2/28 @Hamamatsu

The effect of the thickness of alumina adhesion to the collection plate on aluminum precipitation

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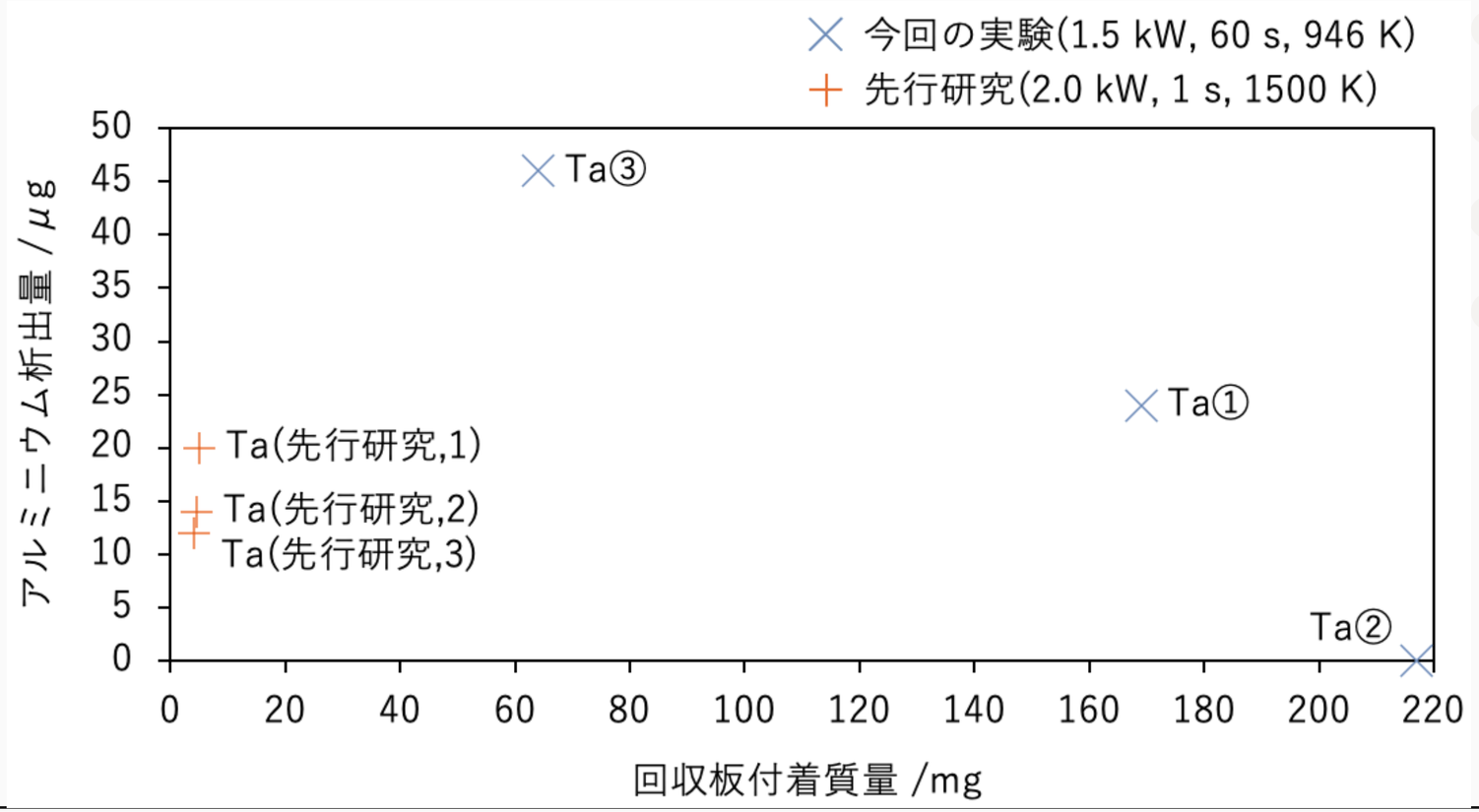
Abstraction

3 experiments with ~1000 K Ta plates were conducted

- 2 of 3 experiments confirmed the existence of Al, **24 µg, 46 µg** respectively
- High adhesion mass(**64~217 mg**) & Thick adhesion layer(**0.68 mm** ~) were achieved



Contents

01

Introduction

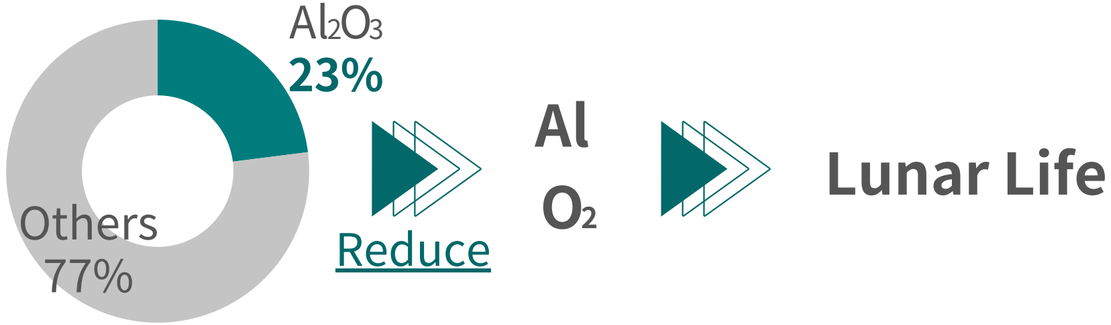
- Backgrounds
- Previous study
- Objective
- Review of Last Lab Seminar
- Summary of introduction

01

Laser regolith reduction is prospective for ISRU

Regolith reduction for ISRU

- Regolith reduction helps to realize lunar life



Regolith composition

- For lunar base, **In-situ resource utilization(ISRU)** is indispensable

10 million yen/kg (Earth→Moon)

CW laser ablation

- Thermally dissociate and reduce alumina by laser

Laser ablation

- **ISRU**
- **Middle energy efficiency**

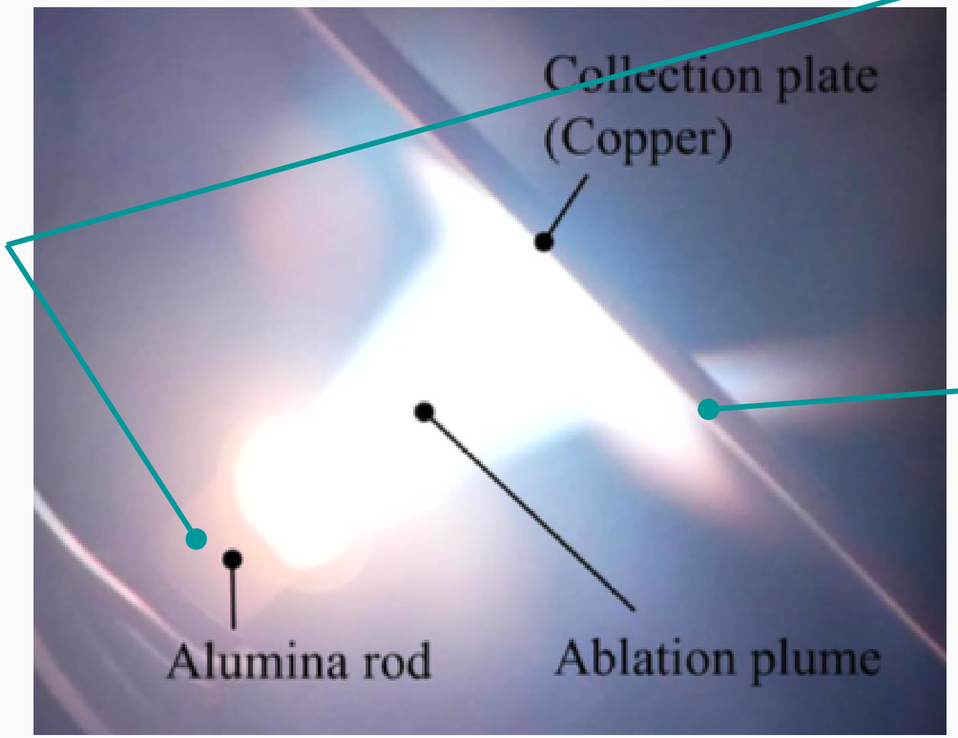
- **CW laser is superior** in terms of practical application

