Study of H^- extraction from a single-hole plasma electrode of C12A7 electride: A way to a Cs-free H^- Source

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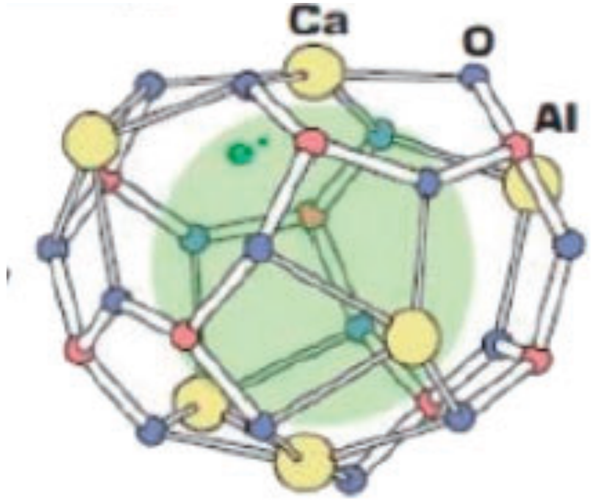
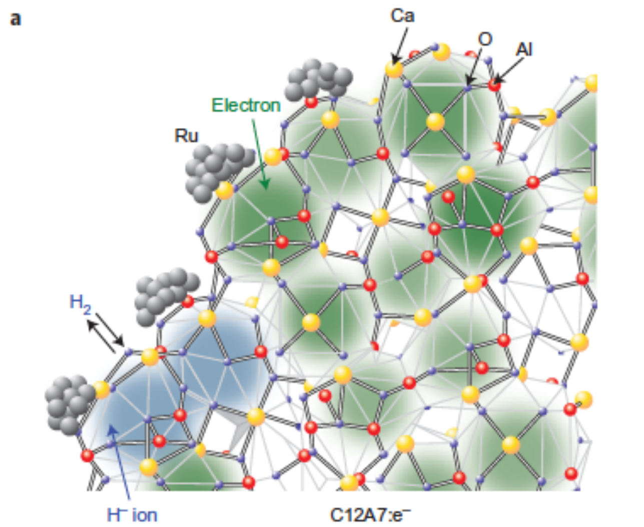
Gilles Cartry (Aix-Marseille University)
Motoi Wada (Doshisha University)



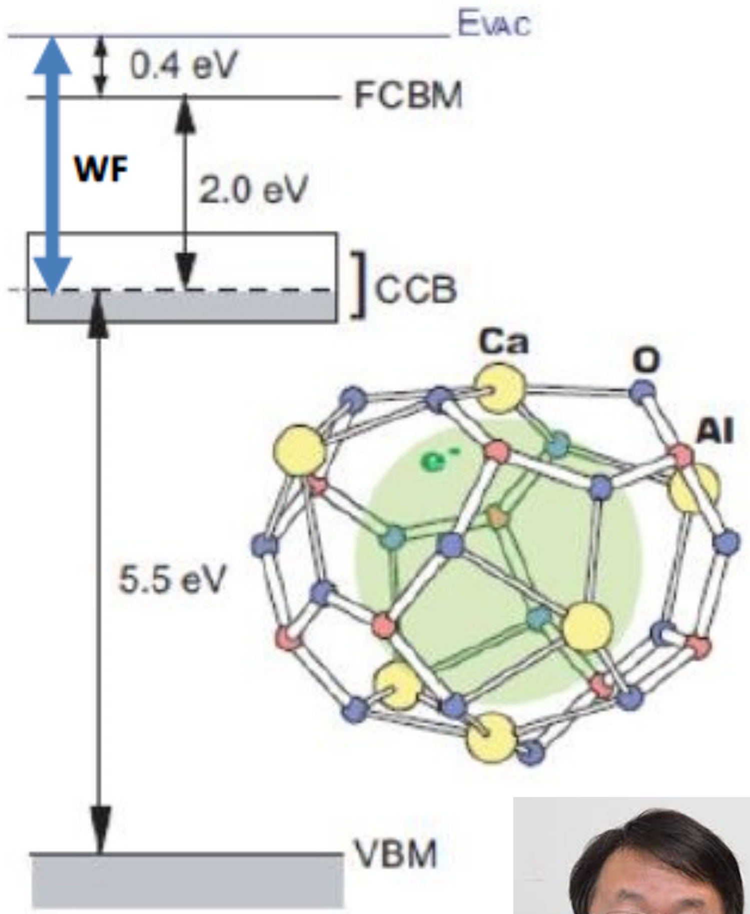
H⁻ surface production from a C12A7 Electride Surface

What is a C12A7 Electride

H. Hosono and his coworkers have found that 12CaO.7Al2O3 (C12A7) can be transformed to an electride , which was formed by removal of clathrated oxygen ions from the cages in a single crystal of C12A7 leading to formations of high-density electrons in the cages.
The connected cages form a new conduction band called "cage conduction band" (CCB), below the cage flame conduction band minimum (FCBM). The work function (WF) is 2.4 eV.



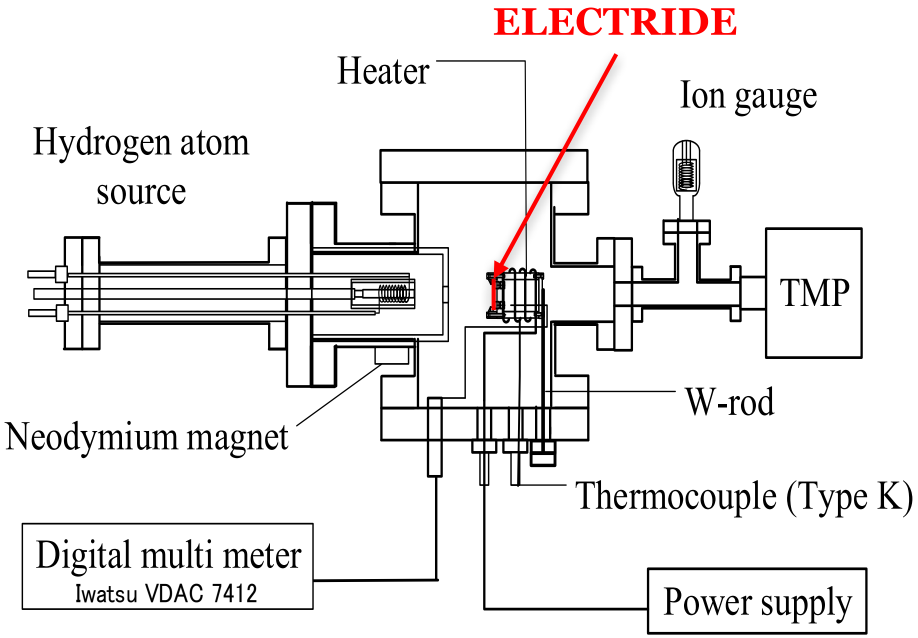
Kitano et al., NATURE CHEMISTRY | VOL 4 | NOVEMBER 934 2012

