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Measurements of work function and negative Ion spectra from C12A7 electride immersed in a hydrogen plasma.

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ABSTRACT

The C12A7 electride attracts much attention as one of the possible plasma electrode material of Cs-free negative hydrogen isotope ($H^-/D^-/T^-$) ion sources[1-2]. In this work, H-/D⁻ spectra from a C12A7 electride target immersed in an ICP plasma was measured in the apparatus, Phisis[3] . The target was biased negatively against the electrically grounded chamber. The temperature of the target was controllable up to 800 C. Negative ions were energy analyzed by a Hiden EQP300 mass spectrometer. By rotating the target, it can be irradiated by an energy-tunable photon beam, Omni Lamda 300i[4], when the plasma off, and the photo-electric current was measured. The work function of the sample can be obtained from the threshold photon energy. The lowest value of the work function observed was ~2.5 eV. This value was confirmed by UPS measurement with the similar conditioning procedure.Change of the negative ion yield due to the work function was measured.

INTRODUCTION

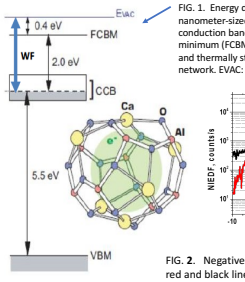


FIG. 1. Energy diagram of C12A7 electride. Anionic electrons are accommodated in the sub nanometer-sized cages which are connected with each other. The connected cages form a new conduction band called "cage conduction band" (CCB), below the cage flame conduction band minimum (FCBM). The work function (WF) is 2.4 eV, comparable to metal potassium, but chemically and thermally stable owing to that electrons are sitting within the cages composed of rigid Ca-AL-O network. EVAC: vacuum level, VBM: valence band maximum. The band gap is 7.5eV. . (from Ref. 1)

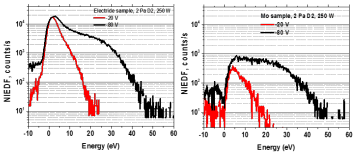
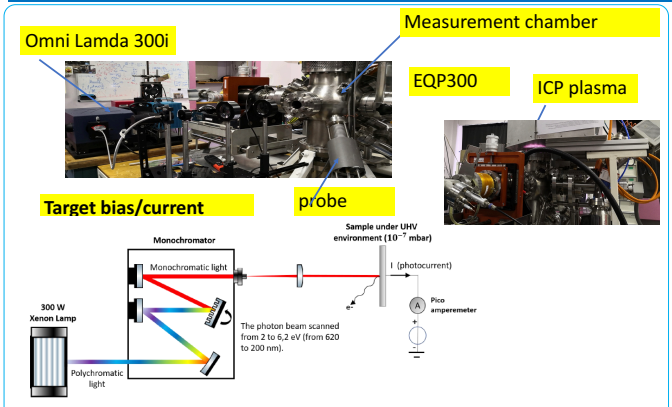


FIG. 2. Negative ion spectrum from a C12A7 elctride (a) and molybdenum (b) in RF plasma. The red and black lines show those obtained when V_s = -20 V and -80 V, respectively. (from Ref. 1)

EXPERIMENTAL SETUP

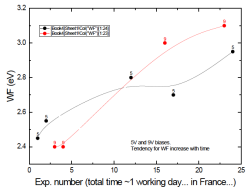


Schematic diagram of the PYS (Photoelectron Yield Spectroscopy) experimental setup

- ✓ The wavelength resolution at the lamp output is **6 nm** when operating the monochromator with fully opened slits. **It limits the energy resolution to +/- 0.1 eV.**
- ✓ The electrons are extracted from the sample using either a positively polarized external cylinder or by biasing it negatively using a -30V battery.

