Interaction of low pressure hydrogen plasma with materials of interest for fusion : study of the negative ion surface production

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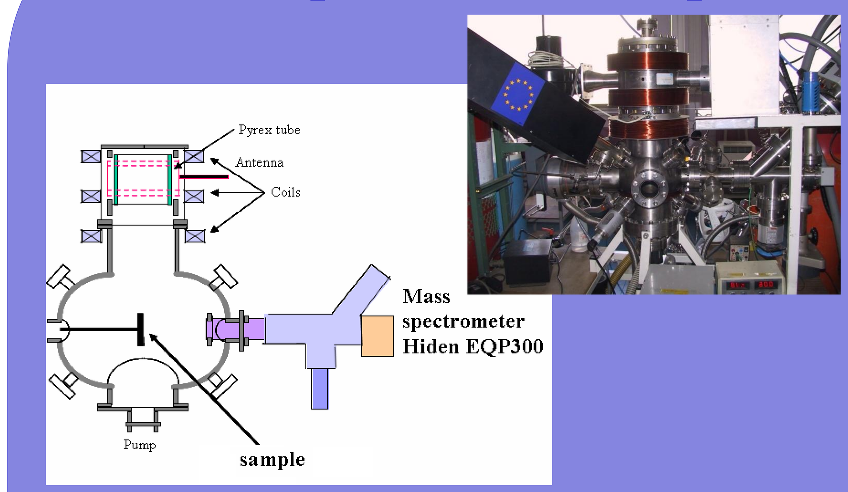
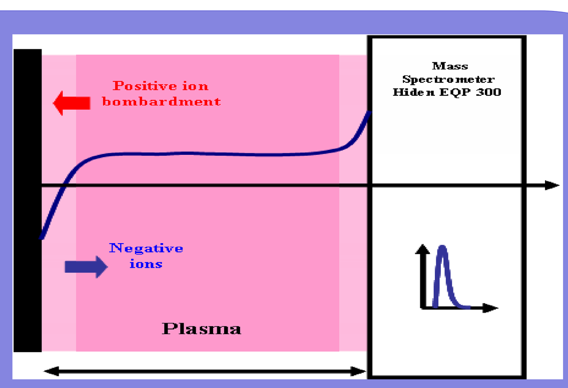
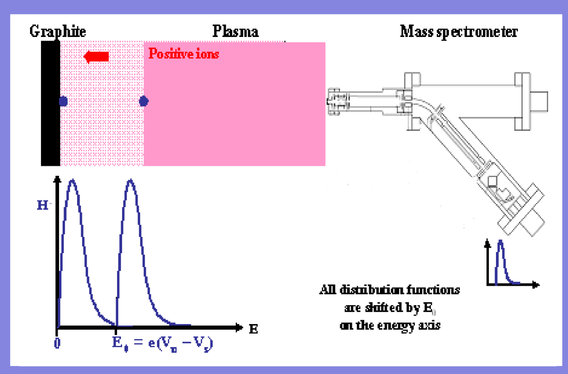
Experimental setup







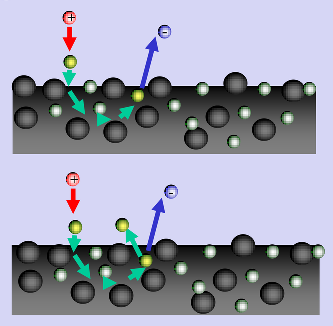
- H_2 and D_2 plasmas - No magnetic field
- P = 30-900 W - Pr= 0.2 - 2 Pa

- Upon positive ion bombardment, some negative ions are formed on the surface
- These negative ions (NI) are repelled by the sheath, cross the plasma and reach the mass spectrometer
- We record and study **surface produced negative ion distribution functions (IDF)**

