

Interaction hydrogène - surface de graphite HOPG : Etude combinée par STM et HREELS

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Equipe Plasma-Surface

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J.-M. Layet (Pr)

E. Salançon (Mcf)

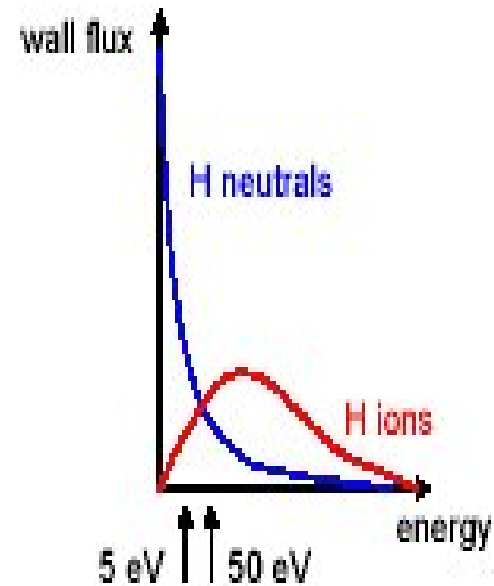
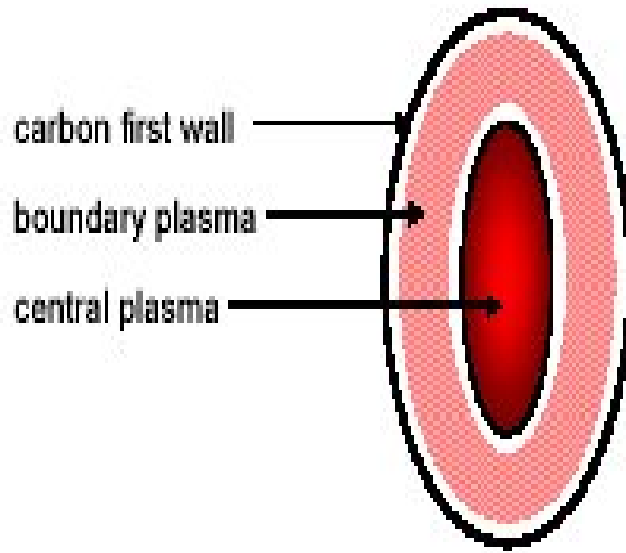
&

C. Brosset

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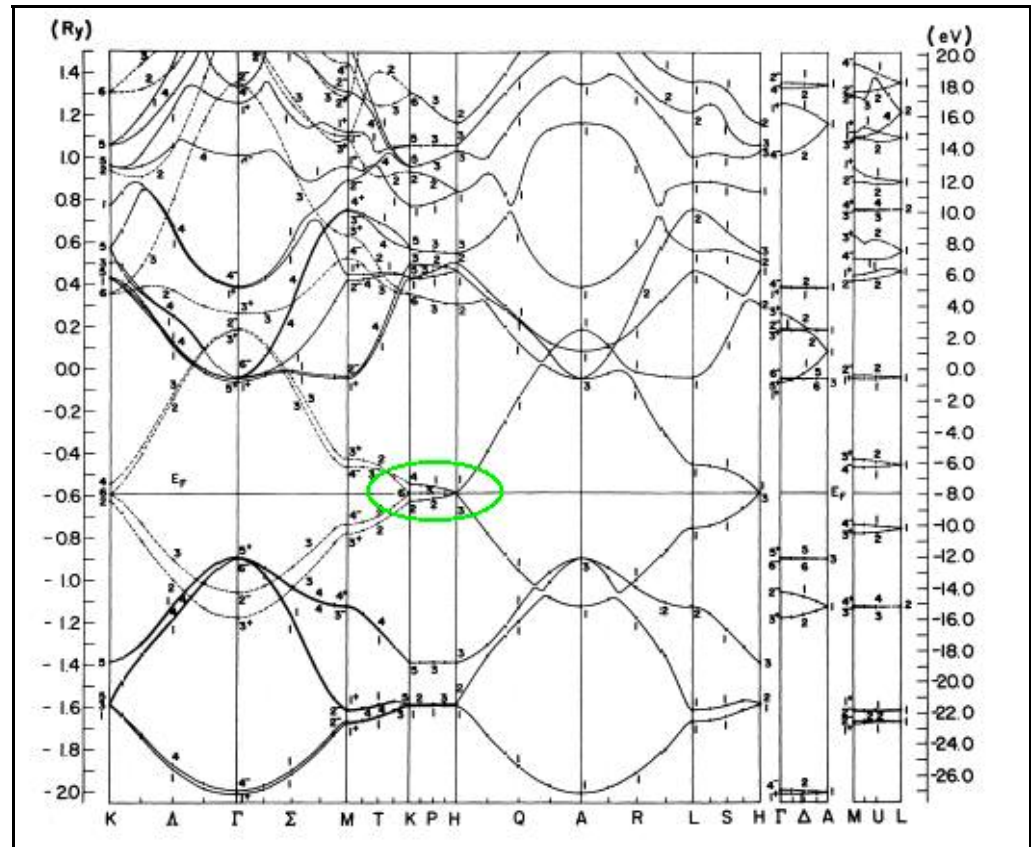
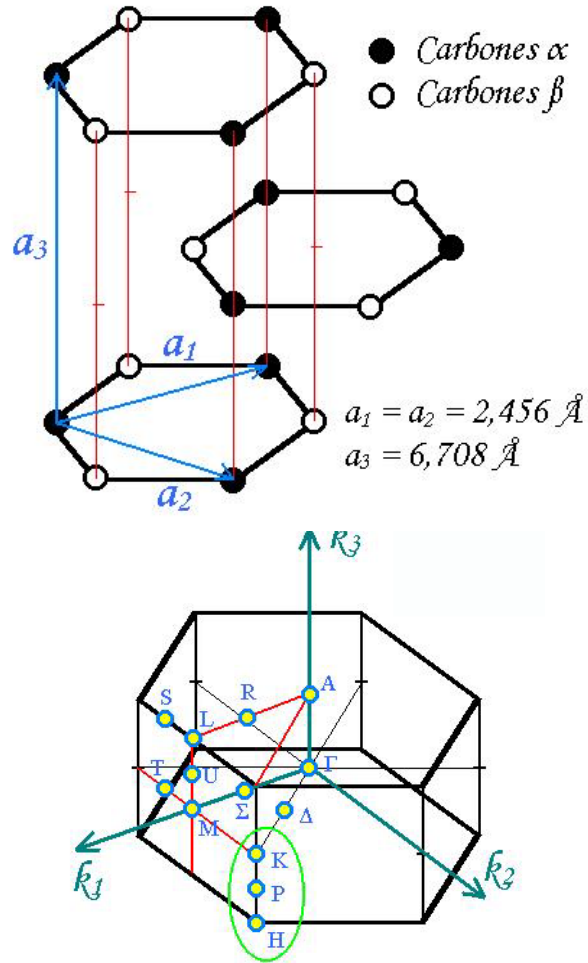
- Interaction Plasma - Paroi (Surface)



1. Etudier l'effet de chaque espèce (neutres atomiques et ions).
2. Les combiner séquentiellement.
3. Réaliser une exposition plasma.

Modélisation expérimentale des parois -> graphite HOPG.

HOPG graphite



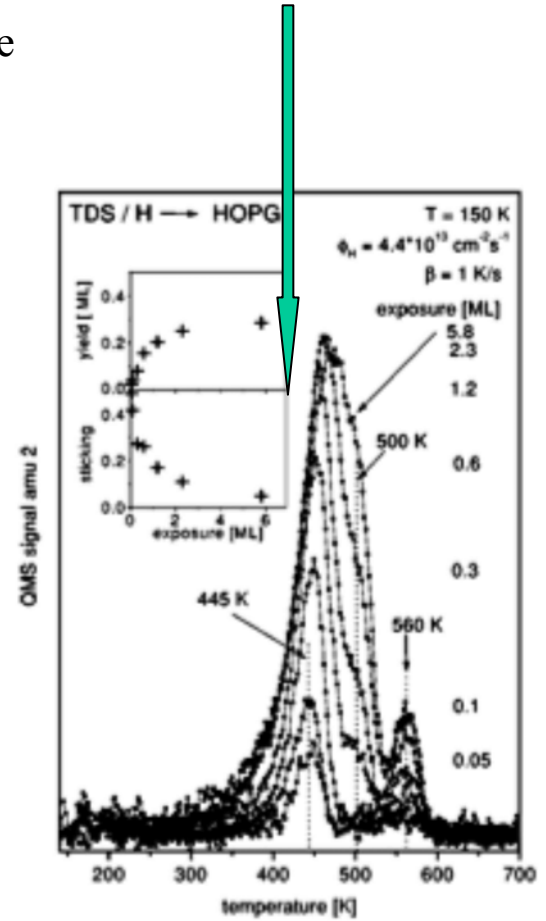
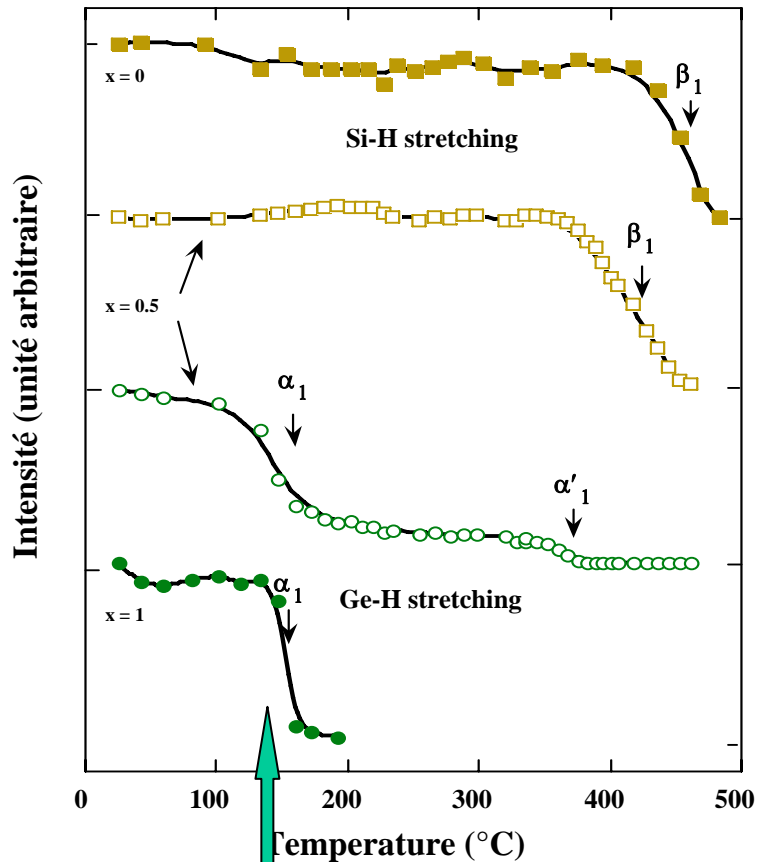
R.C. Tatar, S. Rabii, Phys. Rev. B25, 4126 (1982)

P.R. Wallace, Phys. Rev. 71, 622, (1947)

