Photoelectric current measurement of plasma grid materials for a compact H^- ion source

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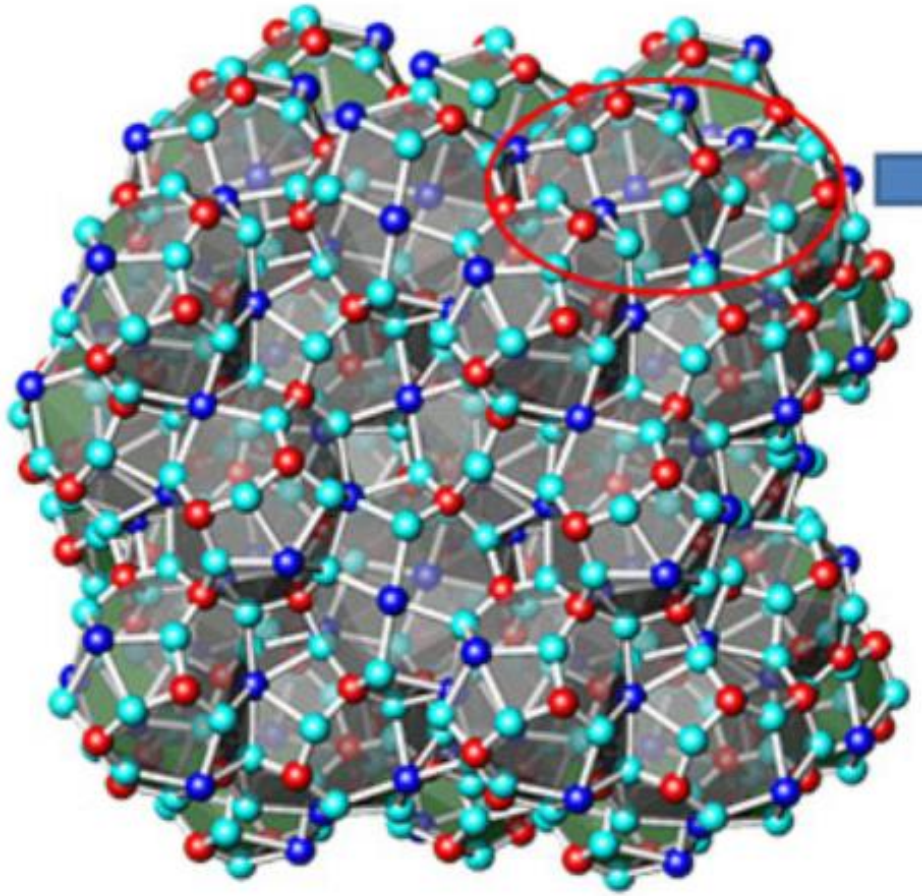
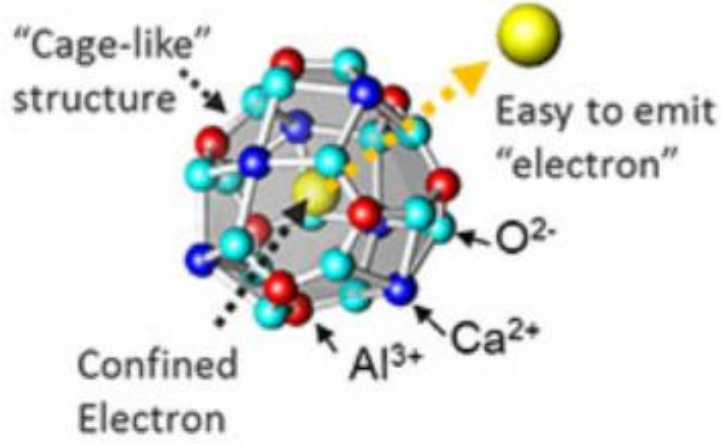
Talk outline

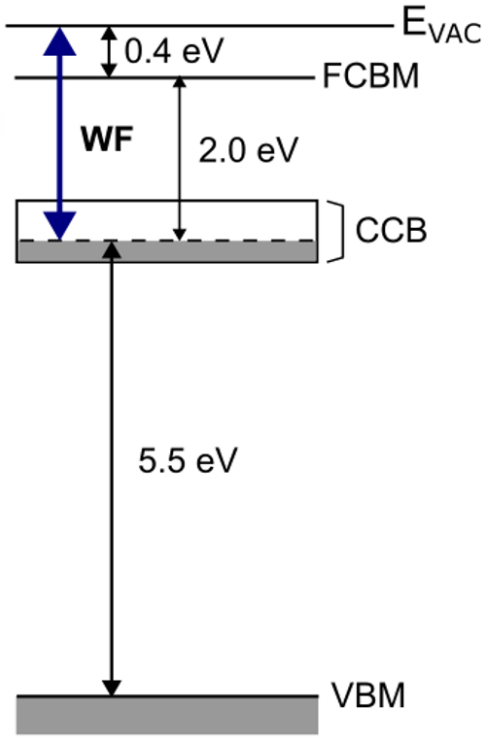
- Electride as a Cs free PG material
- Requirements as the PG material
  - High negative ion production probability (low work function)
  - Low material emission
  - Long life in hydrogen/deuterium plasmas
- Purpose of the PG surface diagnostics
- Experimental setup
- Results
  - LED based photoelectric current measurement
  - Change of surface condition by hydrogen plasma exposure
- Summary and outlook

Electride as a Cs-free PG material





- Known as a component of alumina cement, $12CaO \cdot 7Al_2O_3$ (C12A7 in short)
- Composed of 12 positively charged cages in a cubic unit cell.
- And in this cage, C12A7 electride holds an electron.
- Electrically conductive
- Low work function(emitting electron easily)