H^-/D^- production on HOPG surface

Surface production mechanisms

- I- Backscattering
- II- Sputtering



[1] L Schiesko, M Carrère, G Cartry and J M Layet, Plasma Sources Sci. Technol. 17, 035023 (2008)
[2] L. Schiesko, M Carrère, J.M. Layet, and G. Cartry, Appl. Phys. Lett. 95, 191502 (2009)
[3] L Schiesko, M Carrère, J M Layet and G Cartry, Plasma Sources Sci. Technol. 19 (2010) 045016

SRIM CALCULATIONS

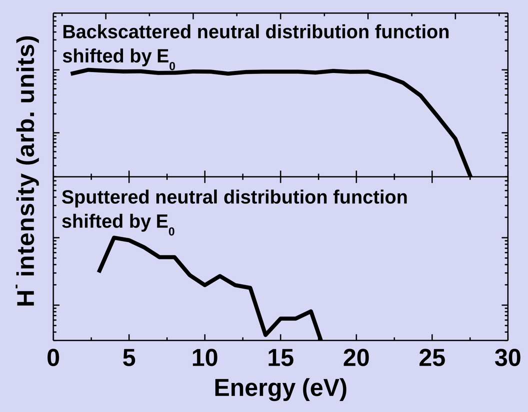
- SRIM calculates energy distribution of backscattered and sputtered **neutral** particles
- Positive molecular ions are assumed to be dissociated at impact and energy is assumed to be shared between fragments ⇒ only H+ or D+ are considered in calculations

H_2^+ impact at energy E_0 ≡ H^+ impact at energy $E_0/2$

H_3^+ impact at energy E_0 ≡ H^+ impact at energy $E_0/3$

- a-CH or a-CD layers (70% C – 30% H or D) are considered
- SRIM calculations are shifted by E_0 to take into account neg. ion acceleration through sheath

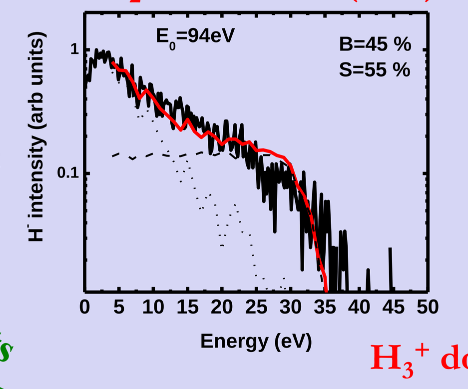
SRIM result



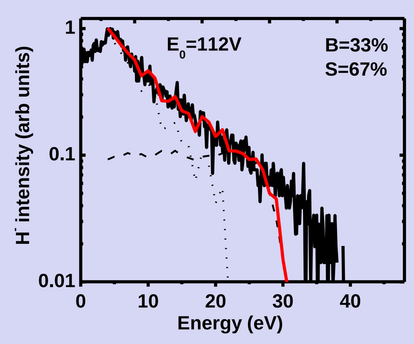
Fits

Fit experiment by: p_1*Back+p_2*Sputt

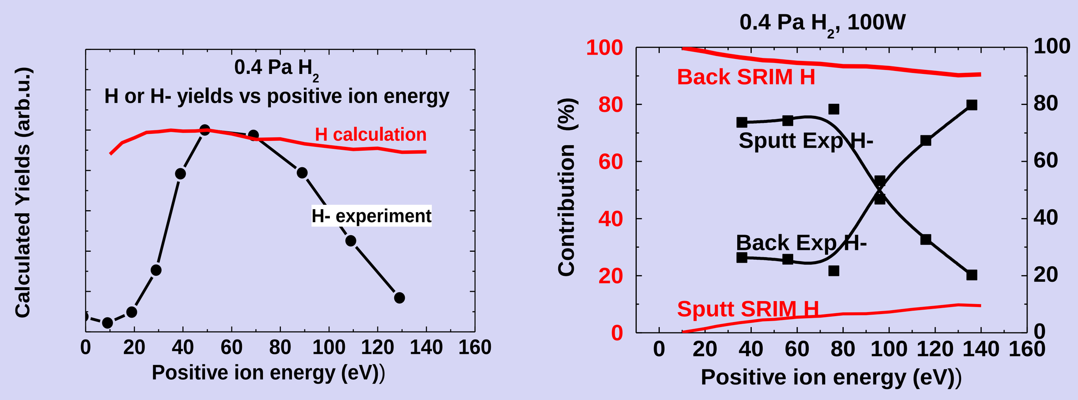
H_2^+ dominates (90%)