Approche expérimentale : physique de l'interaction de l'hydrogène atomique avec les surfaces de semiconducteurs

-> méthode du filament chaud

T. Angot, P. Louis / PRB 60 (1999) 5938



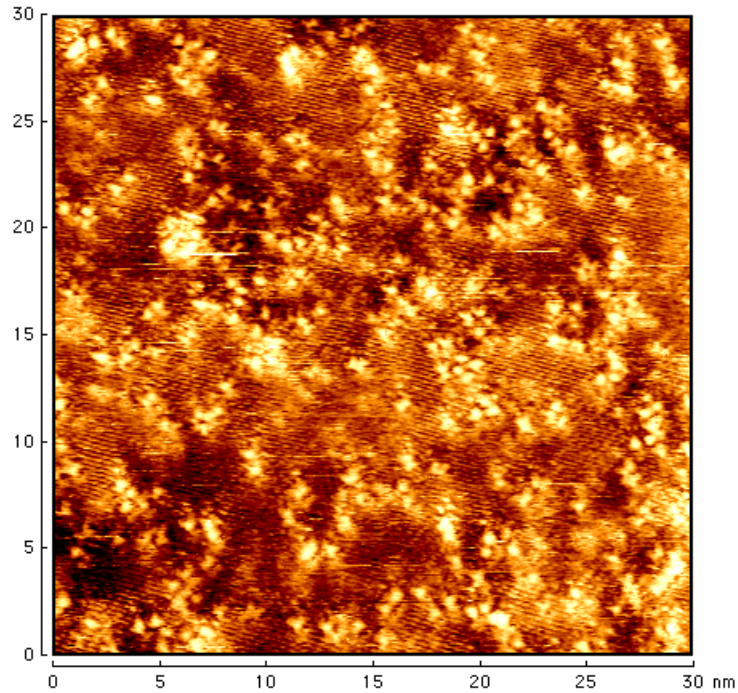
T. Zecho et al. / Carbon 42 (2004) 609–617

-> source d'hydrogène atomique



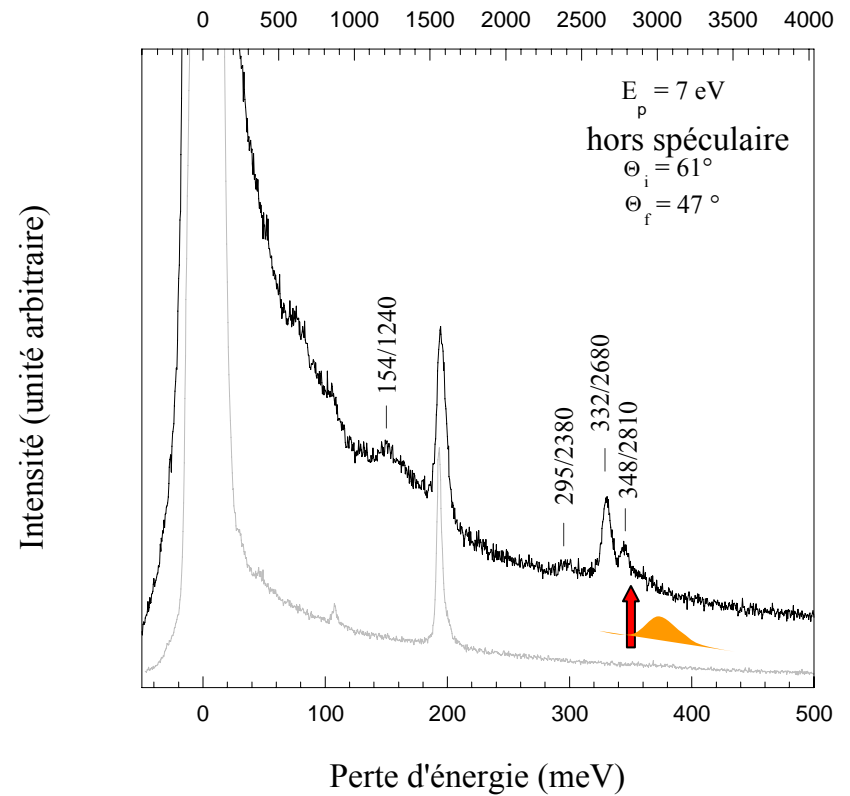
I. Interaction H (D) / graphite HOPG

120 L hydrogène atomique



$V=80$ mV $I=0,1$ nA

Nombre d'onde (cm^{-1})



(H)

(H)

(H)

(H)

(H)

(H)

(H)

(H)

monomère

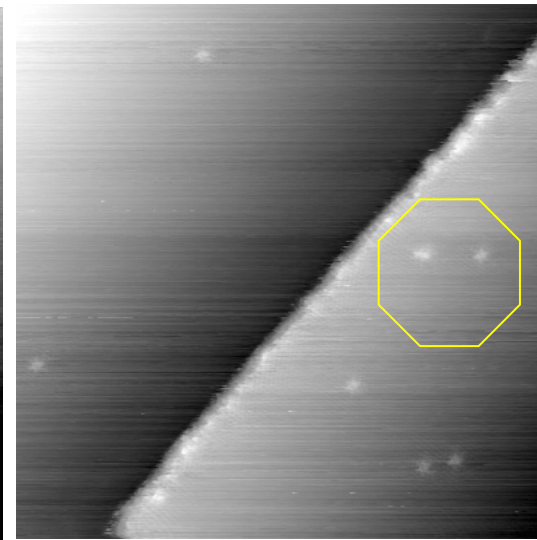
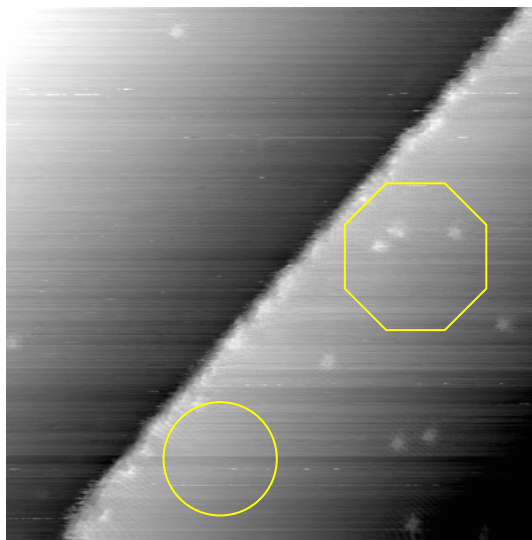
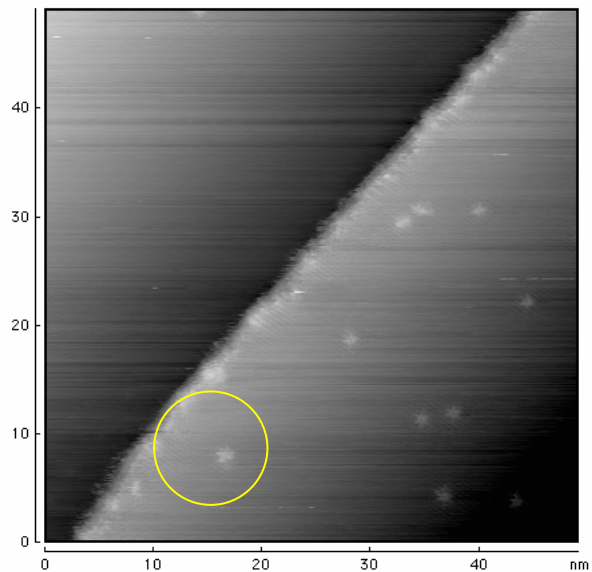
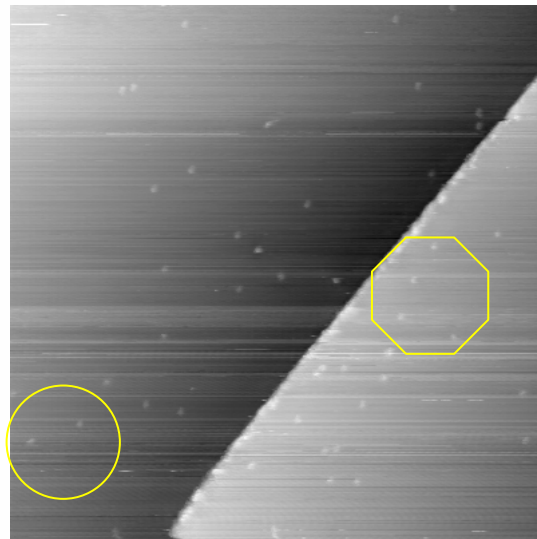
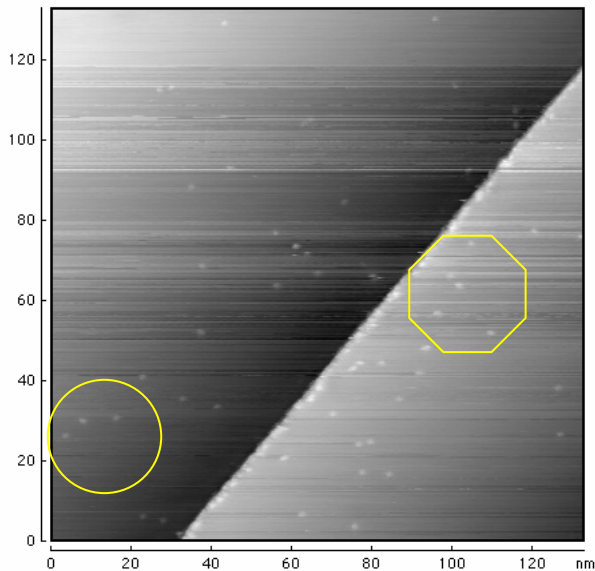
dimère