CW laser

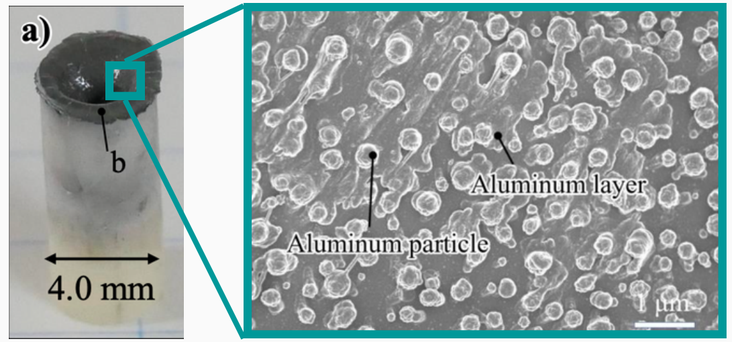
- **Large ablation mass**
- **Low Al collection rate**

High Al mass on the plate hasn’t been achieved

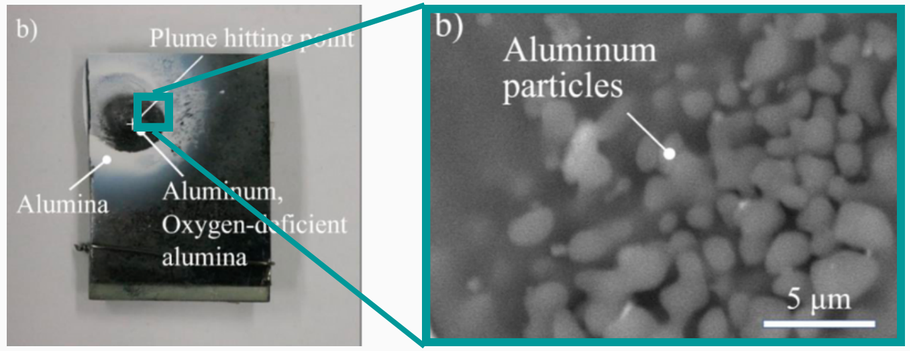
2 types of Al collection



1. On the rod(Al:14 µg @1.5 kW/1 s)



2. On the plate(Al:110 µg @2 kW/1 s)



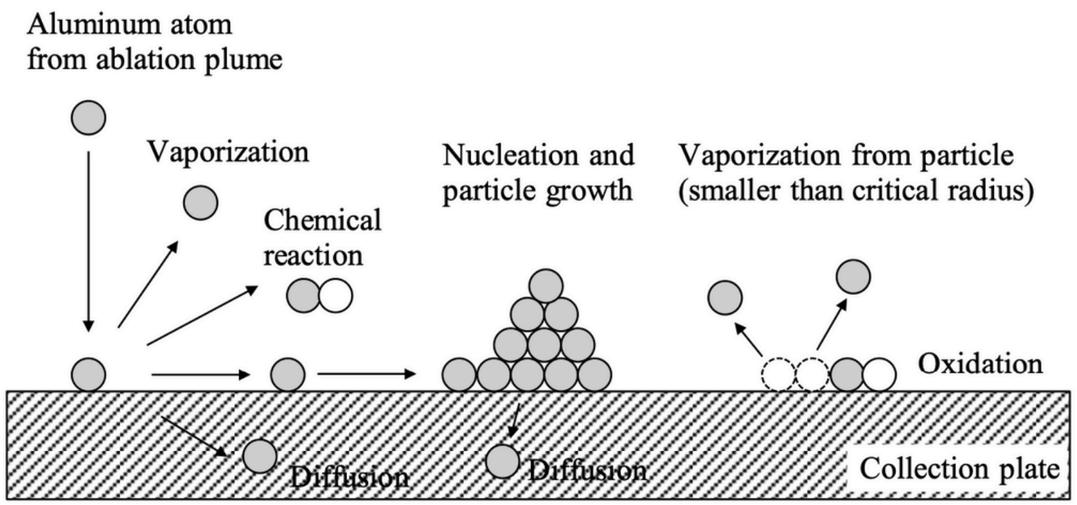
- Plate collection is superior in the terms of Aluminum mass
- The Al collection mass is not enough for the practical use

1. S. Tanaka (2021)

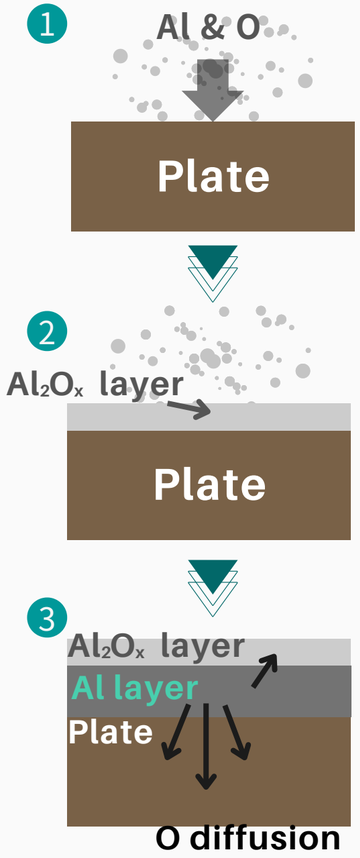
Thickness of Al_2O_x layer is a key for Al reduction

What happens on the plate?

- Reflection, vaporization, recombination & atomic diffusion



Mechanism of Al precipitation[1]



- Separated Al & O reaches the plate
- Form an oxygen-deficient alumina layer
- O atoms in the middle diffuse to the plate & the surface
- High plate temperature encourages the diffusion

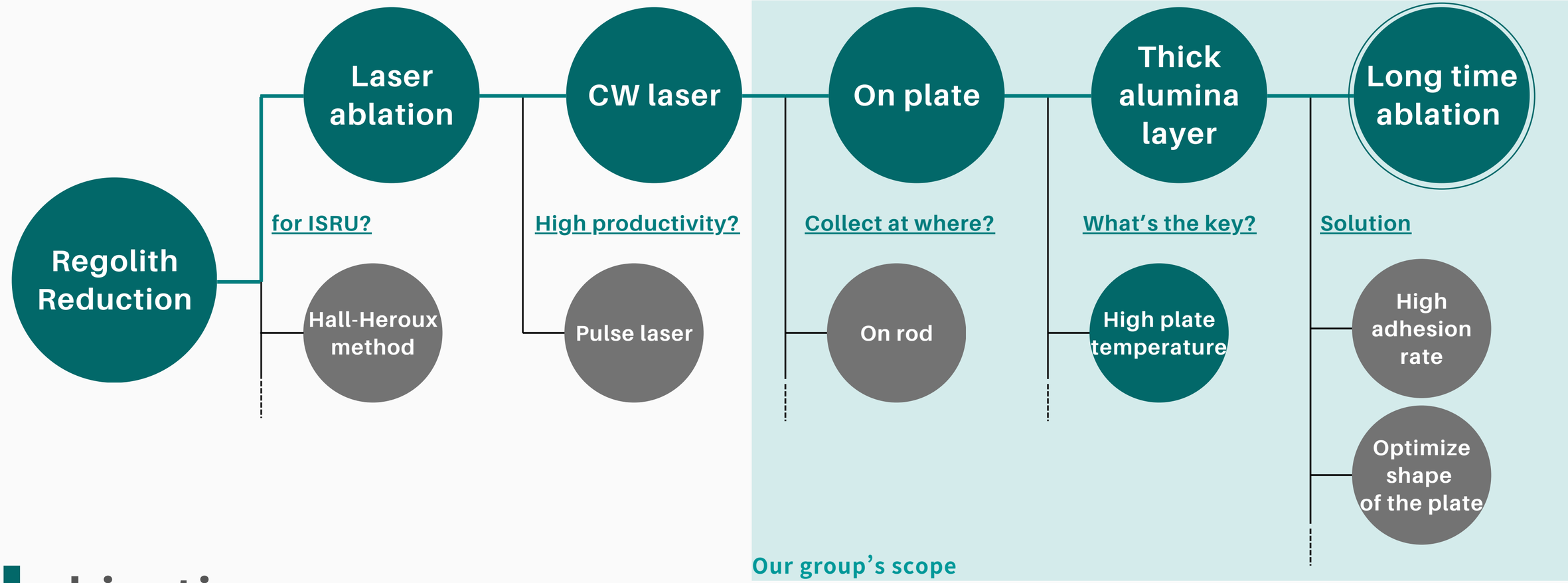
Encouraging O atoms diffusion by thick Al_2O_x layer (& high plate T)