H_3^+ dominates (87%)



- SRIM is able to reproduce experimental datas
- Confirms negative ion are formed by sputtering and backscattering mechanisms



Experiment: strong variation with positive ion energy
Calculations: only 10% variation

Calculations and experiments yields are different

Experiment: sputtering dominates
Calculations: backscattering largely dominates

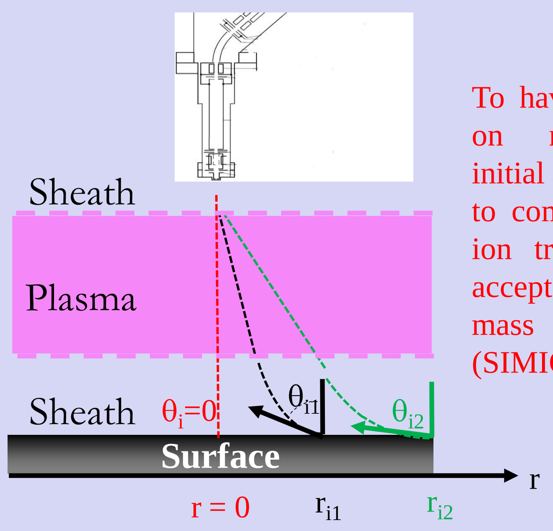
Different percentage for backscattered and sputtered ions in experiment and calculation

Why ?

Angular controlled measurements

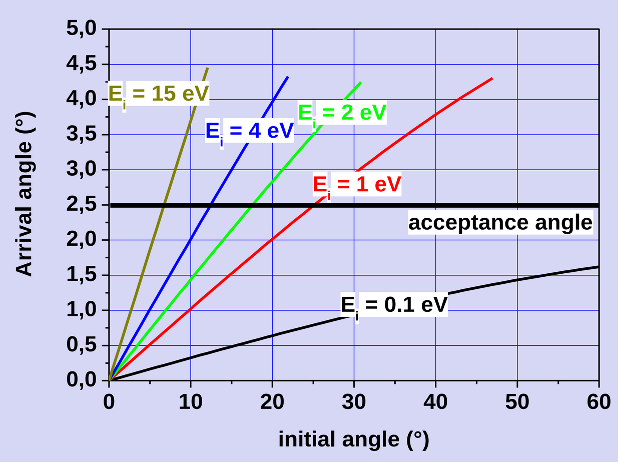
Angular controlled measurements

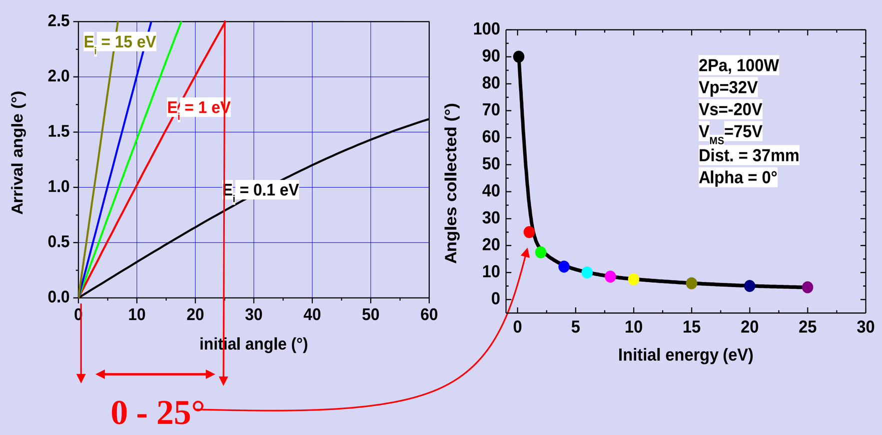
For each radius value (r) on the sample we detect negative ions emitted at one particular angle θ_i