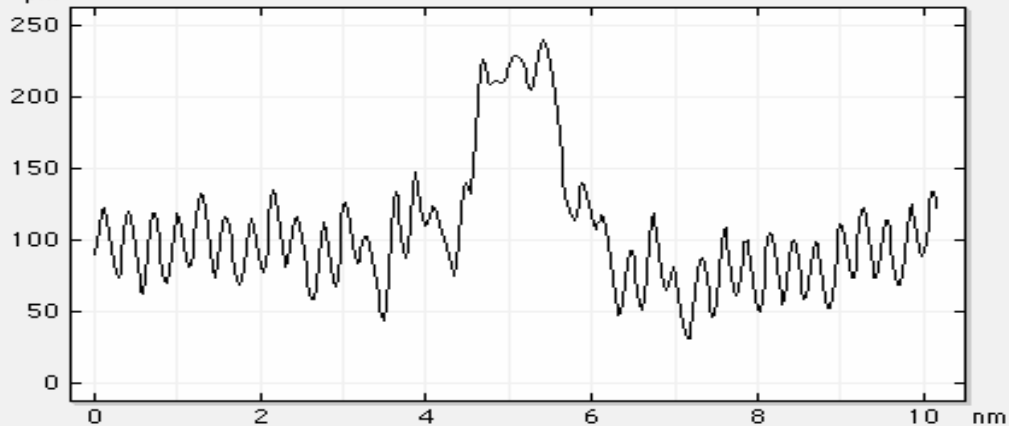
quartet/cluster



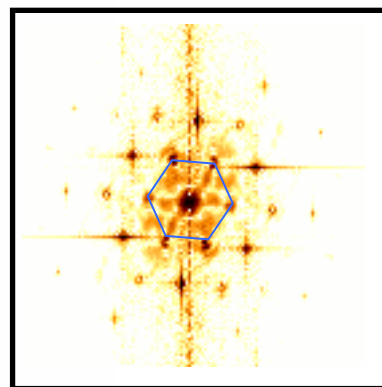
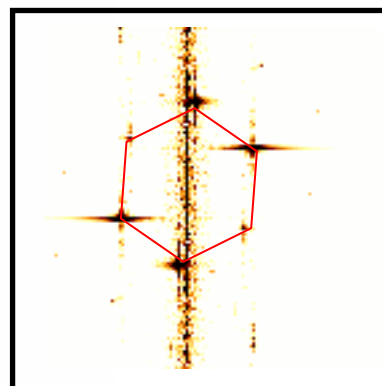
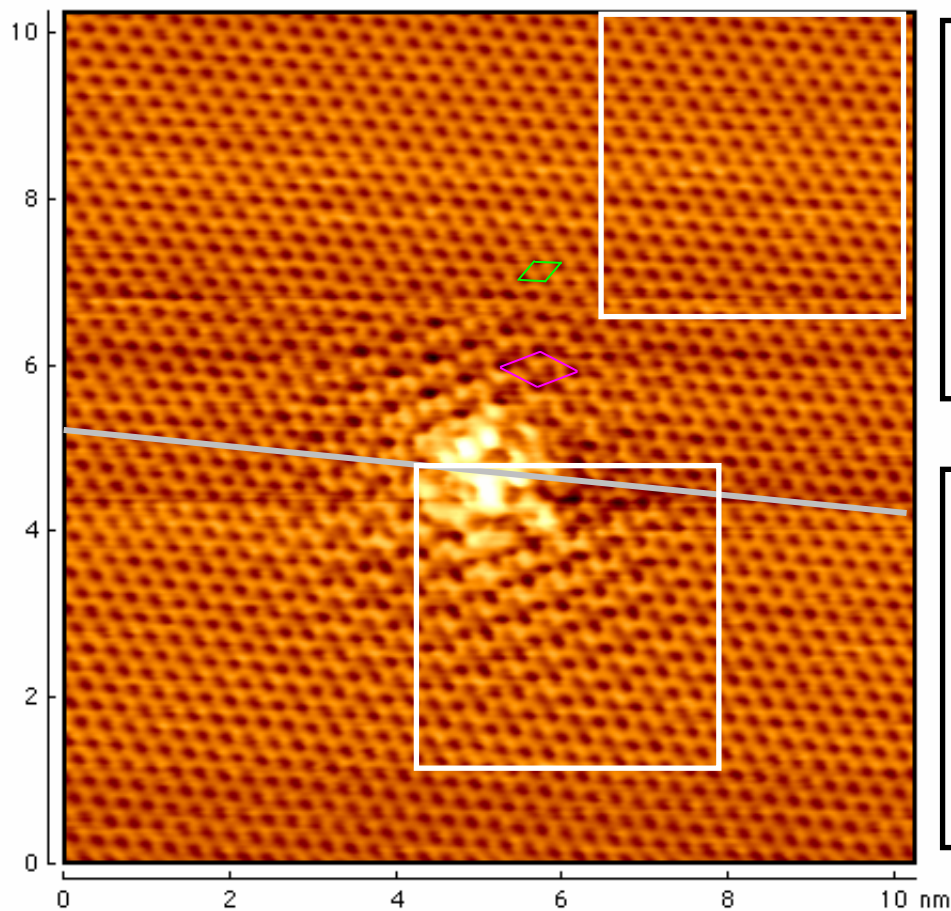
30 L hydrogène atomique

$V_{\text{bias}} = 100 \text{ mV}$
 $I = 0,35 \text{ nA}$

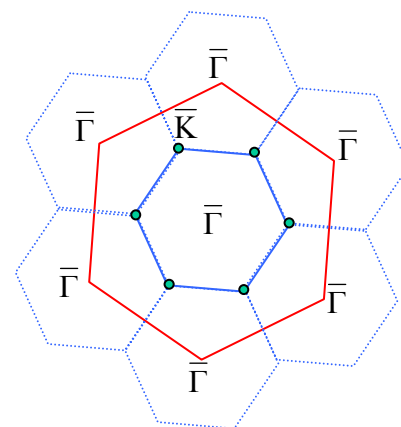




$V_{\text{bias}} = 30 \text{ mV}$
 $I = 0,25 \text{ nA}$



Cellule unitaire du
réseau réciproque

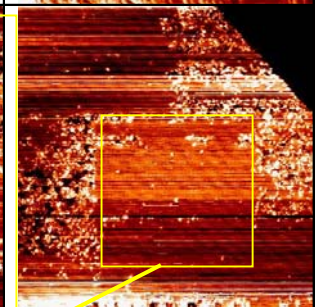
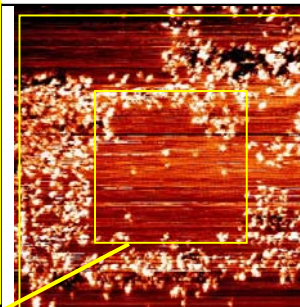
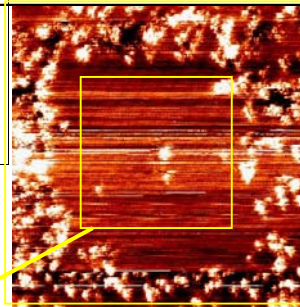
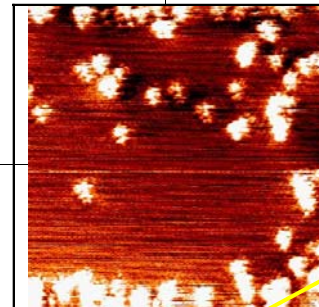
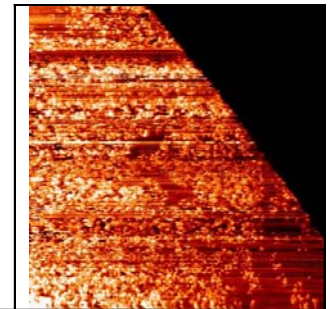
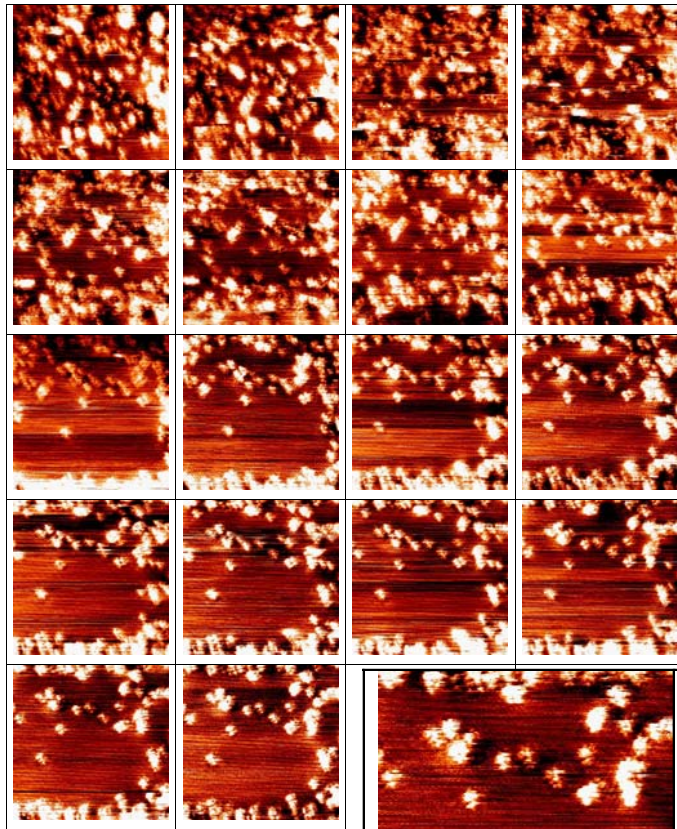