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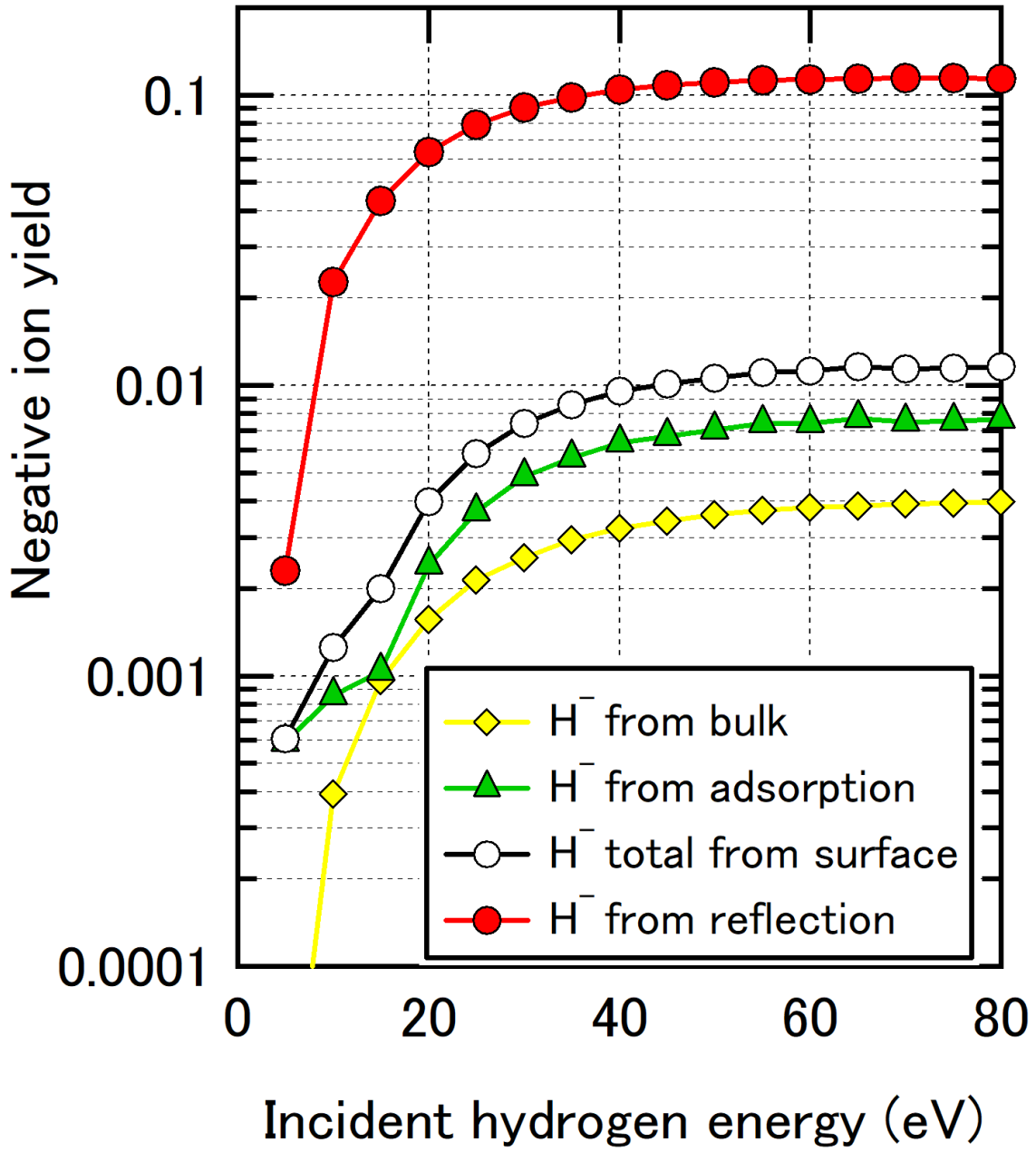
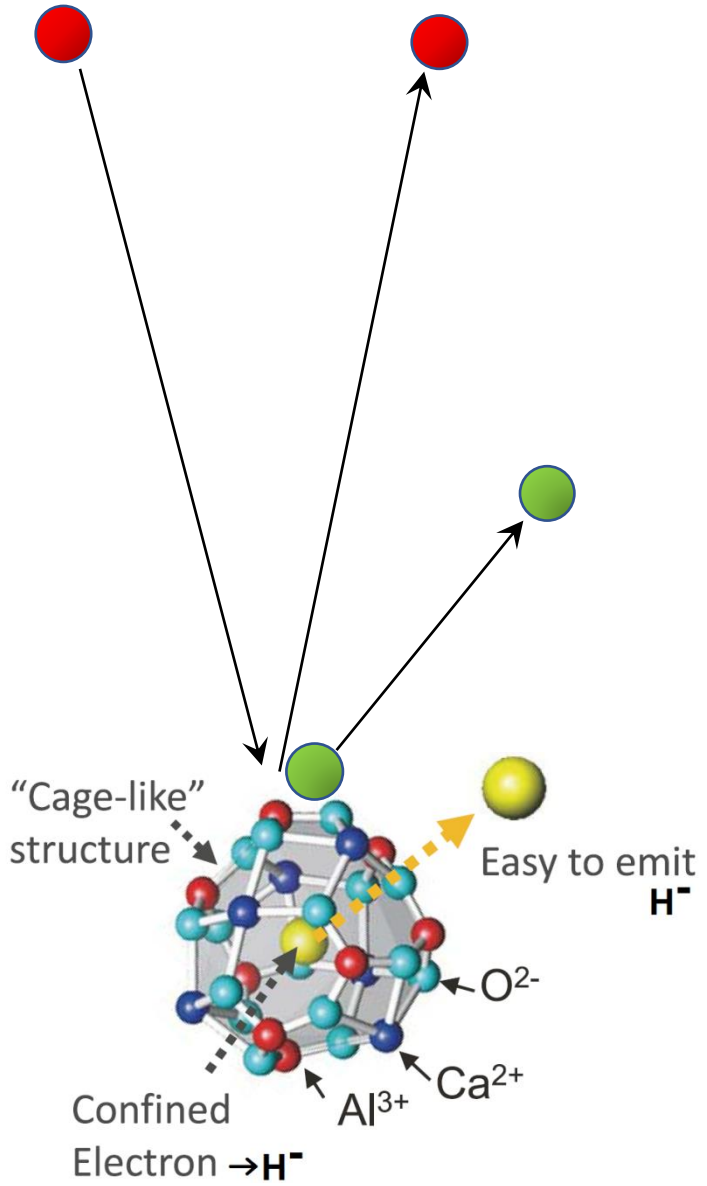
Requirements as the PG material

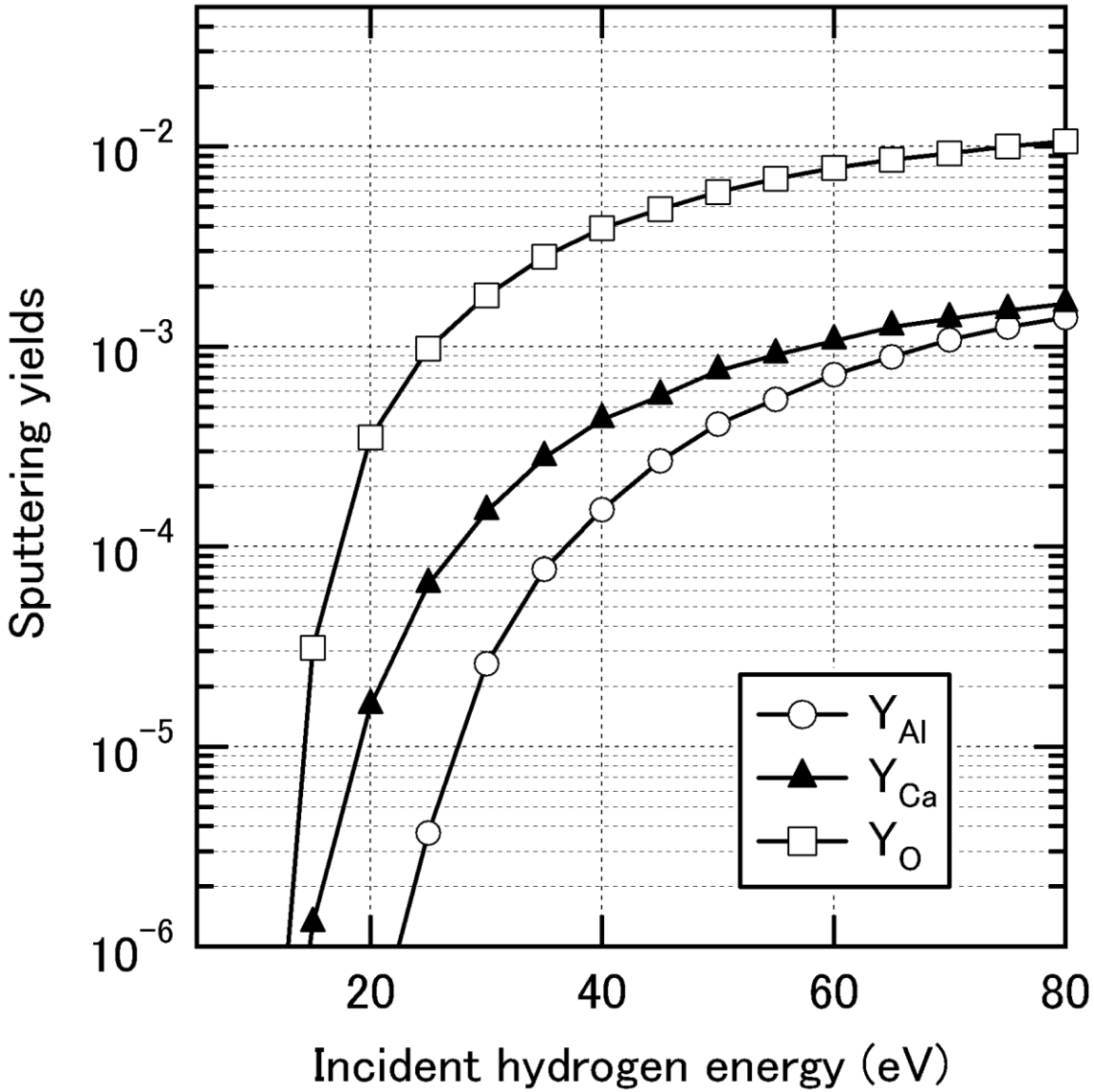
- A PG material should satisfy the following requirements:
  - High negative ion yield for the surface collisions and desorption of hydrogen/deuterium atoms and ions.
  - Robustness against hydrogen/deuterium plasma exposure.
  - Low impurity emission to the hydrogen/deuterium plasmas.
- These characteristics can be evaluated using plasma-surface interaction model.
  - ACAT simulations were done for the corresponding conditions for hydrogen/deuterium plasmas.