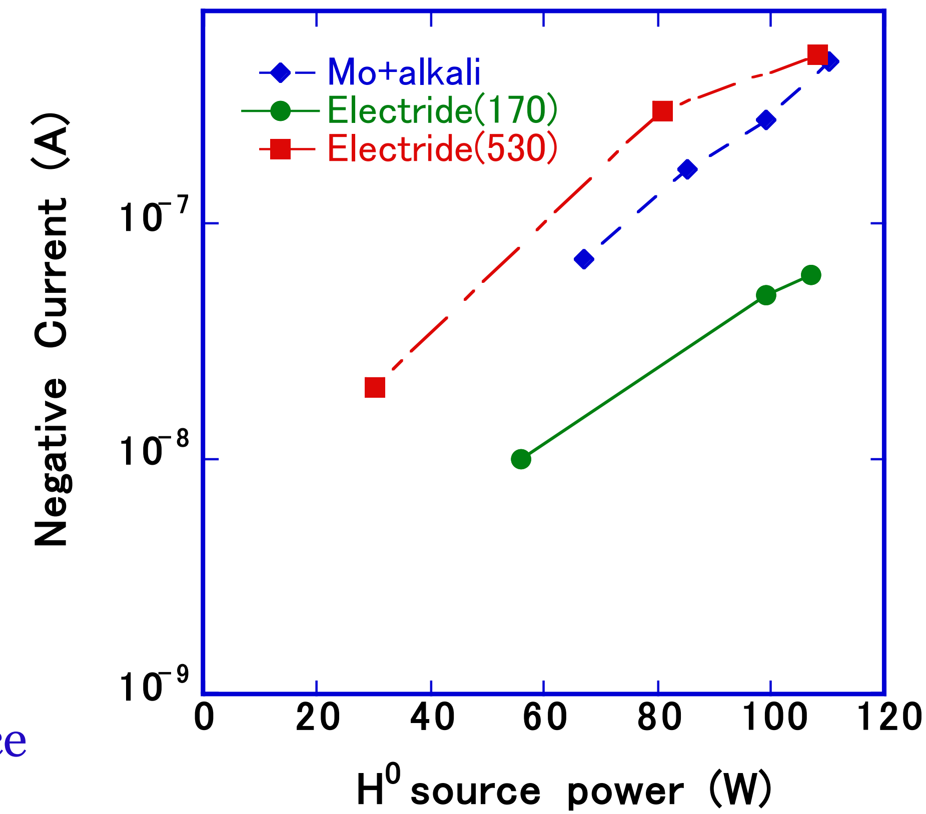


H^- surface production from a C12A7 Electride Surface

Experimental observation I - atomic hydrogen injection

Doshisha

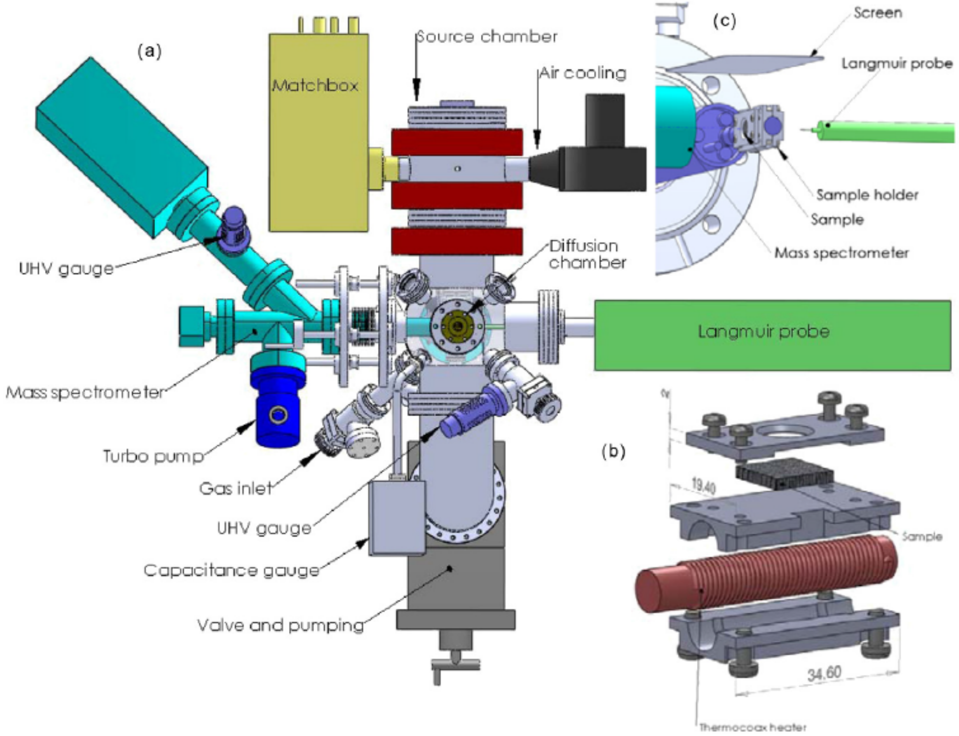




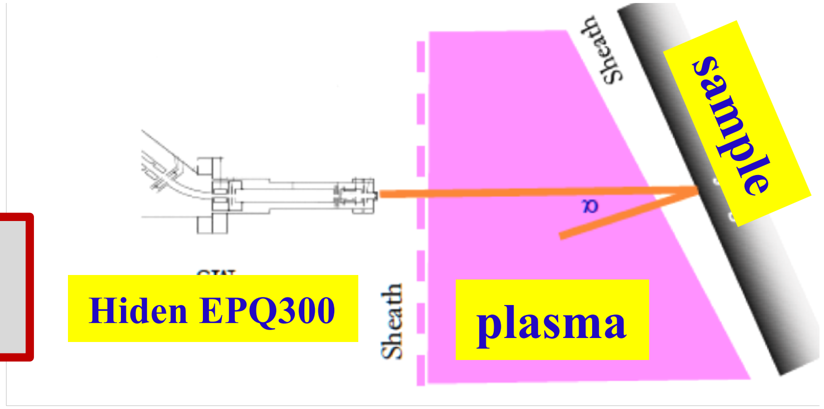
Negative current emitted from the surface was measured. (NIBS2016)

H^- spectra measurement

Aix Marseille University



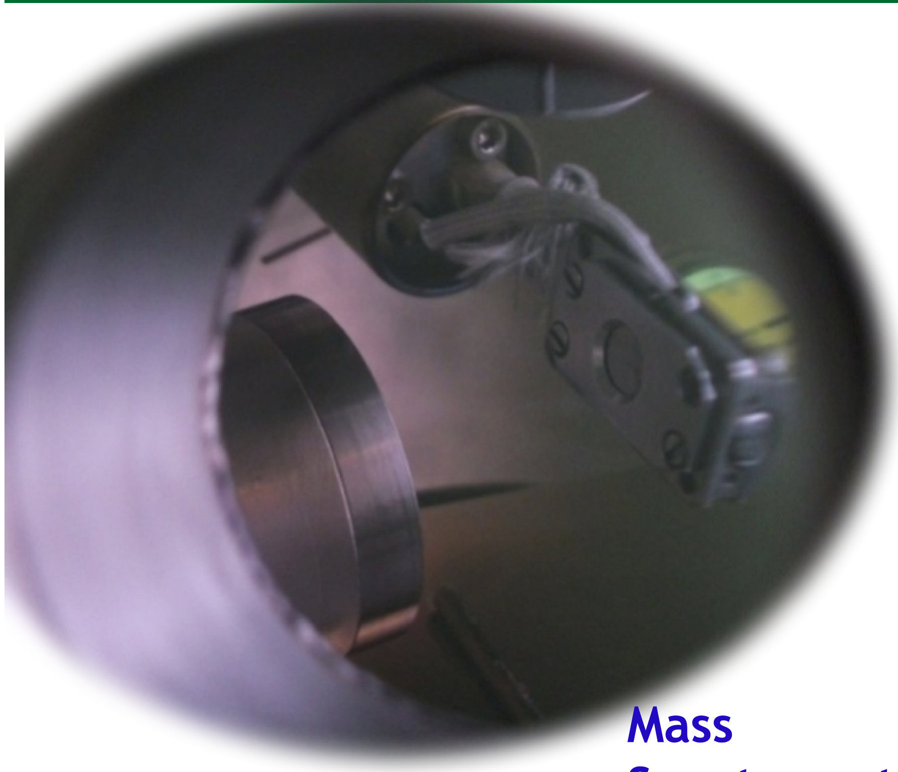
- RF plasma T_e ~ 3 eV, n_e ~ $10^8/cm^3$ without B
- μW plasma T_e ~ 1 eV, n_e ~ $10^9/cm^3$
- H_3^+ ions are dominated.
- HIDEN particle analyzer
- L - probe
- Heater (<650° C) & TC