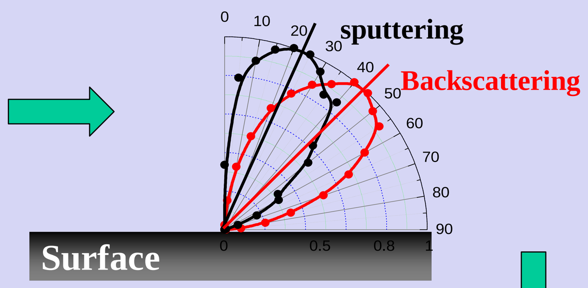


To have information on negative ion initial angle, we need to compute negative ion trajectories and acceptance angle for mass spectrometer (SIMION)

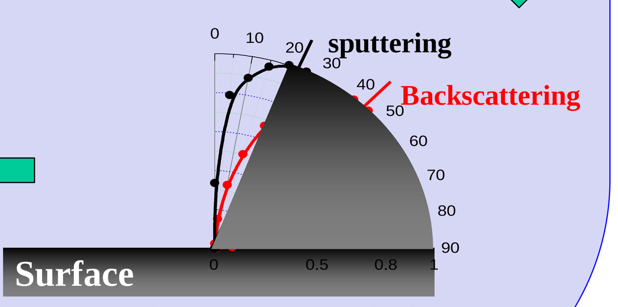
Calculations give the arrival angle (Angle on the mass spectrometer) versus the initial angle (Angle of emission on the surface) :







SRIM results



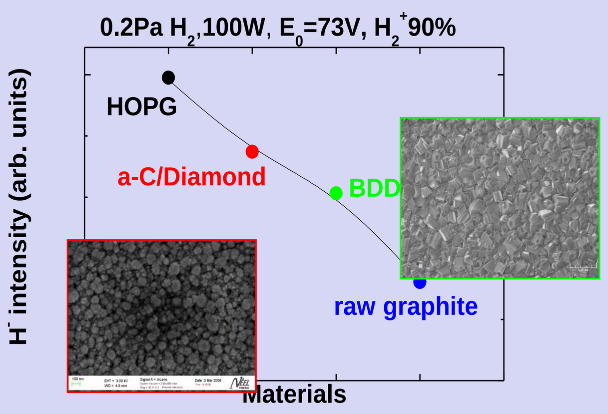
SRIM results + trajectory calculation

Calculations demonstrate that low energy ions are oversestimated . Sputtered ions are more collected that backscattered ions.

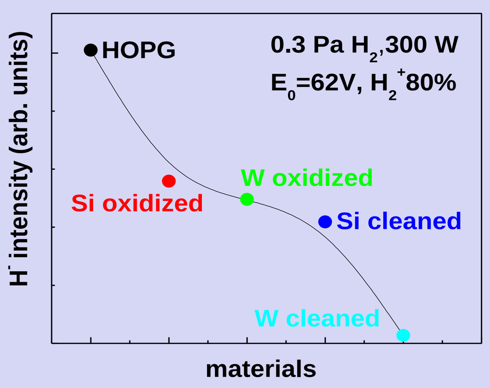
Calculations explain why we have different yields between SRIM and experimental result

H- production on carbon and metal or semi-conductor surfaces

Intensity comparisons



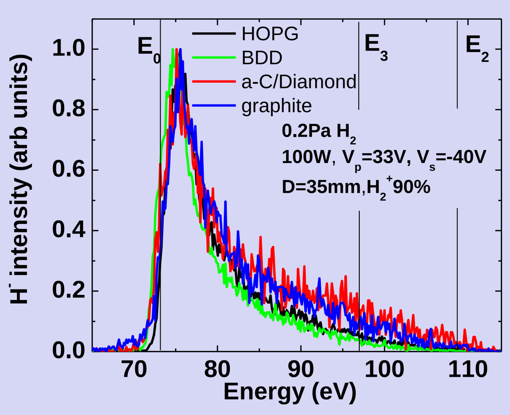
- HOPG: Highly Oriented Pyrolitic Graphite
- BDD: Boron doped diamond (LIMHP)
- a-C/Diamond: nc-Diamond or a-C (Institut Néel)
- Graphite: raw graphite from an electrode

