New tools for understanding Mirror Degradation of Aluminum mirrors with Far Uv and EUV function-

A mirror coating for space with the greatest band width

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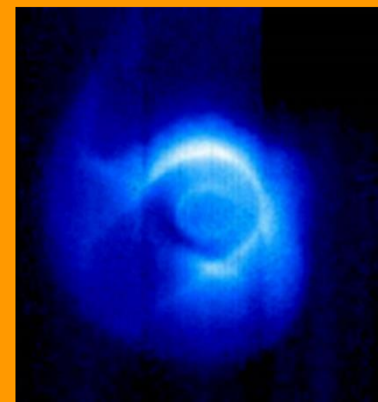
‡BYU College of Physical and Mathematical Sciences Undergraduate RA support.

Our group has made spaces mirrors for Far- Extreme Ultraviolet (EUV)

Thin Film U/Si Multilayer Mirrors

EUV Astronomy: IMAGE Mission

The Earth's magnetosphere is at UHV (<1E-8 torr) but we can see it with the right mirrors.



The Earth's magnetosphere in the EUV-30.4 nm

Tools to study EUV Multilayers

- Al is partially transparent <70 nm
- Surfaces- Non Ideal
  - Roughness, Layers: Oxides, Contamination
- Optical Constants->40nm

Images from www.schott.com/magazine/english/info99/ and www.lbl.gov/Science-Articles/Archive/xray-inside-cells.html.

Summary: What the mirror & coatings might be.

A Multilayer (ML) VUV-EUV Mirror Coated with as Thin as Possible Aluminum Film- without oxide

- Processed in Space -
  - Processing may mean
    - Al coating* on Earth-prepared EUV-ML mirror.
    - It may mean removal of one or more barrier layers.†
    - Probably both need to be developed.
  - Point of use.
  - far from Earth.
- It is helpful to devise and perfect tools.

* Life prolongation of far ultraviolet reflecting aluminum coatings by periodic recoating of the oxidized surface. Juan Ignacio Larruquert, Jo. Antonio Mendez, Jose Antonio Aznarez, Optics Communications 135 (1997) 60-64 † Burton proposed removing

Our Goals:

- Doubling* the effective bandwidth for aluminum mirrors .
- Provide info about tradeoffs to those making decisions for decadal review.
- Advance the TRL for space-processed bare aluminum mirrors with EUV beneath.
- Educate students
- Develop tools

*From current 0 to ~10 eV to 0 to ~20 eV or 0 to 15 + another 5eV further on in EUV
124nm to 62nm or e.g., 124 to 83 & 62-56 nm

OUTLINE

- Introduction:
- Tool development: How to get bare aluminum in space & study it here:
  - Development of two kinds of optical characterization tools
  - Atomic Hydrogen
  - Processing at point of use-
  - Removable protective coatings - Two varieties

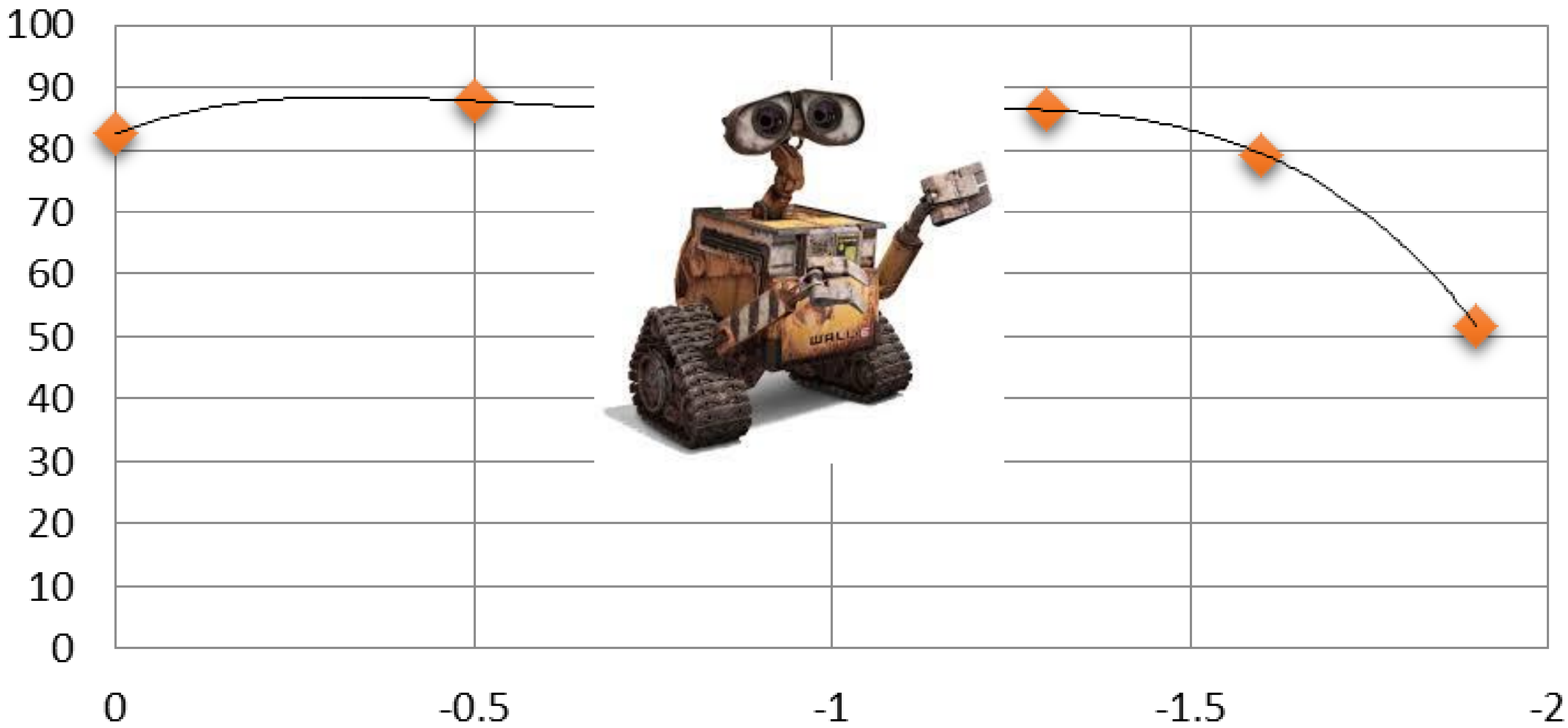
1. Preliminary Atomic Hydrogen processing Experiment: Polymer Film removal

- Tasks:

1. Plastic on wafer & fresh PMMA wafers
2. Use a sputter system to plasma etch samples in 100% H_2

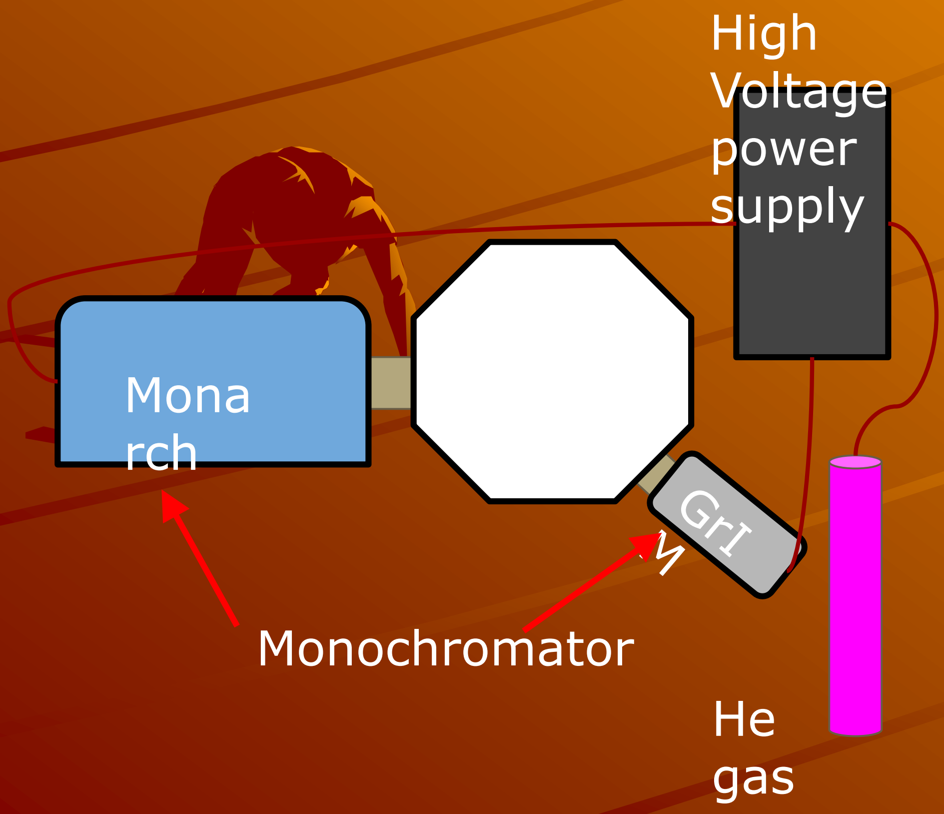
$CH_XO_Y + H \rightarrow$ Volatile compounds like Hydrocarbons & H2O

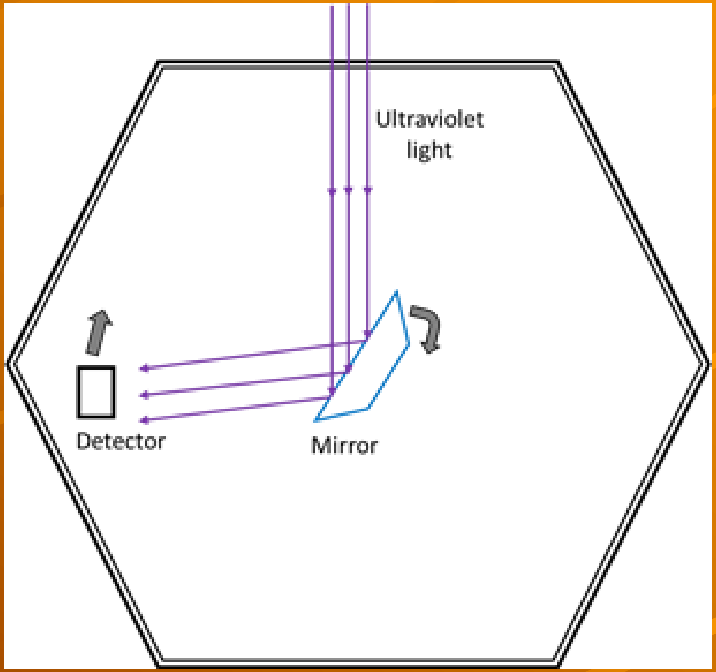
nanometers etched in 8 min. H2 plasma- from wafer center (0) outward to edge (-2 inches)



2. VUV measurement of Al mirror made in Situ

- An evaporator is being set up to coat the mirror in the chamber itself
- the mirror will rotate around to where it's used.
- The evaporator will be pulled back up out of the way so the rotation measurements can be made.

