H^- formation by scattering of hydrogen atoms/ions on carbonaceous surfaces

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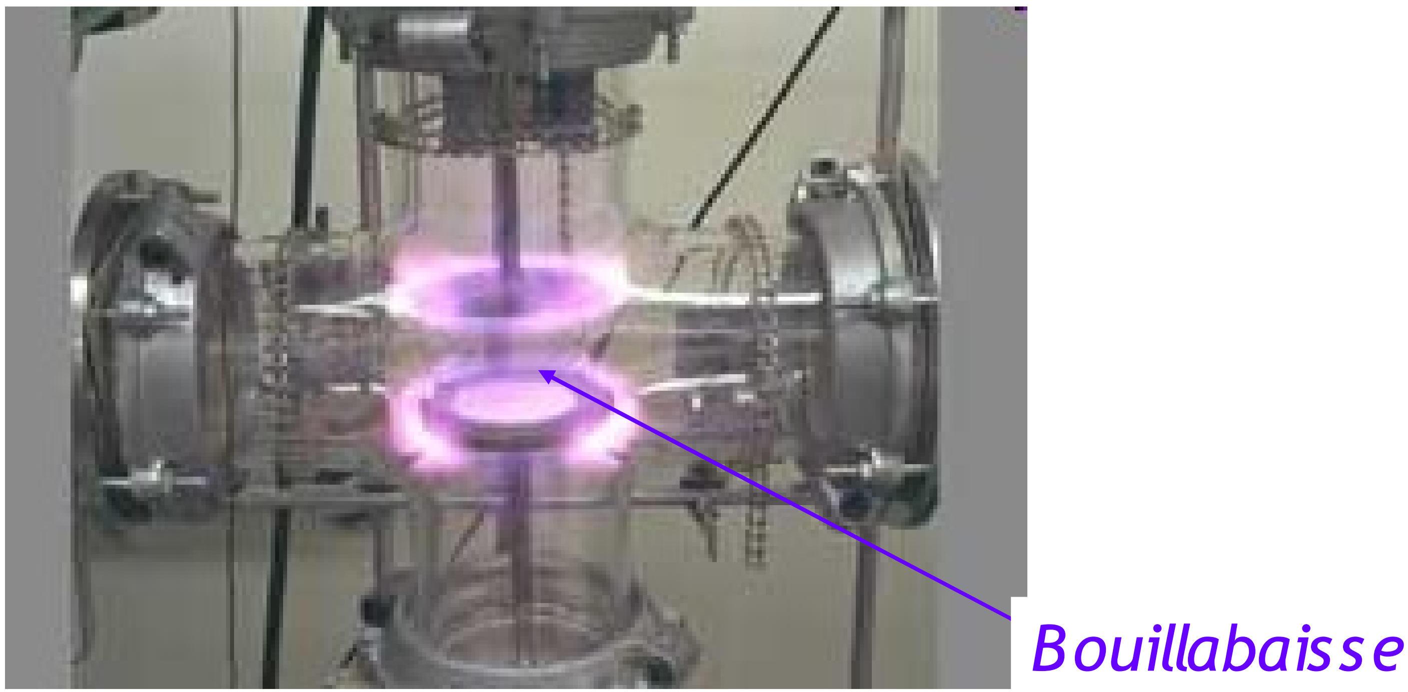

Bouillabaisse

Fundamental processes: metals v.s. insulators

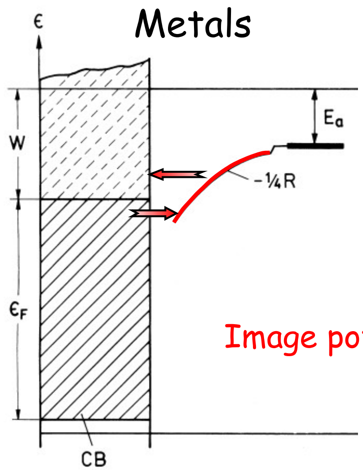
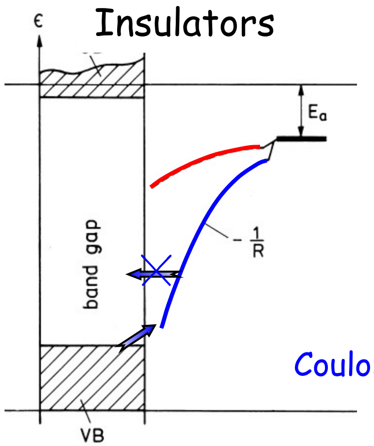


