Exploration of Amorphous Silicon as a Removable Barrier Layer for Aluminum Mirror Coatings

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Overview

Purpose: expand farther into UV Al mirror coating service

Obstacle: Al oxidizes rapidly decreasing reflectance

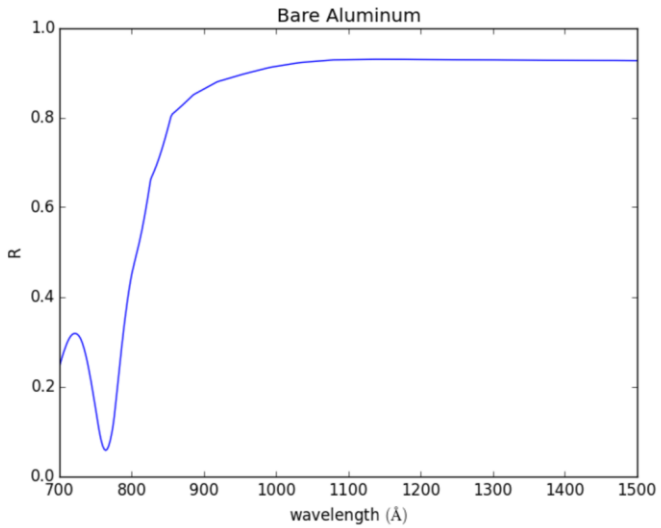
Solution: Protect the Al mirror with a-Si and remove it once the space observatory is in space

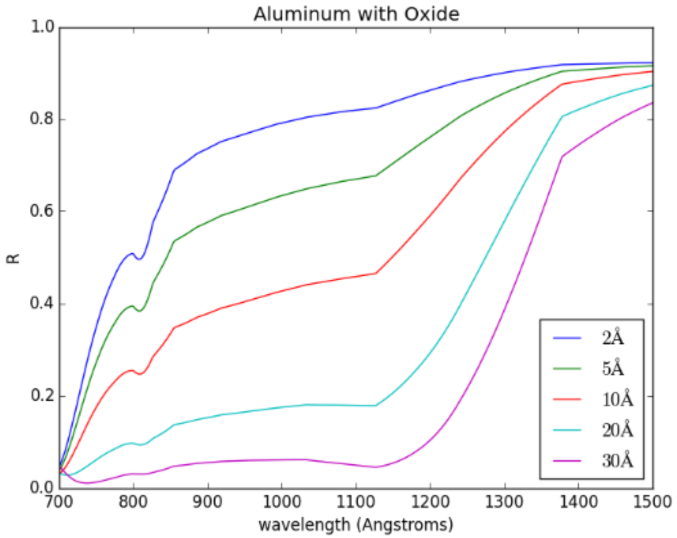
But a question: How do we take it of?

Solution: Dry chemical processing

Aluminum

- Bare Aluminum has good reflection above 90nm
- Aluminum oxidizes quickly once it comes into contact with the atmosphere, decreasing its reflectance.





Amorphous Silicon

- The structure of a-Si could prevent oxygen from reacting with the Al layer
- It can be nonreactive.

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Overview

Purpose: Make UV multilayer Al mirrors

Obstacle: Al oxidizes rapidly decreasing reflectance

Solution: Protect the Al mirror with a-Si and remove it once the space observatory is in space

More Obstacles: How do we take it of?

Solution: Dry chemical processing

Overview

Purpose: expand farther into UV Al mirror coating service

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Dry Chemical Processing

- One concept:
- a plasma made with H_2 gas produces hydrogen atoms.
- a-Si + H→SiH_4 ; which vanishes into out of space leaving mirror intact.
- Al will serve as an etch stopping.

Josh’s Summer ‘17 Project

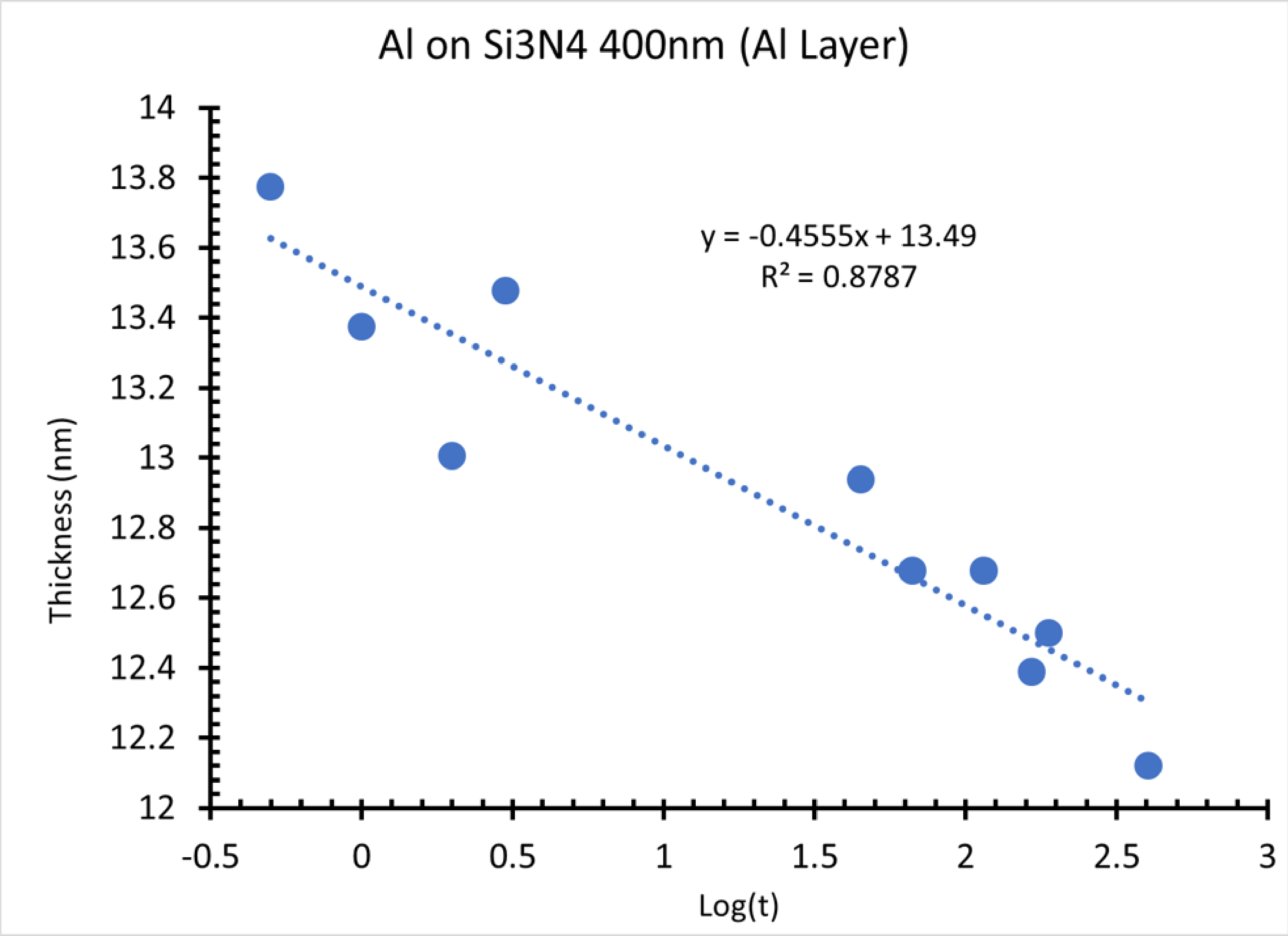
- Find out how much Al oxidizes over time.
- Find out how a-Si changes overtime.
- Find out if Al oxidizes or not with a layer of a-Si on top.
- Examine if dry chemical processing removes the a-Si layer and if it roughens the Al layer.