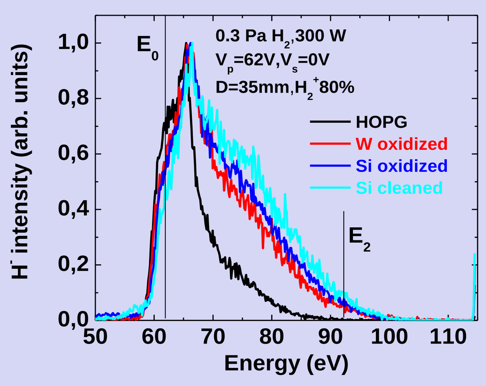


- Oxidized materials = materials as introduced
- Cleaned materials = after 10-20 mn Ar plasma, 1Pa, 100W, 200eV positive ion bombardment
- Clean Ta, copper and clean stainless steel (not shown here) behaves similarly to clean tungsten (very low signal)

IDF shape comparisons

all IDFs normalized to one



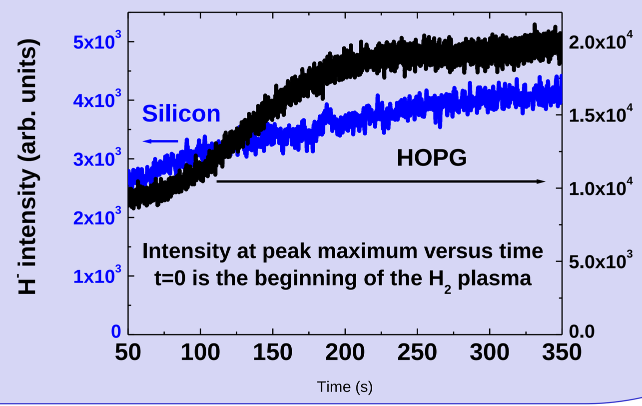


- Same shape for all carbon materials
NI are produced by backscattering and sputtering with same proportion of each mechanism for all carbon materials

- Shapes different between HOPG and Si or W
NI are produced by backscattering and sputtering but the proportion of each mechanism strongly differs between HOPG and metals or semi-conductors