Image potential : V ~ -1/(4.R)

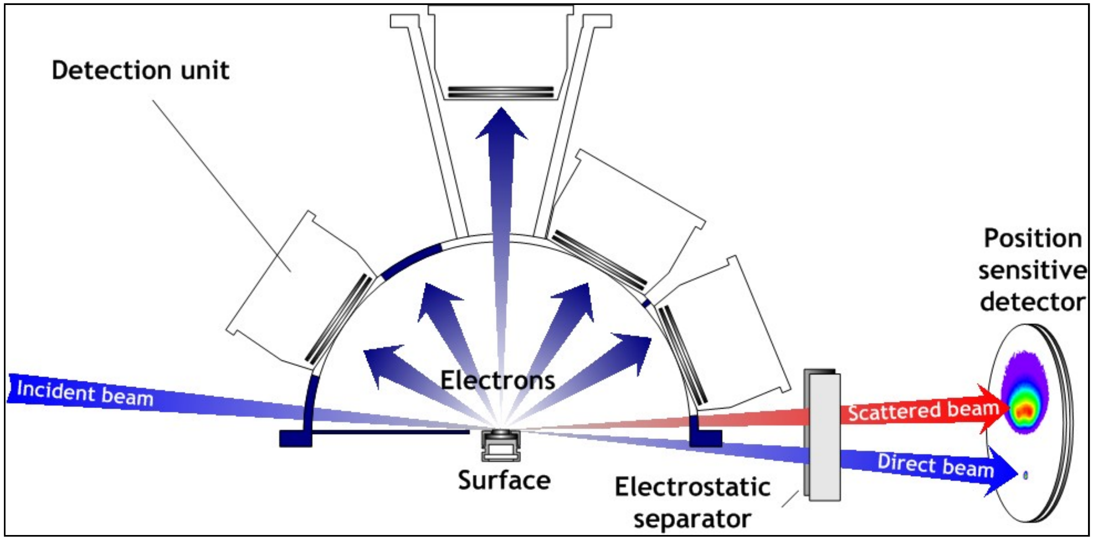
- Binding energy of negative ions < 3.5 eV
  work-function of metals ~ 5 eV
  ⇒ Requires small distance of approach
- Large density of empty levels above Fermi
  ⇒ large probability for electron loss

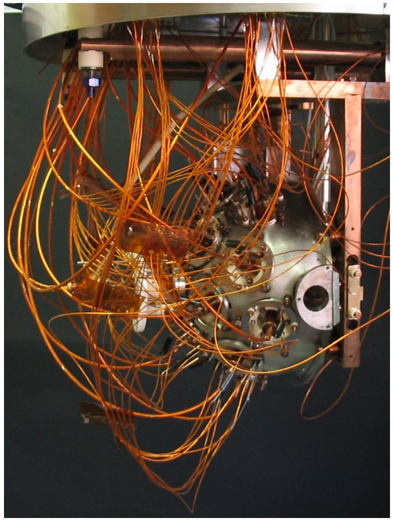


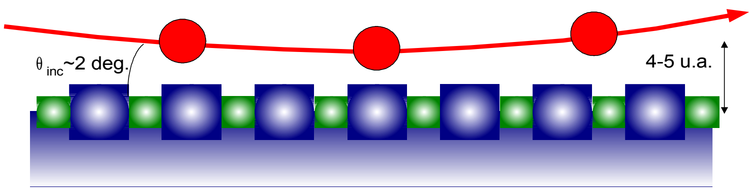
Coulomb potential: V ~ -1/(R)

- Localized hole induces an additionnal coulomb potential
  ⇒ stronger shift of affinity level
- Large band gap
  ⇒ suppression of electron loss