Zone de Brillouin 2D



25 nm × 25 nm

180 L hydrogène atomique



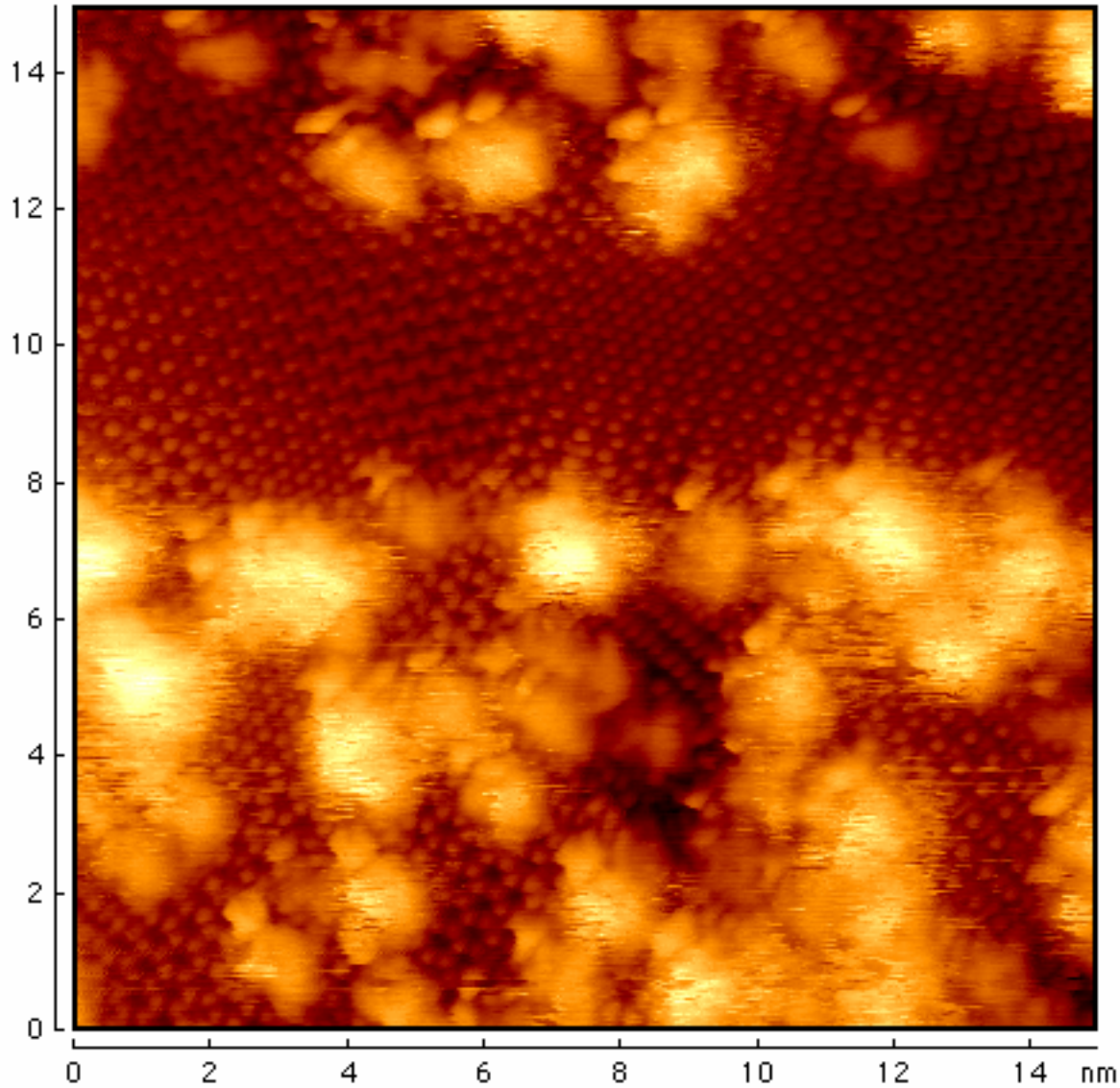
25 nm × 25 nm

50 nm × 50 nm

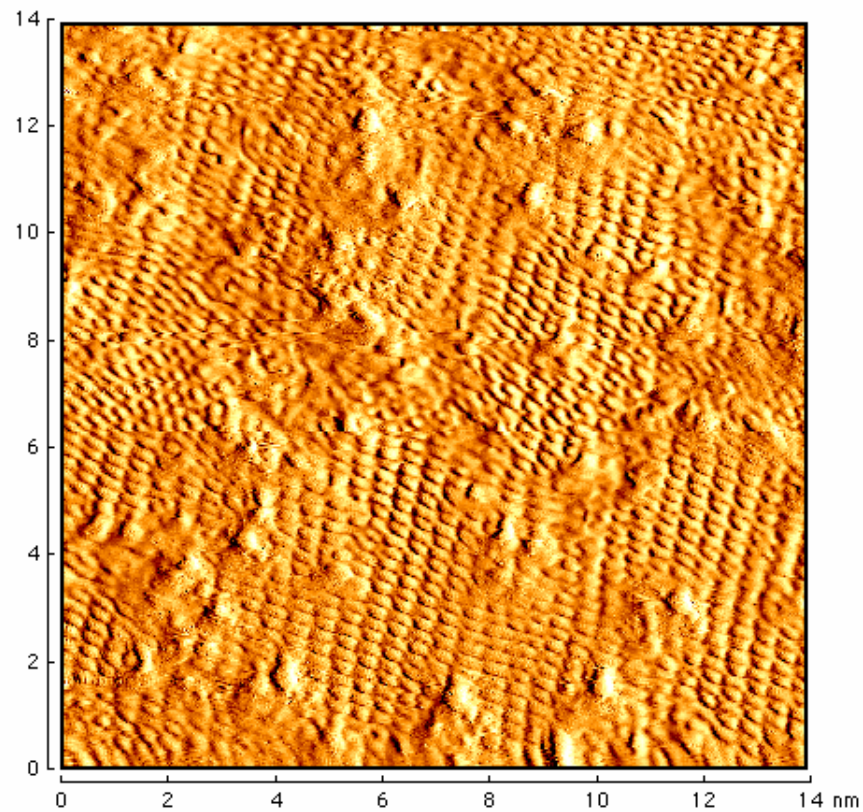
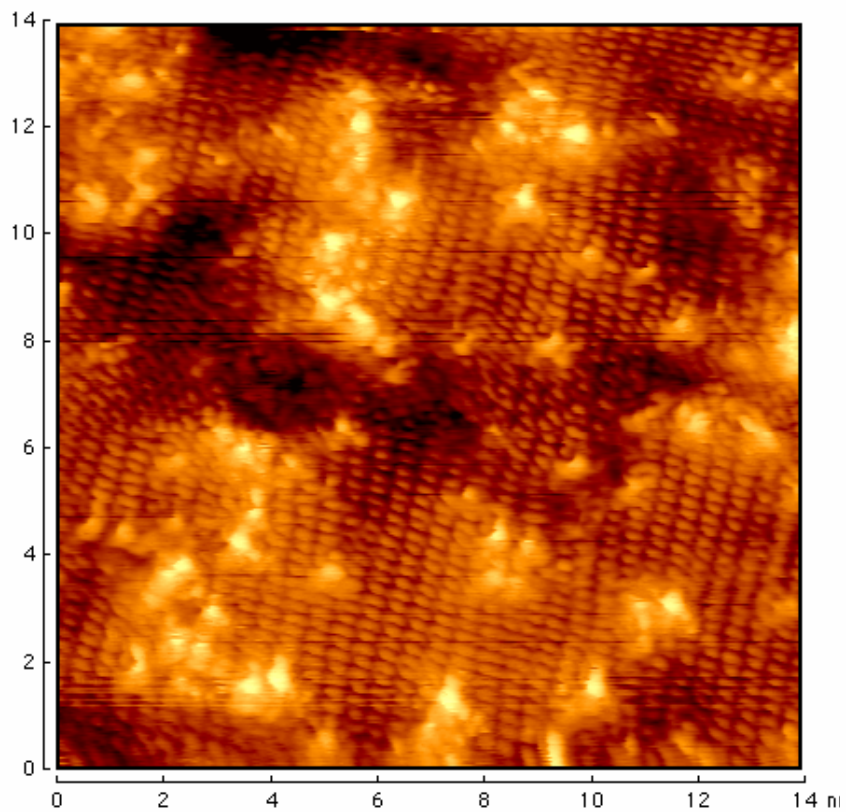
100 nm × 100 nm

200 nm × 200 nm



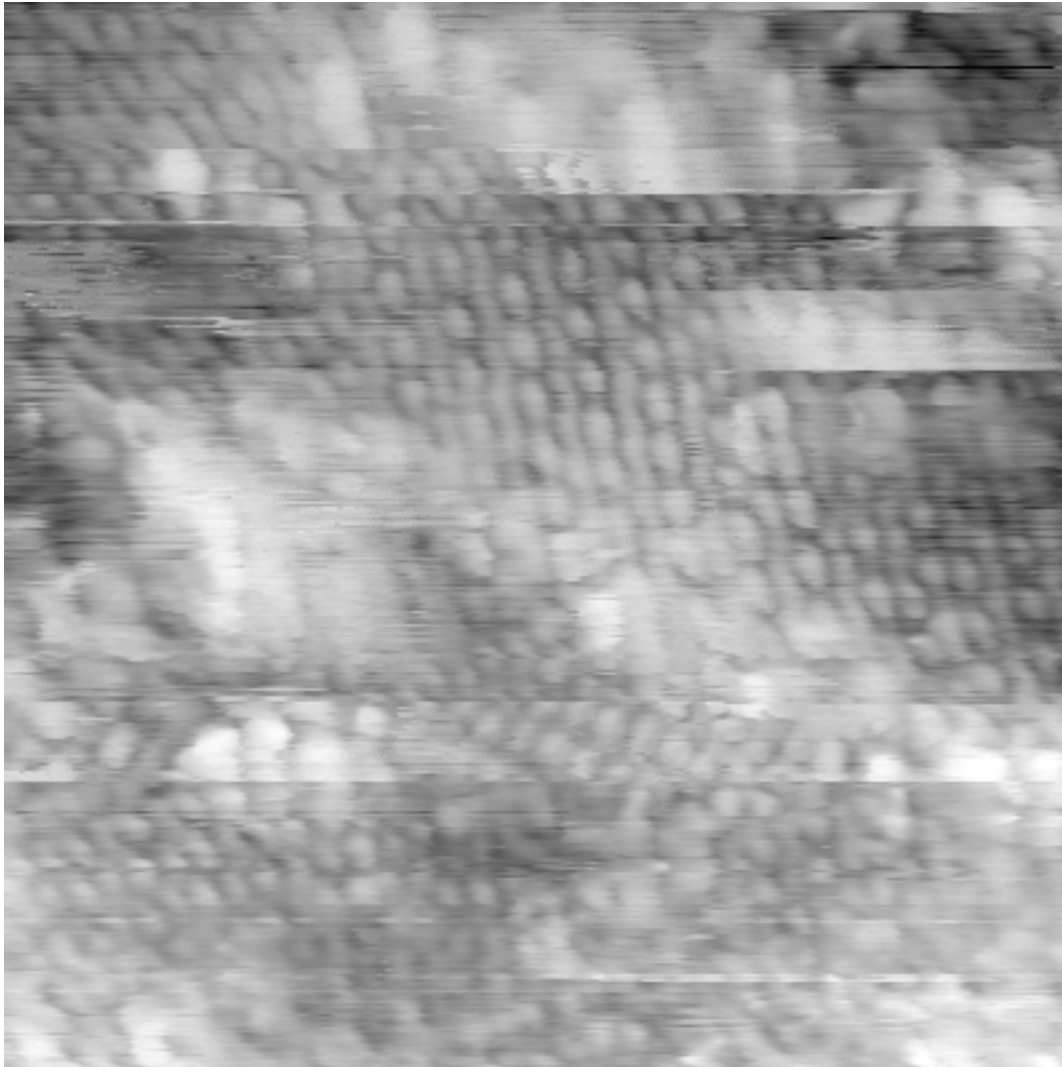


$V_{\text{bias}} = \pm 50 \text{ mV}$
 $I = 0,35 \text{ nA}$

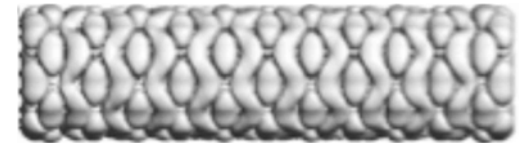
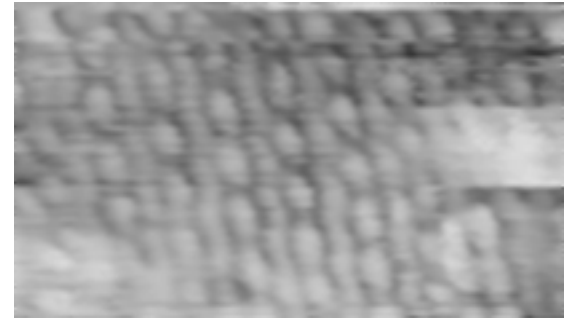