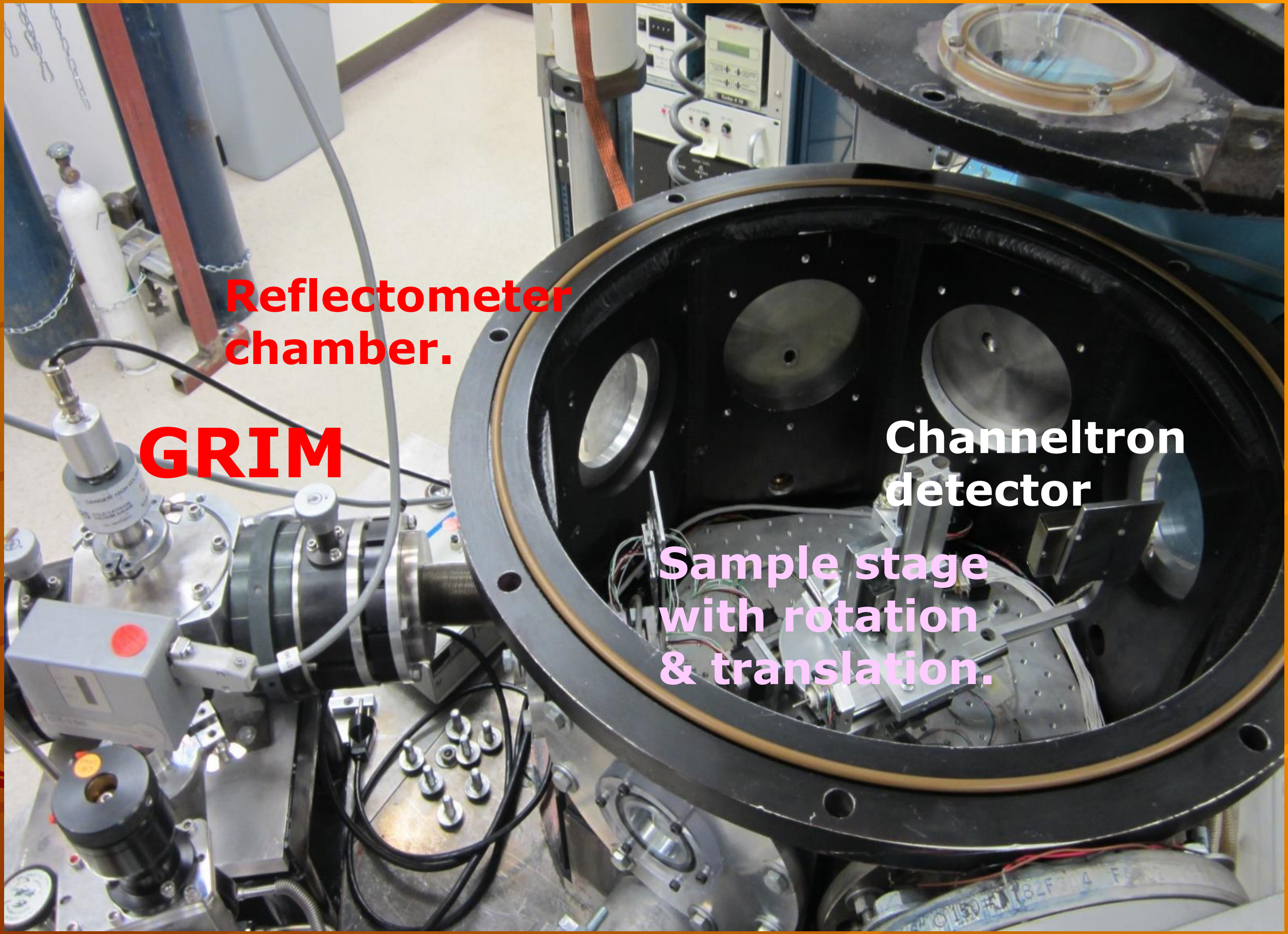




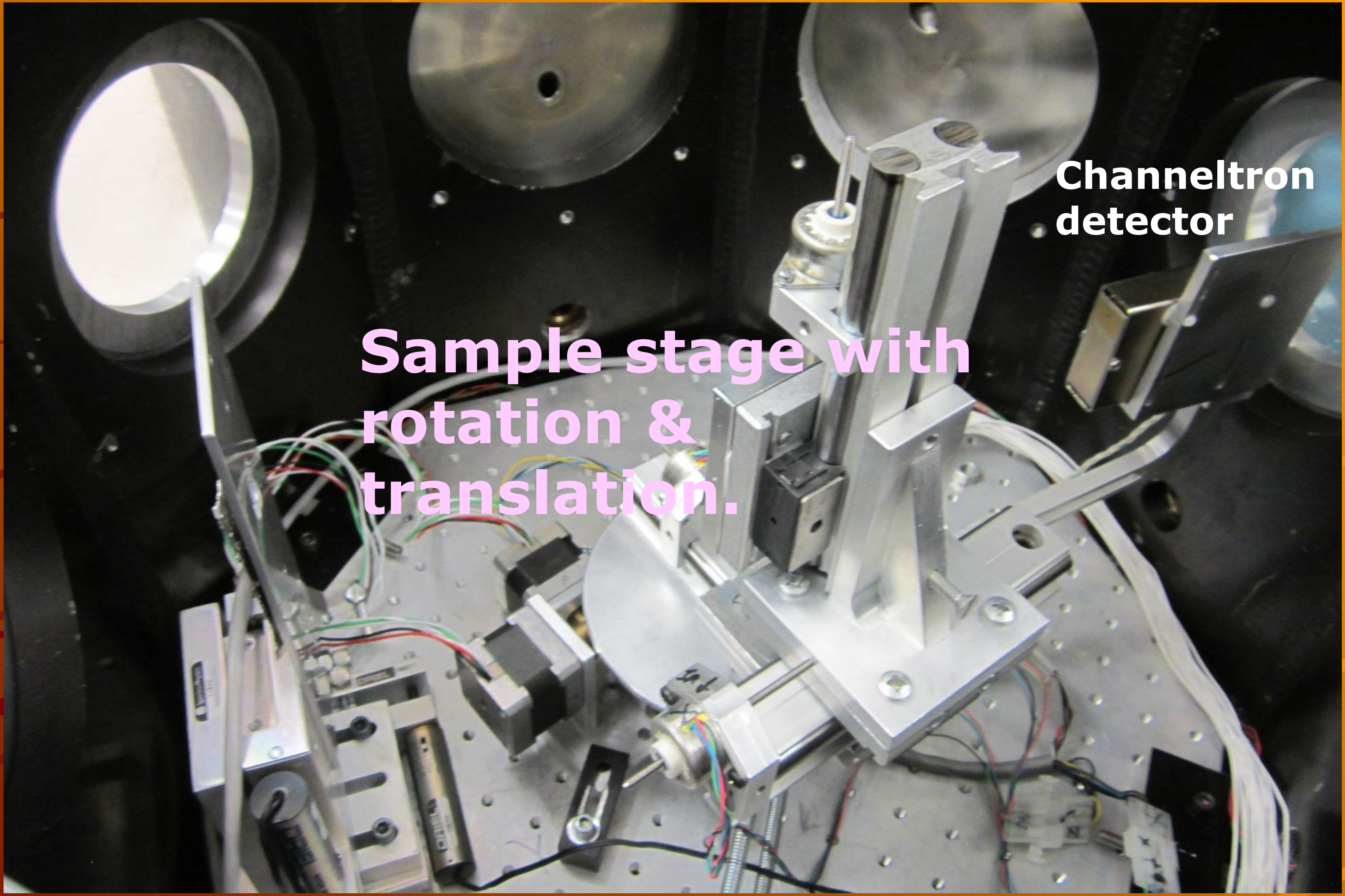
VUV measurement of Al mirror made in Situ

The team:
R Steven Turley with Margaret Miles and Alexandra V. Davis.

One of 2 VUV monochromators bring UV light



VUV measurement of Al mirror made in Situ



VUV measurement of Al mirror made in Situ

- Margaret Miles, R Steven Turley
- VUV monochromators bring light to scattering chamber.
- An evaporator is being set up to coat the mirror in the VUV-measurement chamber.
- The mirror will rotate around to where it's used.
- The evaporator will be pulled back up out of the way so the rotation measurements can be made.