Experimental approach: grazing incidence





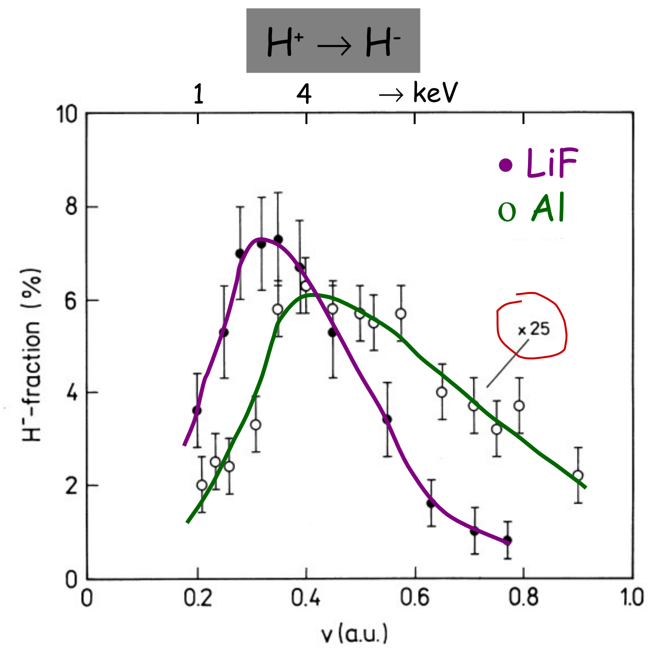


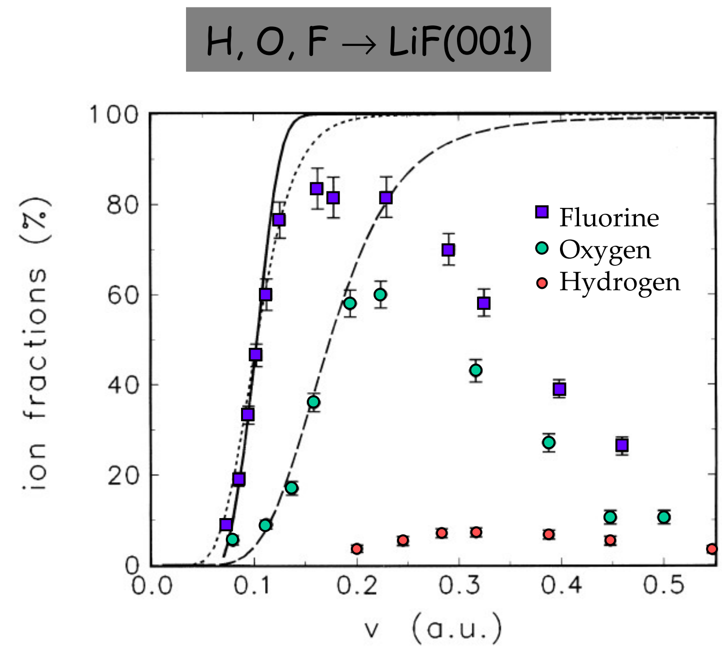
$$200 < E_0 < 10000\ eV$$

$$E_\perp = E_0 \sin^2(\psi) \qquad 20\ meV < E_\perp < 10\ eV$$

Limited number of inelastic processes ⇒ access to individual basic processes

Fundamental processes: metals v.s. insulators





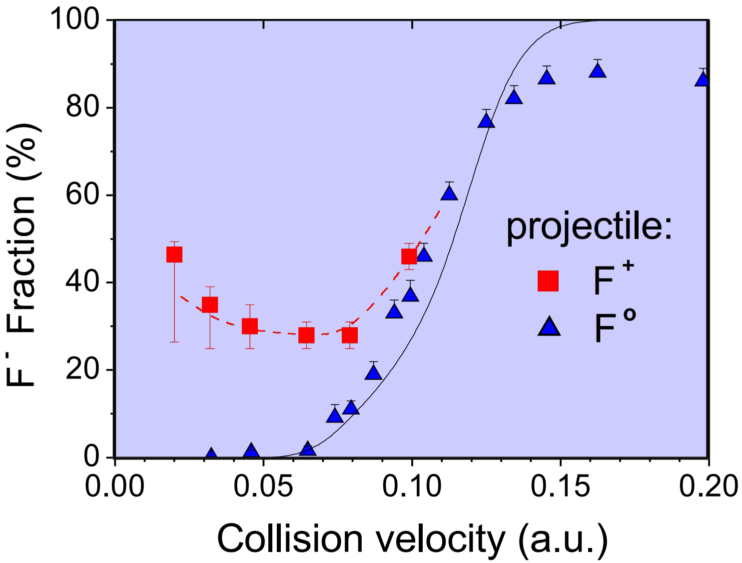
H. Winter, Progress in Surface Science **63**, 177, 2000
A.G. Borisov, V. Sidis