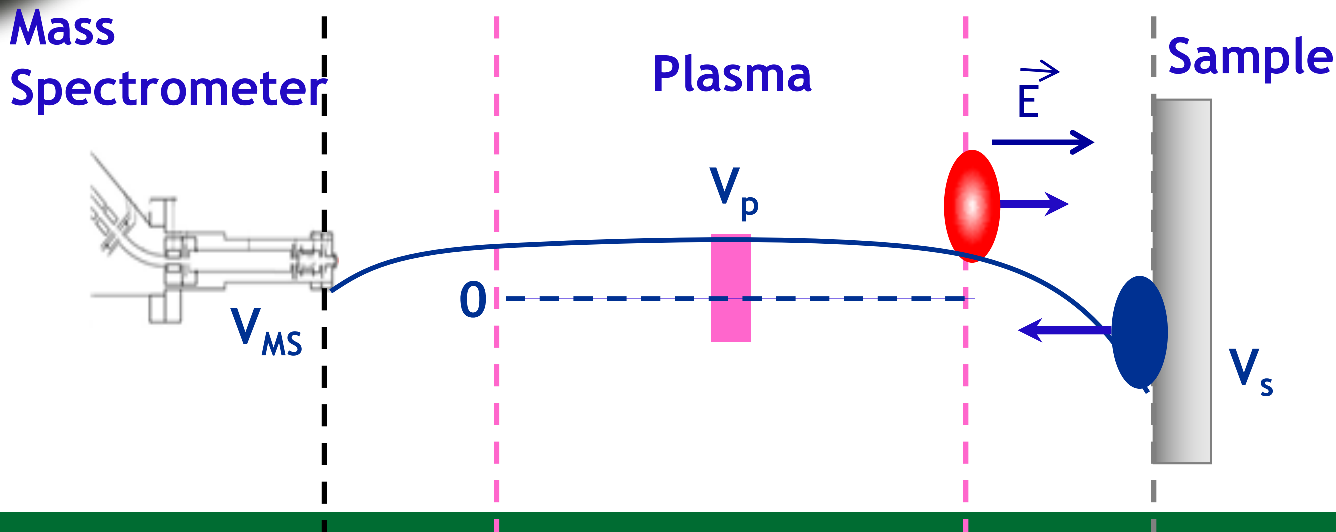


H-/H+ ion spectra from the sample surface were measured by Hiden EPQ300

H^- spectra measurement

Aix Marseille University



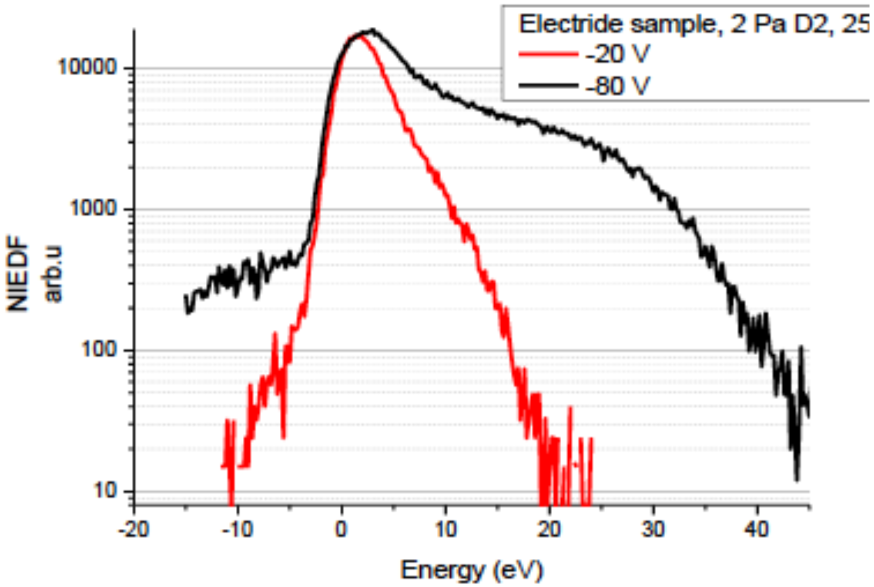


H⁻ surface production from a C12A7 Electride Surface

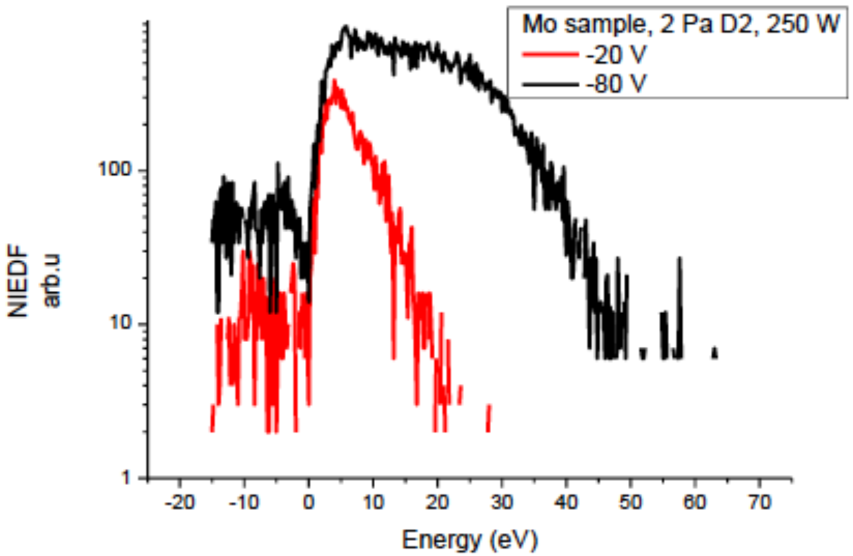
Experimental observation II

Marseille

Electride



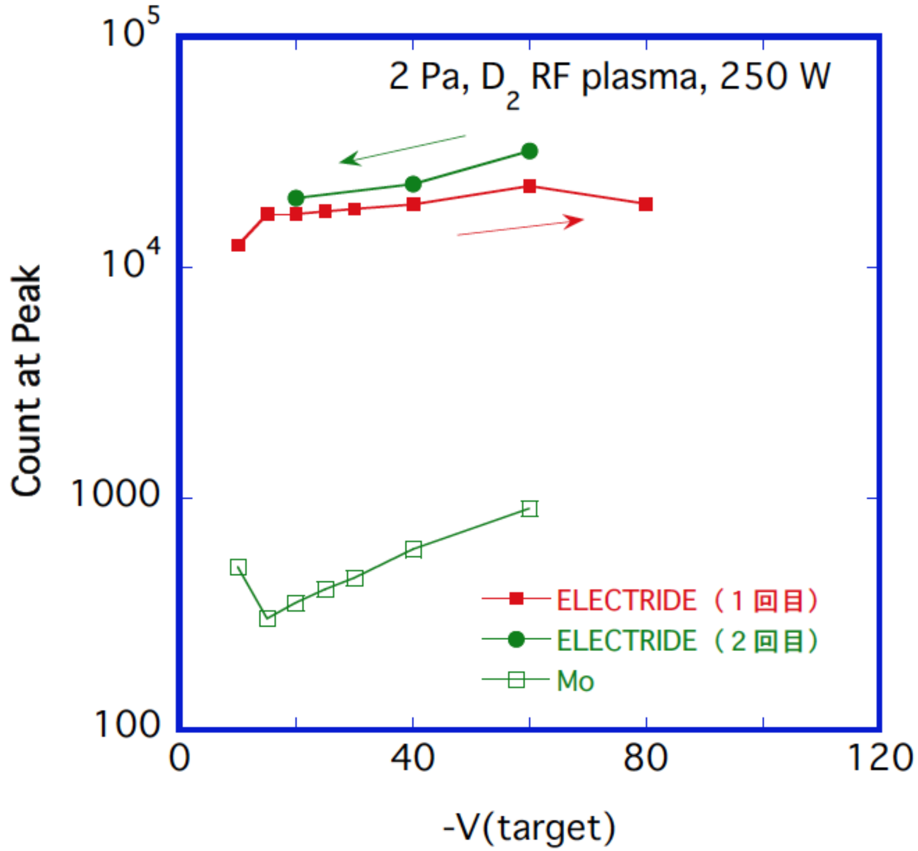
Mo



H^- surface production from a C12A7 Electride Surface

Experimental observation II

Marseille



Details of experimental results will be presented on Friday, by

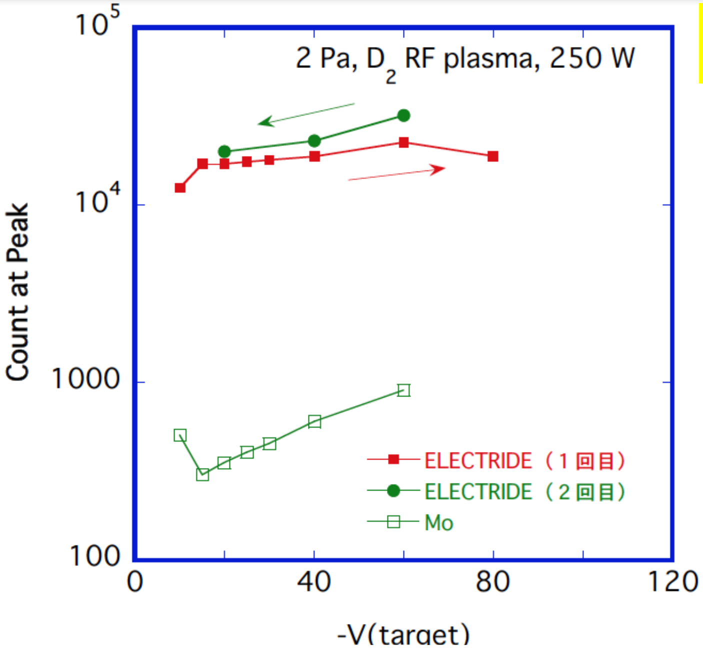
Roba Moussaoui
Aix-Marseille Univ..

Id: 37
Negative-ion production study on nanoporous 12CaO.7Al2O3 electride surface in low pressure H2 plasma

H^- surface production from a C12A7 Electride Surface

Experimental observation II

Marseille



Wada et al., 1990

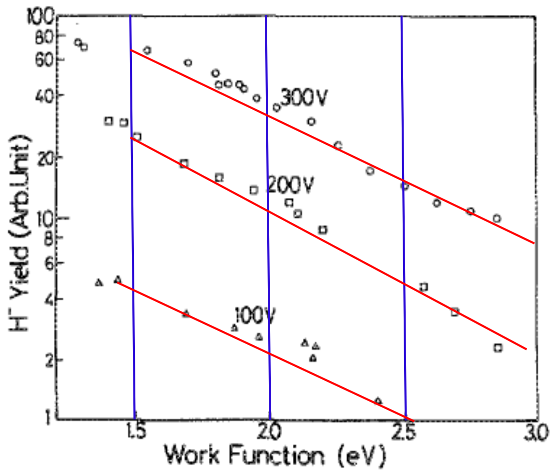


FIG. 2. Dependence of the H^- yield upon the work function of the converter.

Using the pseudo exponential work-function (ϕ) dependence, the ratio of H^- yield from a cesiated molybdenum surface of the lowest work-function to that from a clean molybdenum surface (ϕ =4.3 eV) can be evaluated to be about 40 at 100 V, while the ratio of total H^- yield from a C12A7 electride surface bombarded at 80 V to that from a clean molybdenum surface is about 10. The ratio became larger as the bias voltage V_s became lower, and the ratio was 50 at V_s = 20 V.

Rapid report : Applied Physics Express 11, 066201 (2018)

Study of H- extraction from a single-hole plasma electrode of C12A7 electride.

OUTLINES

1. Objectives : Aiming a Cs-free H^- Source

   Can a high production rate be expected in a real ion source when the plasma grid is fabricated with the C12A7 electride?