VUV measurement of Al mirror made in Situ

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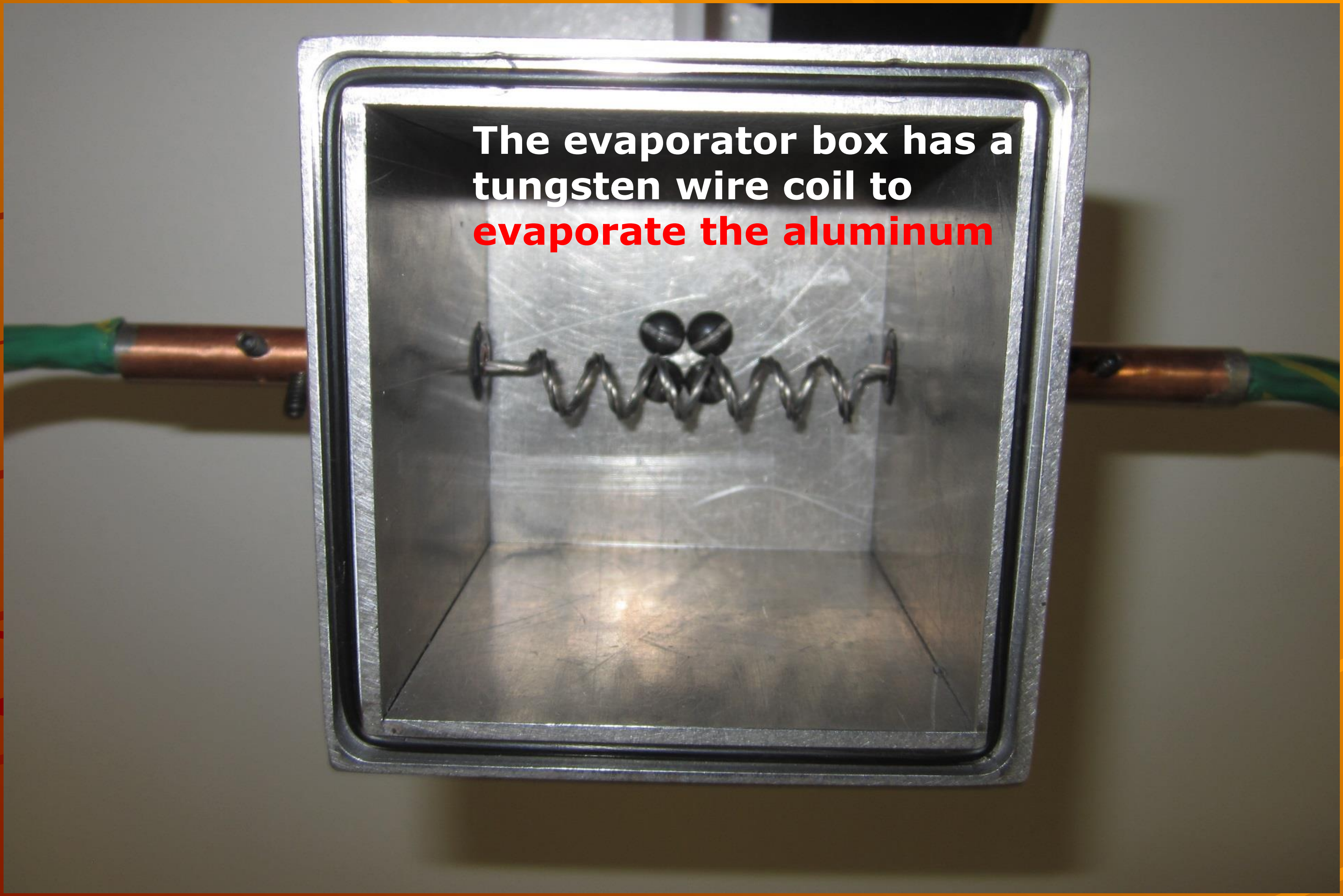