Methodology

- **Evaporation (deposition)**
  - Deposit layers of a-Si and Al onto substrates
  - Denton DV-502A resistance-heated evaporation sources.
- **Characterization by spectroscopic ellipsometry**
  - John A. Woollam M2000 variable-angle spectroscopic ellipsometer
  - W-VASE software – layer thicknesses and oxide layers
- **Dry Chemical Processing**
  - Take off the a-Si layer

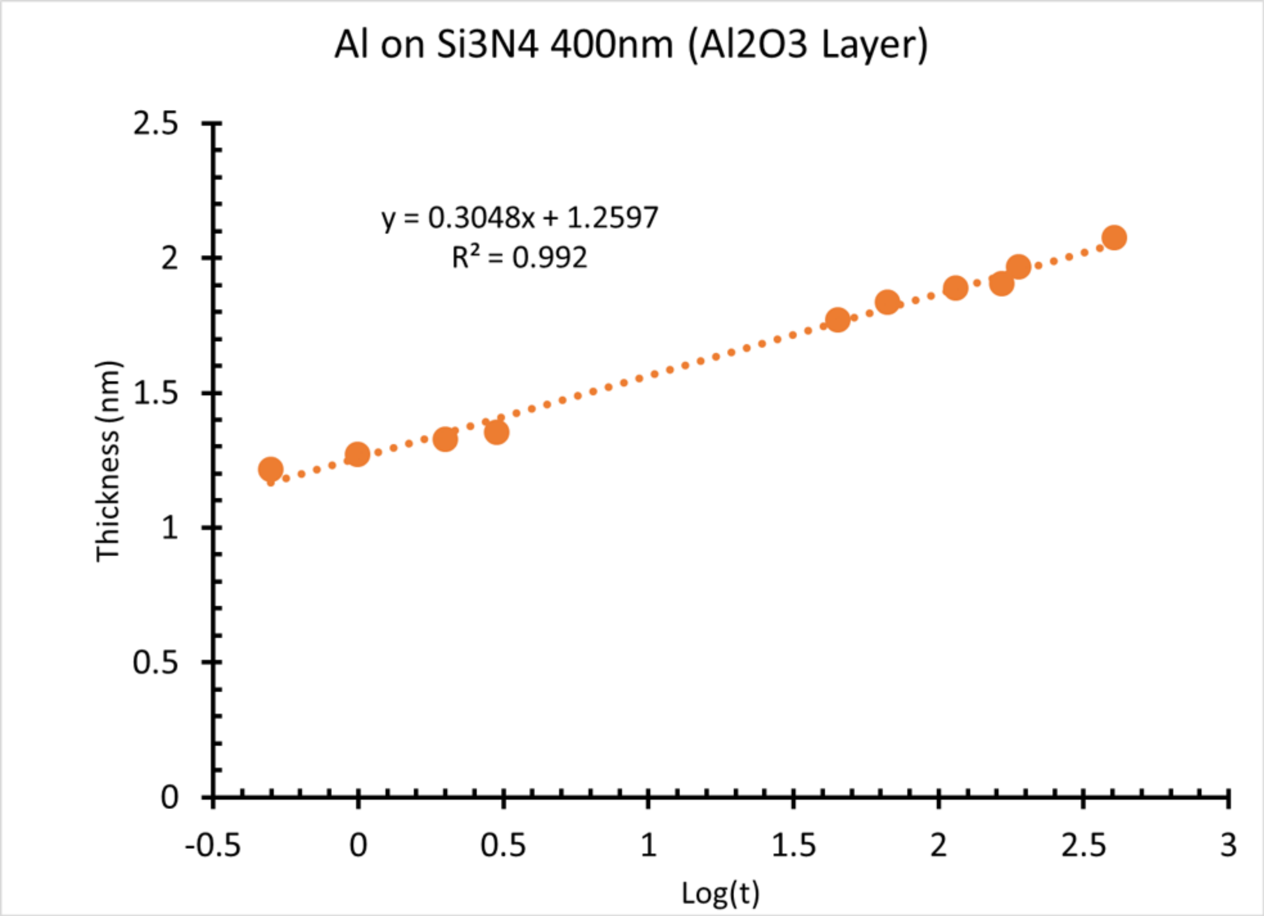
Results: Al on Si_3N_4 400nm (MSE= 13.180)

- Al decreases over time.

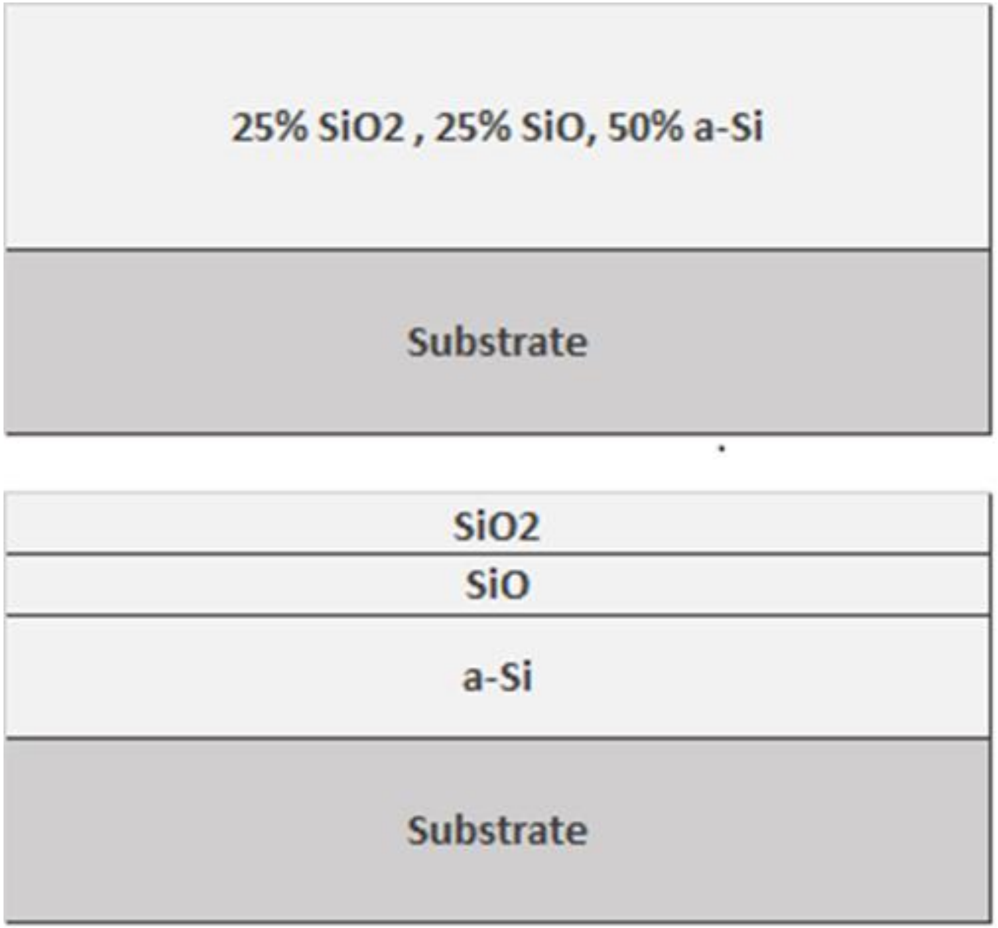


Results: Al on Si_3N_4 400nm (MSE= 13.180)

- Al decreases over time.
- Al_2O_3 increases over hundreds of hours.