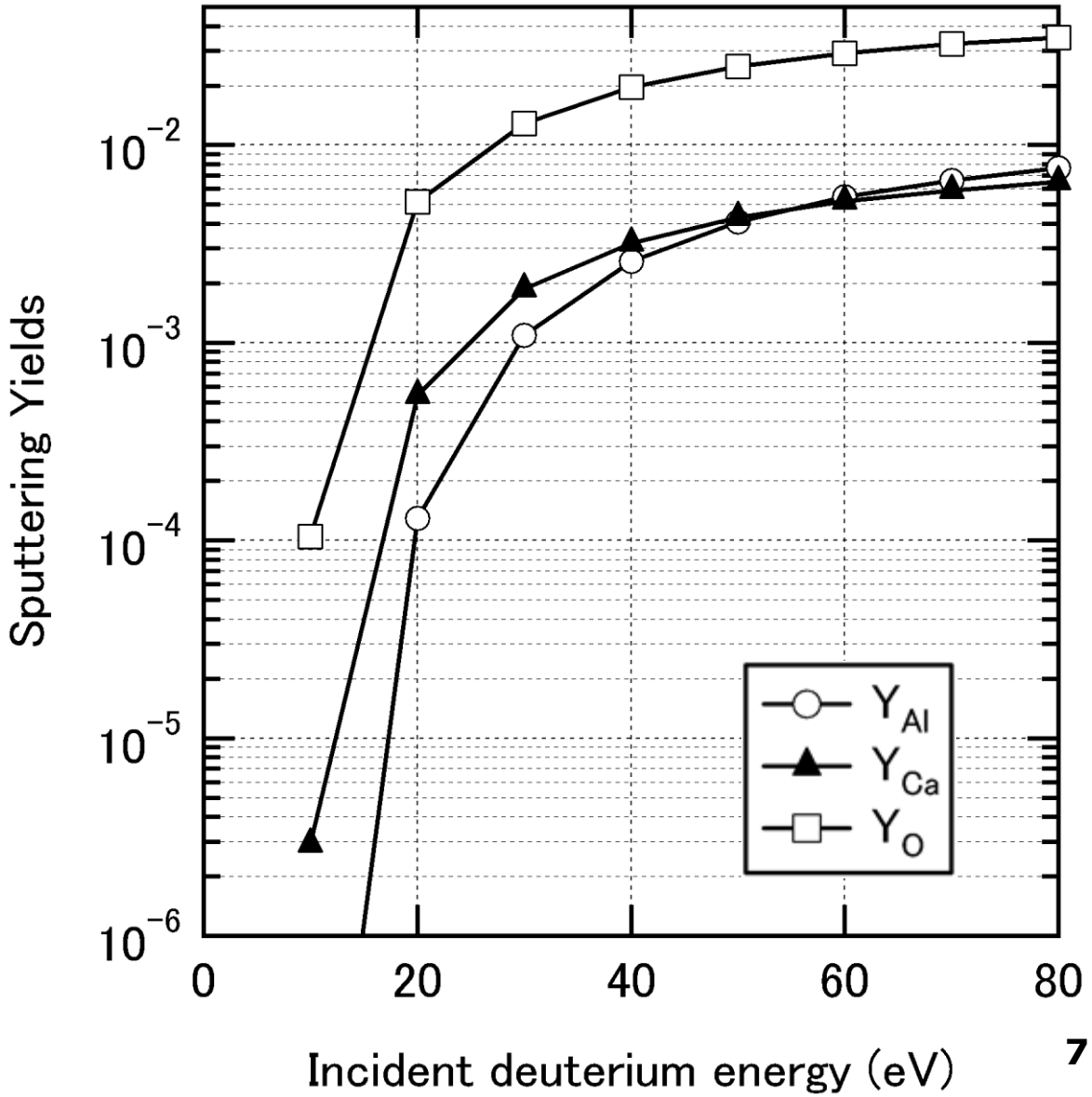
Three components: two from surface





Deuterium erodes electride PG





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Purpose of the PG surface diagnostics

- For long term usage of bulk electride PG, deterioration due to long term plasma exposure: impurity accumulation/removal of surface cage structure, must be monitored.
- The PG surface layer can be renewed after confirming

the depletion of the electride deposition. (Electride PG can be prepared by through sputtering process.)

- Both operations requires proper time for the PG surface treatment.
- Thus, we need to monitor the electride PG surface condition.

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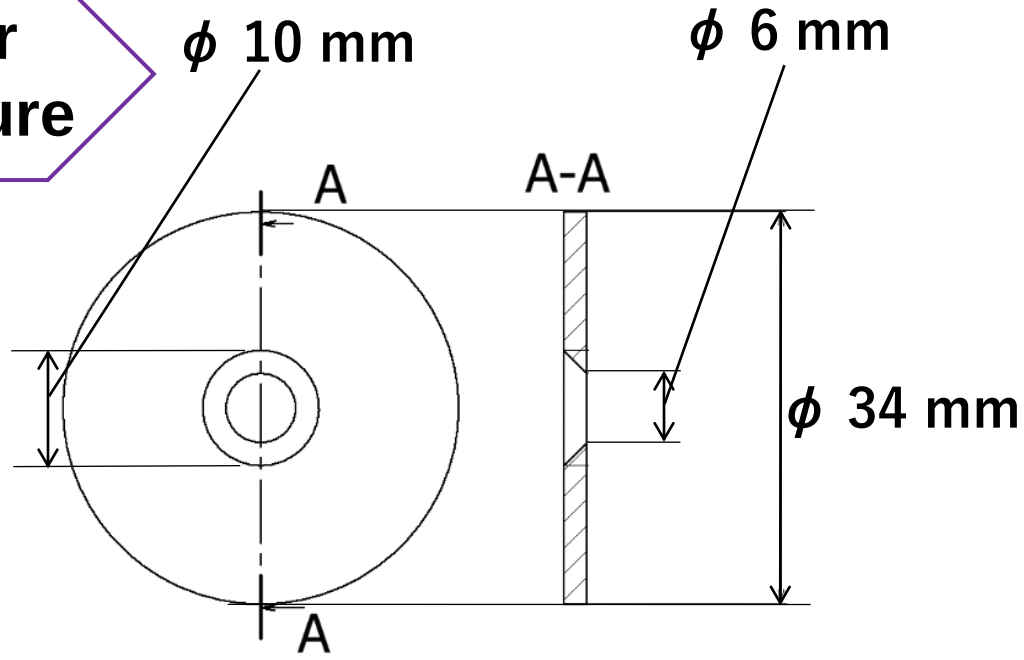
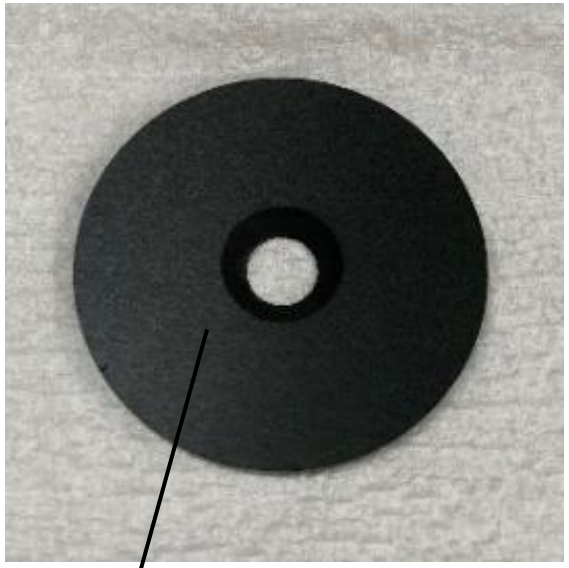
Experimental setup –Plasma grid

Taper Structure



Hole diameter : Φ4mm, 6mm
Thickness : 2mm
Material diameter : Φ34mm

Plasma grid (front)