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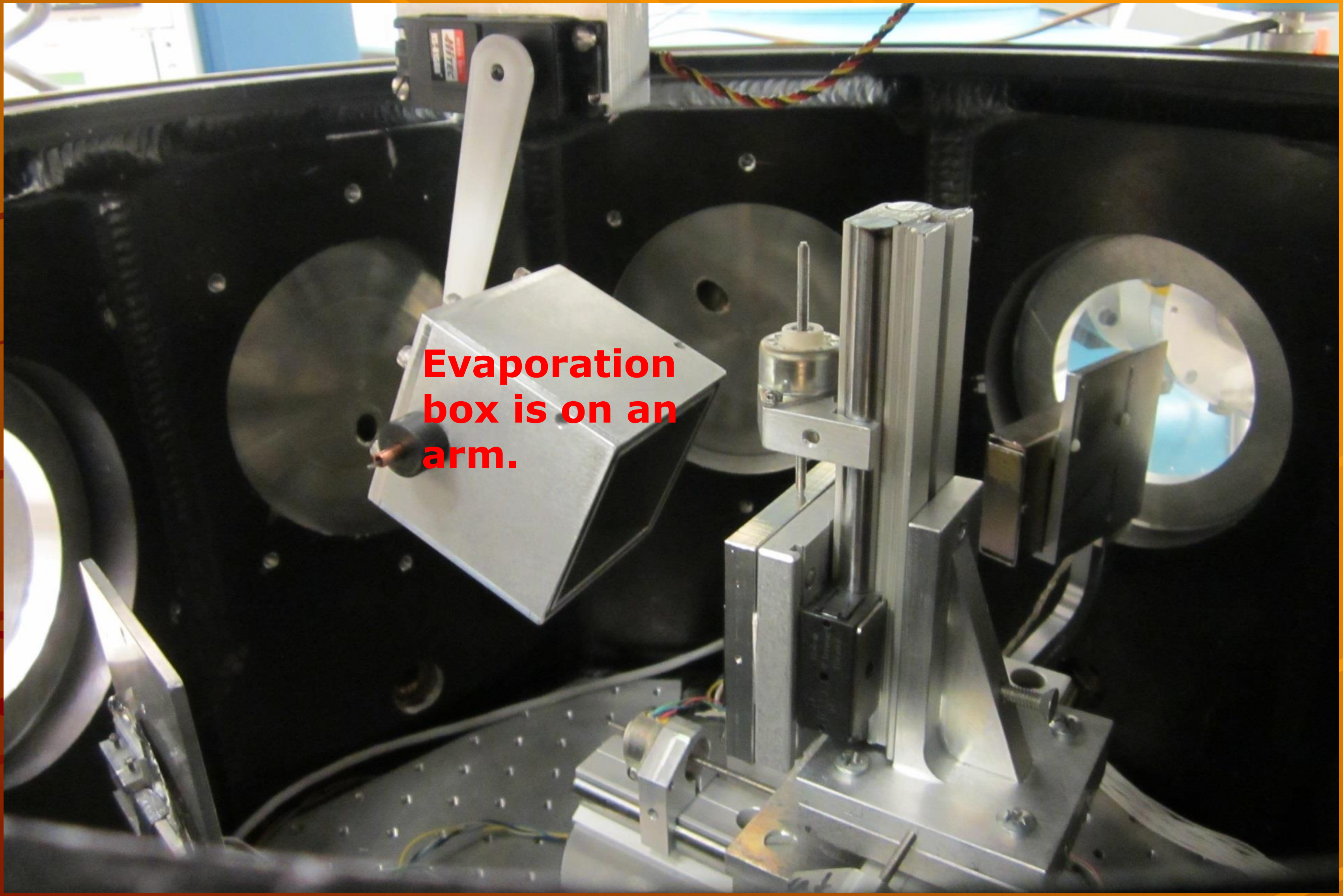
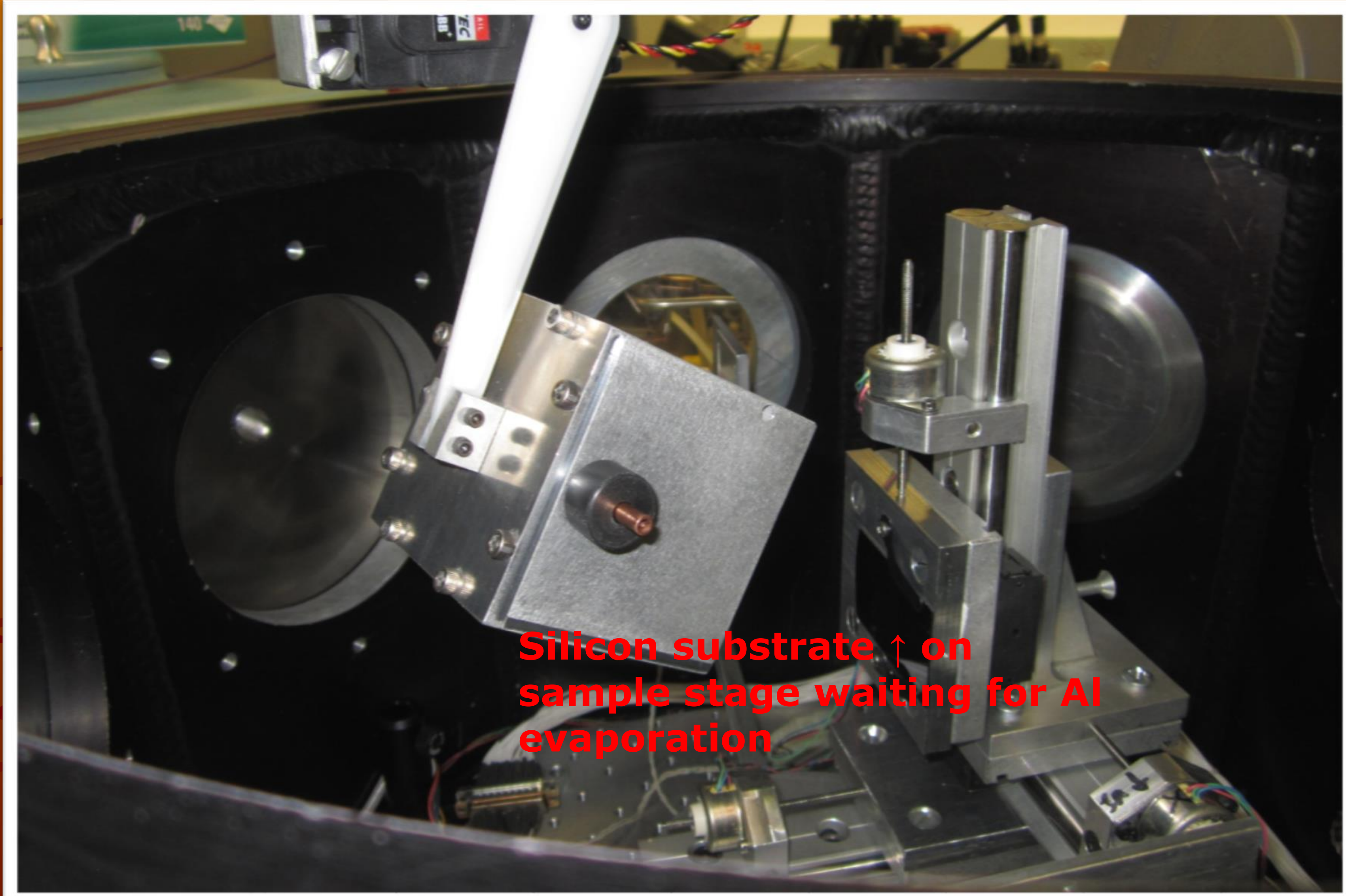


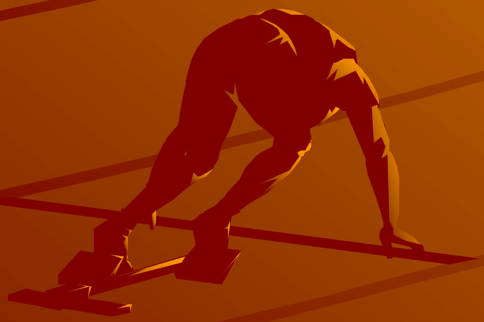
VUV measurement of Al mirror made in Situ



VUV measurement of Al mirror made in Situ

VUV measurement of Al mirror made in Situ

- Results are still coming.