$V_{\text{bias}} = -40 \text{ mV}$ $I = 0,35 \text{ nA}$

Confinement d'onde de densité de charges



$$V_{\text{bias}} = -2 \text{ mV}$$
$$I = 0,5 \text{ nA}$$

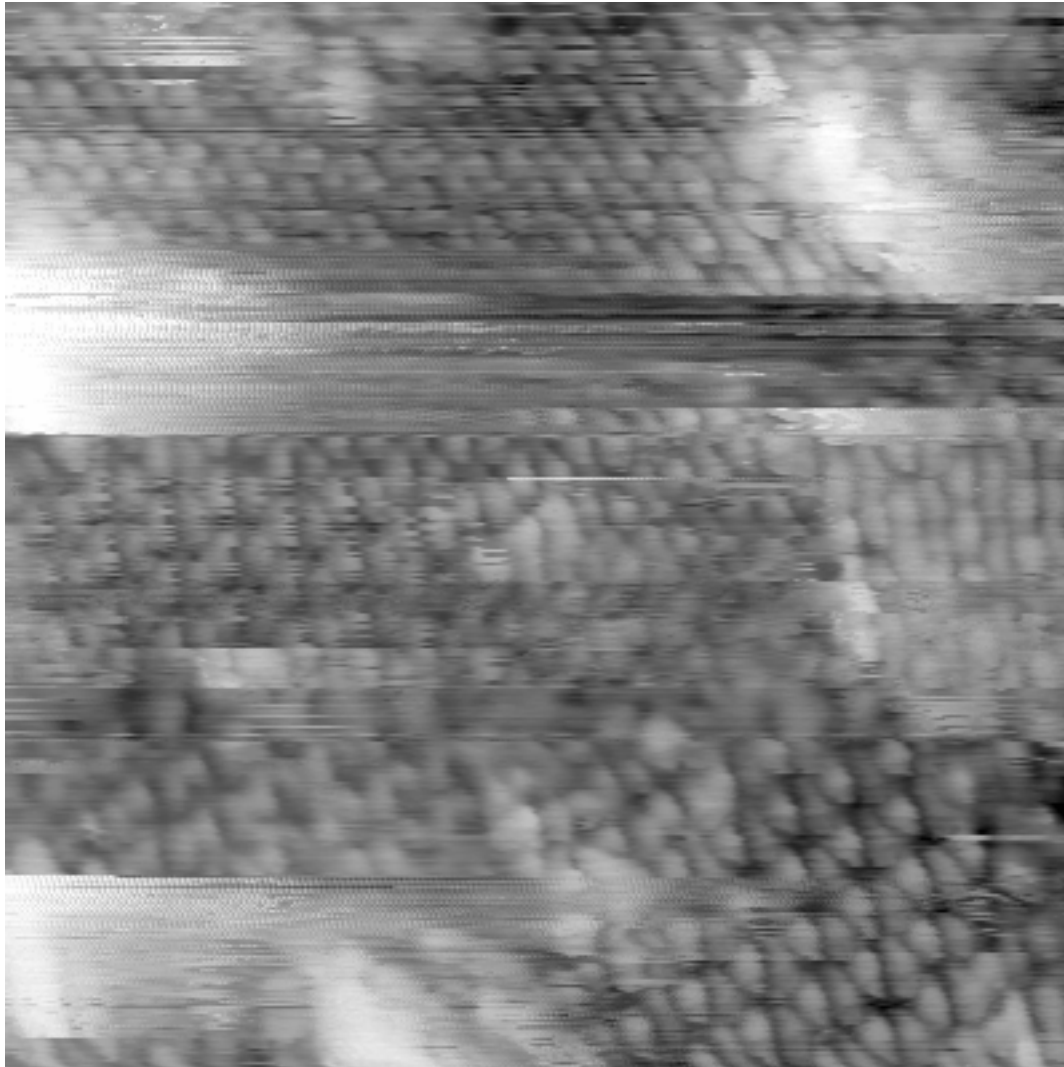


HOMO, nanotube 4,18 nm

A. Rubio & al. PRL 92, 3520 (1999)



Confinement d'onde de densité de charges



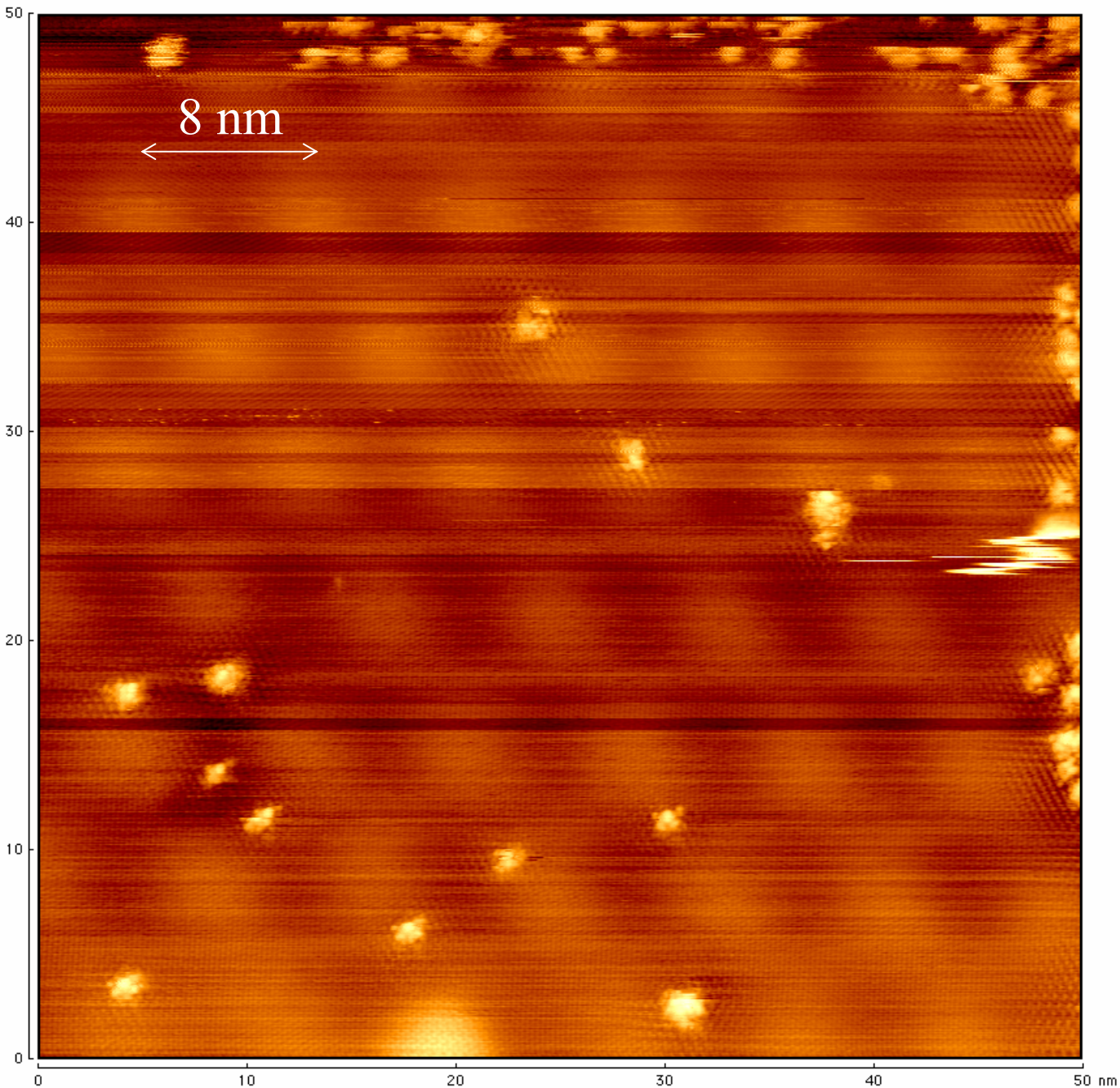
$$V_{\text{bias}} = -2 \text{ mV}$$
$$I = 0,5 \text{ nA}$$