2. Experimental Setup
3. Experimental Results
4. Discussions
5. Future Plans

ACKNOWLEDGMENTS

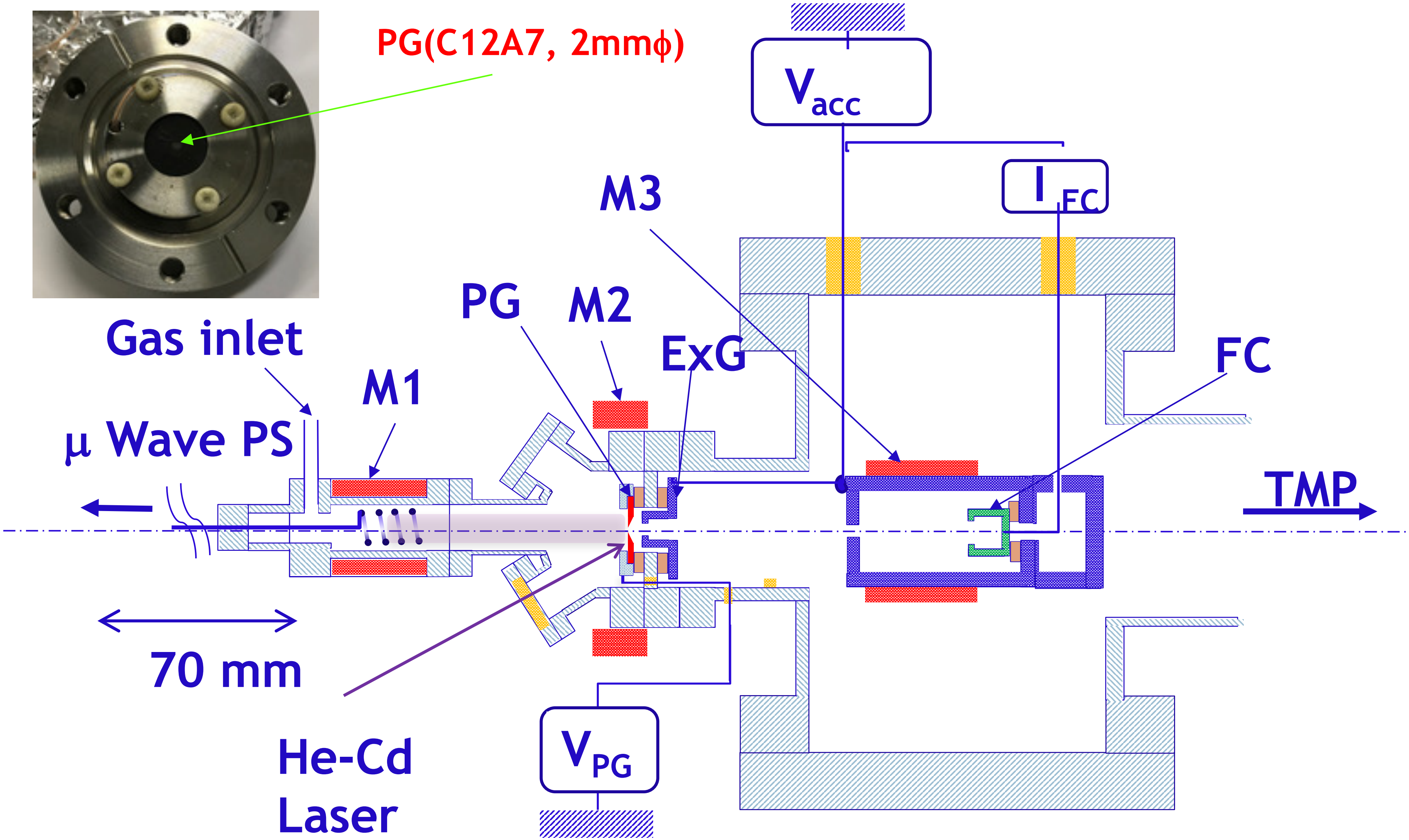
Prof. H. Hosono (TIT)
Dr. N. Miyakawa (AGC)
Dr. M. Kisaki (NIFS)

Study of H- extraction from a single-hole plasma electrode of C12A7 electride.

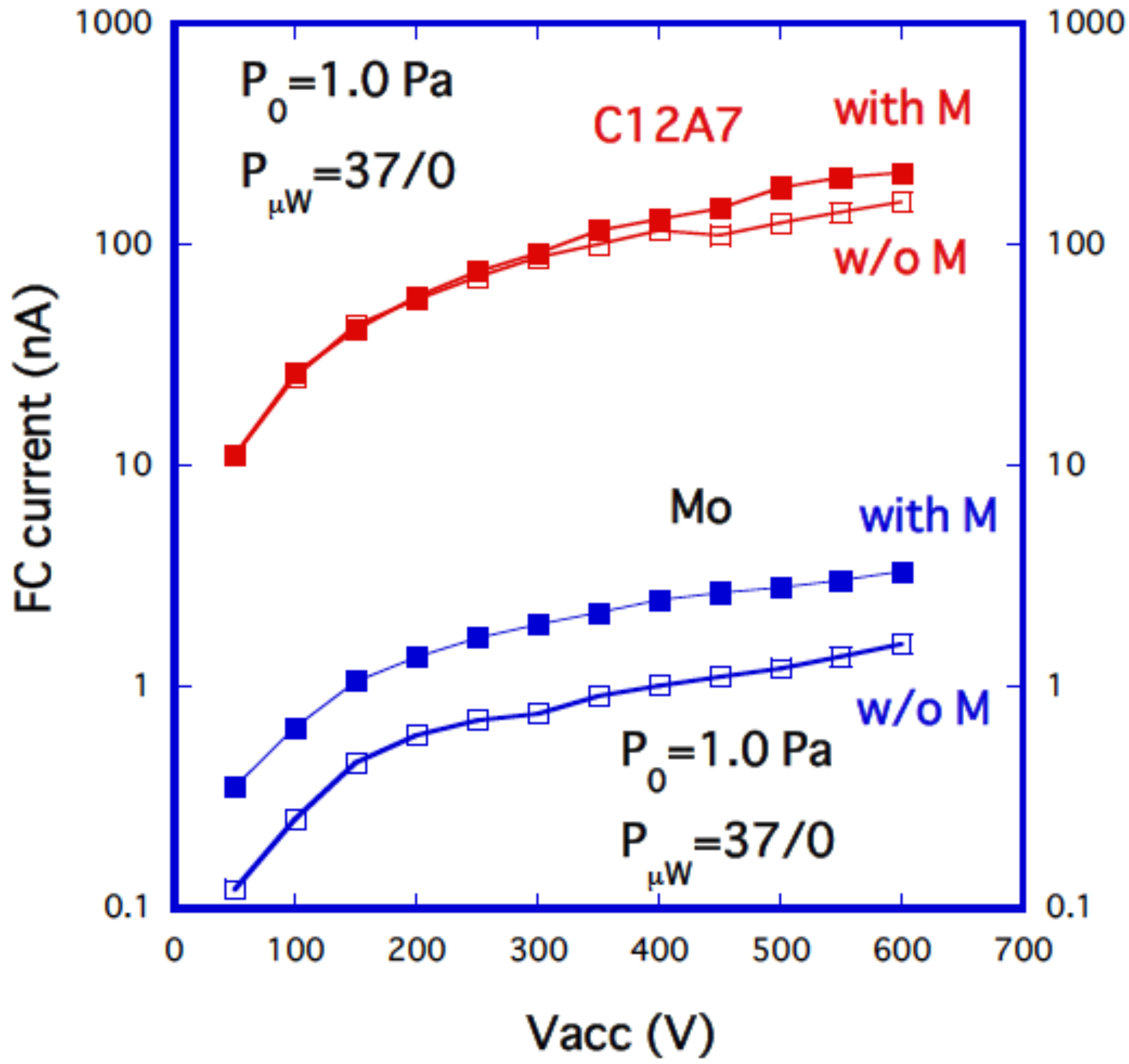
Experimental Setup

1. A small ECR plasma source of 50W(max) (Tamaoki Electronics Co. LTD)
2. An ECR plasma is diffused to a plasma chamber of ~ 10 cm^3 toward plasma grid.
3. A plasma grid of C12A7 electride or clean Mo of 16 mm ϕ, 2 mm t was used. The extraction hole is a 2 mm ϕ tapered.
4. Pretreatment of C12A7 electride =>annealing at ~520°C for 2 hrs. => take-out to air (dry) after cooling and install to the ion source.
5. A single stage extraction grid of 6 mm ϕ is used.
6. A Faraday cup with permanent magnets is installed, and the current was measured by a picoammeter, ADVANTEST TR8641.
7. He-Cd Laser (Kimmon Electric Co. LTD) of 13 mW, 325 nm or another diode laser is injected.

Experimental Setup



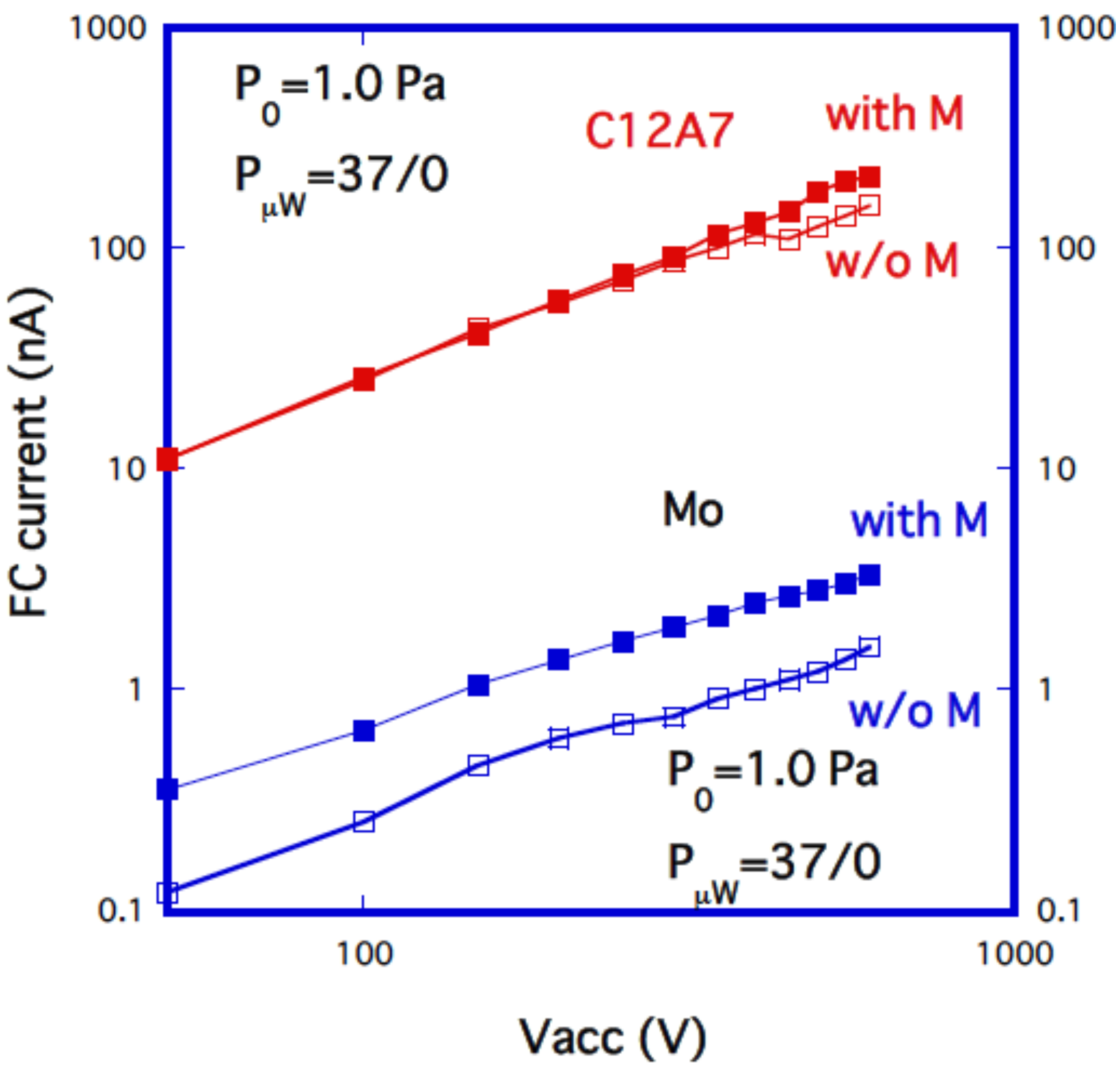
Experimental Results : FC current



Higher production rate was observed with a C12A7 Electride PG, than a clean Mo PG, by a factor of 40 – 100.