Representation of the changes in a-Si



- Effective medium model

- 3 layer representation

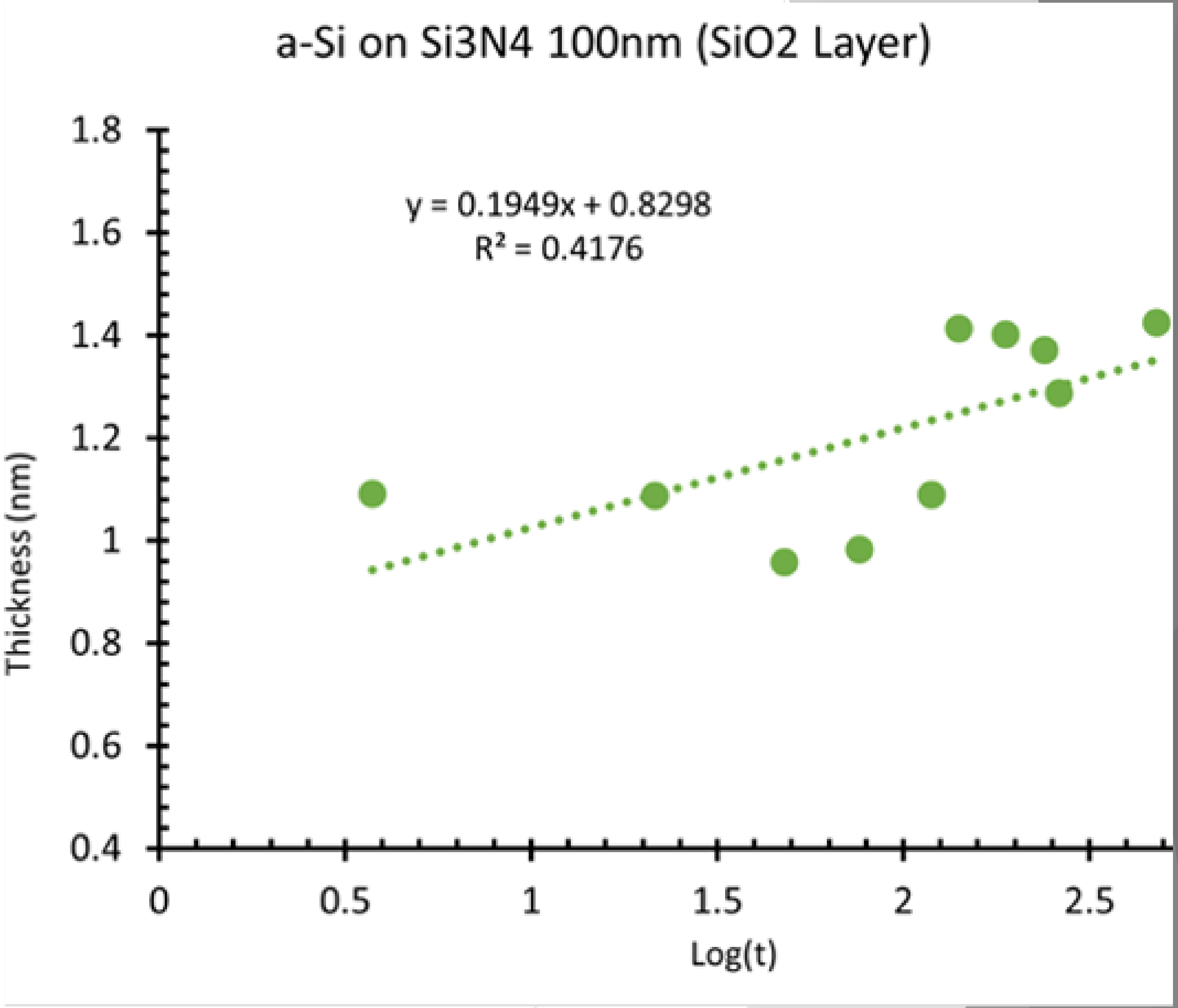
Results: a-Si on Si_3N_4 100nm after 100's hours

model ema with a-si aspnes and sio palik

7 srough	1.600 nm
6 sio2_jaw	1.089 nm
5 ema (a-si_aspnes_cl)/41.2% si	10.489 nm
4 a-si_aspnes_cl	0.000 nm
3 sin about 109nm	111.700 nm
2 sio2_jaw	1.400 nm
1 intr_jaw	0.400 nm
0 si_jaw	10 mm