→ Long ablation (& preheating the plate) is a way

1. M. Nakano (2023)

Summary so far

Increasing adhesion rate on plate is the key for Al collection



objective

- Increasing the thickness of Al_2O_X layer by long time ablation

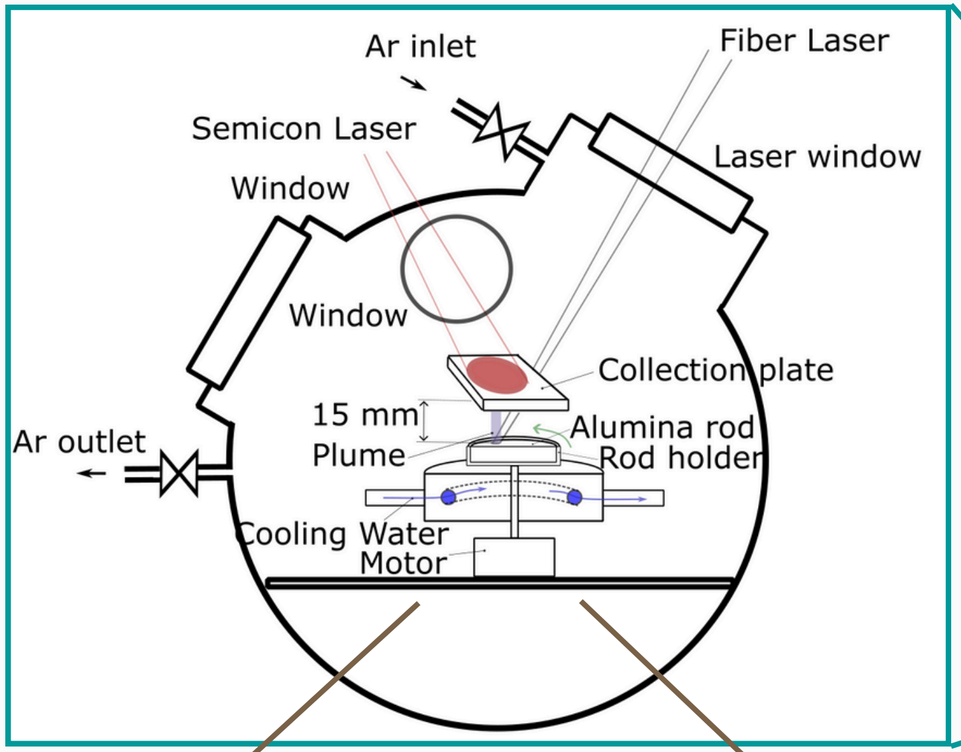
02

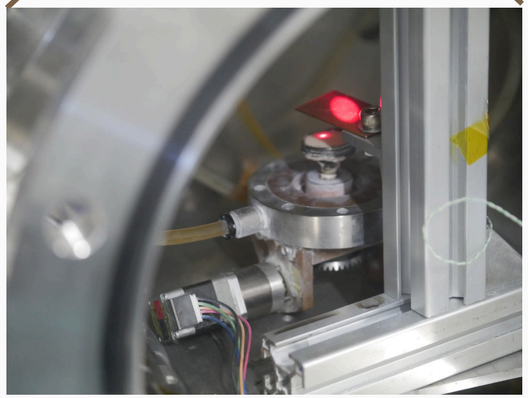
Methods

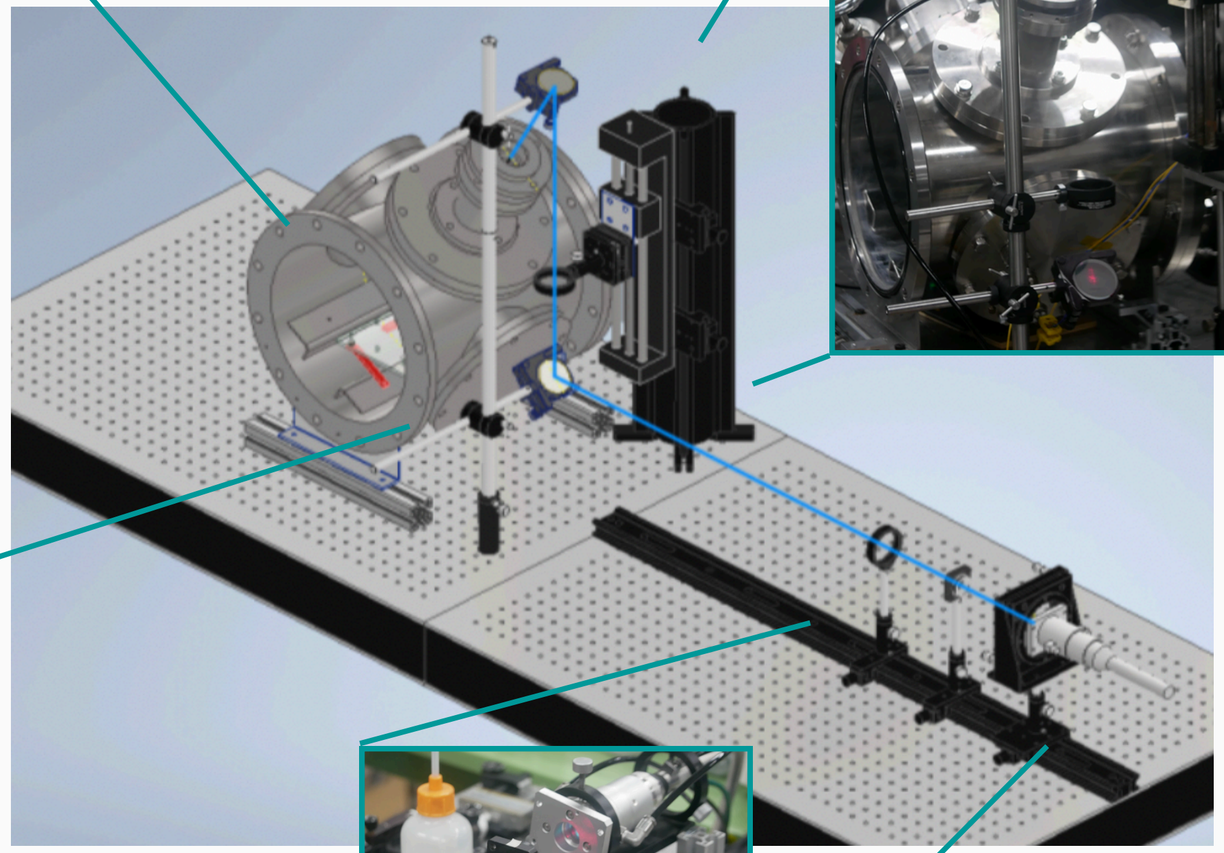
- Setup & condition
- Experiment procedure
- Analysis method