Effect of electron suppression magnets near the extraction region is clearly seen with a Mo PG.

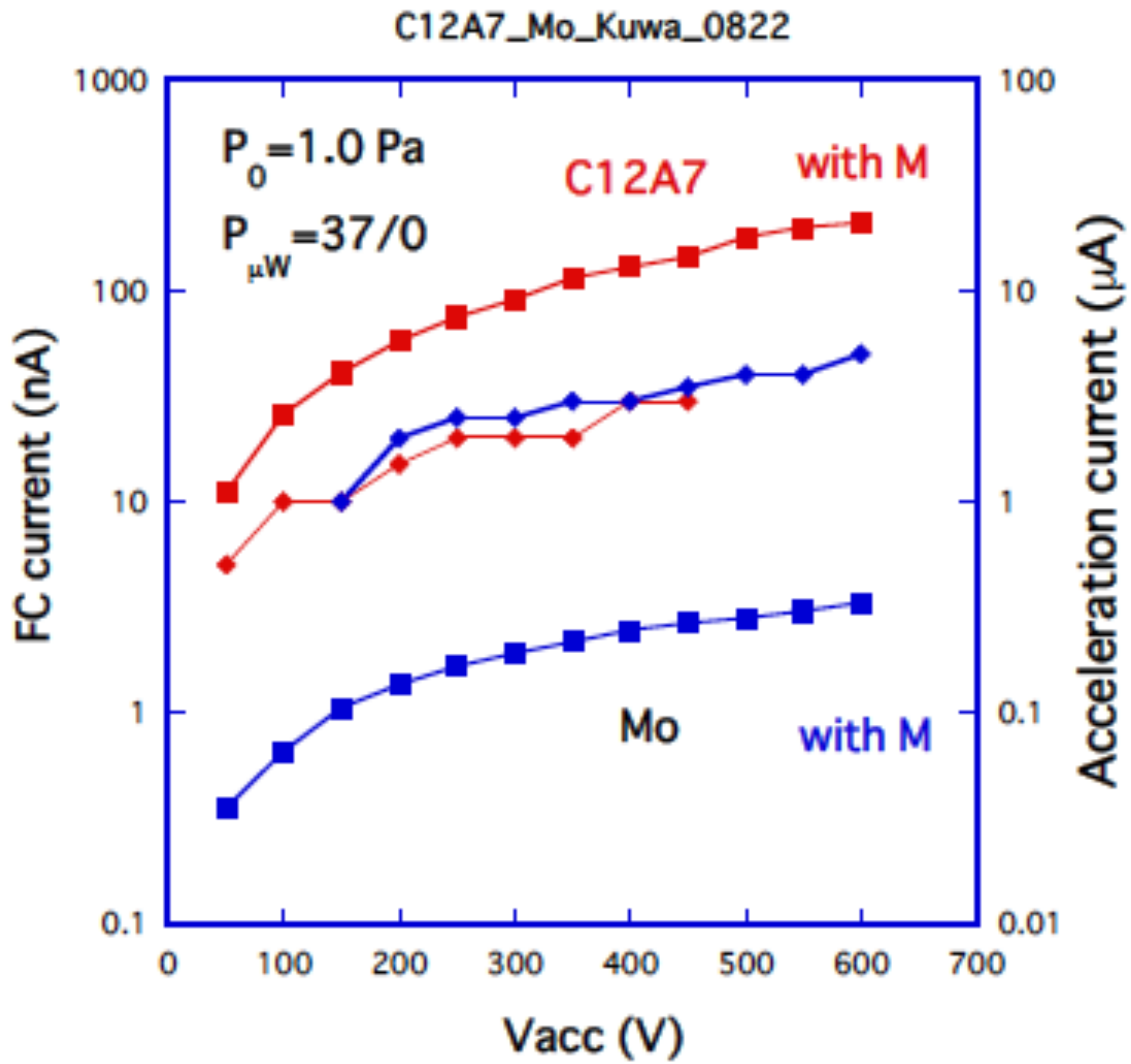
Experimental Results : FC current



FC Current with C12A7 Electride PG, increases as (V_{acc})^1.2 , and that with Mo PG as (V_{acc})^0.9.

More data will be presented by M. Kobayashi in the PS #2, Tuesday

Experimental Results : Extraction



Acceleration current was compared with the FC current.

Remind:
FC current would be less than the total H^- current extracted, because the extraction was not optically optimized.

Acceleration current contained secondary electron current.

Nevertheless, the ratio of H^-/e in the extraction current might be larger than 1/23 for C12A7 electride PG, and 1/1300 for Mo.

Discussions and Summary

- C12A7 Electride is a stable, robust, machinable material, with low work function, and fabrication of PG for a H^- source is possible.
- Preliminary study of H^- extraction from C12A7 electride PG has been carried out using a compact ECR ion source.
- The extracted H^- current was compared with that from a clean Mo PG, and the former is higher than the latter by factor 40 – 100.
- Margins

    Extraction voltage should be increased, up to ~ several kV.

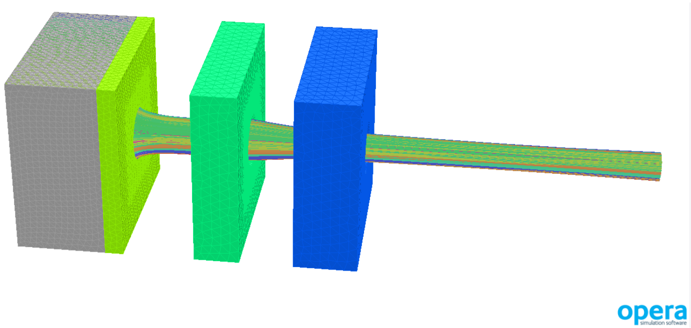
    Plasma density, not measured in this work, could be increased.

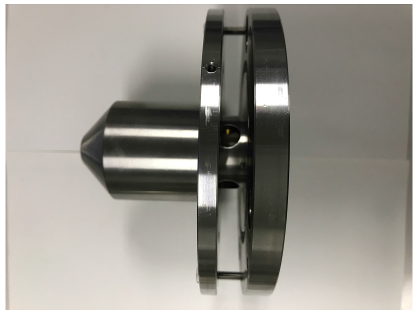
    Surface condition of C12A7 electride was not optimized. The surface conductivity was not high enough. Work function was not low enough.
- Nevertheless, the ratio of H^- from C12A7 electride to that from clean Mo is consistent with our results of Marseille experiment*.

* Roba Moussaoui et al.[Id: 37], will be presented on Friday morning.

Future Plans

- Present compact ECR ion source of C12A7 elctride (Source 1) will be upgraded, so that we can anneal the PG in-situ, measure the ϕ, and measure the plasma parameters.
- Source 2 a bucket type source having an ECR plasma source and a three electrode extractor: acceleration and deceleration grids, with the electride plasma grid having an indirectly heating system, is now under construction.*





Extraction Grid and Acc.Dcc Grid.