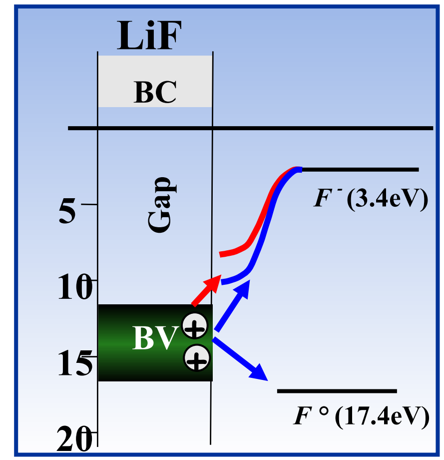
<u>Negative ion formation from neutrals:</u>

- threshold in parallel velocity (kinematic effect)
- competition between capture and electron loss

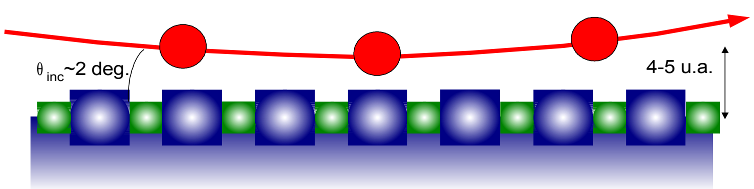
Incident atoms with low energy ⇒ very low yield of negative ions…
…unless surface has a low work-function (Cs)

Fundamental processes: simultaneous double capture





At low energy, it is easier to capture two electrons rather than one !!!



<u>Systemes where double capture has been obeserved:</u>

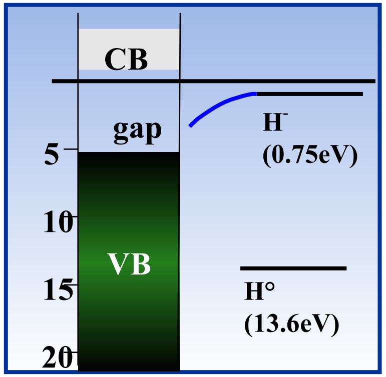
- F^+ on LiF(001) ⇒ F^- fraction ~ 40 %
- O^+ on NaCl(001) ⇒ O^- fraction ~ 7 %
- H^+ on NaCl(001) ⇒ H^- fraction ~ 1 %

Results from diamond

<u>CVD grown diamond, naturally hydrogenated</u>

- band gap ~ 5.5 eV
- very deep valence band
- negative electron affinity (-1 eV), depending on H surface coverage

⇒ Virtually very good candidate for negative ion formation & survival

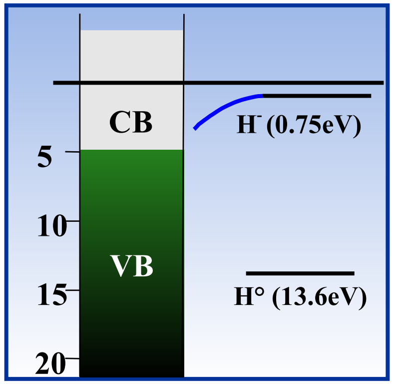


Projectile E=1 keV	Fraction of H^- (%)
H^+	**2.5 ± 0.5**
H°	**3.0 ± 0.8**
H_2^+	**1.6 ± 0.5**

Résults with H_2^+ in agreement with literature
(Wurz P. , Schletti R. and Aellig M.R., Surf. Sci **373**, 56, 1997)