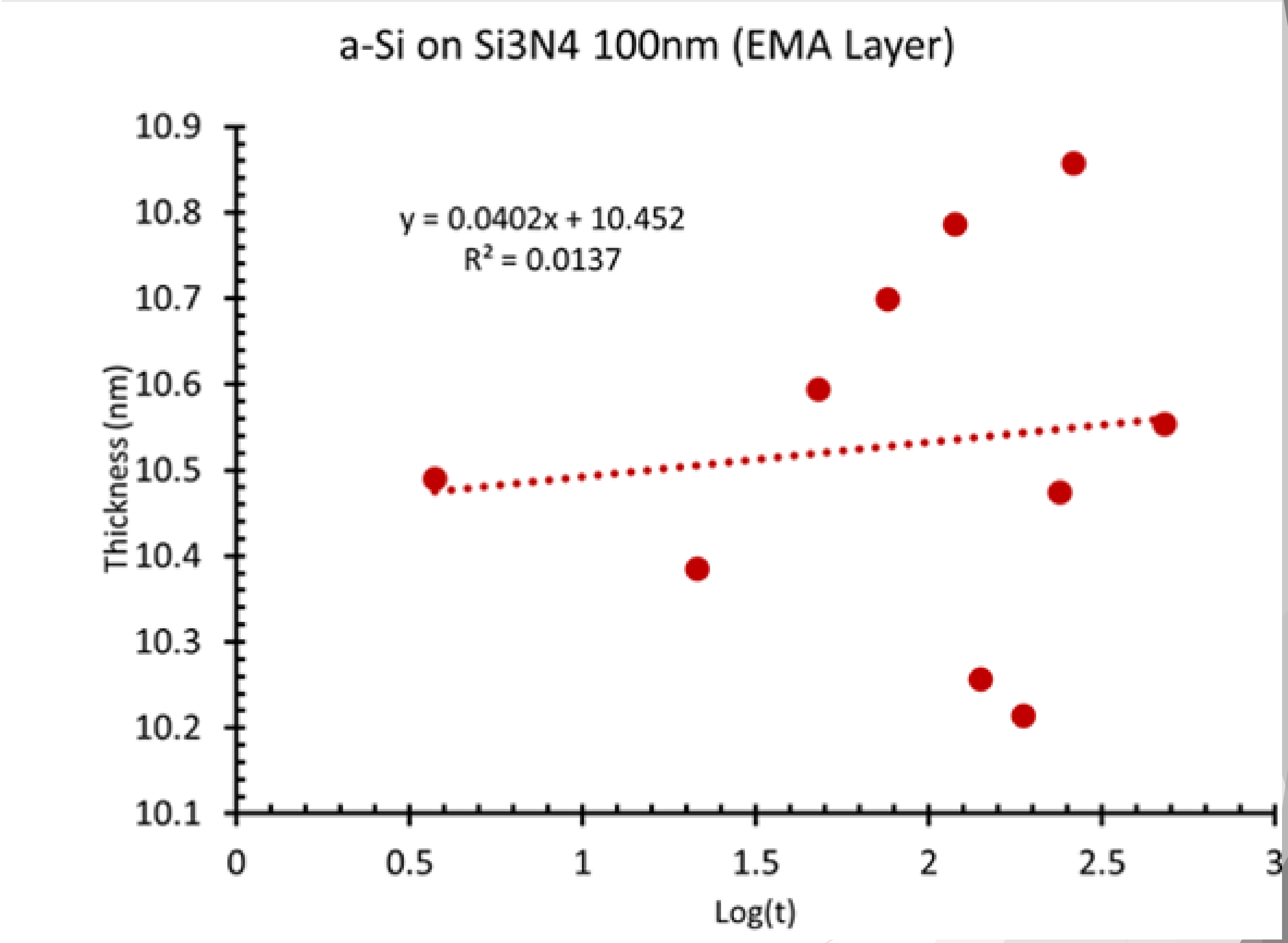
Results: a-Si on Si_3N_4 100nm

- SiO_2 increases over time
- EMA layer slightly increases over time.
- SiO increases over time
- a-Si decreases over time



Results: a-Si on Si_3N_4 100nm

- SiO_2 increases over time
- EMA layer slightly increases over time.
- SiO increases over time
- a-Si decreases over time



Results: a-Si on Si_3N_4 100nm

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- SiO increases over time
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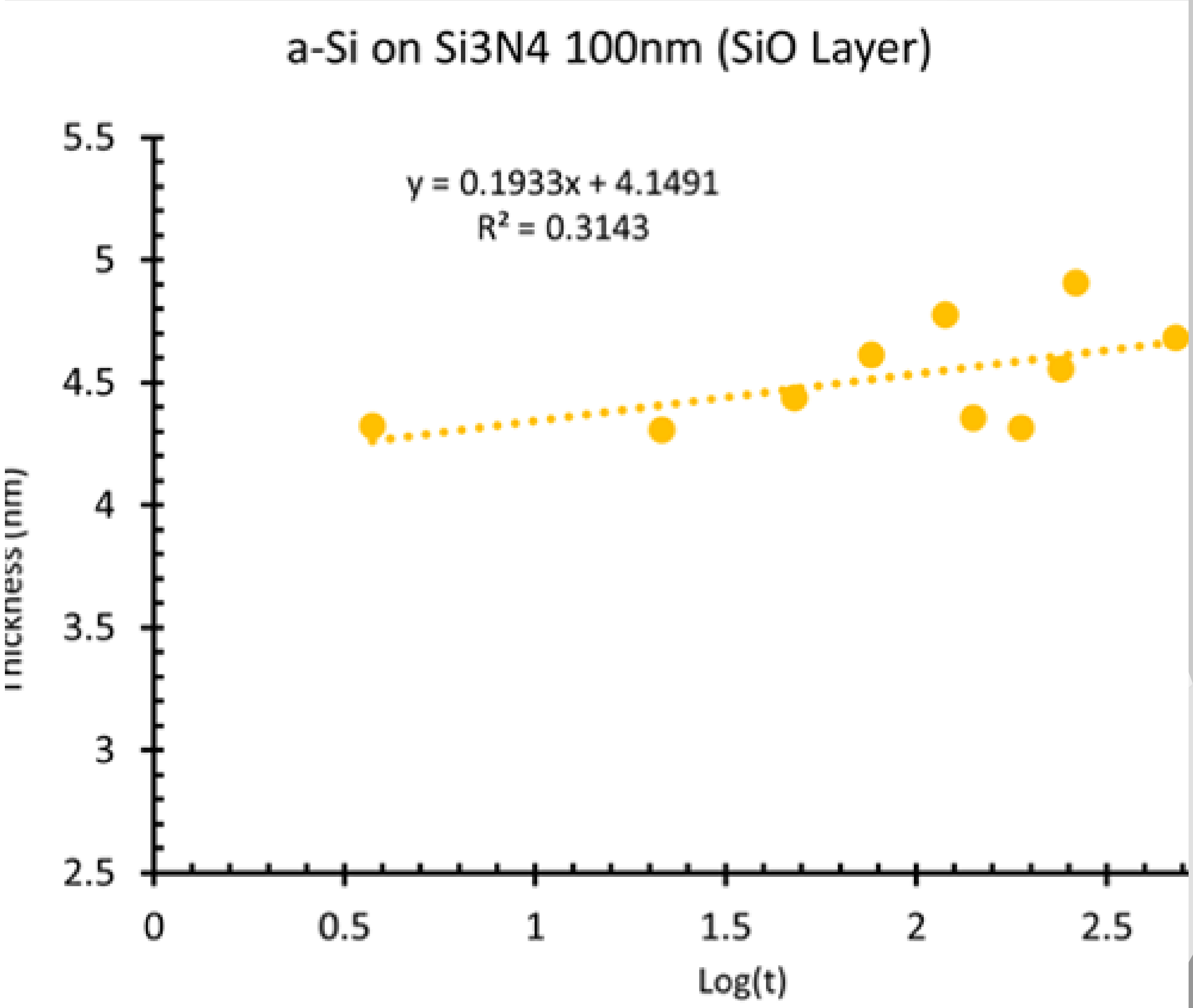
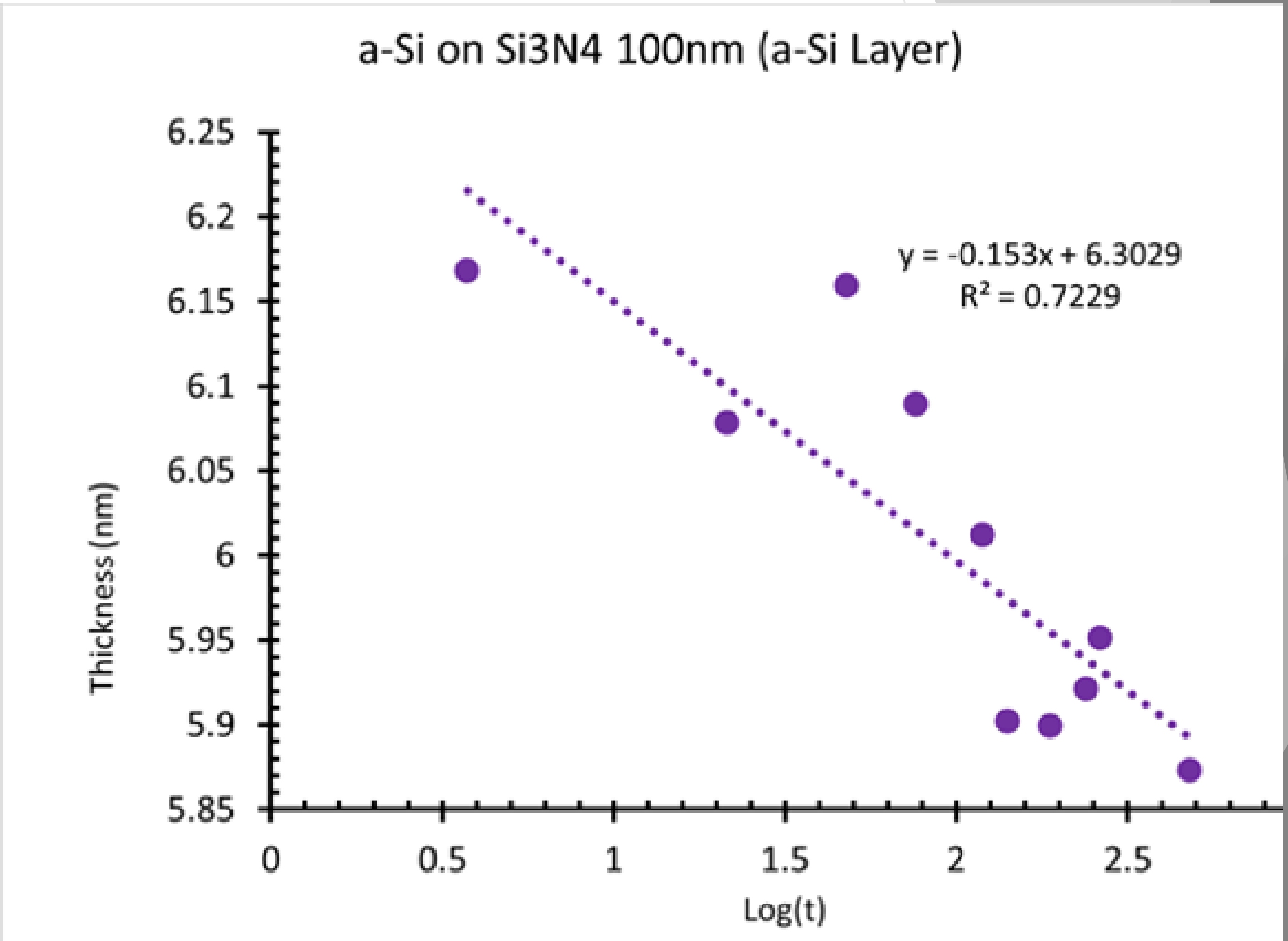