* M. Kobayashi et al.[Id: 52], in the PS #2, on Tuesday.

supplement

Measurement of Photoelectric Response

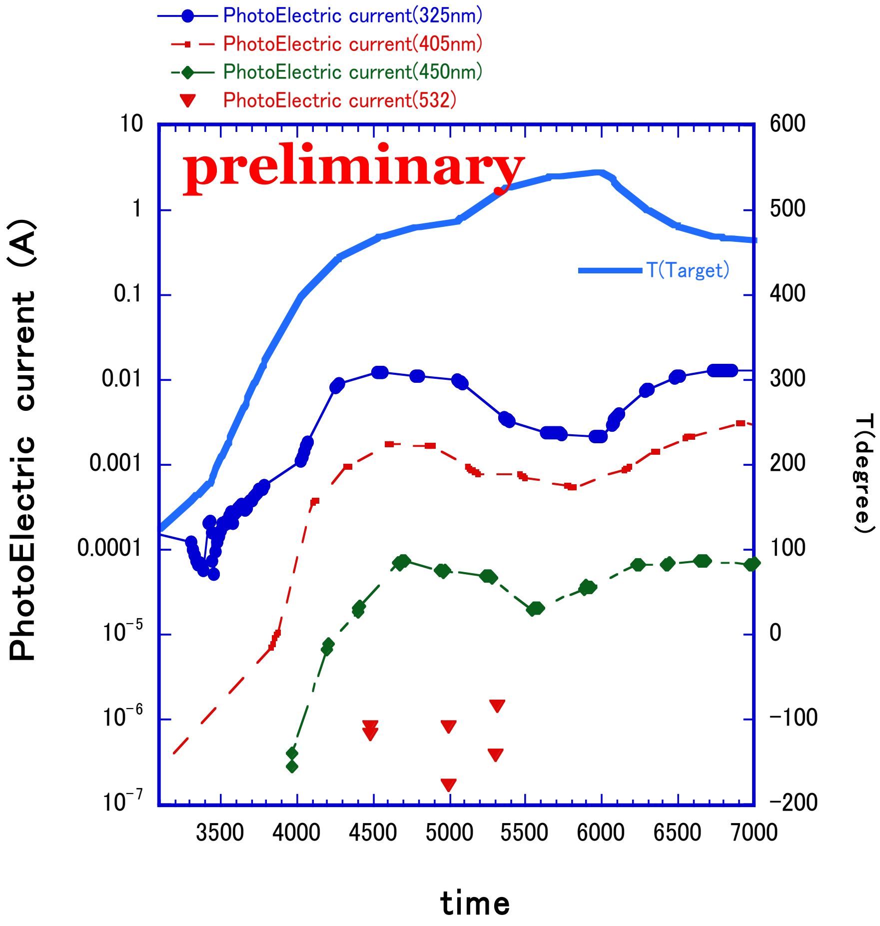
The time evolution of the target temperature and photoelectric current for 325 nm, 405 nm, 460 nm, 532 nm diode laser injection on to the C12A7-Electride.

The present data do not fit into the Fowler's formula,

$$\frac{I(\chi_0 - h\nu)^{1/2}}{T^2} = Af(\mu) = Af\left(\frac{h\nu - \chi}{kT}\right)$$

$$f(\mu) = \frac{\pi^2}{6} + \frac{1}{2}\mu^2 - e^{-\mu} + \cdots\cdots$$

The fitting photoelectric currents in the region of high energy photon incidence to this formula indicated that the work function at 450° C is lower than 2.7 eV.

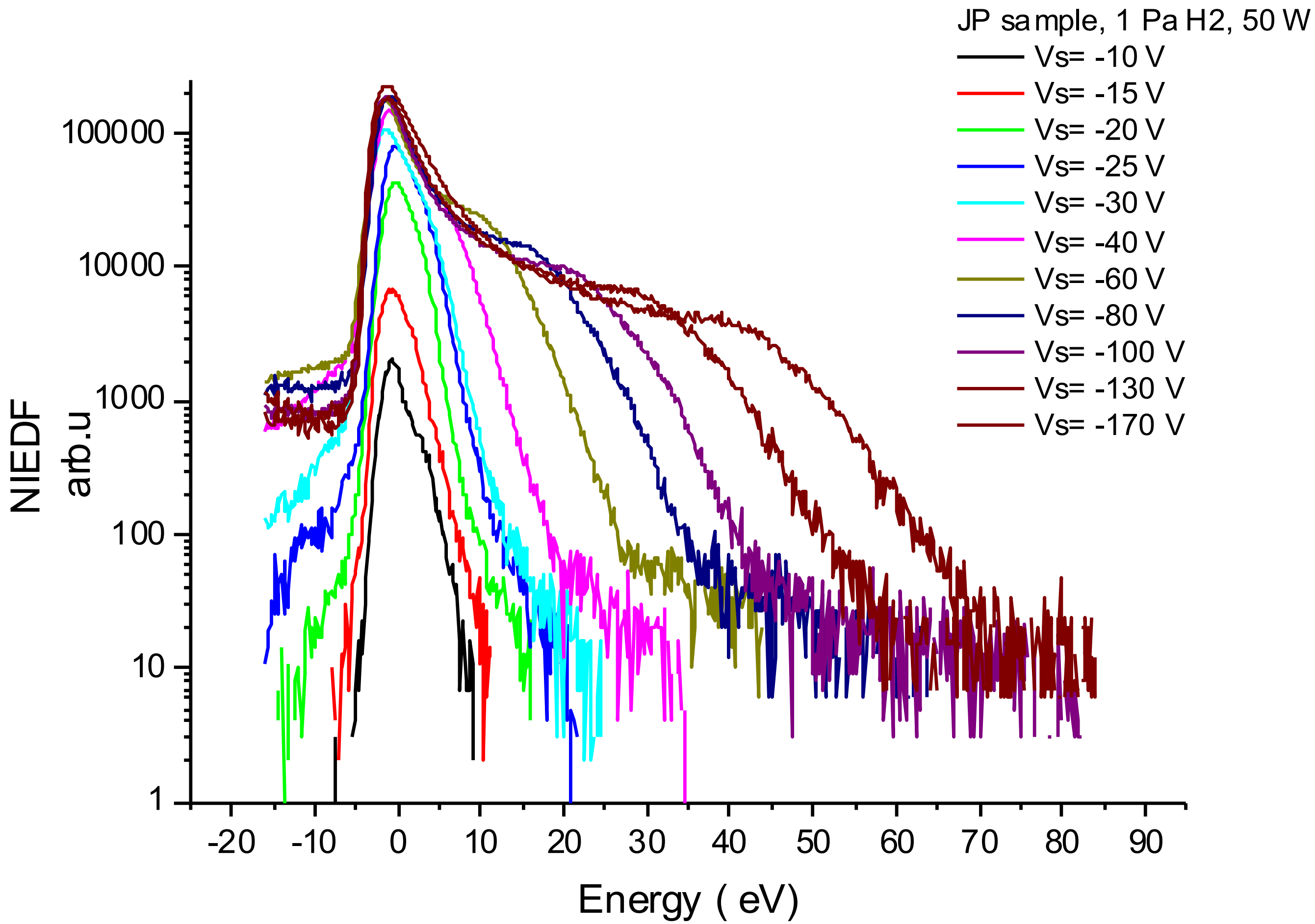


H^- surface production from a C12A7 Electride Surface

Experimental observation II

Scan of Target bias from -10 V to -170 V

Marseille



H^- surface production from a C12A7 Electride Surface

Experimental observation II

Marseille

Ar Bombardment

Comparison of normalized Negative Ion energy Spectra bombarded in Ar plasma and H2 plasmas at Vs = -60 V