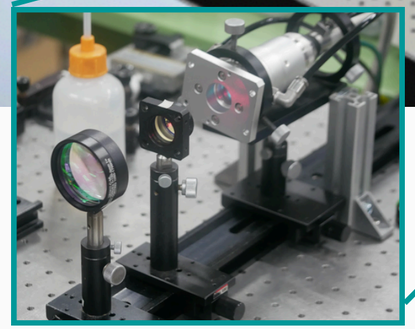
02

Overview of experimental set up

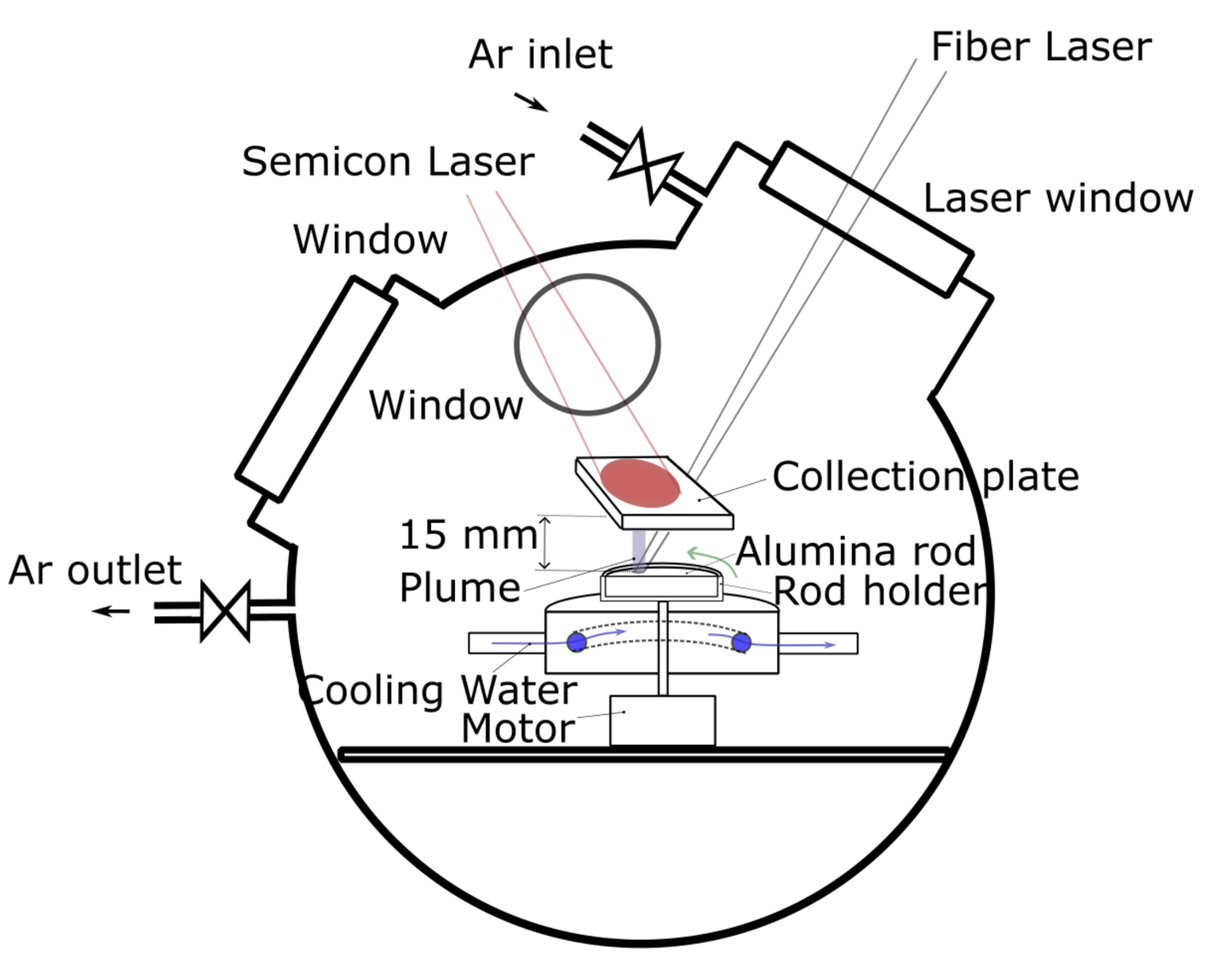








Set up detail & condition



RotatingAlumina rod

- ϕ20 mm
- 5 mm thickness
- 1 rpm

Collection plate

- Tantal
- 20 mm × 50 mm

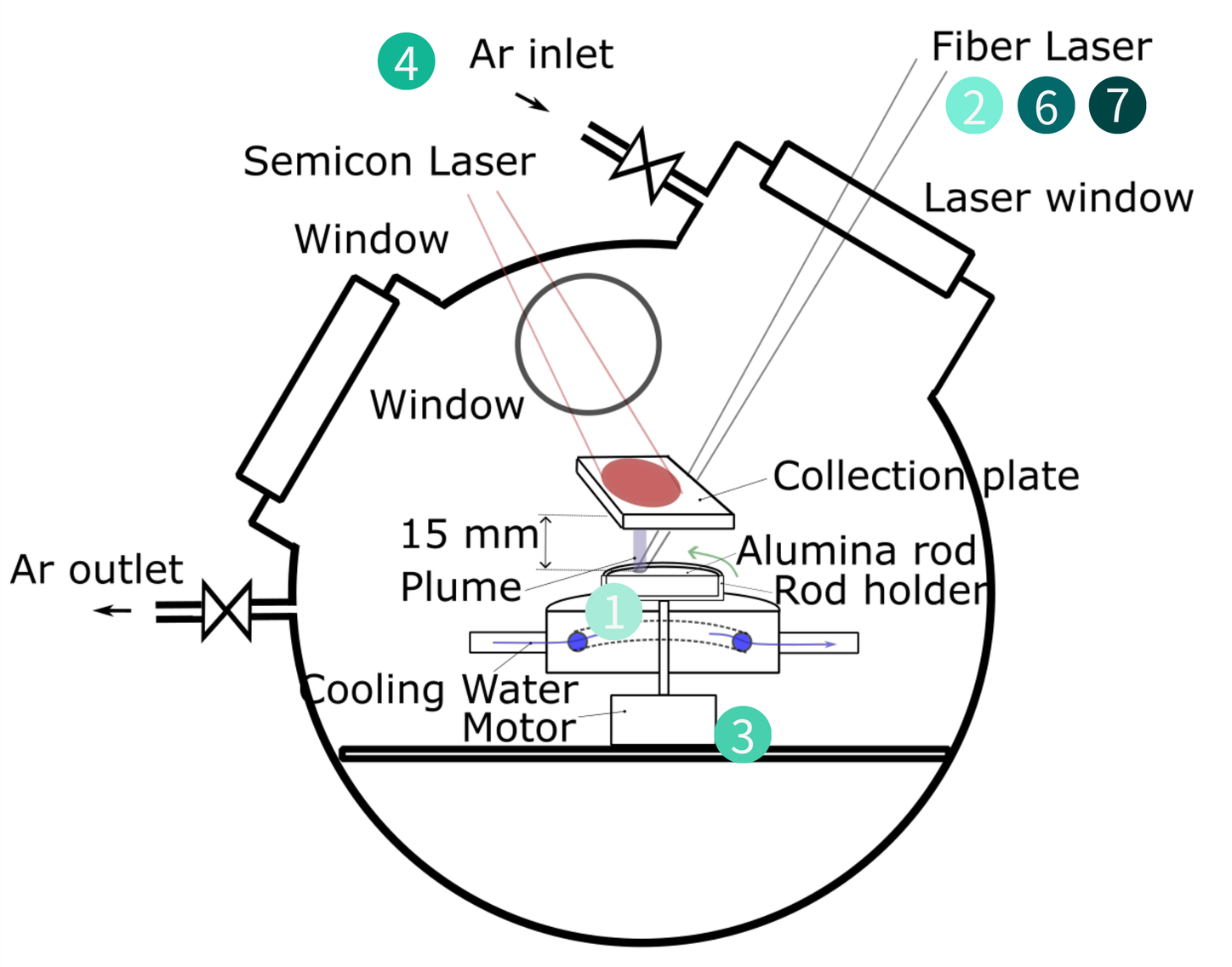
Atmosphere

- Ar
- 1 atm

CW laser

- 1.5 kW, ϕ2.2 mm
- 10%, 3 min(preheat)
- 100%, 60 s(ablate)