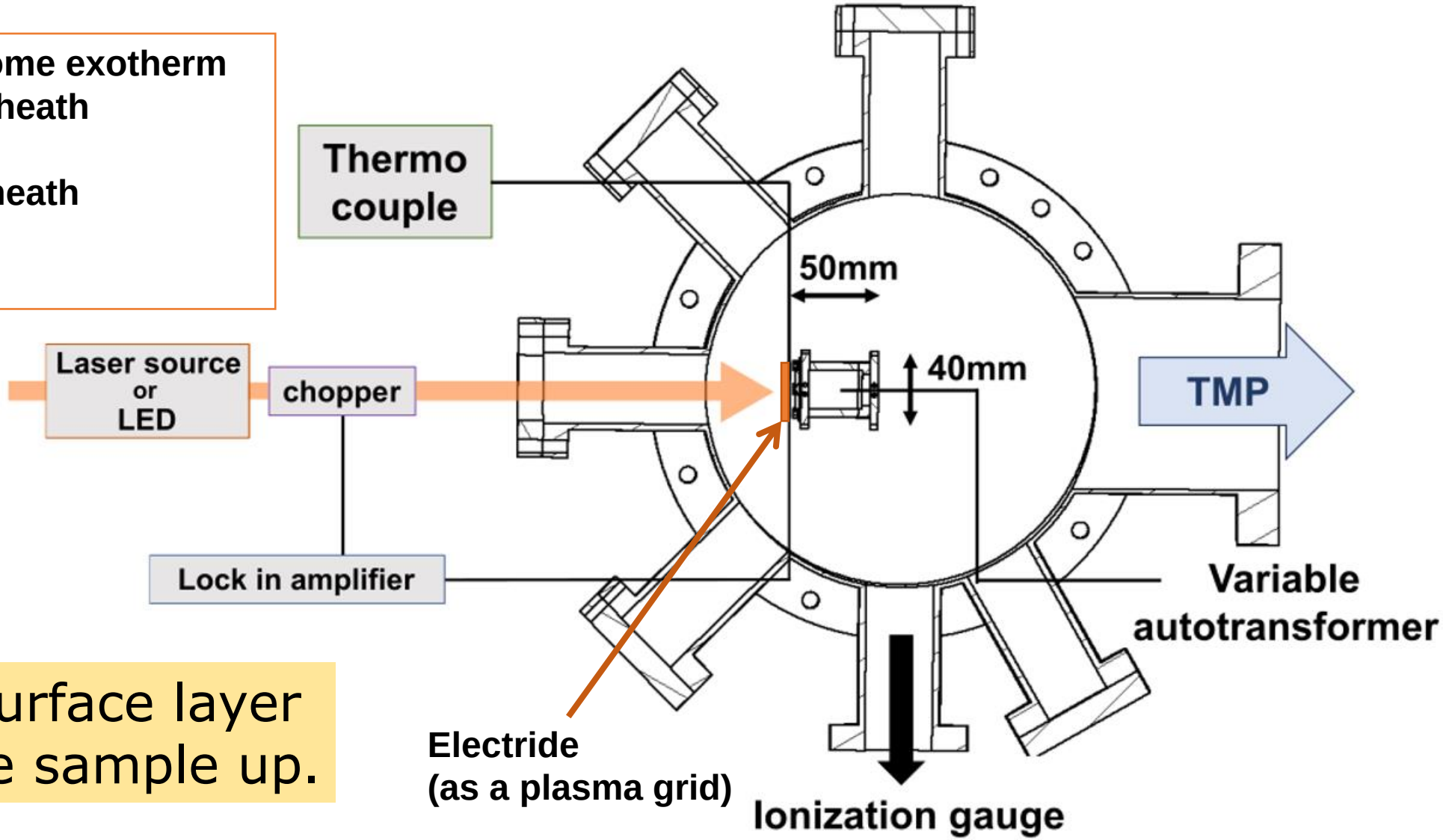
C12A7 electride

Plasma grid (back)

Molybdenum

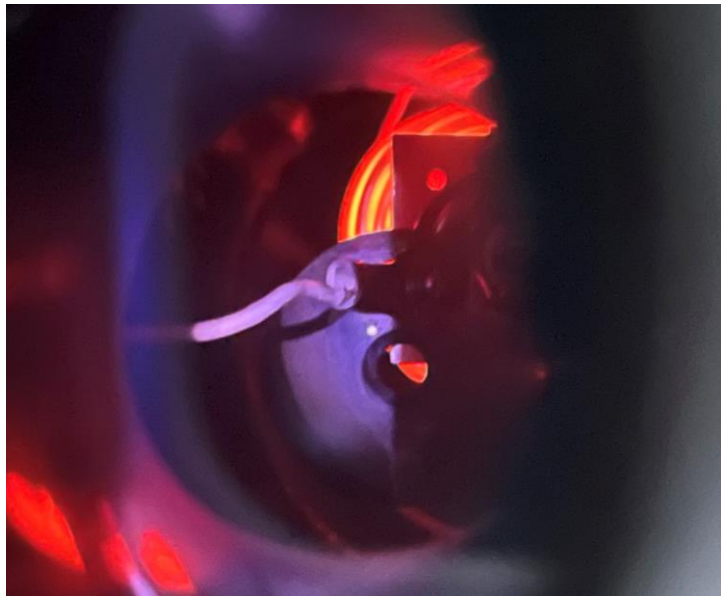
Experimental setup –Electride heating system

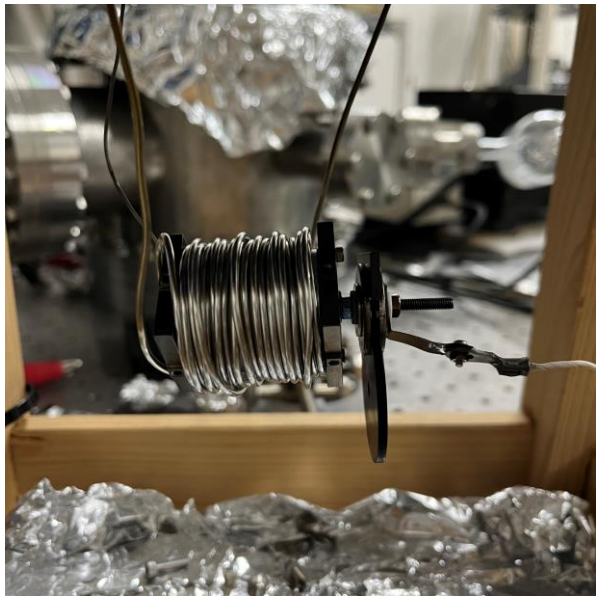
Heater	: Nichrome exotherm SUS sheath
Thermocouple	: K type SUS sheath
Heater base	: Mo
Holder	: SUS

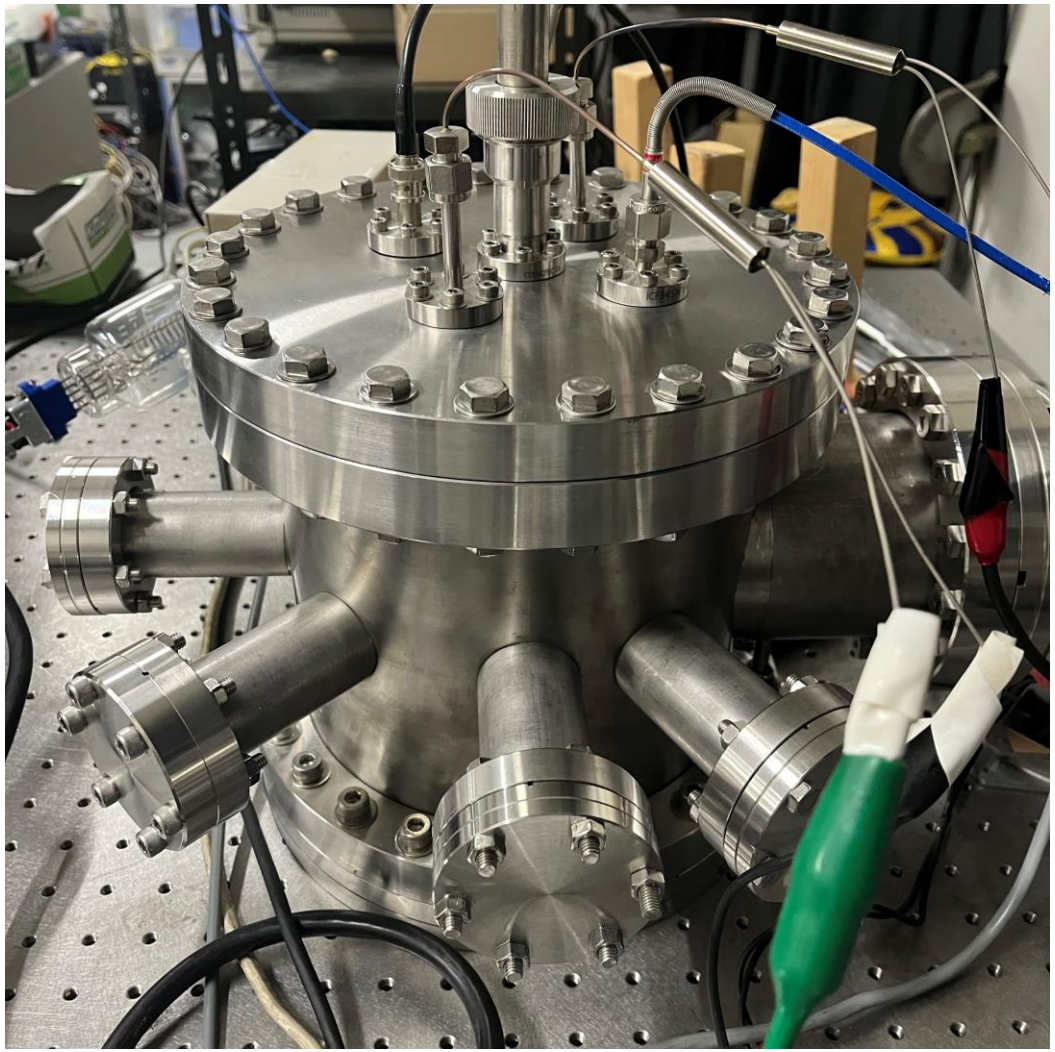


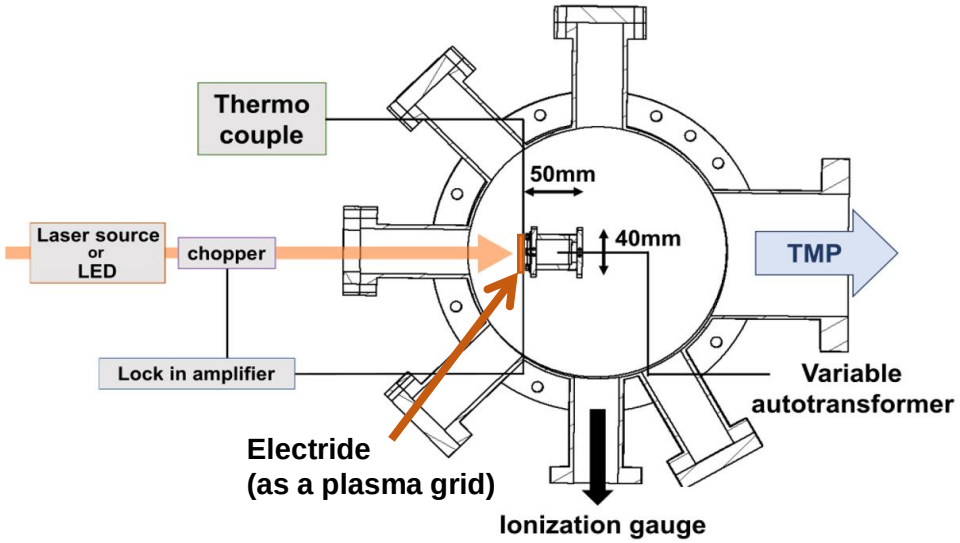
Remove the surface layer by heating the sample up.