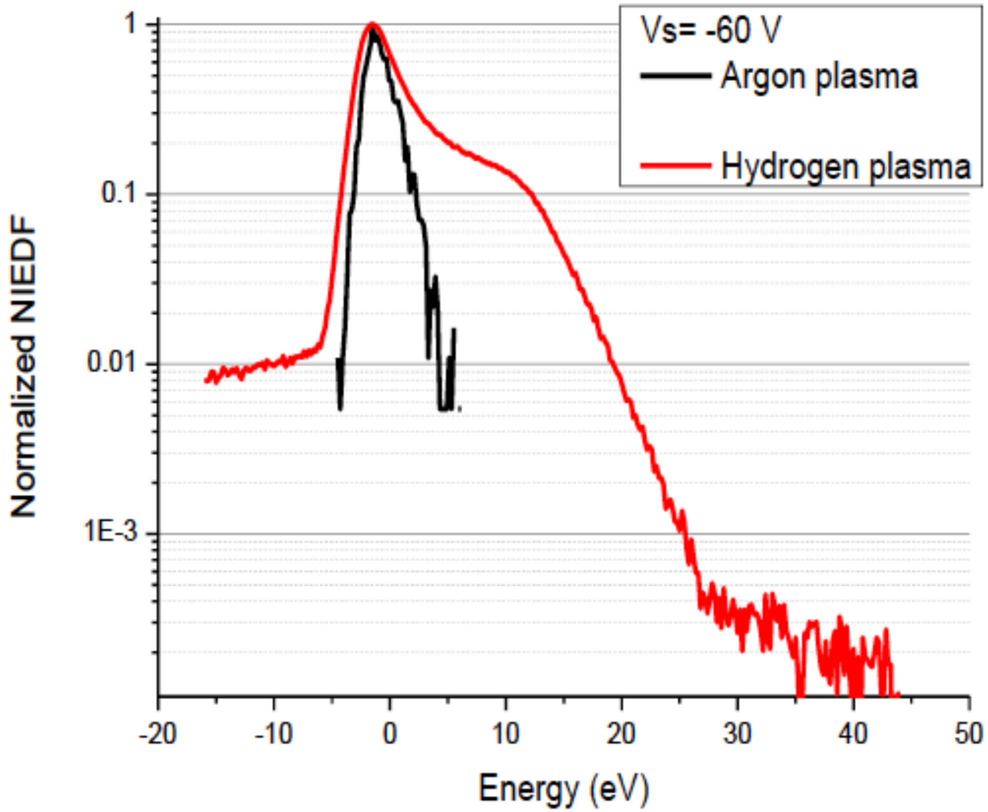


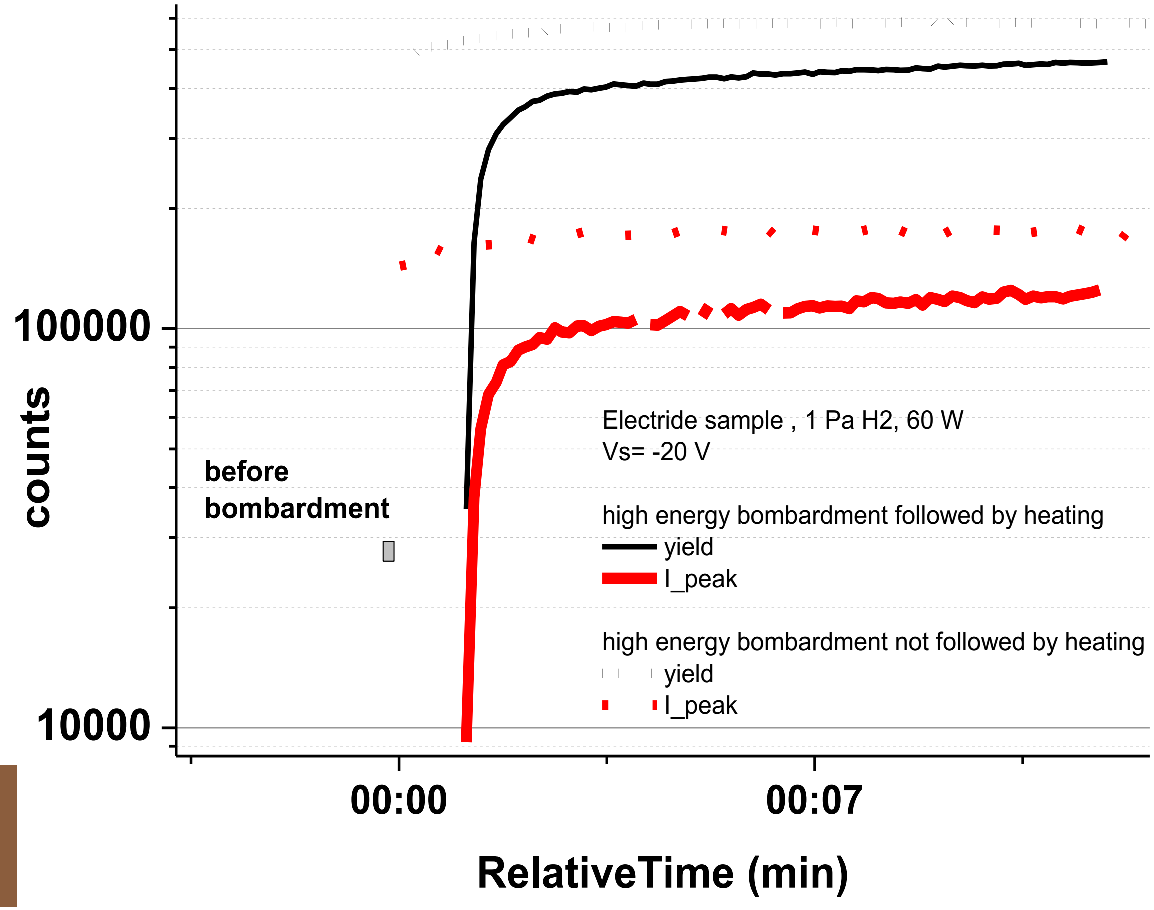
Figure 63 comparison of normalized NIEDF measurement in Ar plasma and in H2 plasma at VS= -60 V

H^- surface production from a C12A7 Electride Surface

Experimental observation II

Marseille

Time evolution of Negative ion yield after 10 min. of high energy bombardment followed by a heating in vacuum and not followed by a heating in vacuum



Dominant process is desorption by sputtering

Future plans

- Compact H- source with a plasma grid of C12A7 Electride is now under construction.
- Absolute H- current from the source will be measured.

Thank you for your attention

H^- surface production from a C12A7 Electride Surface

What is a C12A7 Electride

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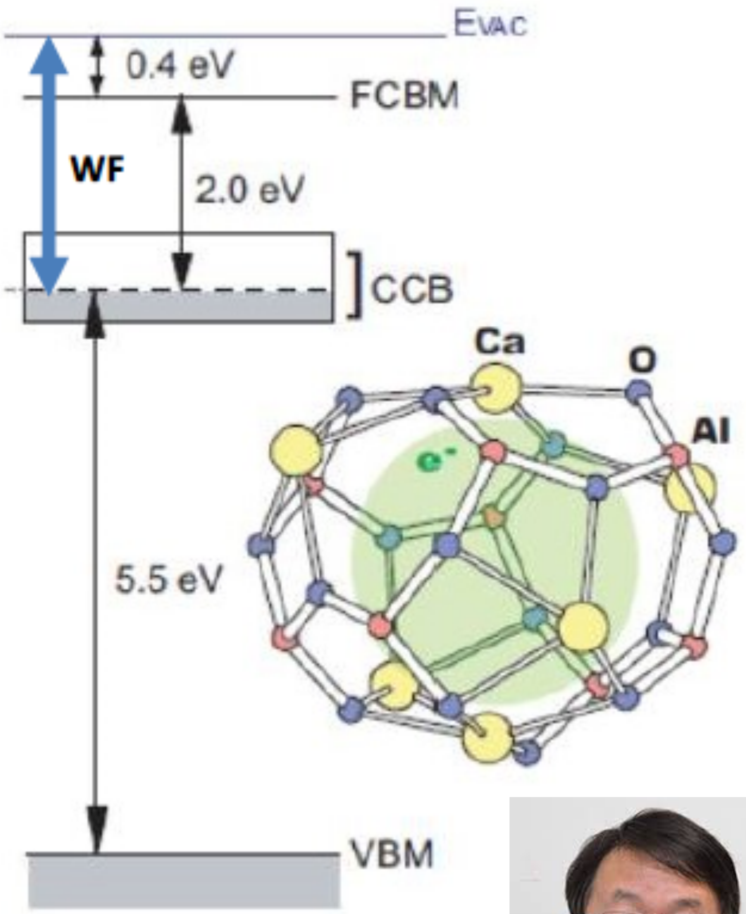
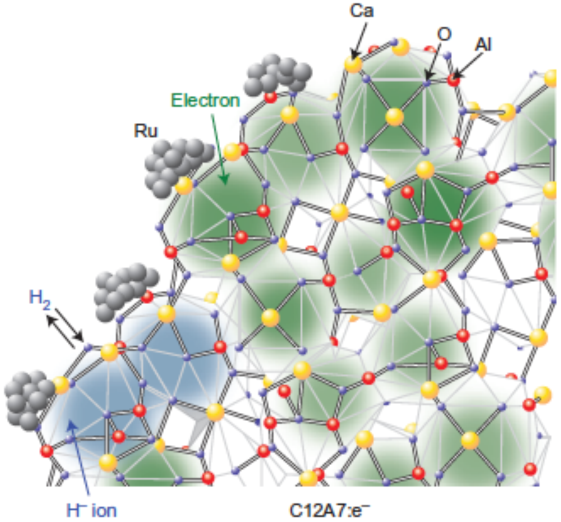
The connected cages form a new conduction band called "cage conduction band" (CCB), below the cage flame conduction band minimum (FCBM). The work function (WF) is 2.4 eV. VBM: valence band maximum. The band gap is 7.5eV.[a]