Experiment procedure

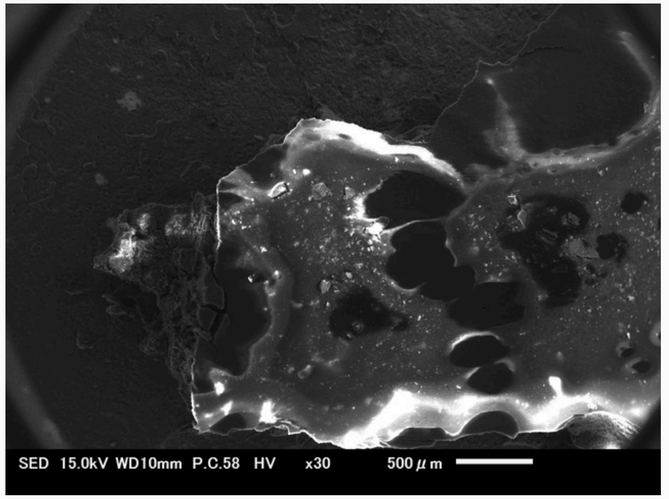


1. Fix the Rod & the plate
2. Align the laser
3. Activate the motor
4. Evacuate & inlet Ar
5. Start recording
6. Turn on the laser
7. Stop the laser

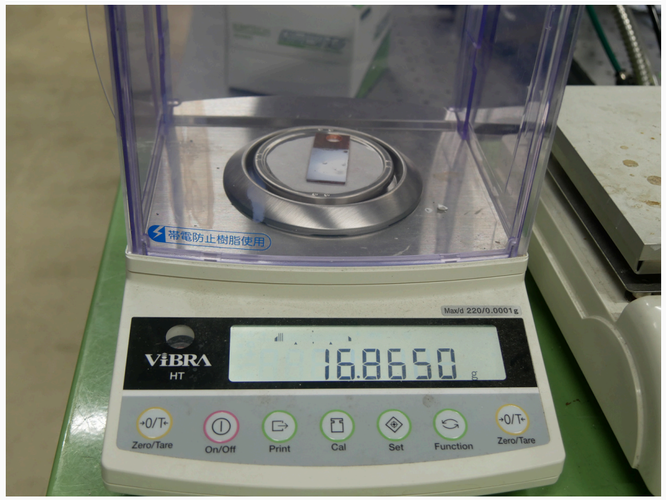
Several data was collected

Collection plate

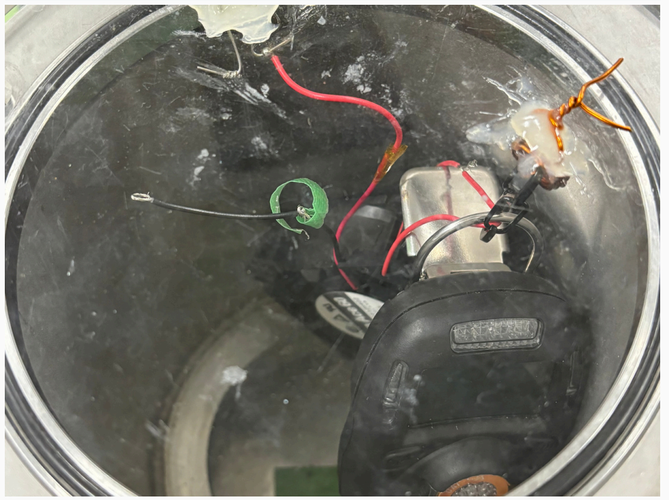
SEM/EDX



Adhesion mass



H_2 detection



03

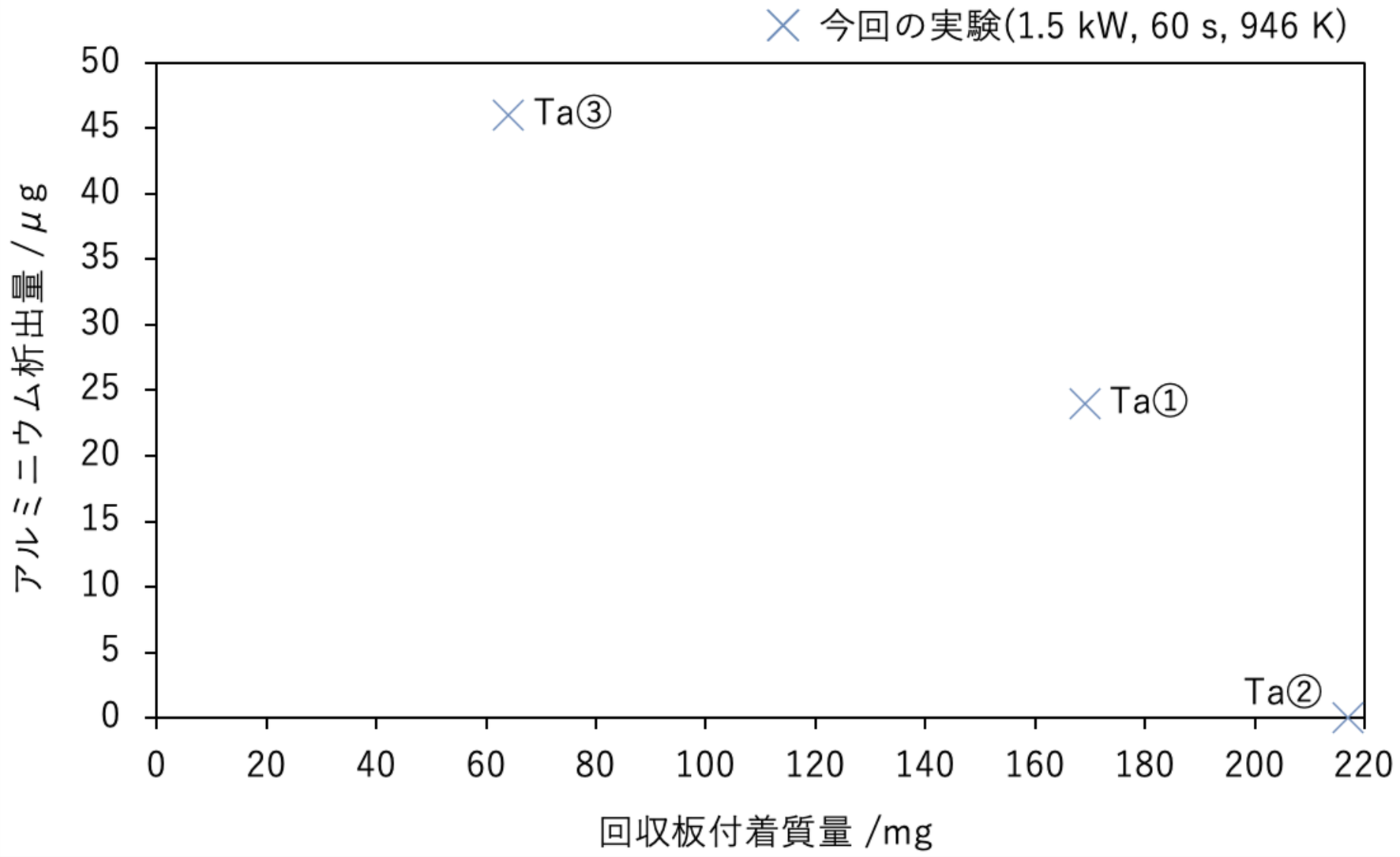
Results & Discussion

- Results

03

2 of 3 experiments confirmed Al on the Ta plate

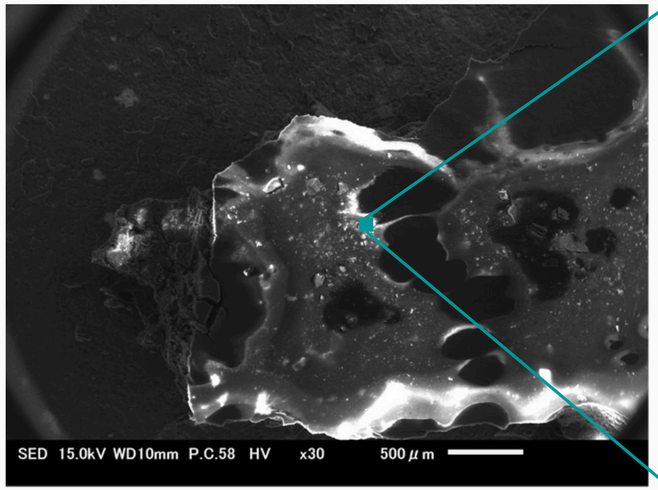
The deposition masses of Al were 26 µg & 42 µg, respectively

