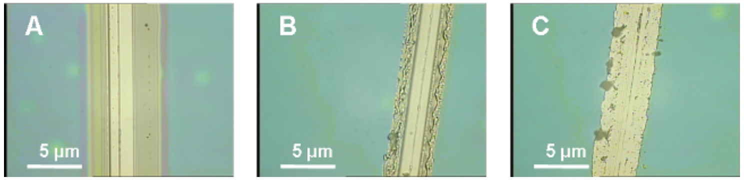
•La vitrification a lieu quand $T_g=T_{échantillon}$

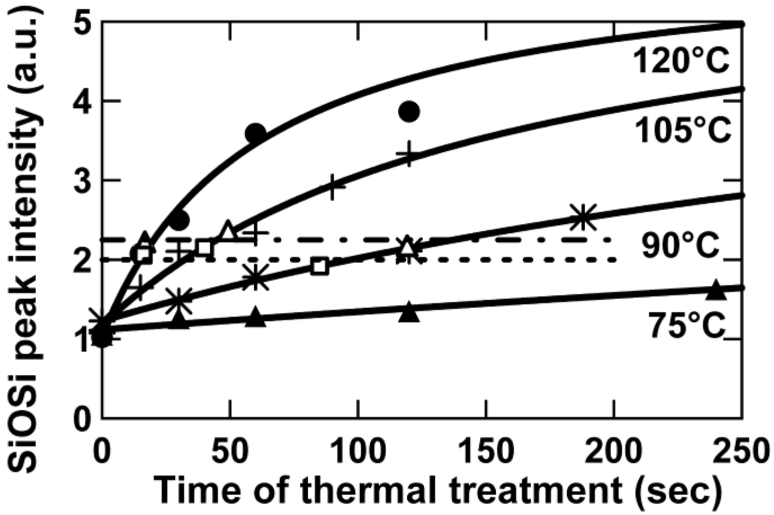


Alban Letailleur

Rappel: Etude structure interne



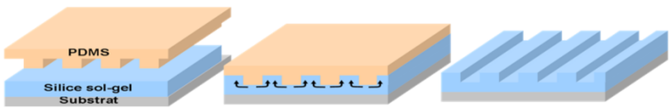


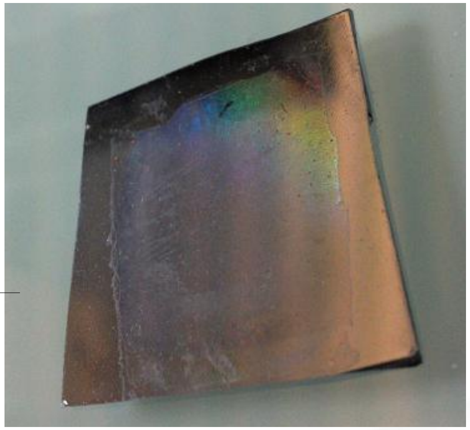


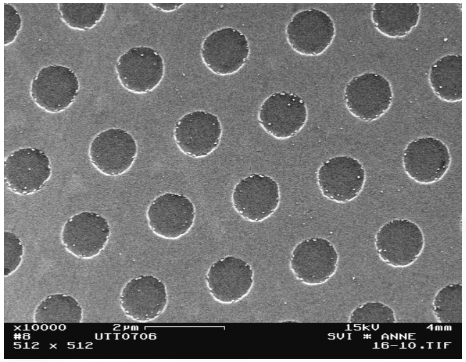
- 2 modes de vibrations SiOSi
- Un seuil de condensation indépendant de la température pour la vitrification

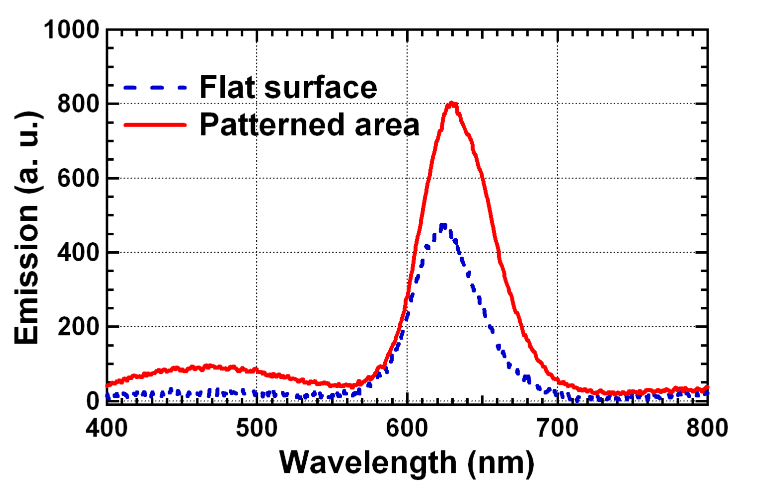
Alban Letailleur

Etude de l'influence de la structuration









Luminescence observée sur les films
Augmentation de la luminescence pour les zones structurées

Alban Letailleur

- comprendre la physique de la surface texturée
- développer les moyens d'élaboration pour les surfaces de grande taille