Results: a-Si on Si_3N_4 100nm

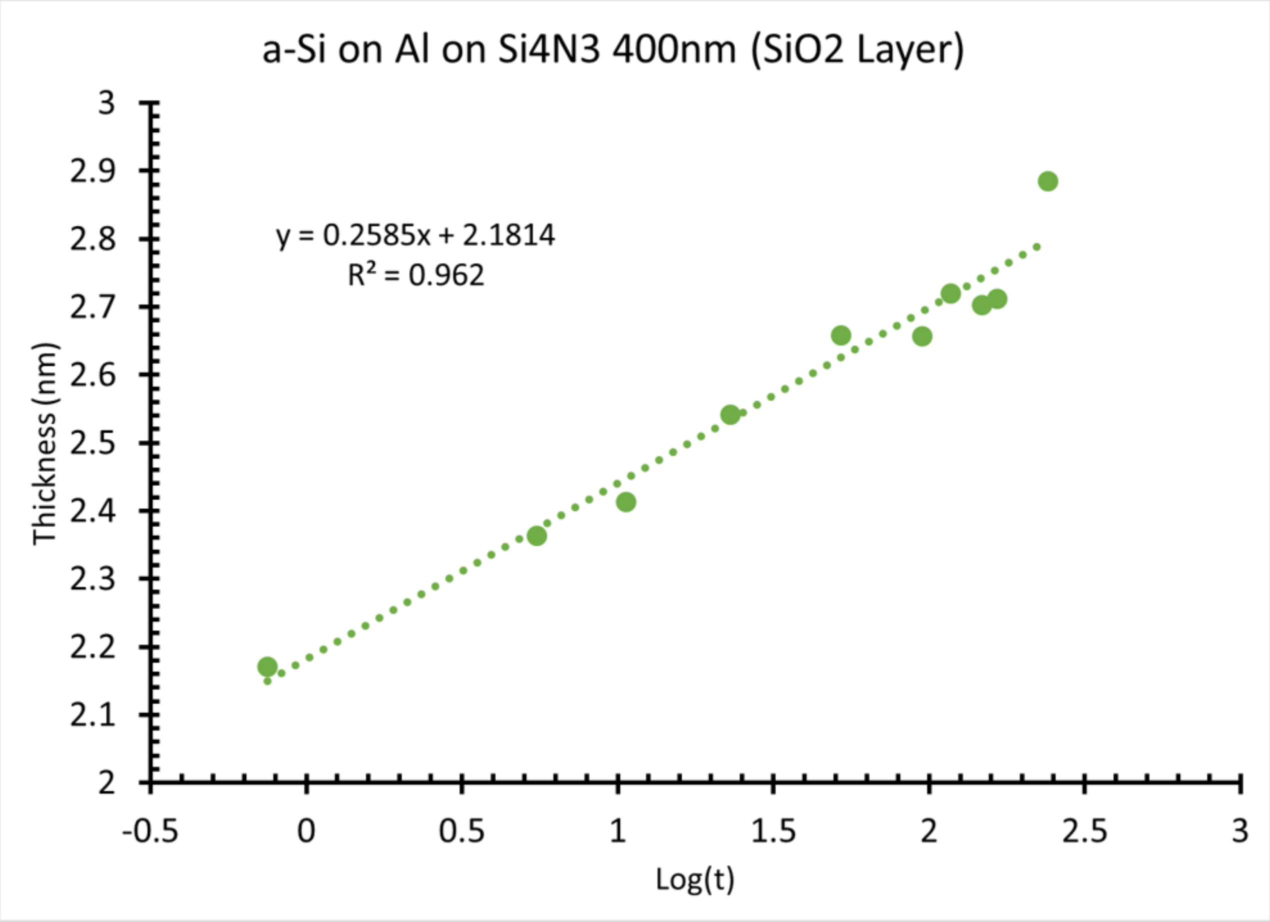
- SiO_2 increases over time
- EMA layer slightly increases over time.
- SiO increases over time
- a-Si component decreases over time