HOMO, nanotube 4,06 nm

A. Rubio & al. PRL 92, 3520 (1999)





$$D = \frac{d}{2 \sin \frac{\Theta}{2}}$$

$$\Theta \propto 1,7^\circ$$

$$V_{\text{bias}} = 10 \text{ mV}$$

$$I = 0,30 \text{ nA}$$



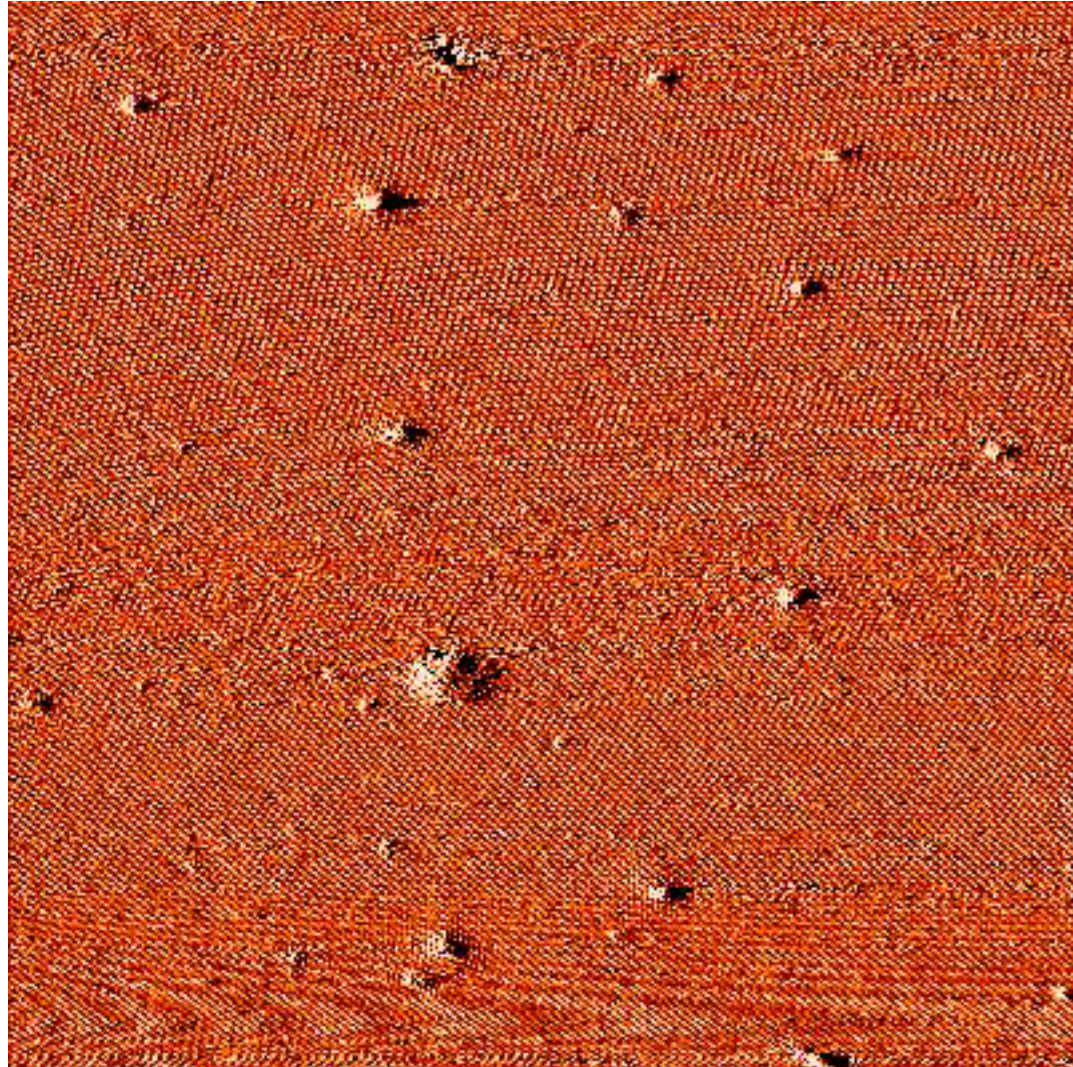
PIIM

CRS

II. Interaction H^+ / graphite HOPG

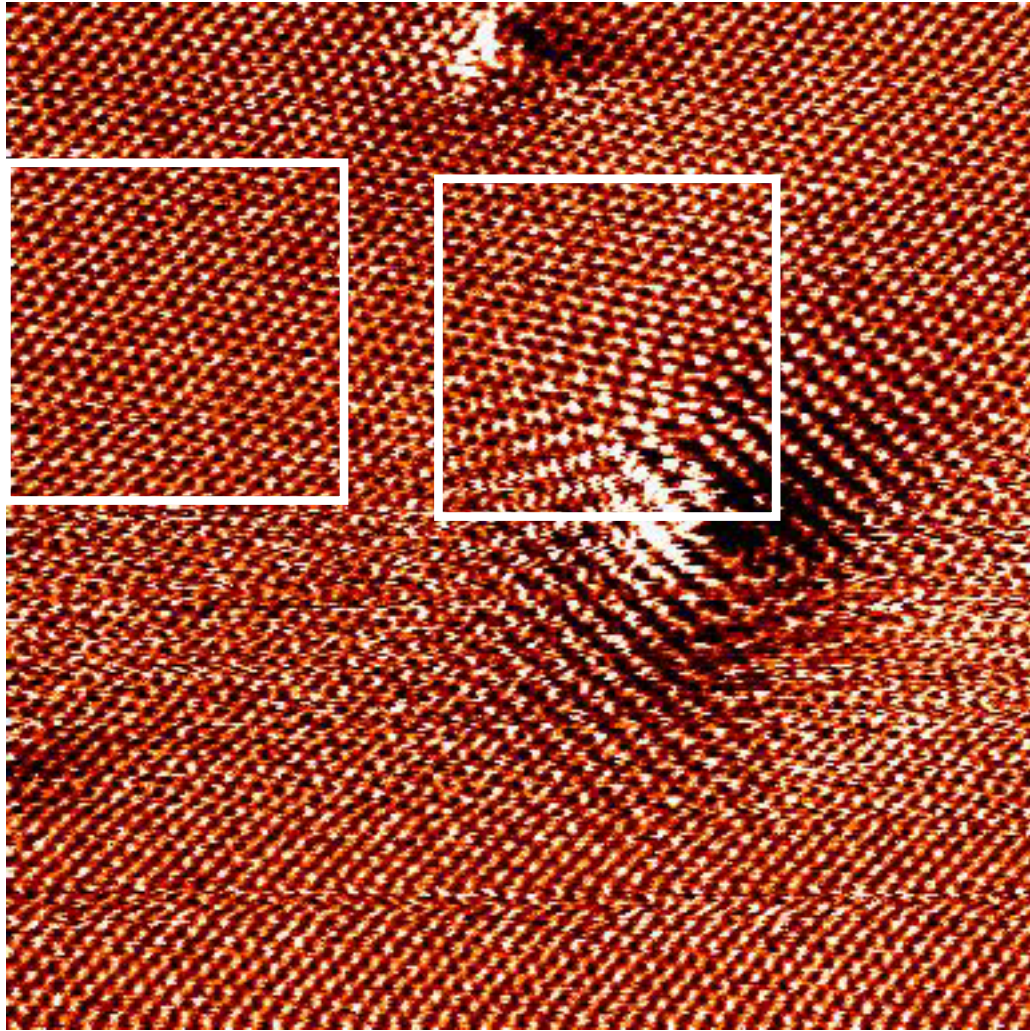
Fluence = $5 \cdot 10^{13} H^+/cm^2$
 $E_{ions} = 300 eV$

100 nm x 100 nm

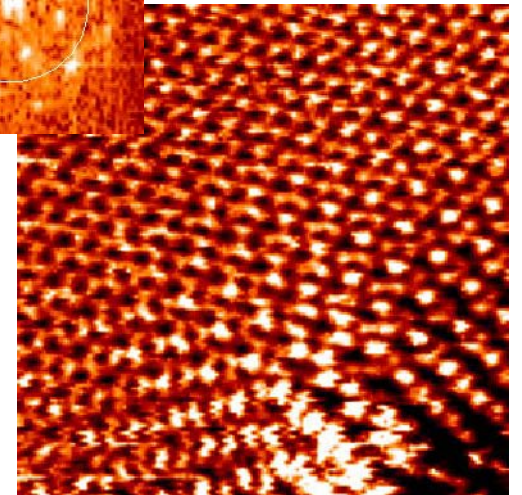
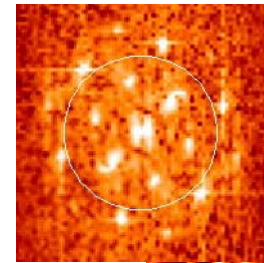
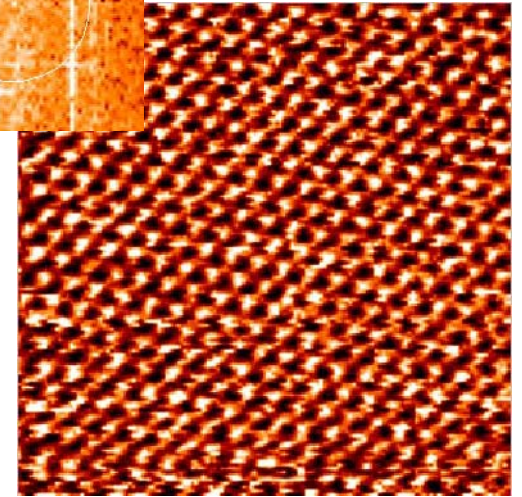
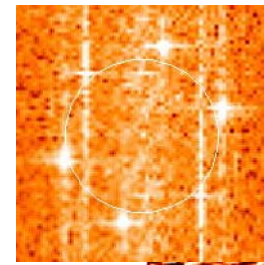


... La densité de surface est de $3.86 \cdot 10^{15} C \text{ atomes}/cm^2$

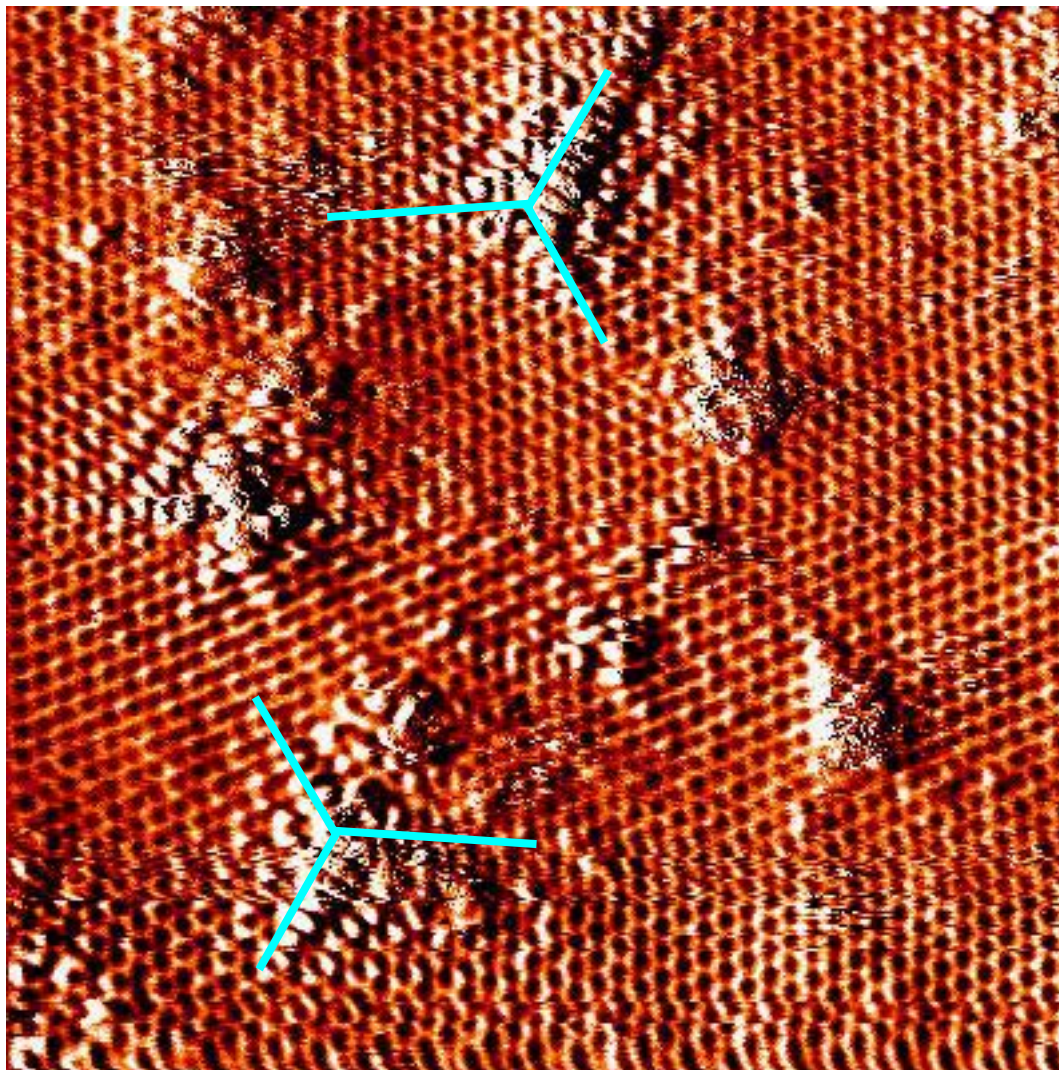
Fluence = $5 \cdot 10^{13} \text{ H}^+/\text{cm}^2$ $E_{\text{ions}} = 300 \text{ eV}$



15 nm x 15 nm



Fluence = $3 \cdot 10^{14} \text{ H}^+/\text{cm}^2$ $E_{\text{ions}} = 300 \text{ eV}$



10 nm x 10 nm

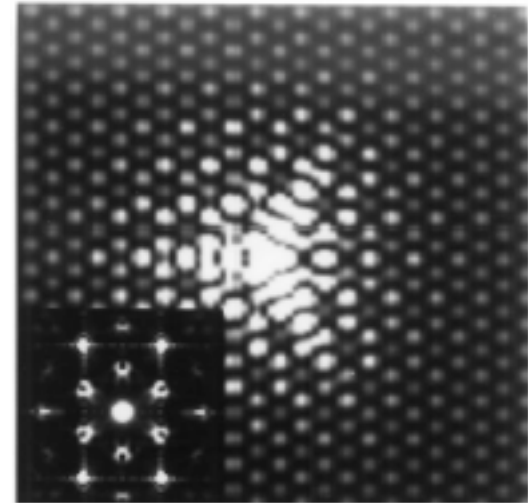
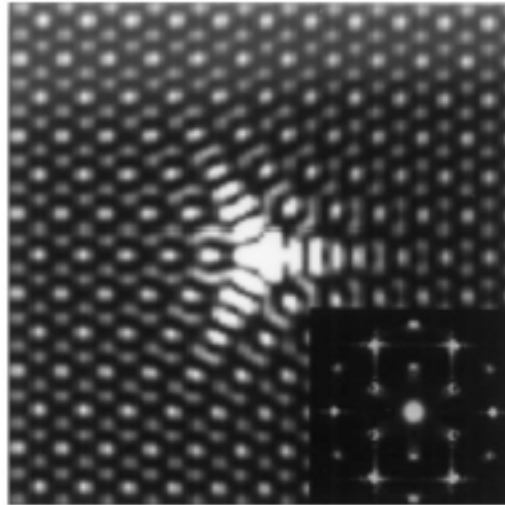