Experimental setup –Electride heating system









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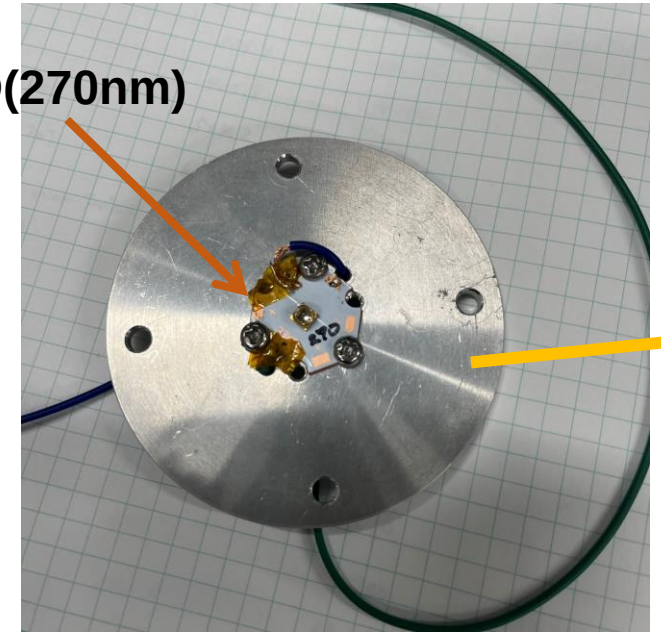
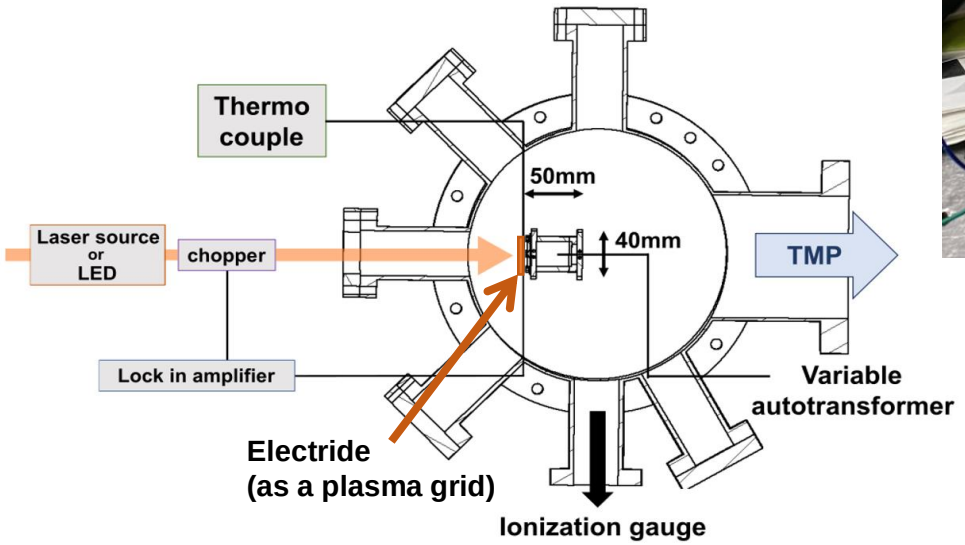
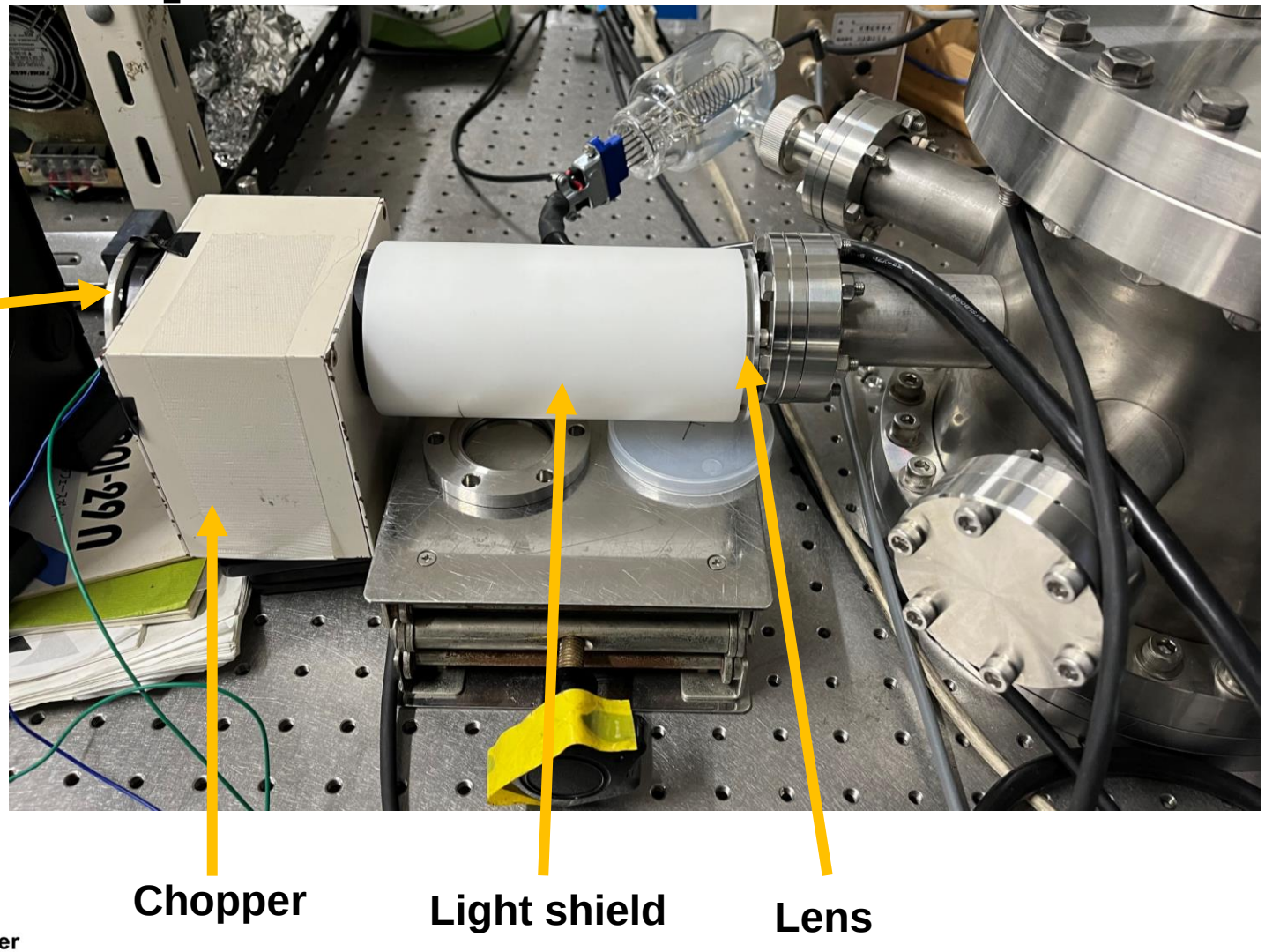
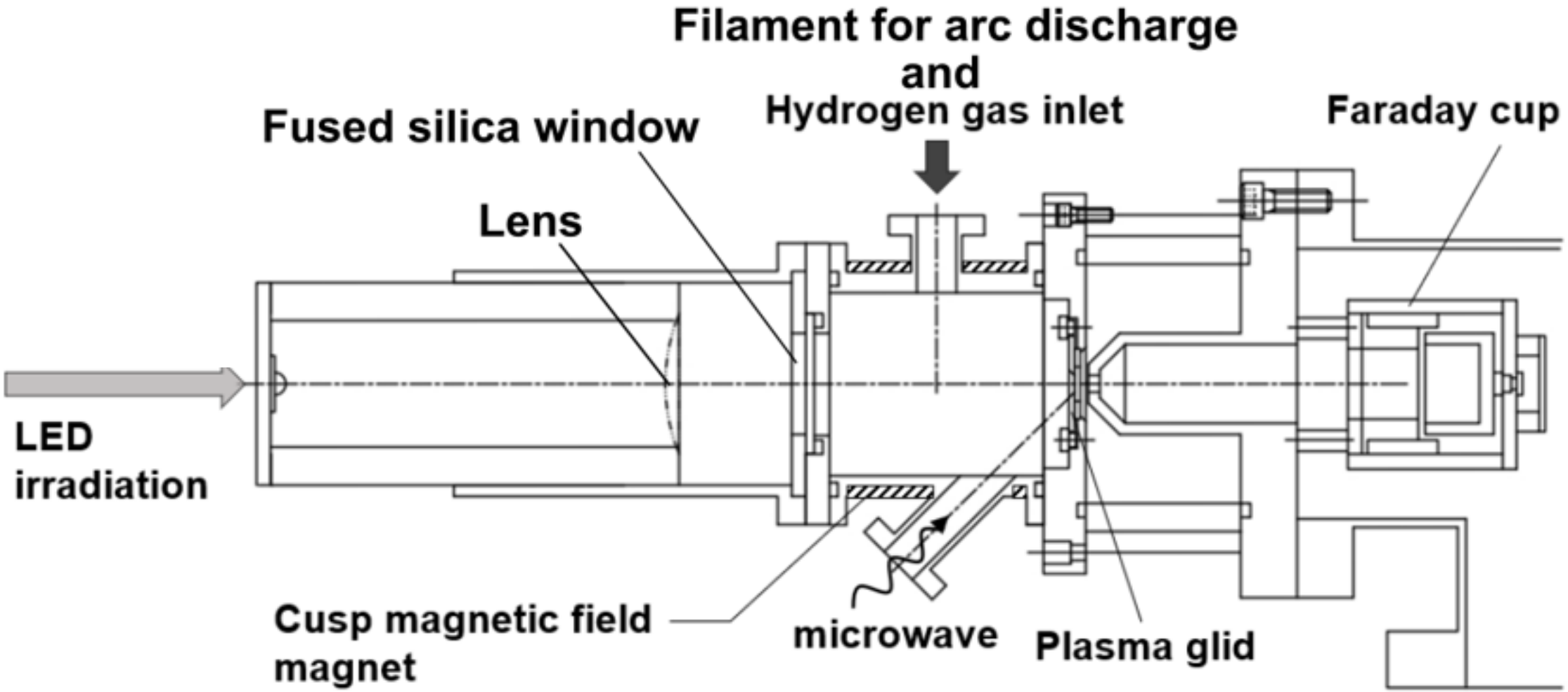