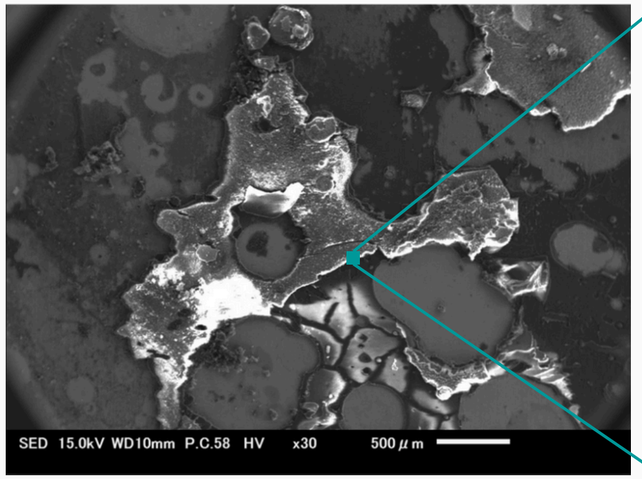


Not oxygen-deficient alumina, but Al_2O_3 deposited

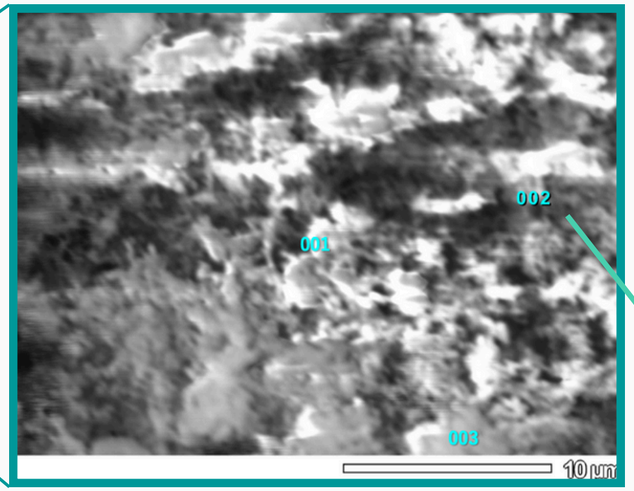
Atomic number ratio of Al & O on the plate was 2：3

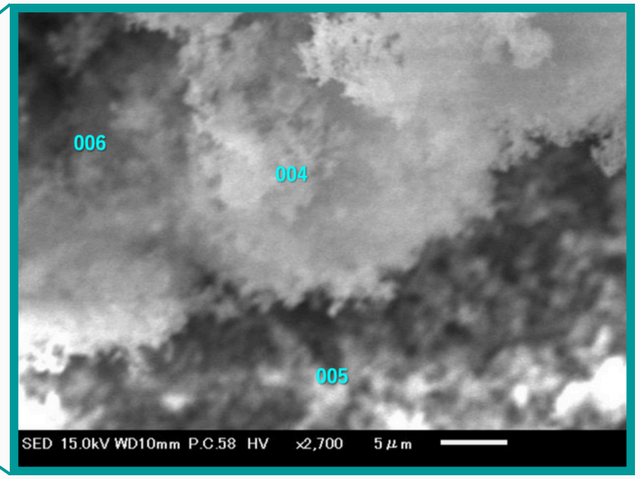
SEM





Enlarged SEM



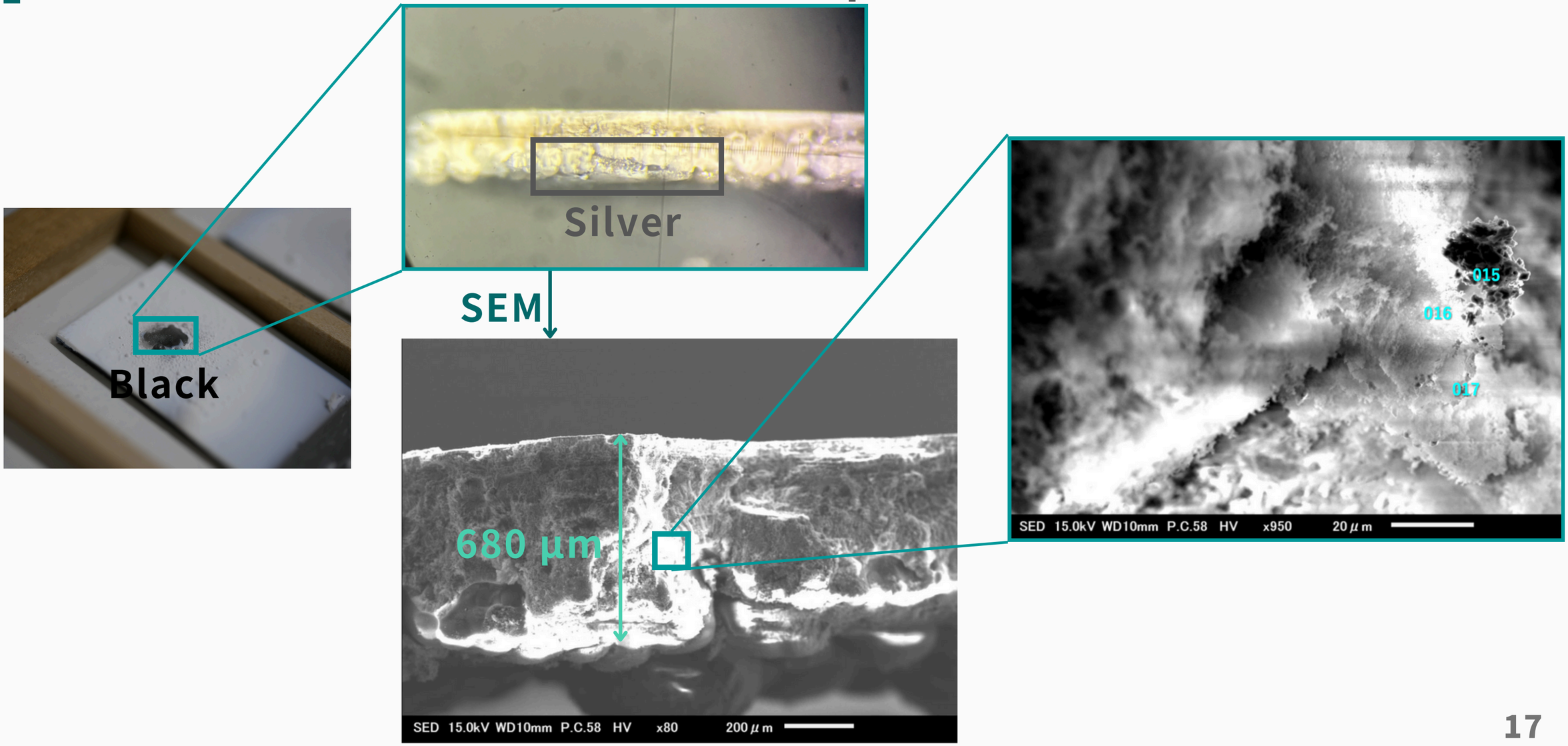


Example of EDX(002)