a-Si is more stable than aluminum



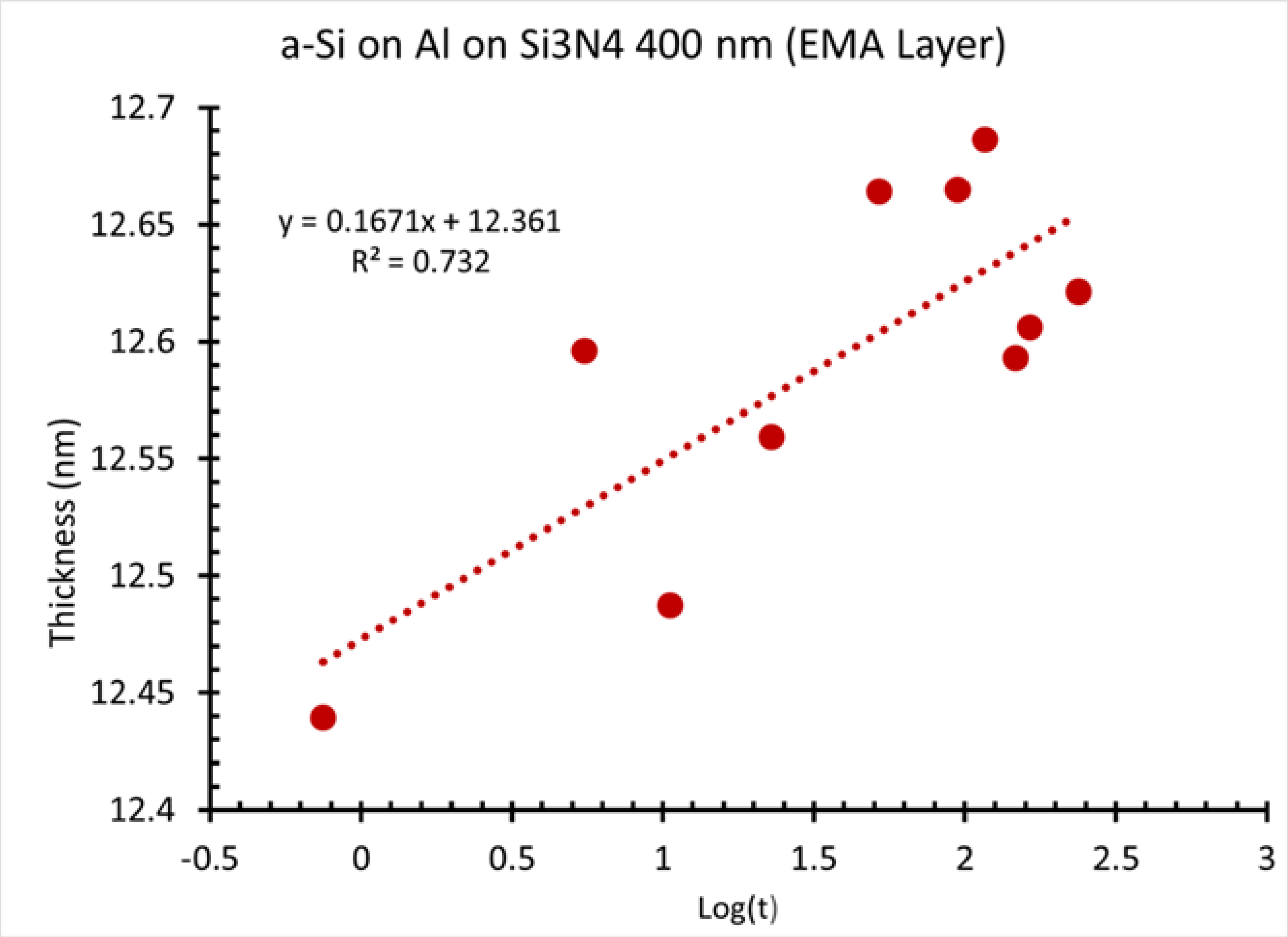
Results: a-Si on Al on Si_3N_4 400nm (MSE=56.08)

- SiO_2 increases about 0.8nm over 400 hours.



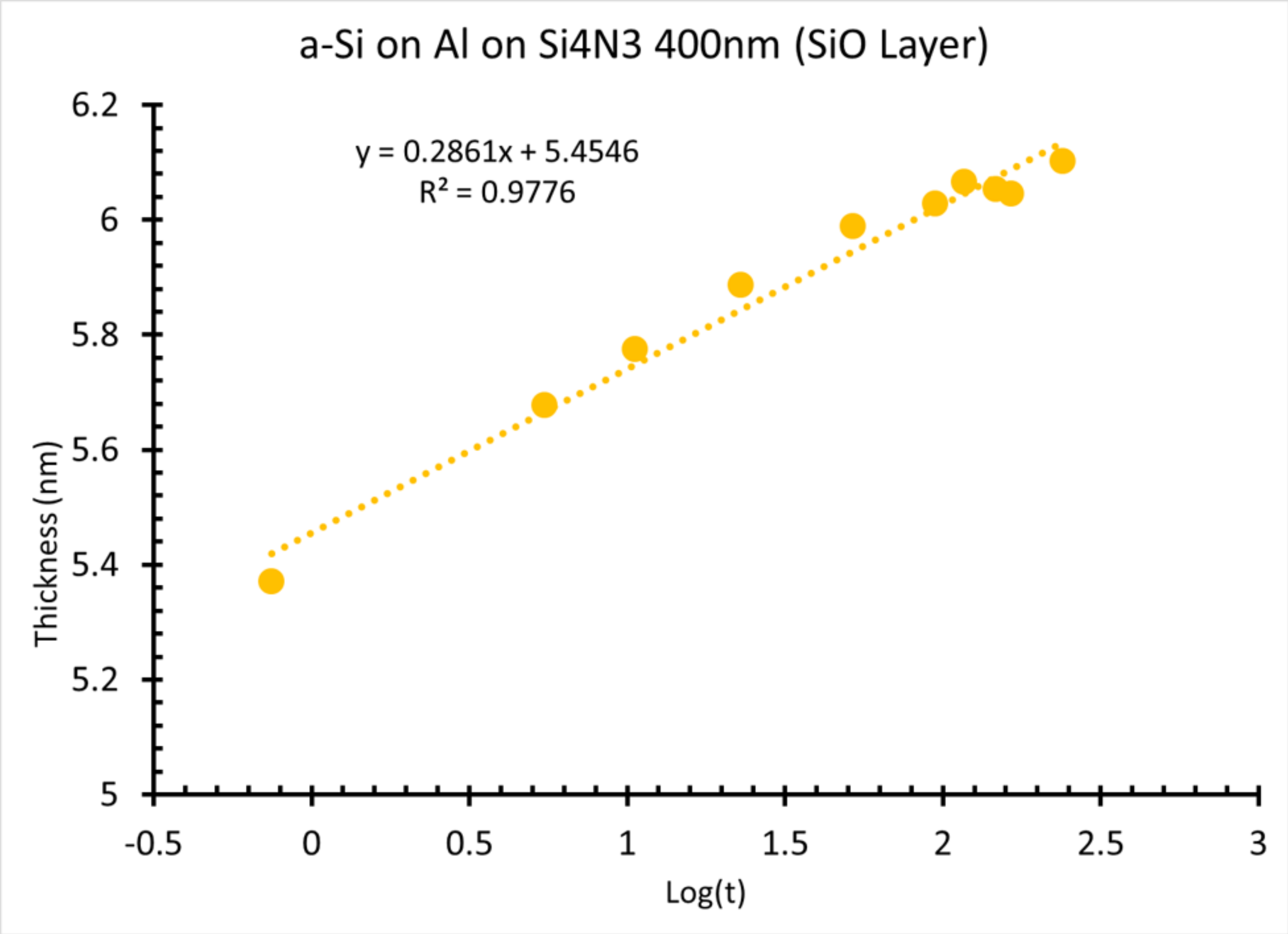
Results: a-Si on Al on Si_3N_4 400nm (MSE=56.08)