3. Developing ex situ Tools to see if (& how fast) a surface is oxidizing

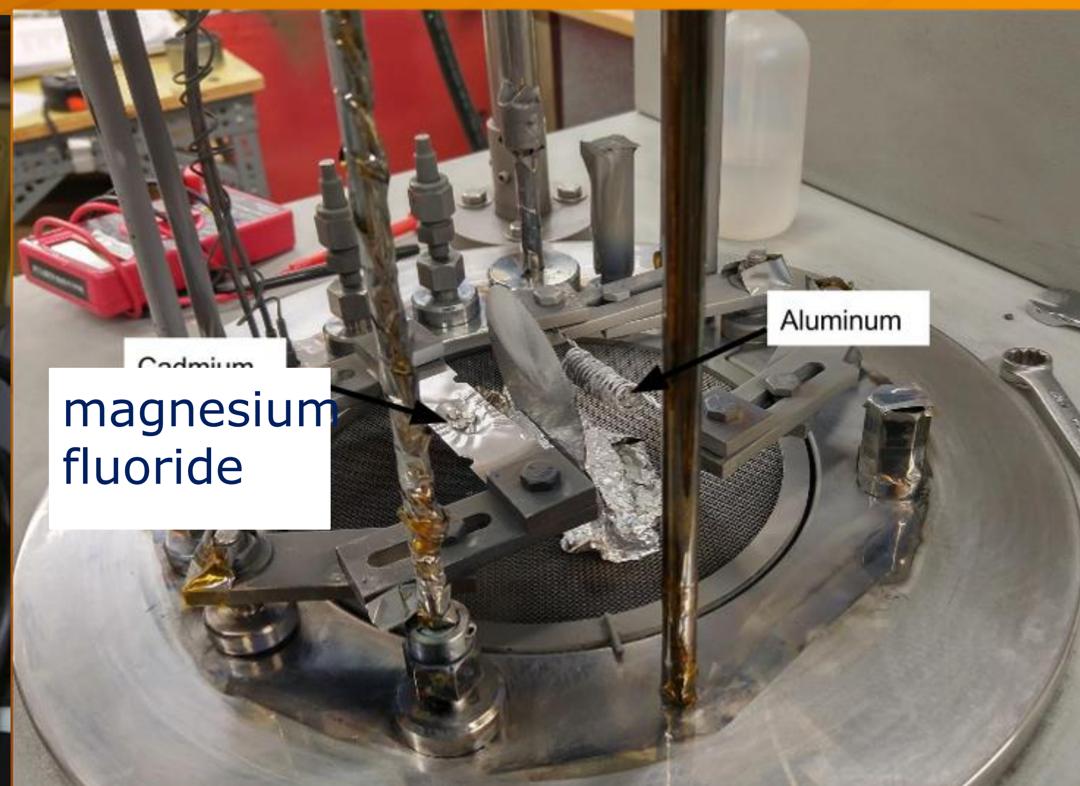
- **Ellipsometry** and xps (x-ray photo-electron spectroscopy)

Tool development-

Studying barriers that may or may not be removed.

Watching Al oxidize ex situ under a barrier layer via multiangle, spectroscopic ellipsometry. Michael J. Greenberg

- We evaporated aluminum and then immediately after magnesium fluoride



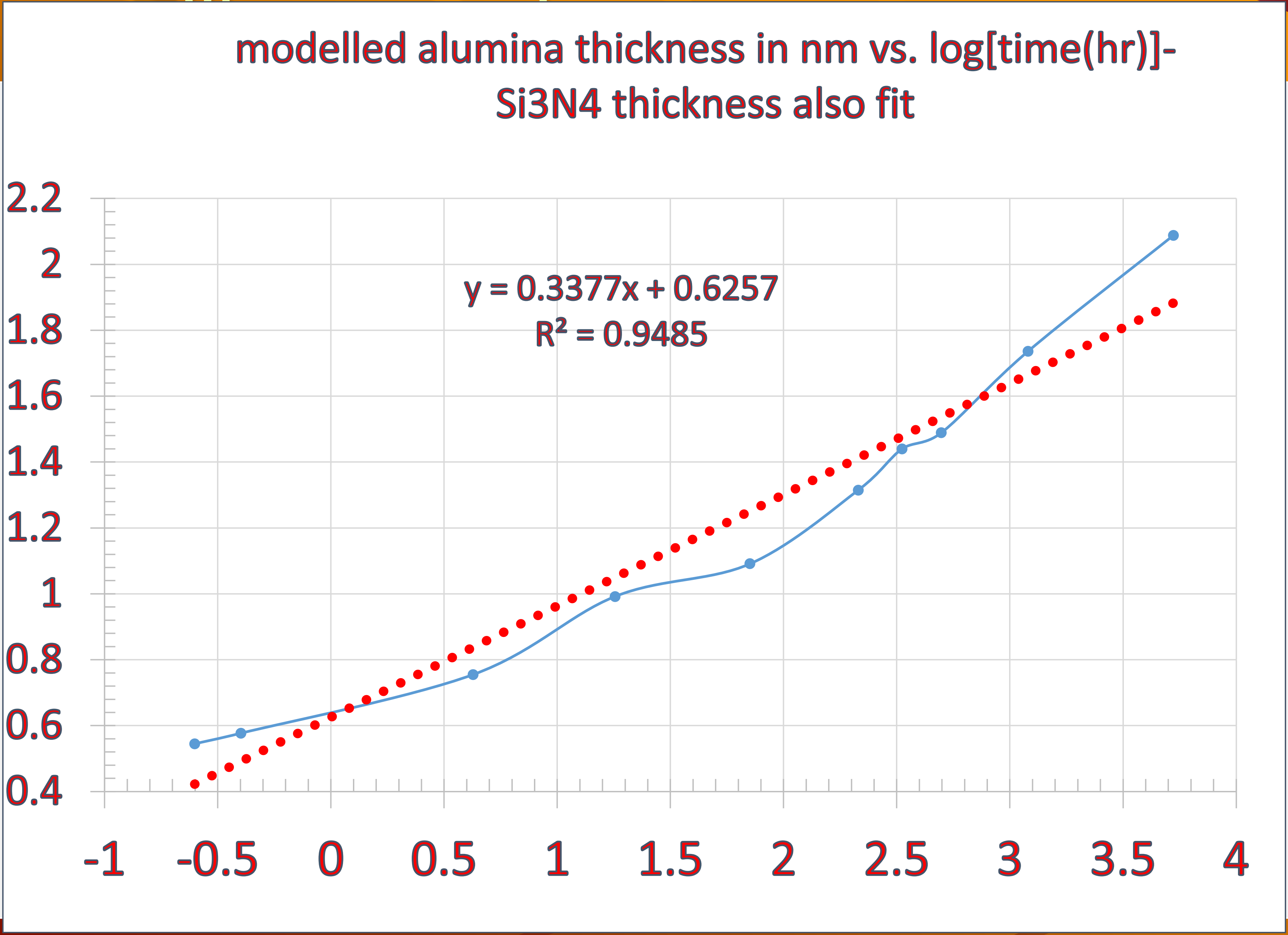
Facts about this evaporation:

- **Purpose: see if we can find a simple technique to quantify oxidation**
- **Wasn't meant to provide the best aluminum.**
- Al dep. not fast.
- Starting pressure 4-6x10^{-6} torr.
- Purpose: limit oxygen level on Al under MgF_2