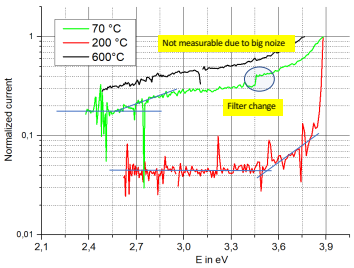
Work Function Measurement

UPS (ultraviolet photoelectron spectroscopy)



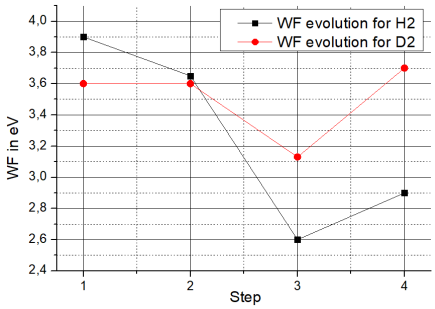
A slight tendency of WF increase with time.

PYS (Photoelectron Yield Spectroscopy)



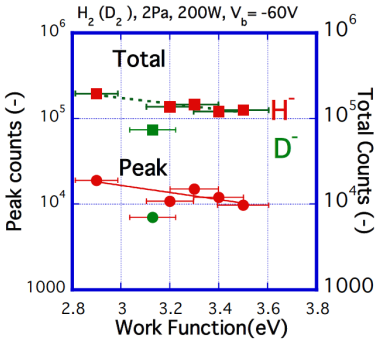
EXPERIMENTAL RESULTS : WORK FUNCTION

Work function changes by annealing procedure, temperaature, plasma exposes (Ar, H_2, D_2), ion bombardment (Ar, H_2, D_2), UV irradiation (?), etc.



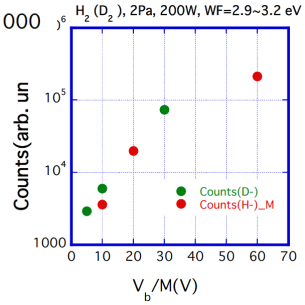
Step 1 : ctly the same for H2 and D2. H2 campaign was carried out right after heating at 300 °C 20 minutes to clean the surface while D2 campaign was done after letting the sample under vacuum overnight (10^-8 mbar base pressure)
Step 2 : Argon plasma 120 eV 5 minutes cleaning procedure, same for both H2 and D2 campaign.
Step 3 : Exposed to the studied H/D Plasma without any bias.
For H2 : the work function is lowered to 2,6 eV. Again, we see the beneficial effect of exposing a non-biased electride sample to a H2 plasma. And again, two slopes for H2 measurements.
For D2 : the WF is lowered compared to step 2, showing that D2 has the same effect as H2.
Step 4 : WF measurements after applying a voltage to the sample (-10 V, -20V then -60 V) for NI measurements. For both cases, the last applied bias was -60 V, which correspond to 60 eV PI bombardment on the surface.

EXPERIMENTAL RESULTS : NEGATIVE ION YIELD



Negative Ion (H-/D-) counts measured in EQP 300, vs. work function measured by PYS. Peak counts are mostly contributed by Desorption by Scattering. The exponential dependence on the work function is weak, while the desorption conponents show slightly steeper tendency. The H/D difference can be explained as shown below.

NI counts measured versus different (PI energy)/Mass on the sample. The red symbols corresponds to H species, green for D species. The 2nd sample : 2,8 eV measured in UPS was used.



Concluding remarks

The work function close to 2.4 eV (as reported by Hosono et al.), was confirmed by UPS and PYS. Work function changes by annealing procedure, temperaature, plasma exposes (Ar, H_2, D_2), ion bombardement (Ar, H_2, D_2), and probably UV irradiation. The change shows an isotope effect. The exponential dependence on the work function is weak, while the desorption components show slightly steeper tendency. The H/D difference can be explained by incoming ion velocity.

Referenced: [1] Y. Toda, et al., Advanced Materials 19, 3564 (2007). [2] M. Sasao, et al., Applied Physics Express 11, 066201 (2018). [3] G. Cartry, et al., A, New Journal of Physics 19 025010 (2017).
[4] L. Tahari, et al., presented at JSI 2020 - Journées Surfaces & Interfaces(Sorbonne Université, 22-24 janvier 2020).