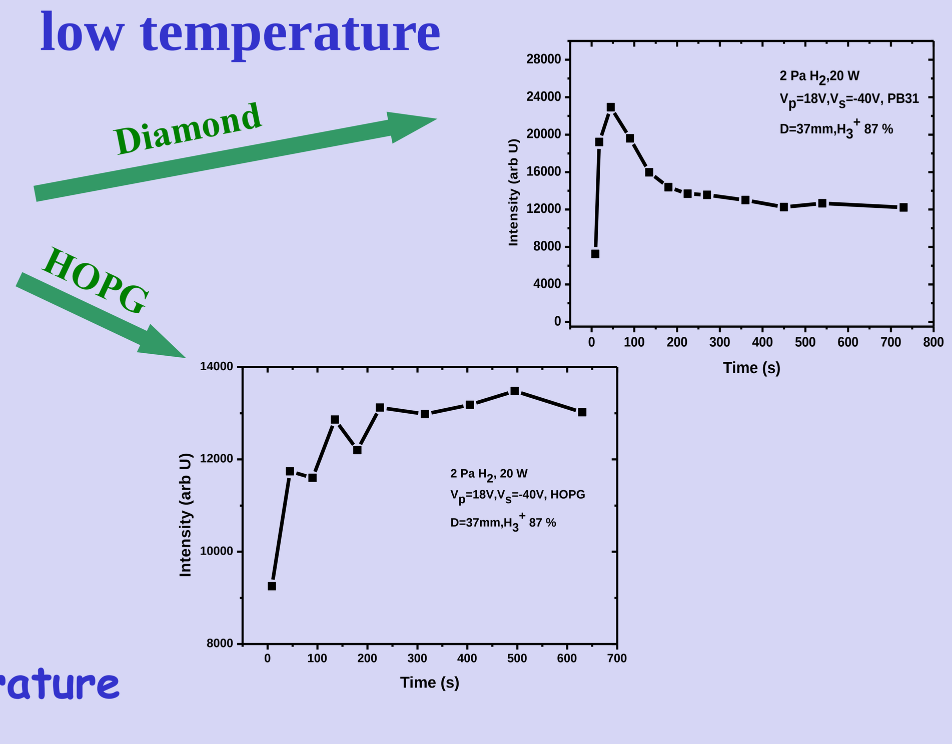
NI intensity vs time

- Hydrogenation of silicon and HOPG favors NI production



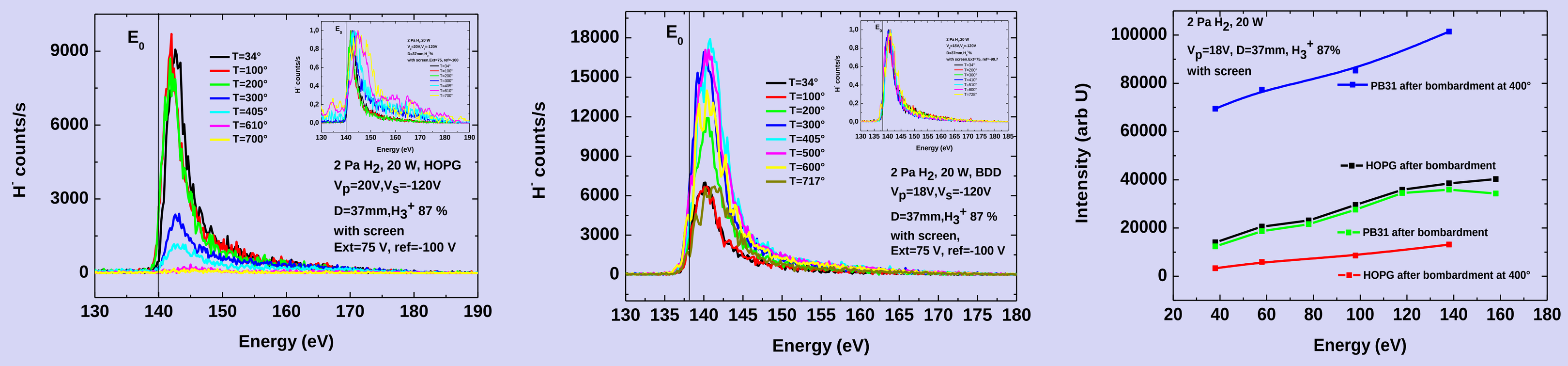
H- production on HOPG and Diamond surfaces at high and low temperature

Variation of surface state in time after the first exposure to the plasma



- Surface evolves in time due to ion bombardment
- Intenisty increases to maximum and then decreases – BDD
- Intensity increases and saturates- HOPG

IDFs vs surface temperature



- Yield decreases with increasing temperature - HOPG
- Yield increases first and then decreases with increasing temperature – BDD
- HOPG and BDD behaves differently at high temperature
- Sputtering decreases with temperature for HOPG while proportions of sputtering and backscattering seem constant with temperature for BDD

Conclusions

- **Angular controlled measurements are very important to understand better NI production**
- **HOPG is the most efficient material for producing negative ions at room temperature**
- **All carbon materials behave similarly at low surface temperature**
- **HOPG and Diamond strongly differ at high temperature**
- **Diamond gives 6 times more signal at 400° than HOPG at the same temperature**
- **Oxidized surfaces are more efficient for producing negative ions than clean surfaces**
- **Clean metal surfaces are not efficient at all to produce negative ions**