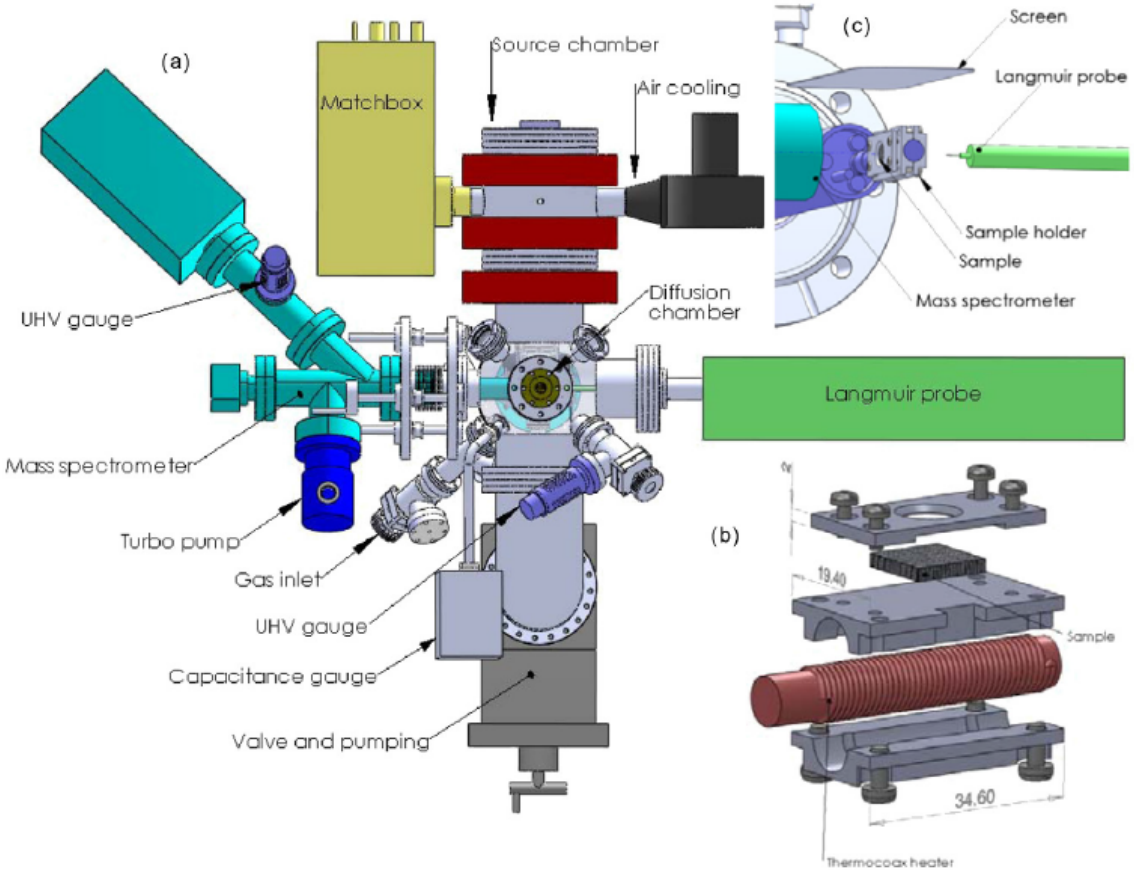


Kitano et al., NATURE CHEMISTRY | VOL 4 | NOVEMBER 934 2012

H^{-} surface production from a C12A7 Electride Surface

Experimental observation II - H^{-} spectra measurement

Marseille

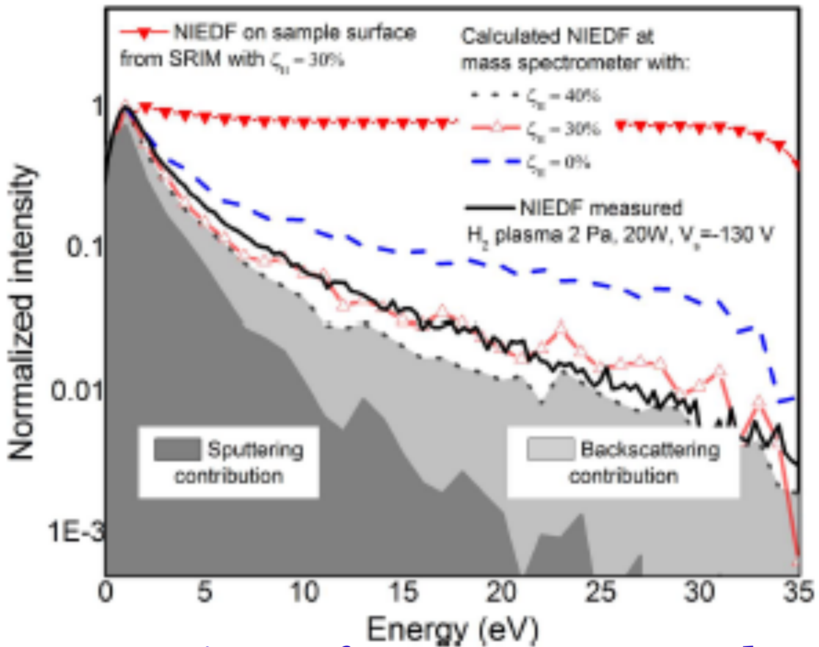


Gilles Cartry
Drmitry Kogut
MOUSSAOUI Roba
ELLIS James

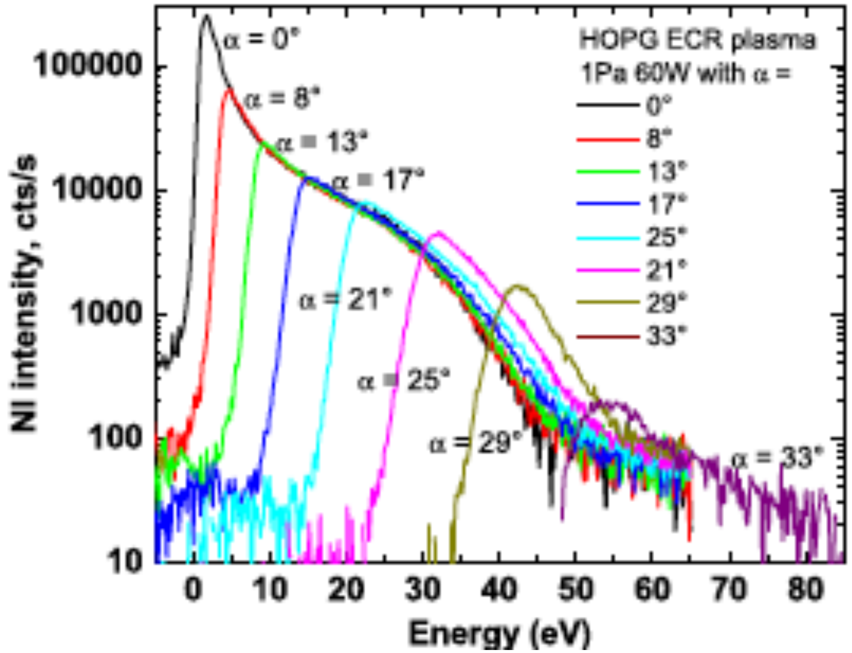
Plasma Surface Interaction – Refection & Desorption

Gilles Cartry, et al., New J. Phys. 19 (2017)

HOPG:Highly oriented pyrolytic graphite



Comparison of measurement and SLIM calculation



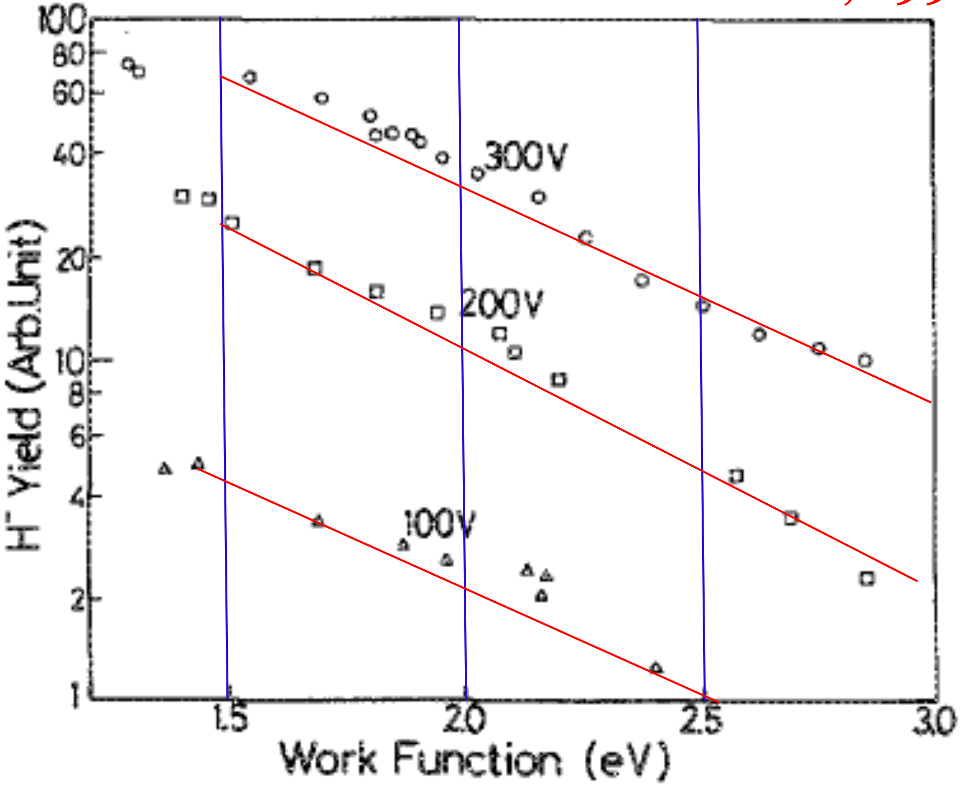
Experimentally measured energy spectra for different tilt angles of the HOPG sample

Refection : Mirror/Cone Angular Distribution, continuous up to the incident energy distribution

Desorption by Sputtering : Normal Angular Distribution, low energy distribution.

Wada et al., 1990

J. Appl. Phys. 67 (10), 15 May 1990



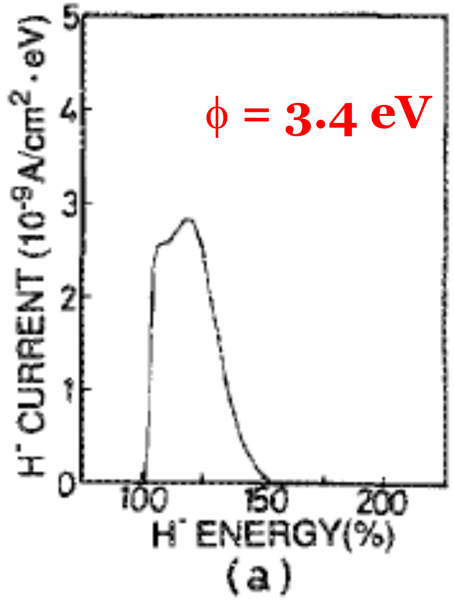
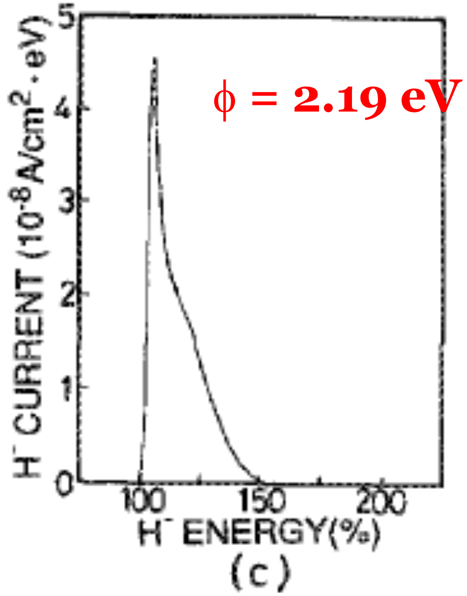


FIG. 2. Dependence of the H⁻ yield upon the work function of the con



Dependence of H⁻ production upon the work function of a Mo surface in a cesiated hydrogen discharge

M. Wada,[a] R. V. Pyle,[b] and J. W. Stearns
Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

(Received 23 October 1989; accepted for publication 30 January 1990)

The photoelectric work function of a cesiated molybdenum converter surface in a cesiated hydrogen discharge and the negative-hydrogen-ion (H^-) current produced at the surface were simultaneously measured. With the negative bias potential of the converter constant, the H^- yield increased exponentially as the work function was decreased by introducing Cs into the discharge. The yield of H^- current was always higher for a higher bias potential on the surface, provided the measured surface work function was nearly the same. When the concentration of Cs in a discharge was nearly constant, the bias potential of the surface at which the H^- production became maximum was observed. At this bias potential, the surface work function was close to the work-function minimum.