PIIM

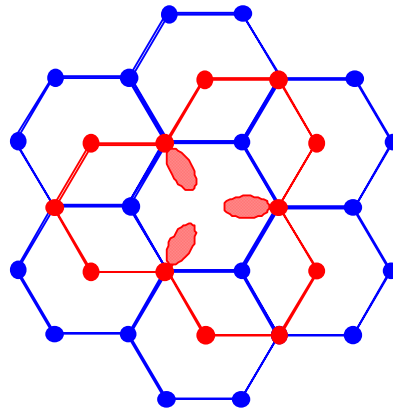
OKS

surstructure $(\sqrt{3}\times\sqrt{3})R30^\circ$

- **adatomes** H.A Mizes & J.S. Foster, Science 244, 559 (1989),
P. Ruffieux & al, PRL 84, 4910 (2000) "Hydrogen Atoms Cause Long-Range Electronic Effects on Graphite"
- **déplacement stable d'atomes de carbone**
B. Rousseau, H. Estrade-Szwarckopf, A-L. Thomann & P. Brault, Applied Physics A 77, 591 (2003)
- **marches et joints de grains**
- **défauts ponctuels**
 - K.F. Kelly, N.J. Halas, Surf. Sci. 416, L1085 (1998)

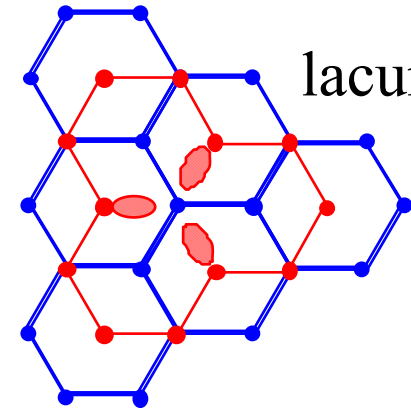


lacune- β

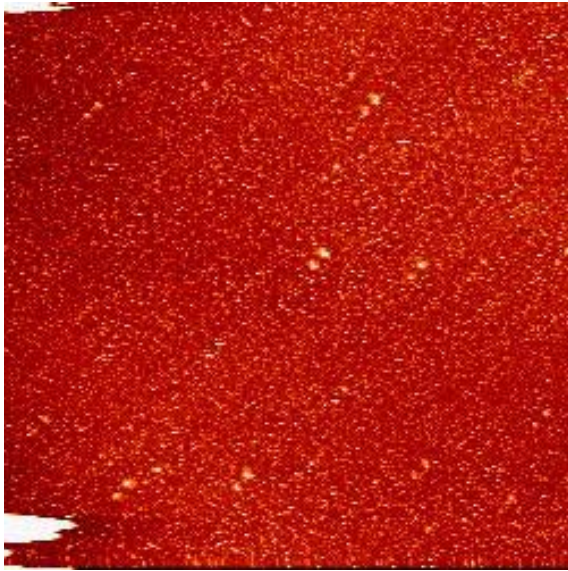


- couche terminale
- 2nde couche

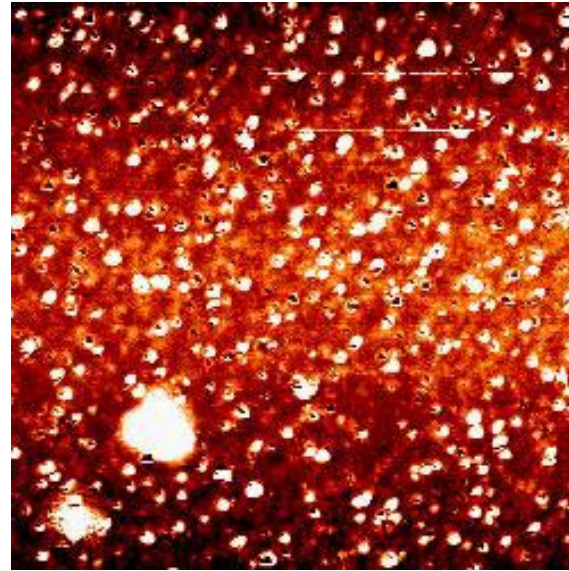
lacune- α



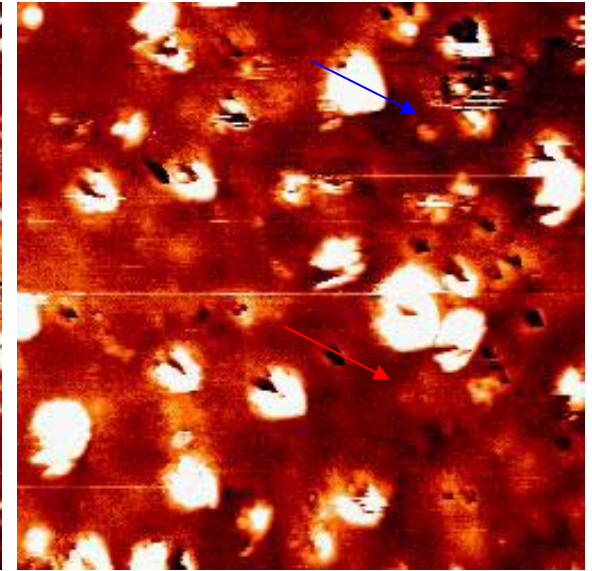
Fluence = $1.3 \cdot 10^{15} \text{ H}^+/\text{cm}^2$ $E_{\text{ions}} = 300 \text{ eV}$



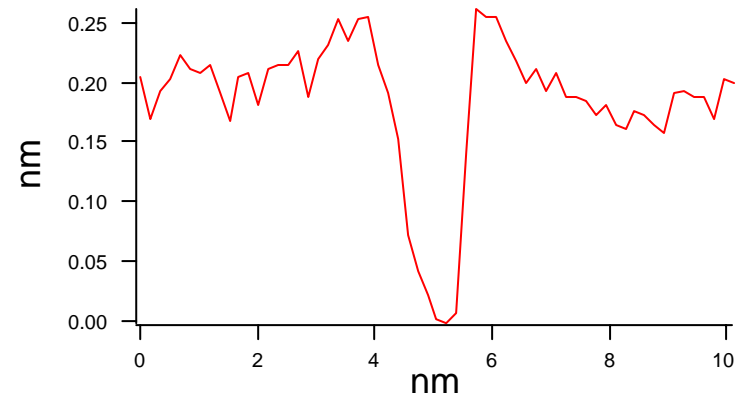
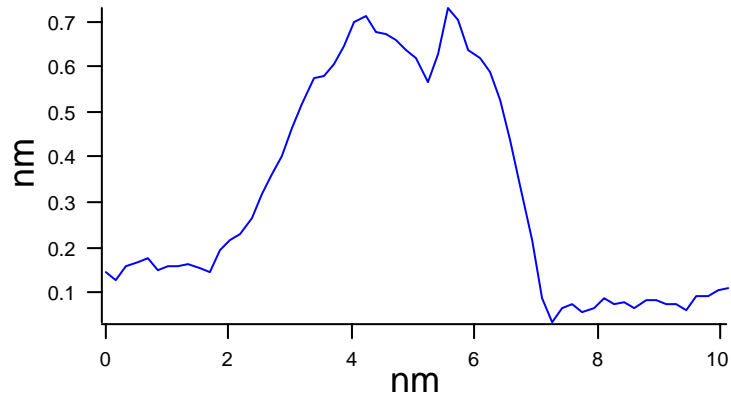
1000 nm x 1000 nm