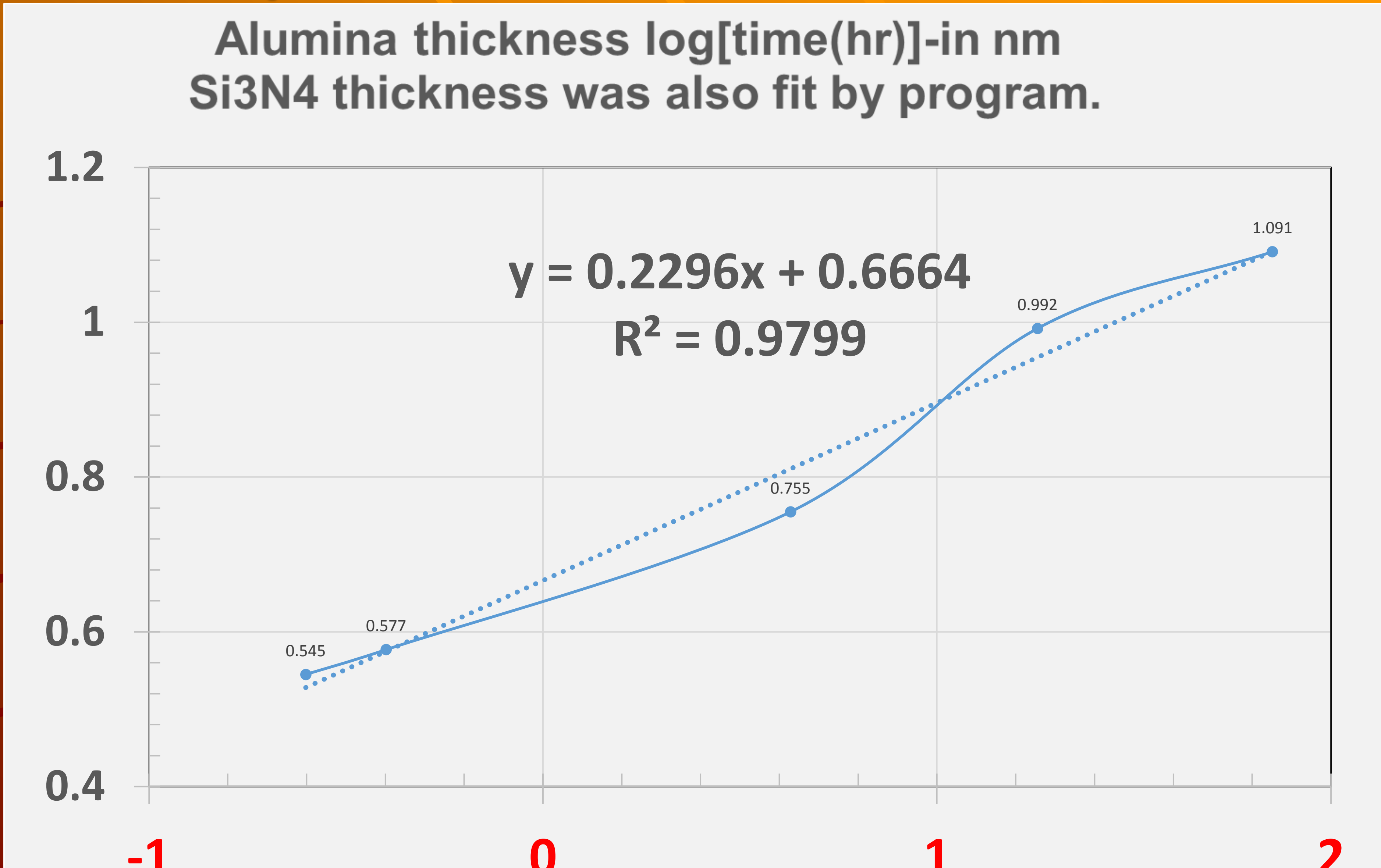
Spectroscopic Ellipsometric measurements

>	8 srough	0.000 nm
	7 mgf2	7.455 nm
	6 (al2o3_cl1) Coupled to #0	0.489 nm
	5 al_palik_g	34.385 nm
	4 sinonsio3	694.805 nm
	3 sio2_jaw	2.000 nm
	2 intr_jaw	0.400 nm
	1 si_jaw	10000000.000 nm

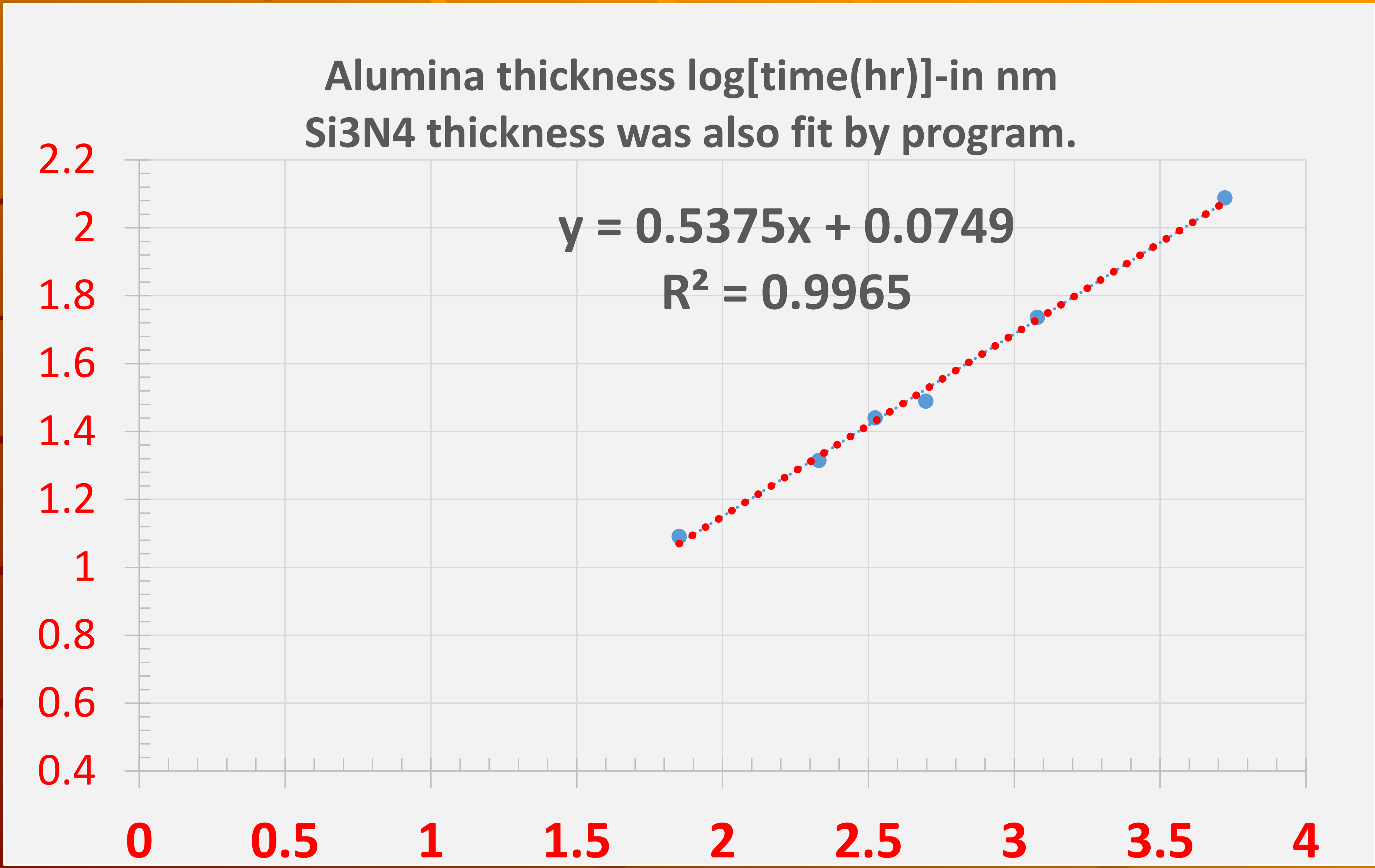
~10,000 values interpreted with small # of numbers: thicknesses & # that describe how index changes with wavelength. (Parametric model)