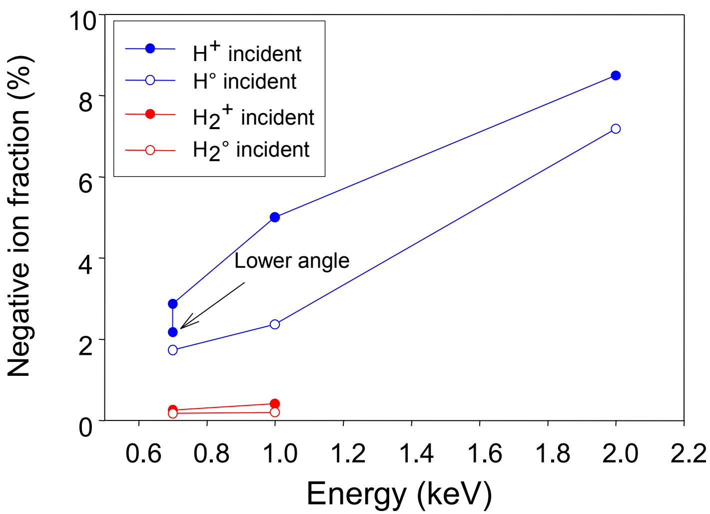
<u>Conclusion</u>: CVD diamond behaves like a common ionic insulator (LiF, NaCl)
⇒ survival of transient H^- favored by band gap

Results from graphite, first glance…



Graphite HOPG

- semi-metal (conductor)
- work-function ~ 5 eV
- deep valence band



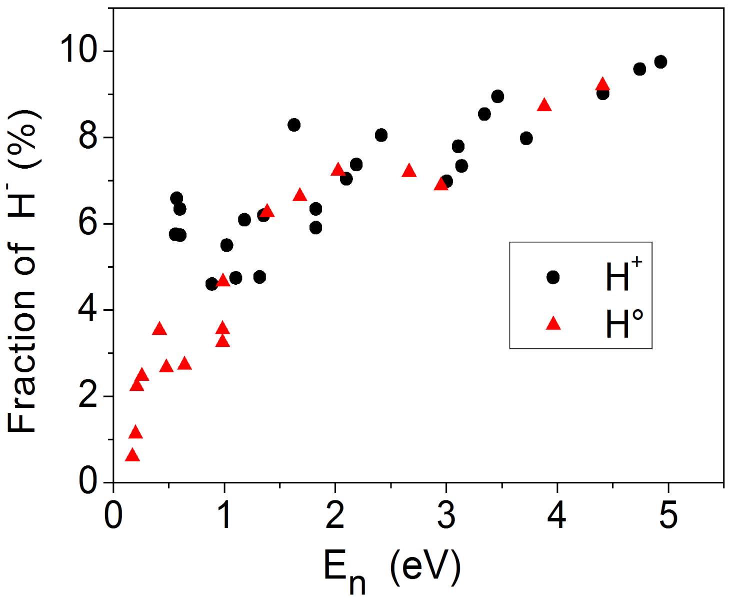
The dissociation probability of H_2 is probably very small

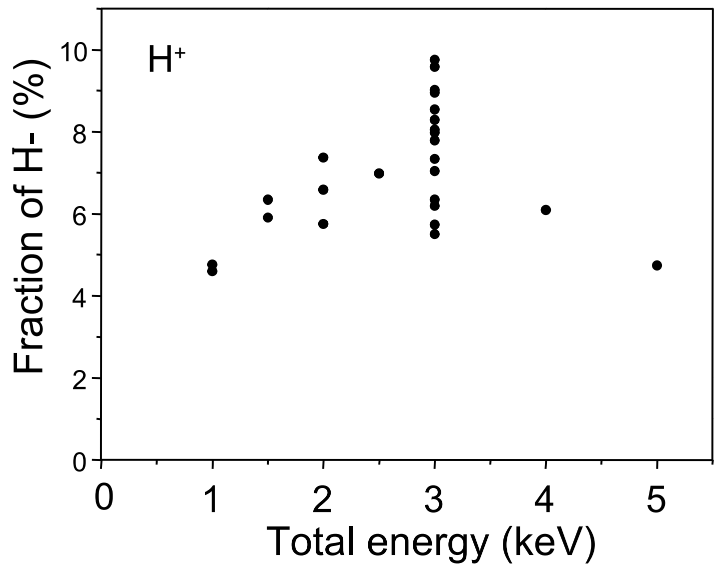
- H^- fractions
- electron emission

⇒ comparable to those measured on ionic insulators (LiF)