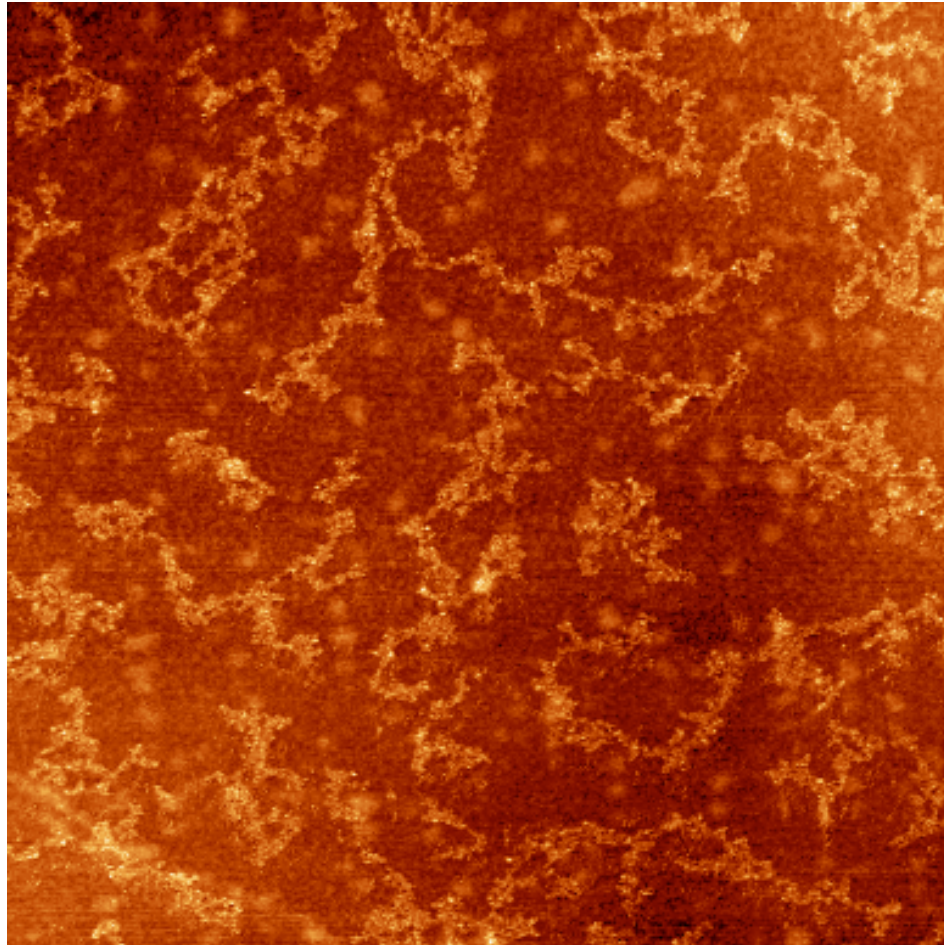
150 nm x 150 nm



42 nm x 42 nm

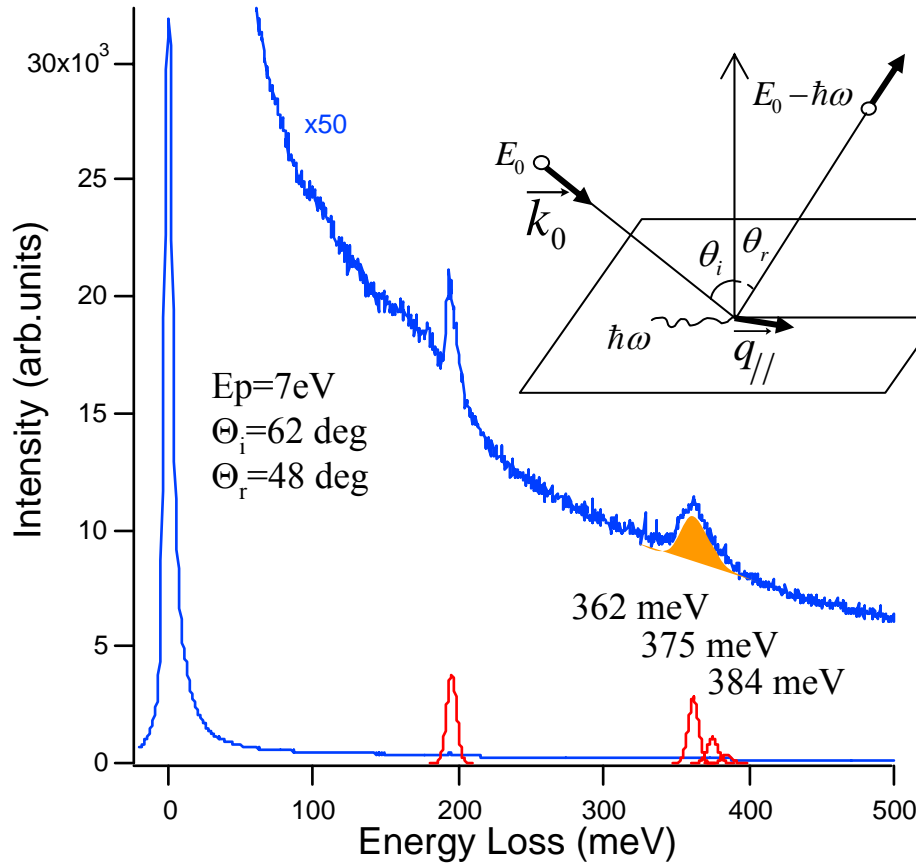


Fluence = $1.3 \cdot 10^{16} \text{ H}^+/\text{cm}^2$ $E_{\text{ions}} = 300 \text{ eV}$



$1 \mu\text{m} \times 1 \mu\text{m}$

graphite HOPG, bombardé : Fluence = $3 \cdot 10^{14} \text{ H}^+/\text{cm}^2$ $E_{\text{ions}} = 300 \text{ eV}$
 + exposition à H atomique (filament chaud!)



	Stretching Frequencies (meV)	
	s	a (d)
sp^3 	375	
	364	371
	361	(372)
sp^2 	382	
	372	383

- Défauts de caractère sp^3 essentiellement
- L'érosion chimique est un effet combiné de H^+ et H

Many thanks to...

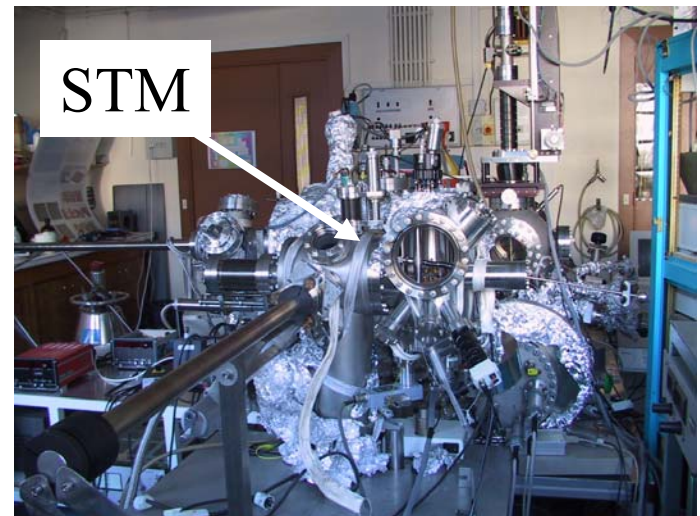
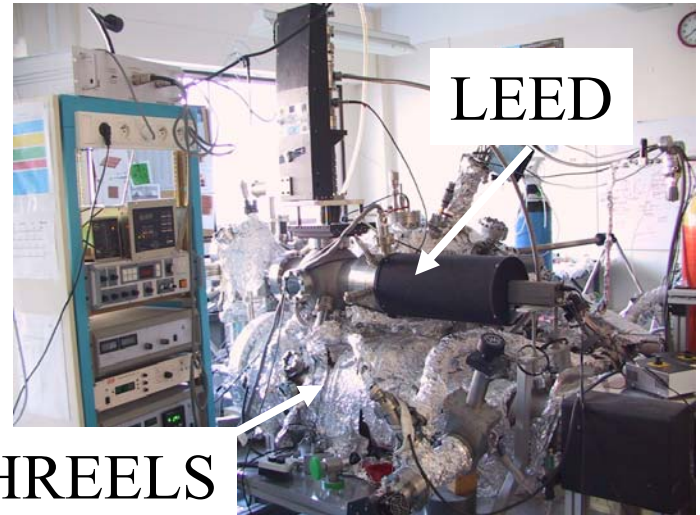


PROGRAMME
COMMUNAUTAIRE
FEDER



UHV experimental set-up Surface Analysis Techniques

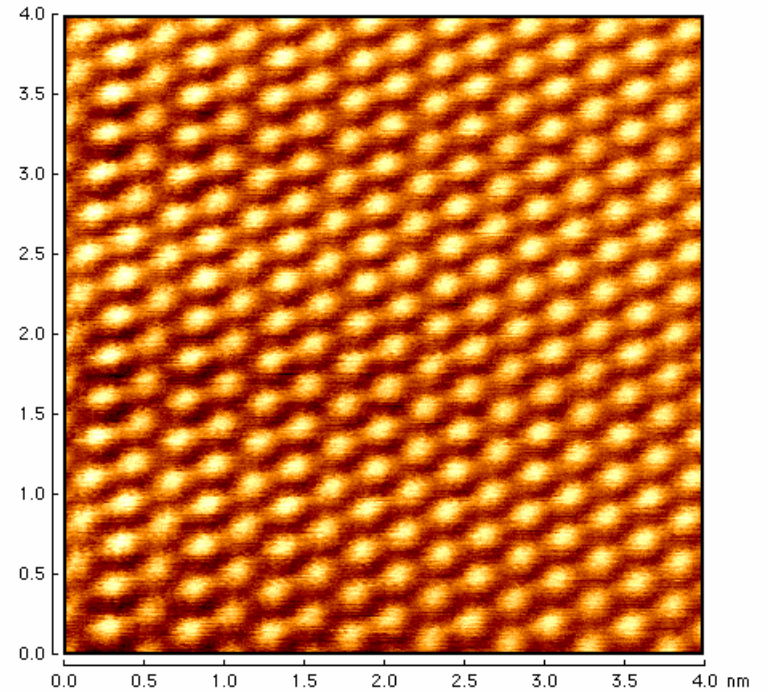
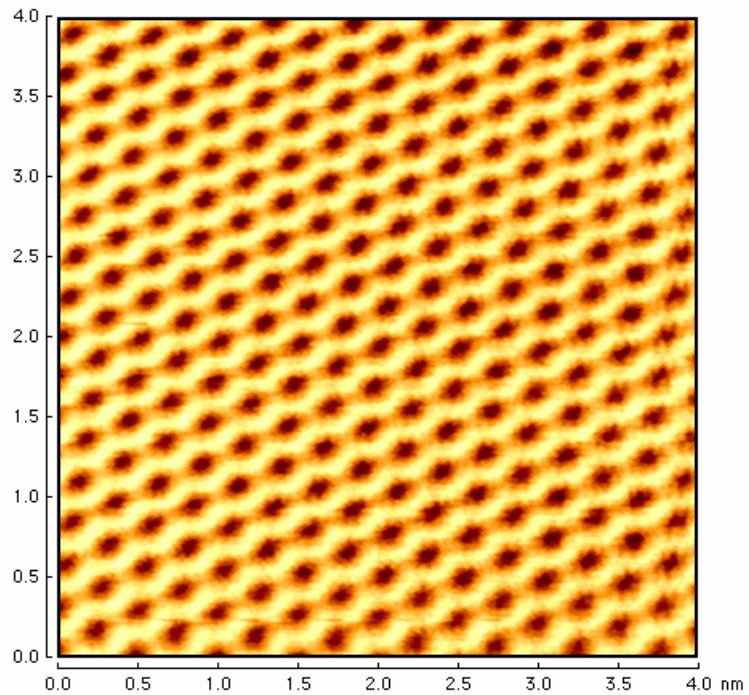
Canon à ion
Source d'hydrogène atomique



$V_{\text{gap}} = -0,07 \text{ V}$
($I = 0,19 \text{ nA}$)
etats pleins

Z constant

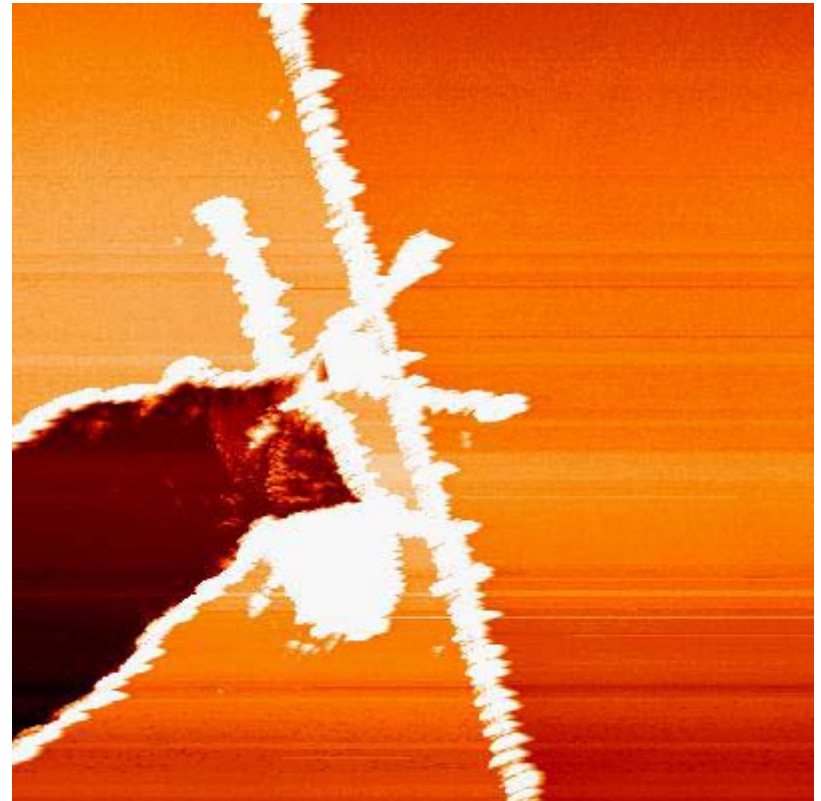
$V_{\text{gap}} = 0,07 \text{ V}$
etats vides



Coming soon !

- passivation of defects

Silicon deposited on clean HOPG graphite



1000 nm x 1000 nm

... and Boron