Experimental setup –ion source



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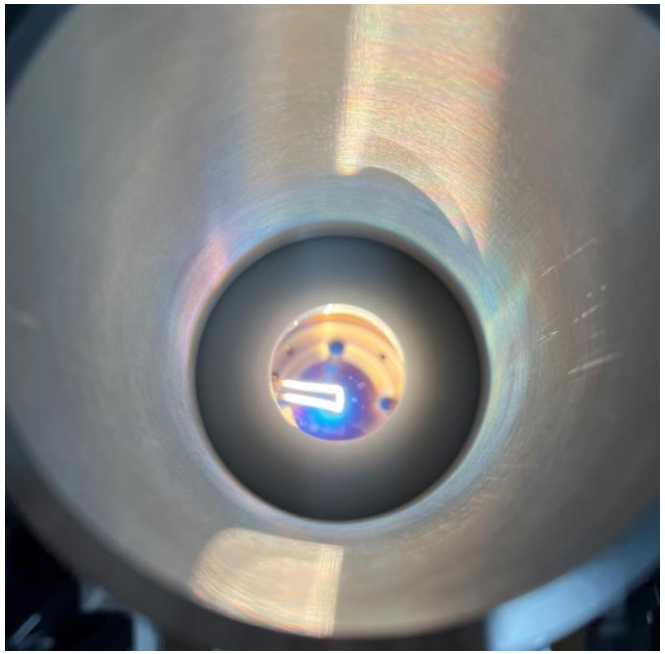
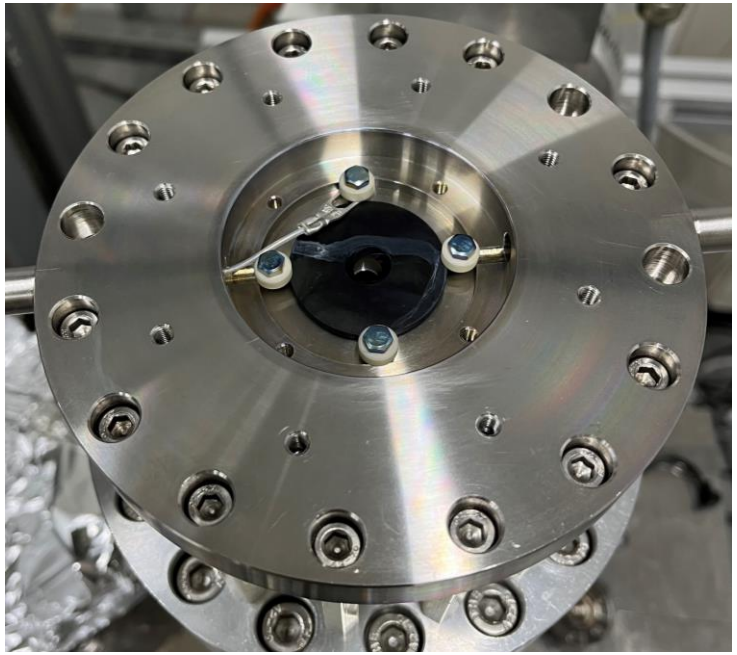
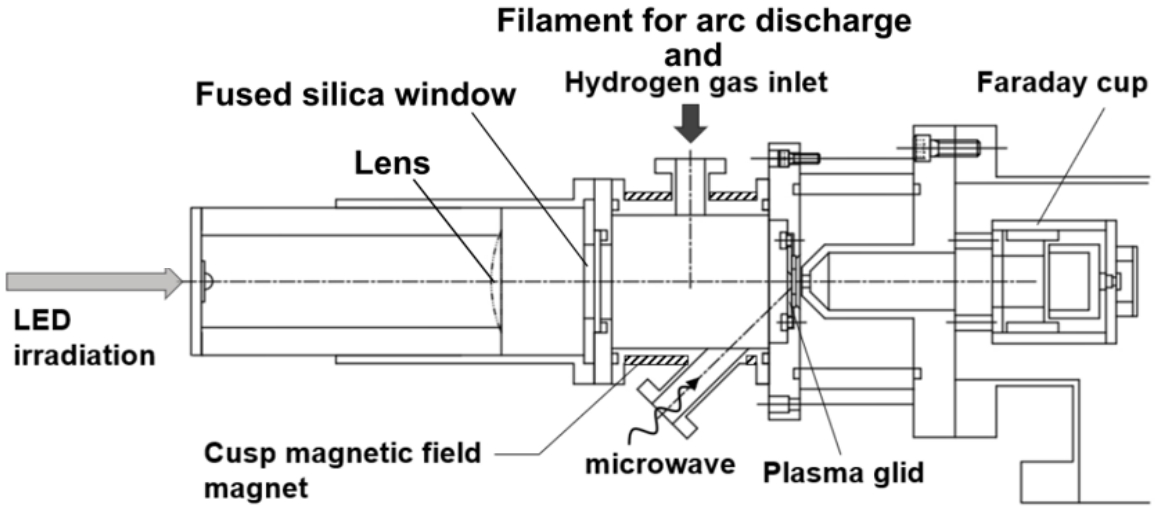
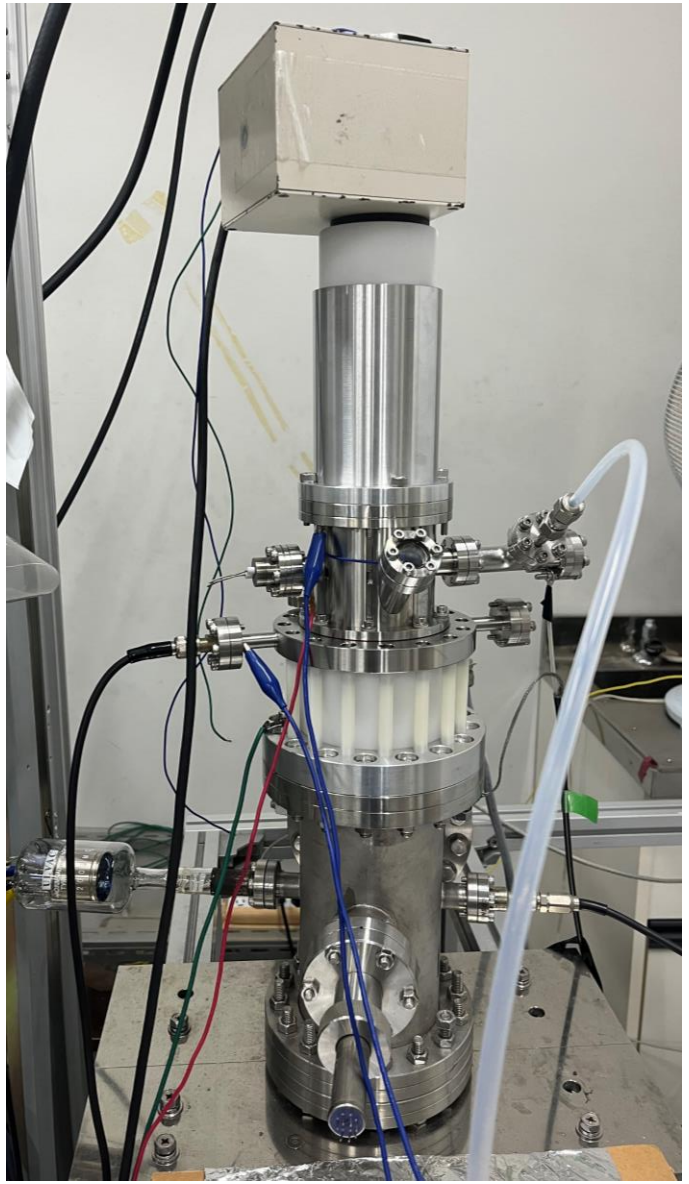