- energy loss ⇒ comparable to that measured on metals

Results from graphite, more…





- H^- fractions barely depend on incident charge state (efficient neutralizaton of H^+)

- variation with E_{total} (competition capture/loss) is comparable to that observed on LiF(001) !

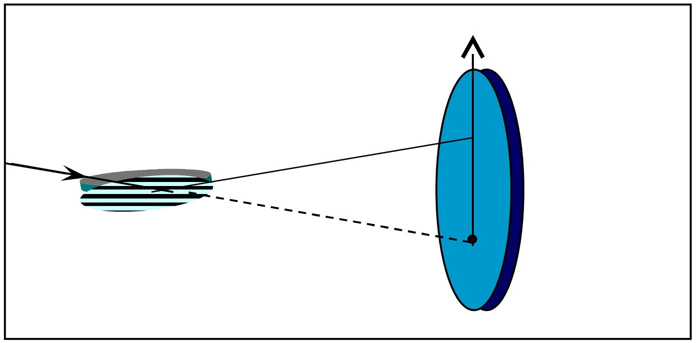
- H^- fractions increase with $E_\perp$

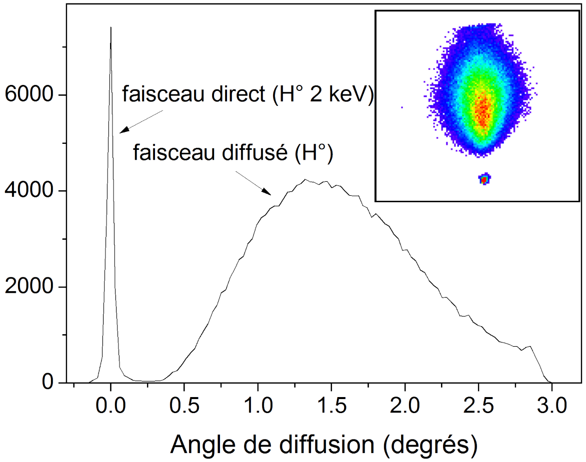
$\Rightarrow$ is there a maximum in En?

Results from graphite, more…

<u>These results are characteristic of a clean graphite:</u>

- H^- fraction increases after annealing to 600°C (no contamination)
- low defect concentration





⇒ Influence of contamination and defects (plasma conditions) on H^- production ?

Conclusions

Diamand:

- results below expectations (not better than LiF)

→ question over actual H surface coverage

→ question over surface quality

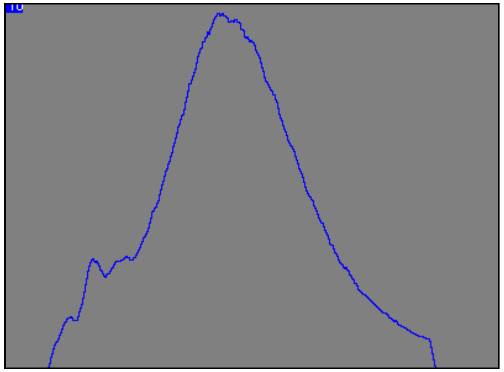
Graphite:

-H^- fractions unexpected and promising (capture from H°)

- possible to get more than 10% H^- for normal energies > 5 eV

→ Formation mechanism not clear

→ HOPG is either a metal (energy loss) or an insulator (H- yield, e- emission)



Energy loss spectrum

Perspectives

It seems that carboneceous materials offer good surprises

-Extend our work on graphite and possibly on hydrogenated diamond

→ exploit energy loss data in coincidence with electron emission

→ go to larger incidence angles (avoid detachment)

→ investigate graphite with H and/or defects

- investigate other carbon based materials (C_{60}…)

Best candidate material (in theory):