- **EMA increases about 0.2nm over 400 hours**



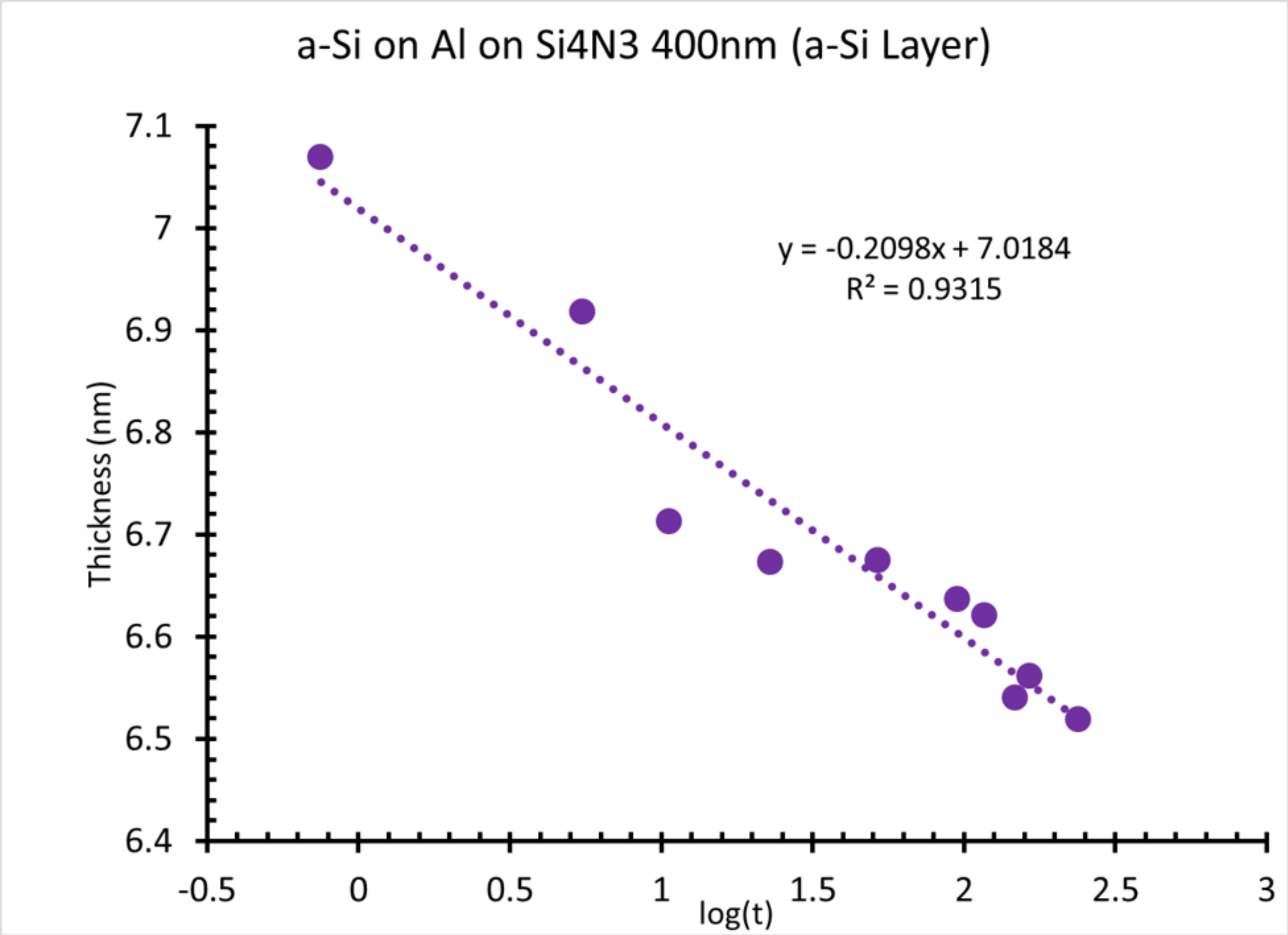
Results: a-Si on Al on Si_3N_4 400nm (MSE=56.08)

- **SiO increases about 0.7nm over 400 hours**



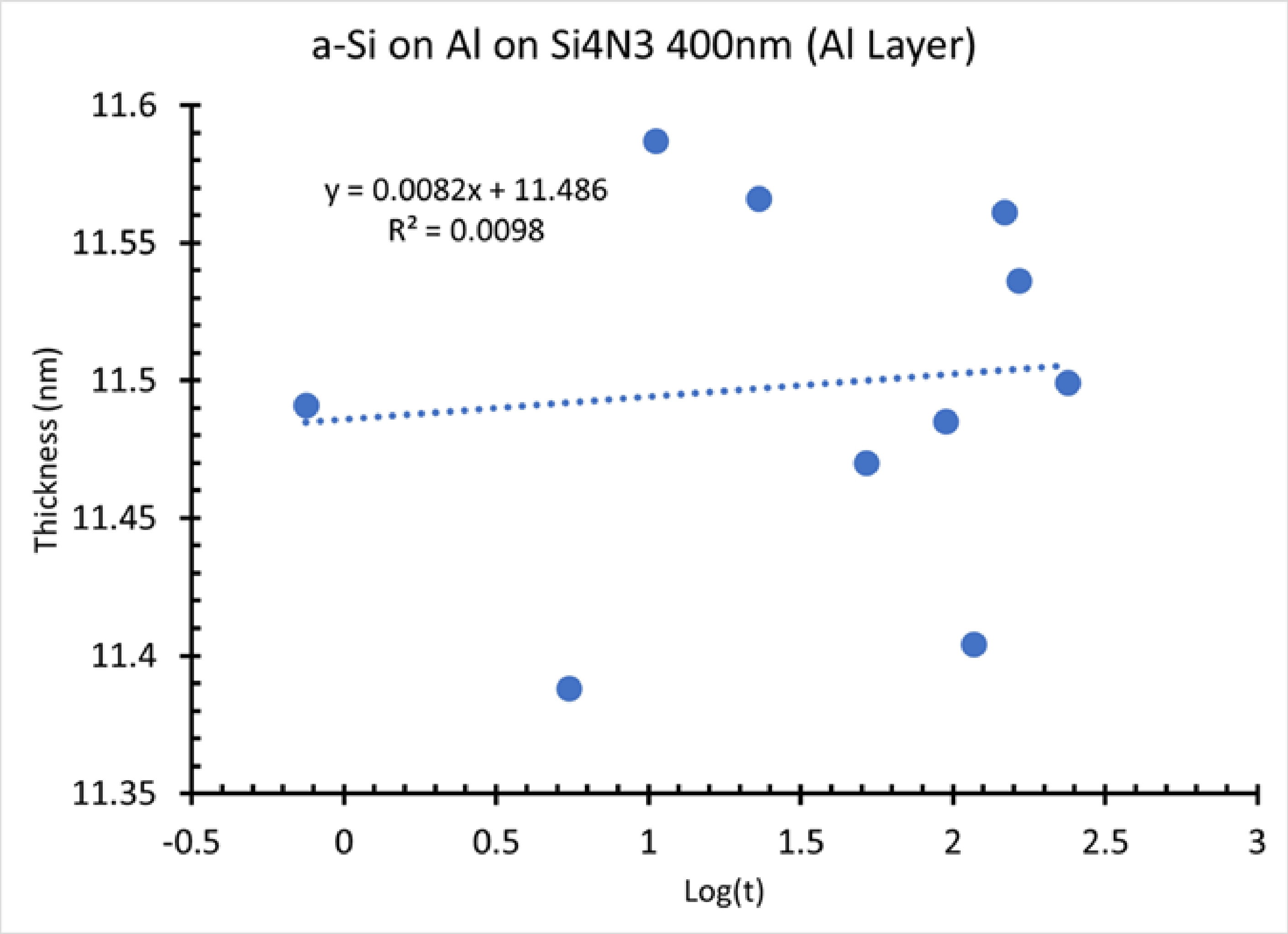
Results: a-Si on Al on Si_3N_4 400nm (MSE=56.08)