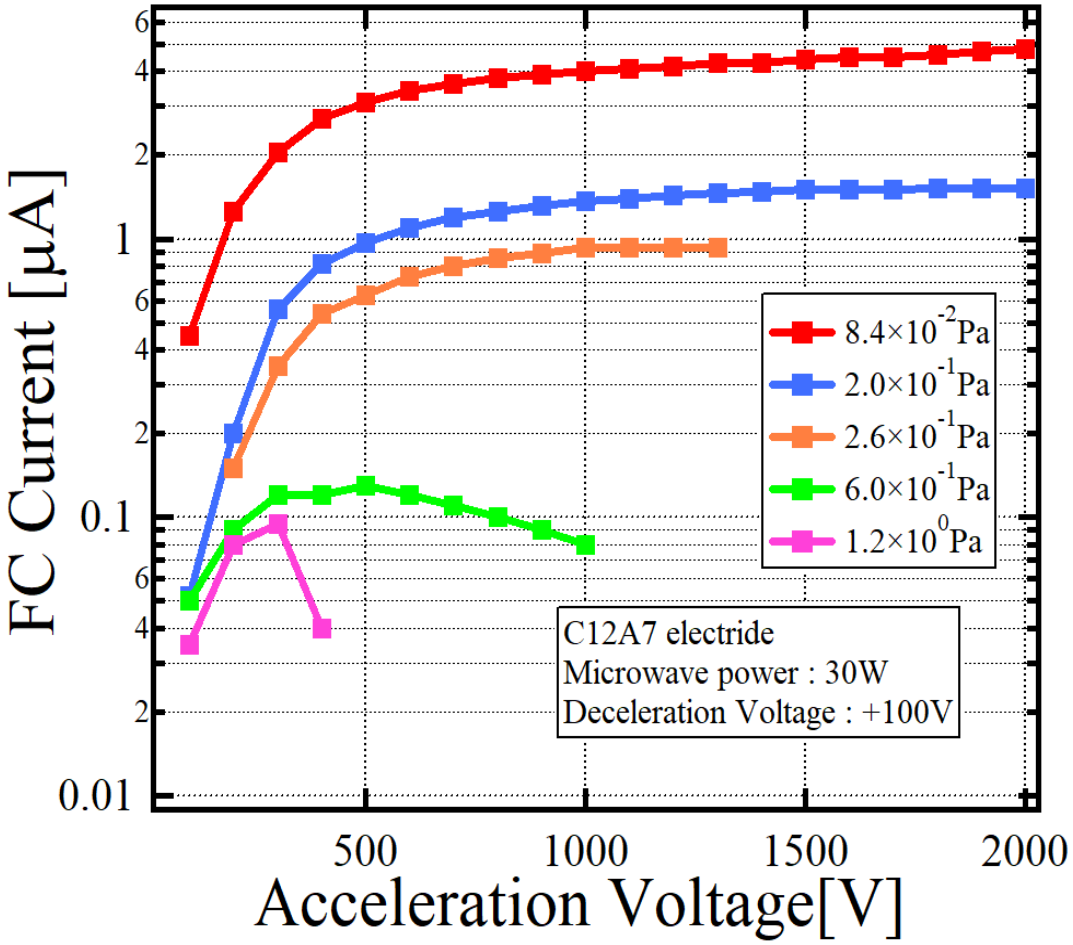




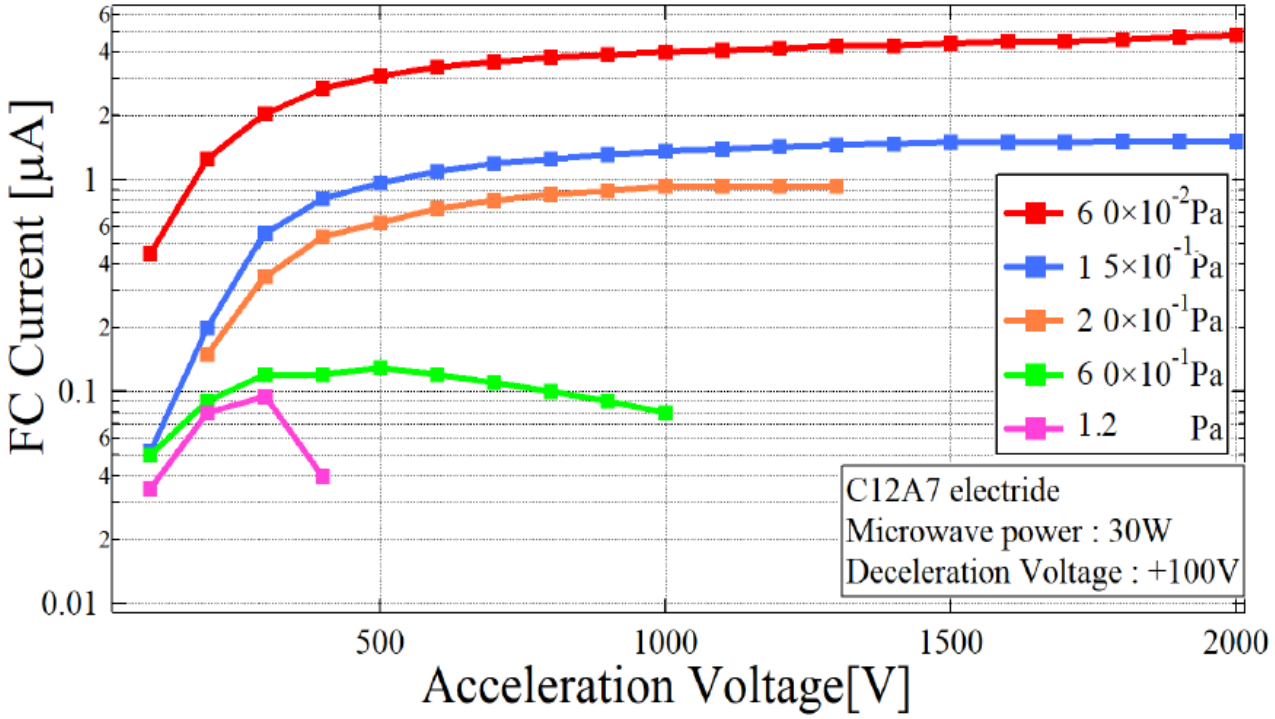


Experimental setup –ion source

After correction



Before correction



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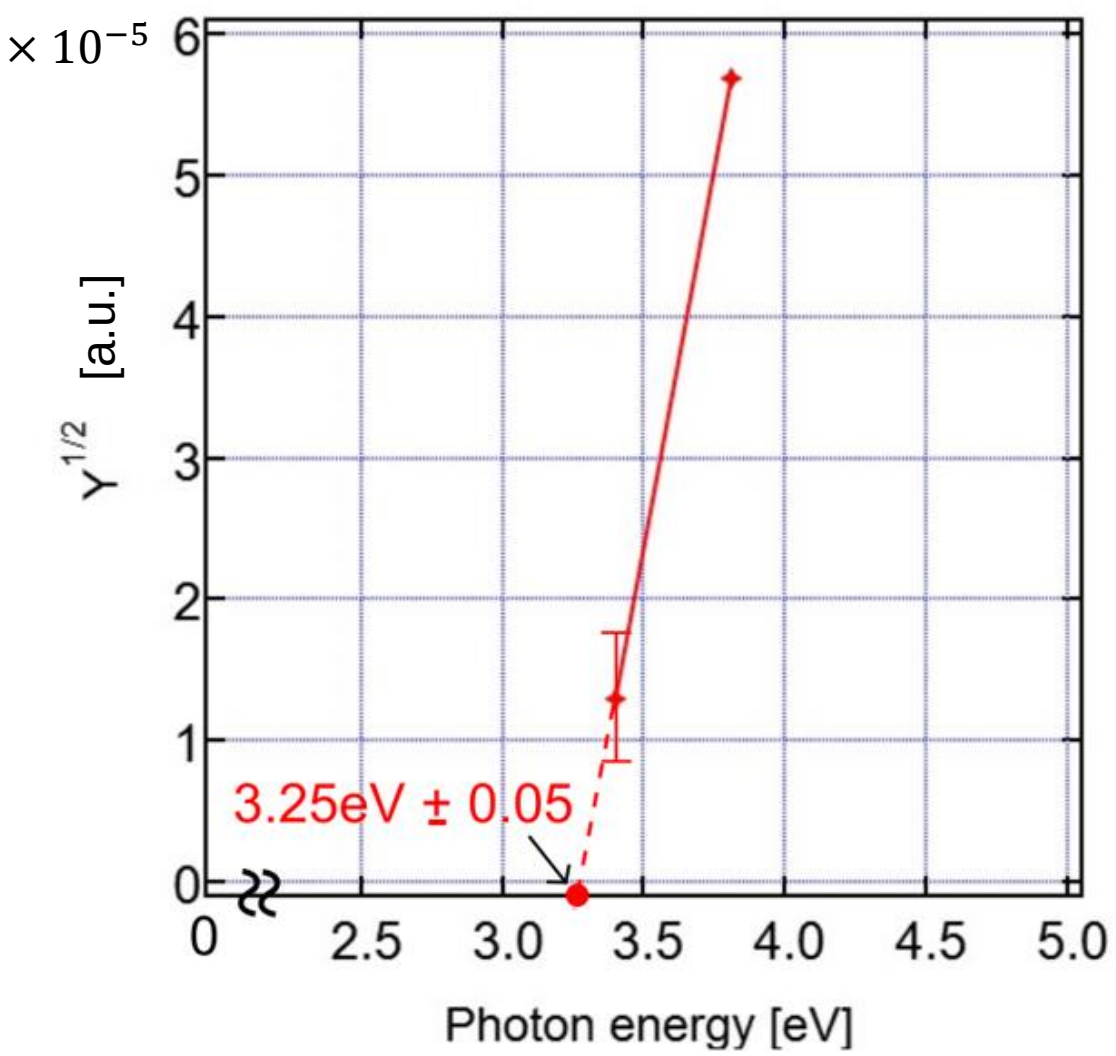
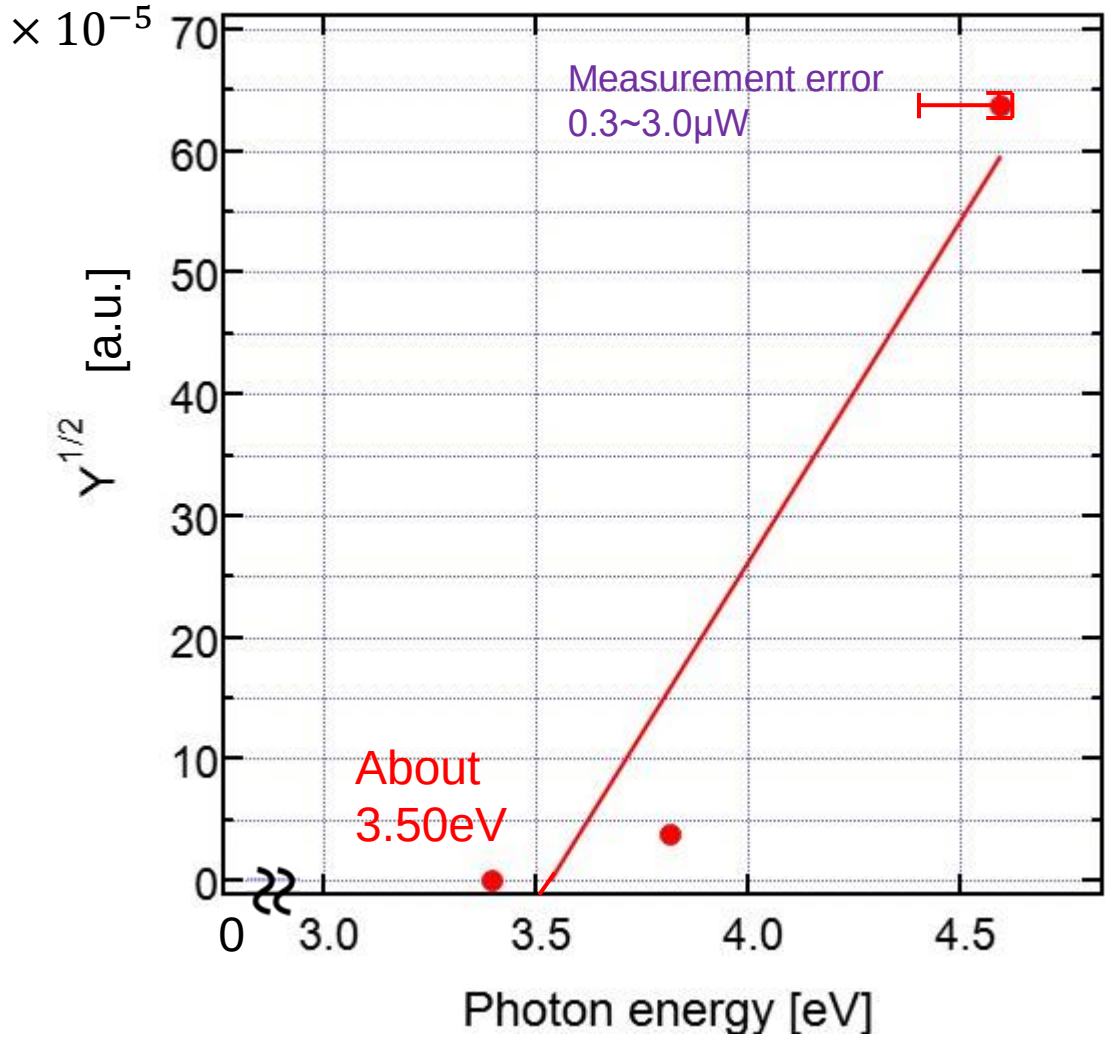
Results –LED based photoelectric current measurement





Comparison of square root of the Quantum Efficiencies of LEDs and Laser.

Results

–Change of surface condition by hydrogen plasma exposure realized with a tungsten hot cathode

The photoelectric current measurement using a LED light (270nm).

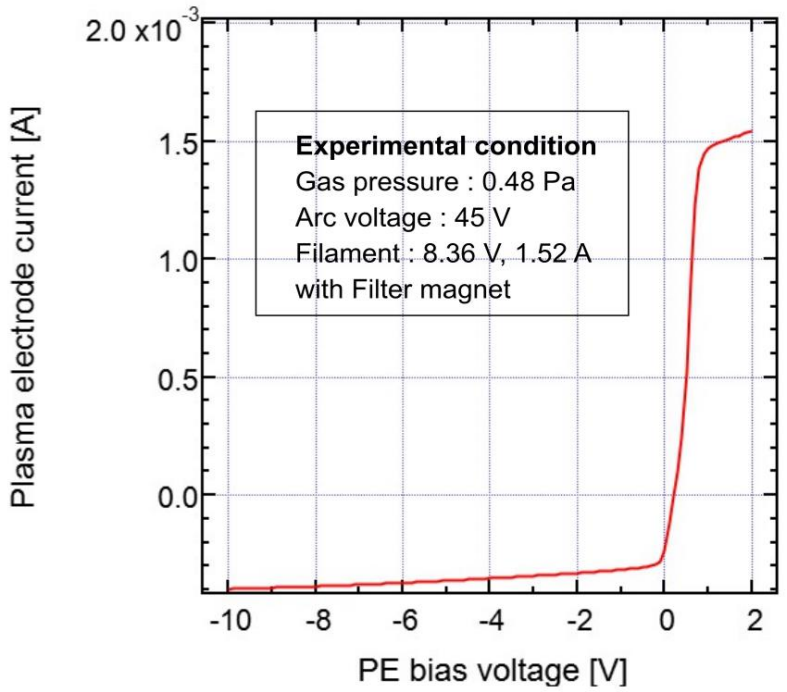
Current flowing in a PG : 0.33-0.39pA
(LED : 4.60eV, I_d =0.07A)

Once the voltage was reduced and re-measured.
Confirmed the reproducibility.

Plasma ignition
Gas pressure : 0.55Pa
Arc voltage : 80.1V
Filament : 10.0V, 1.45A

Current flowing in a PG : 0.01-0.03pA
(LED : 4.60eV, I_d =0.07A)

Photoelectric current cannot be measured after the plasma ignition in an arc discharge.



PE bias characteristics of plasma electrode current.

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Summary and outlook

- The work function of electride has been measured successfully using LEDs.
- New ion source, equipped with large window for LED light injection was assembled and being tuned.
- Tungsten filamen may contaminate electride PG surface to increase the work function. (to be confirmed)
- Need to increase of the number of wavelengths of LEDs (275nm, 310nm) used for photoelectric current measurement.
- Experiment with 2.45 ECR to compare the result with W filament discharge.
- Confirmation of Cs/Mo work function with LEDs.

Thank you for your attention!