modelled alumina thickness in nm vs. log[time(hr)]-
Si3N4 thickness also fit
y = 0.3377x + 0.6257
R² = 0.9485
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4

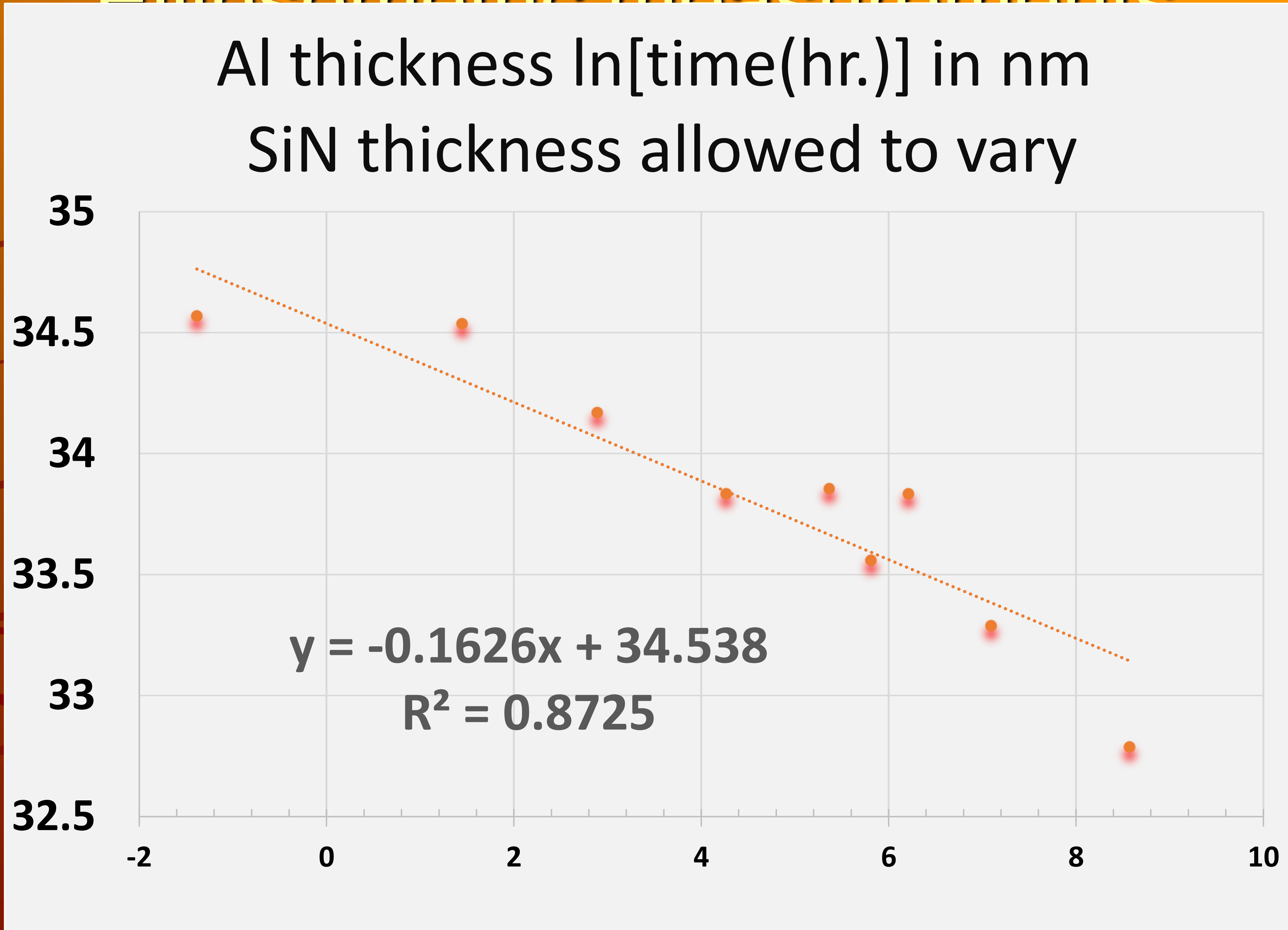
Ellipsometric measurements



Ellipsometric measurements



Ellipsometric measurements



Ellipsometric measurements- summary observations,

- Ellipsometry can be used for time-dependent studies When there's a transparent barrier overlayer
  - The aluminum gets thinner &
  - the aluminum oxide grows thicker
    - Initial layer is on top of Al
  - Logartihmic behavior suggested
  - Angstrom level resolution is possible.
- Microchemical analysis could be helpful EDX or XPS.

Take home

- Spectoscopic Ellipsometry can work as a tool for oxidation of ultrathin layers.
  - work needed to check if these are absolute amounts of materials
- VUV reflectance studies of insitu mirror is coming along
- Atomic Hydrogen etches PMMA adequately
  - Also still to be done is:
  - will the polymer block oxidation long enough to put additional barrier layers that are removable

& Acknowledgements

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50 questions about next-generation broadband mirrors for space-based observatories

- 1 Broadband mirror coatings & aluminum:
- 2 Understand oxidization of aluminum mirrors
  - characterization tools
- 3 Barrier layers against oxidation
  - 3.1 Those that stay on-
  - 3.2 Those that come off:
    - Role of Vacuum deposited/ Vacuum removable barriers-
  - 3.3 point-of-use processing
- 4 Applications
  - 4.1 Beyond 15 eV: Aluminum becomes (partially) transparent below its plasma edge at about 85 nm 4.2 Space observatory applications
- 5 Practicalities: How raise TRL.

Optimizing Reflectance with Aluminum

- Extends range of UV to ~83 nm (15 eV)
- Transparent at small