Atom	Atomic number /%	σ
Al	60.42	0.43
O	39.58	0.30
Other	0.0	-

Even looked like black or silver, it was Al_2O_3

Al & O ratio of the black & silver parts were also 2 : 3



04

Conclusion & Future work

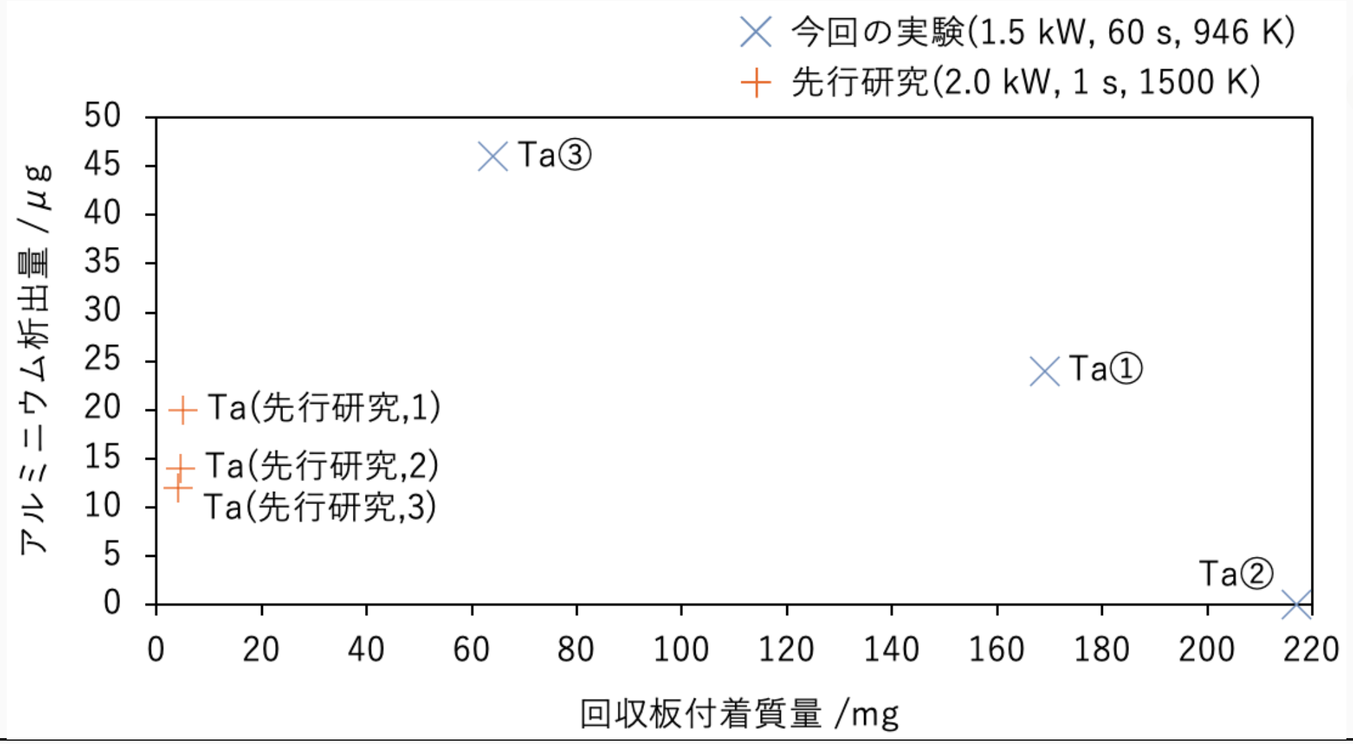
- Conclusion
- Future work

04

Coclusion

3 Experiments with ~1000 K Ta plates were conducted

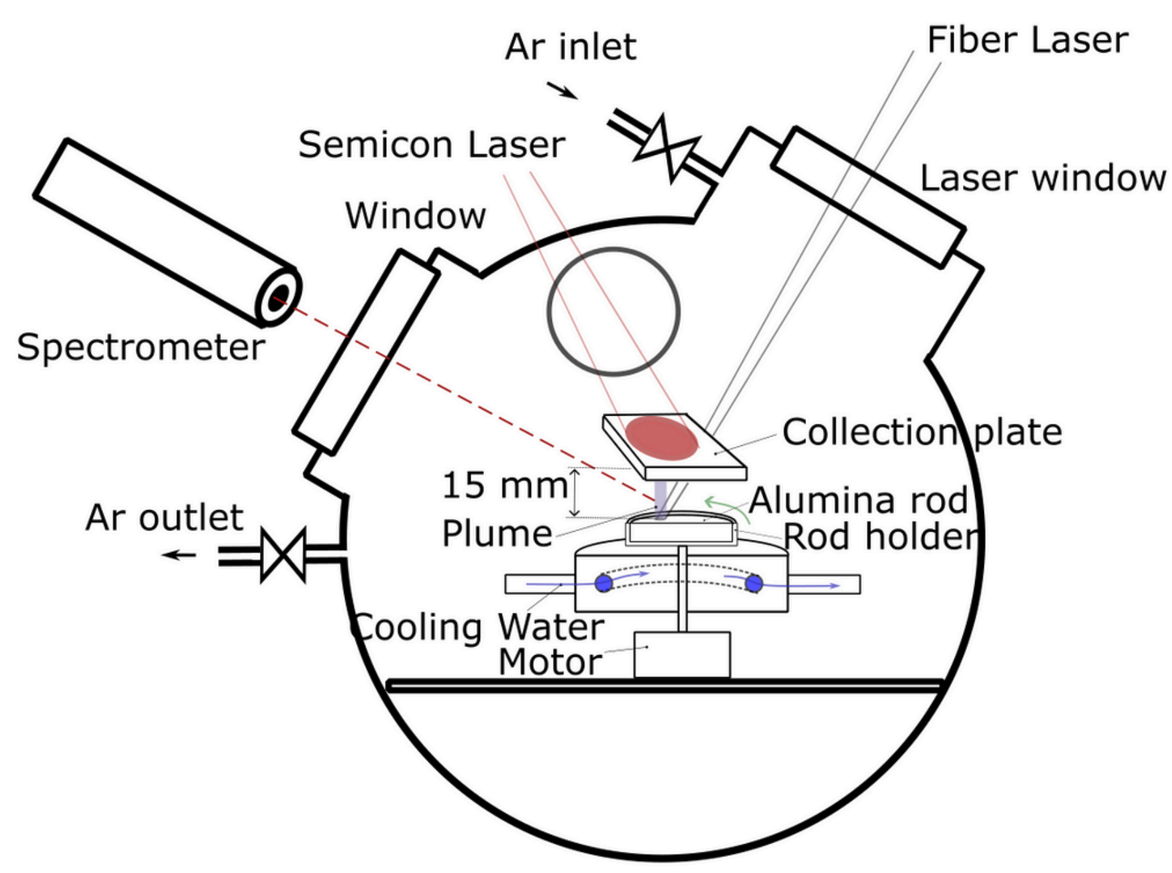
- 2 of 3 experiments confirmed the existence of Al, **24 µg, 46 µg** respectively
- High adhesion mass(**64~217 mg**) & Thick adhesion layer(**680 µm** ~) were achieved
- No oxygen-deficient alumina was confirmed

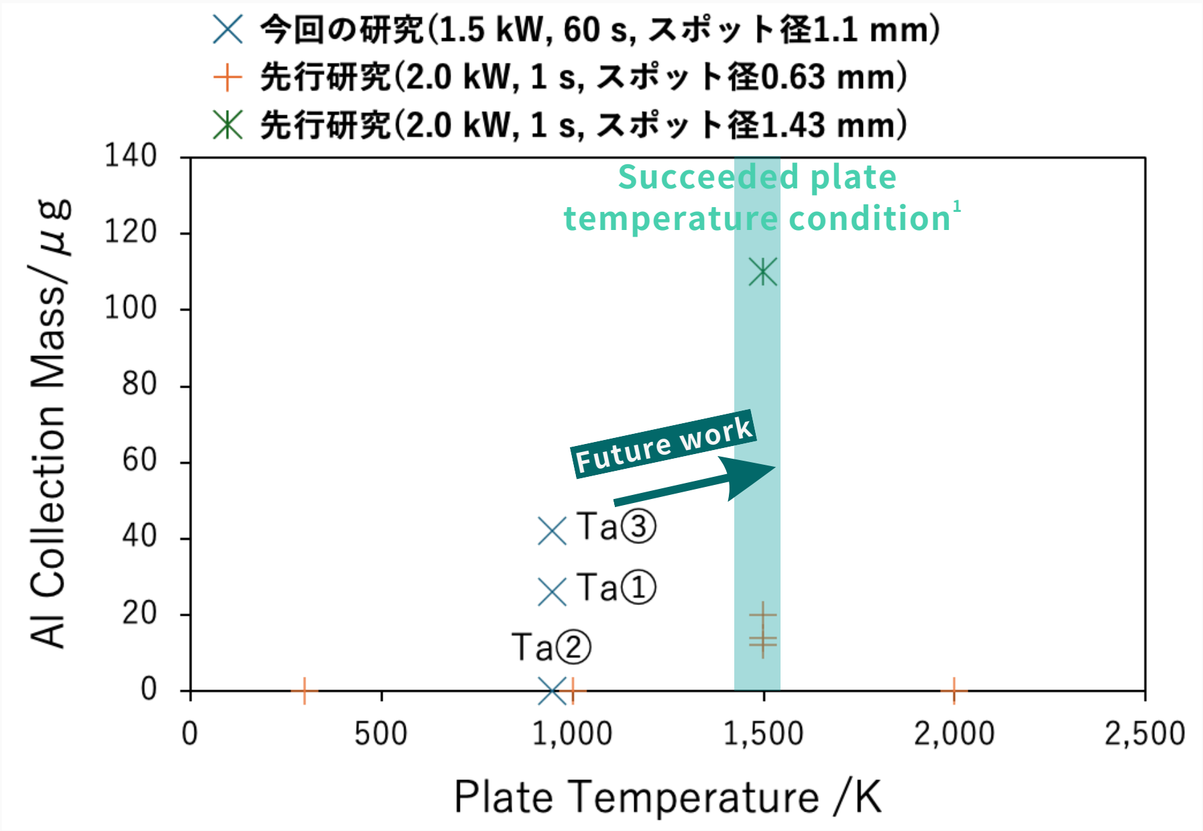


1. S. Tanaka (2021)

Future work

Experiments with ~1500 K plates are planned





1. S. Tanaka (2021)

Thank you for your attention.

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Effect of electric potential on the adhesion rate of alumina particles to the plate in laser abration

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+α

Appendix

Explanations of laser ablation & CW laser

What is laser ablation?

- Thermally dissociate and reduce Alumina by laser
- No Carbon, potentially high energy efficiency

Laser ablation

- 👍 ISRU
- 👍 Middle energy efficiency

Hall-Heroux method

- 👍 Established
- 👎 Not ISRU

Laser sustained plasma

- 👍 ISRU
- 👎 Low energy efficiency

CW laser is focused

- CW laser has advantage when it comes to sustainable useage
- Large ablation mass per unit time due to large total energy input

CW laser

- 👍 Large ablation mass
- 👎 Low Al collection rate

Pulse laser

- 👍 High Al collection rate
- 👎 Low productivity

Adjusted condition for moderate preheating

Preheating power %

15%

13%

Too much preheating makes hemispheric surface

10% — Moderate Preheating

0% — Sudden temperature change causes spallation

Adjusted laser intensity

Optimal laser intensity, 0.32 GW/m^2, was achieved in every experiments

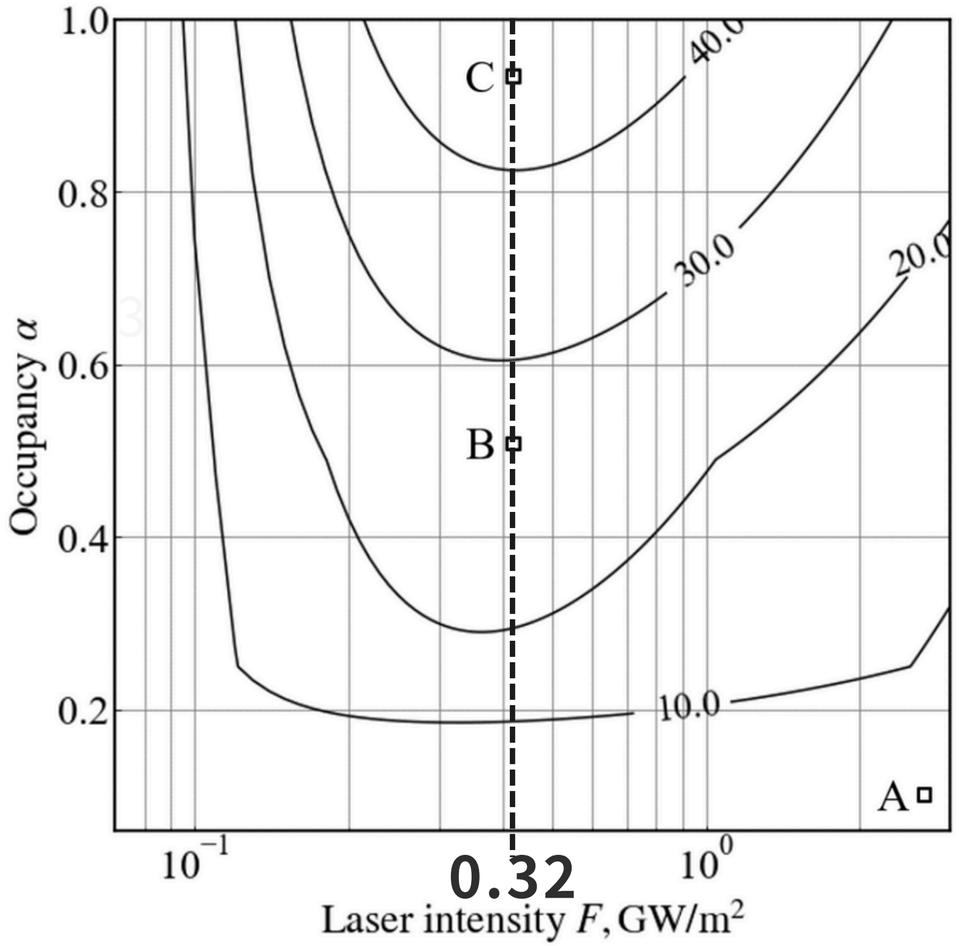
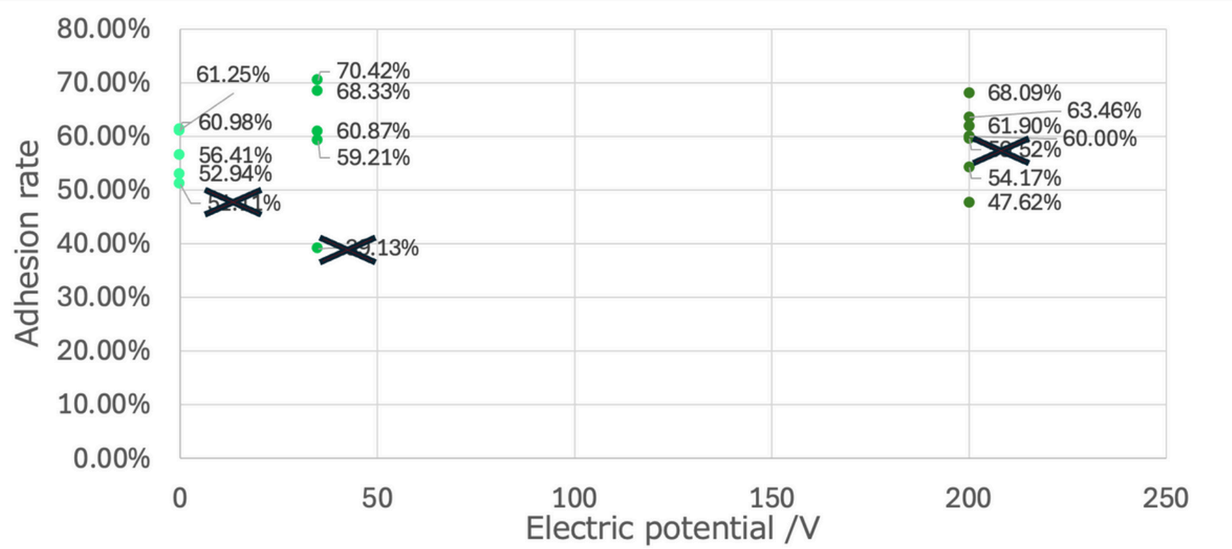


Figure 2-17 Ablation rate map with 2.0 kW laser power in various laser intensities and occupancies (i.e., the area ratio of laser spot to alumina rod surface).

Applying electric potential didn't contribute to the thick Al_2O_X layer

Review of my former research

The effect of electric potential on the adhesion rate, which might contribute to the thick Al_2O_X layer, was not confirmed



Average