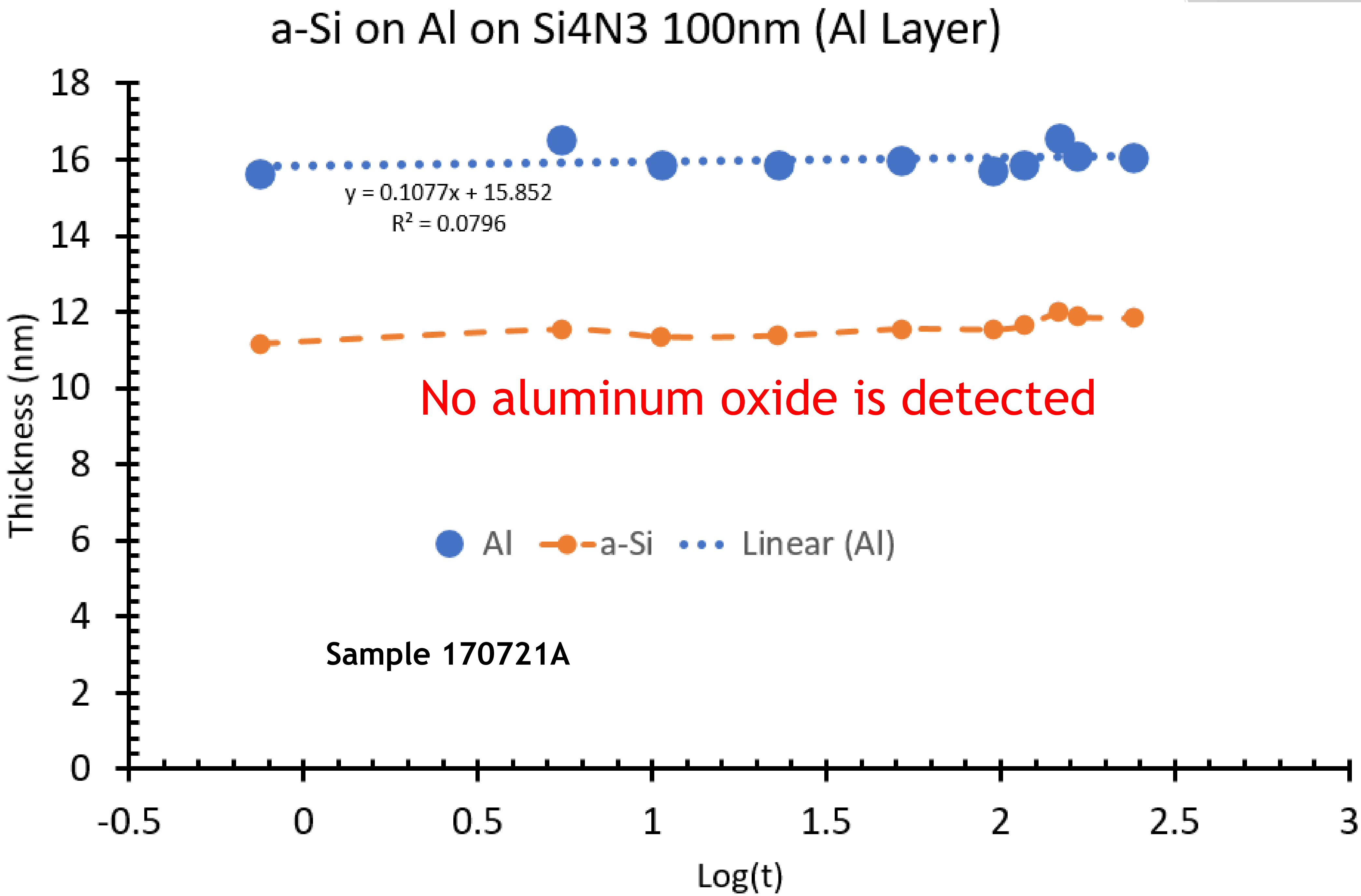
- a-Si component decreases about 0.6nm over 400 hours.



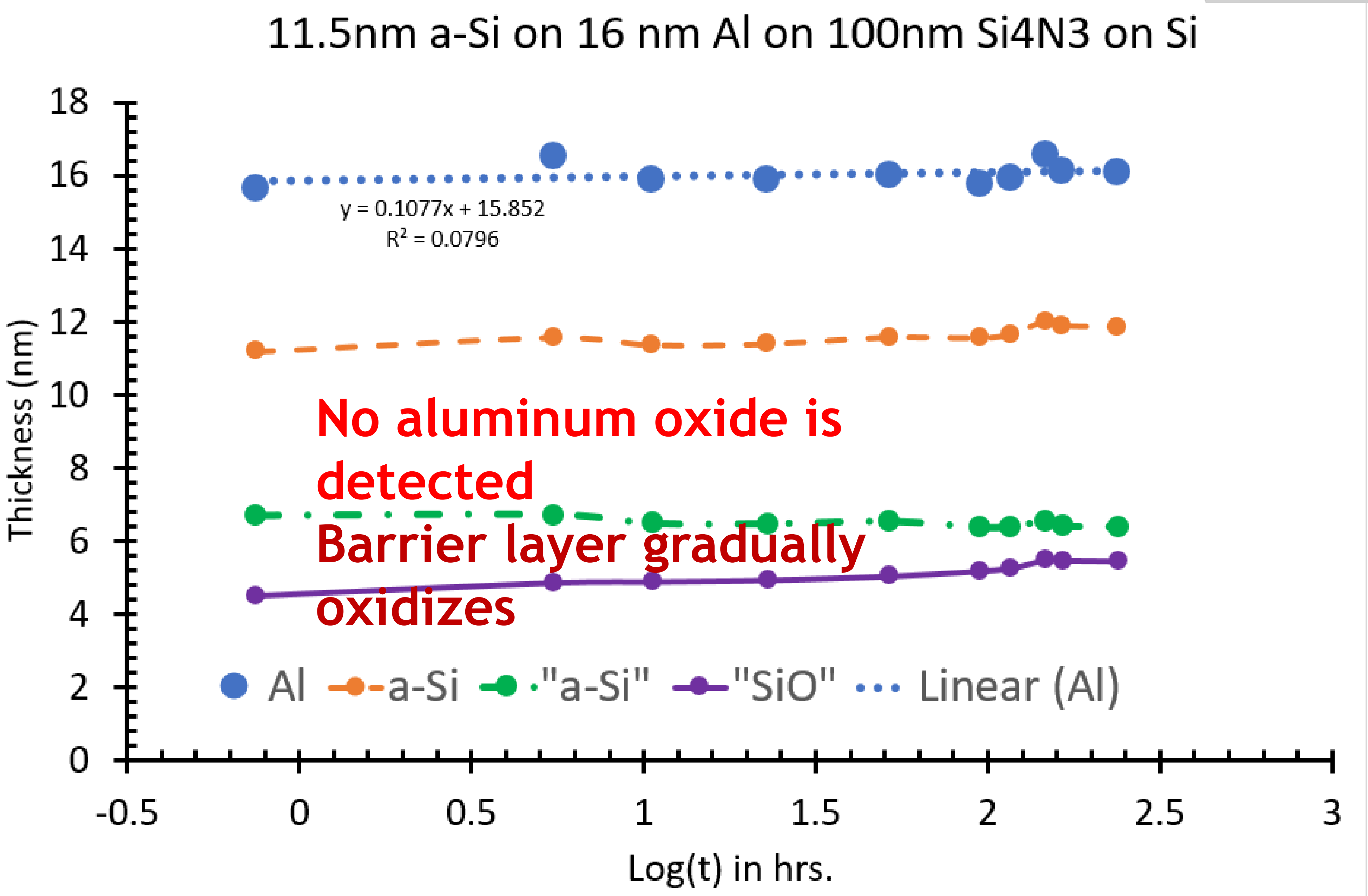
Results: a-Si on Al on Si_3N_4 400nm (MSE=56.08)

- **Al stays constant over 400 hours.**





a-Si on Al on Si4N3 100nm (Al Layer)
y = 0.1077x + 15.852
R² = 0.0796
No aluminum oxide is detected
Al
a-Si
Linear (Al)
Sample 170721A
Thickness (nm)
Log(t)
18
16
14
12
10
8
6
4
2
0
-0.5
0
0.5
1
1.5
2
2.5
3

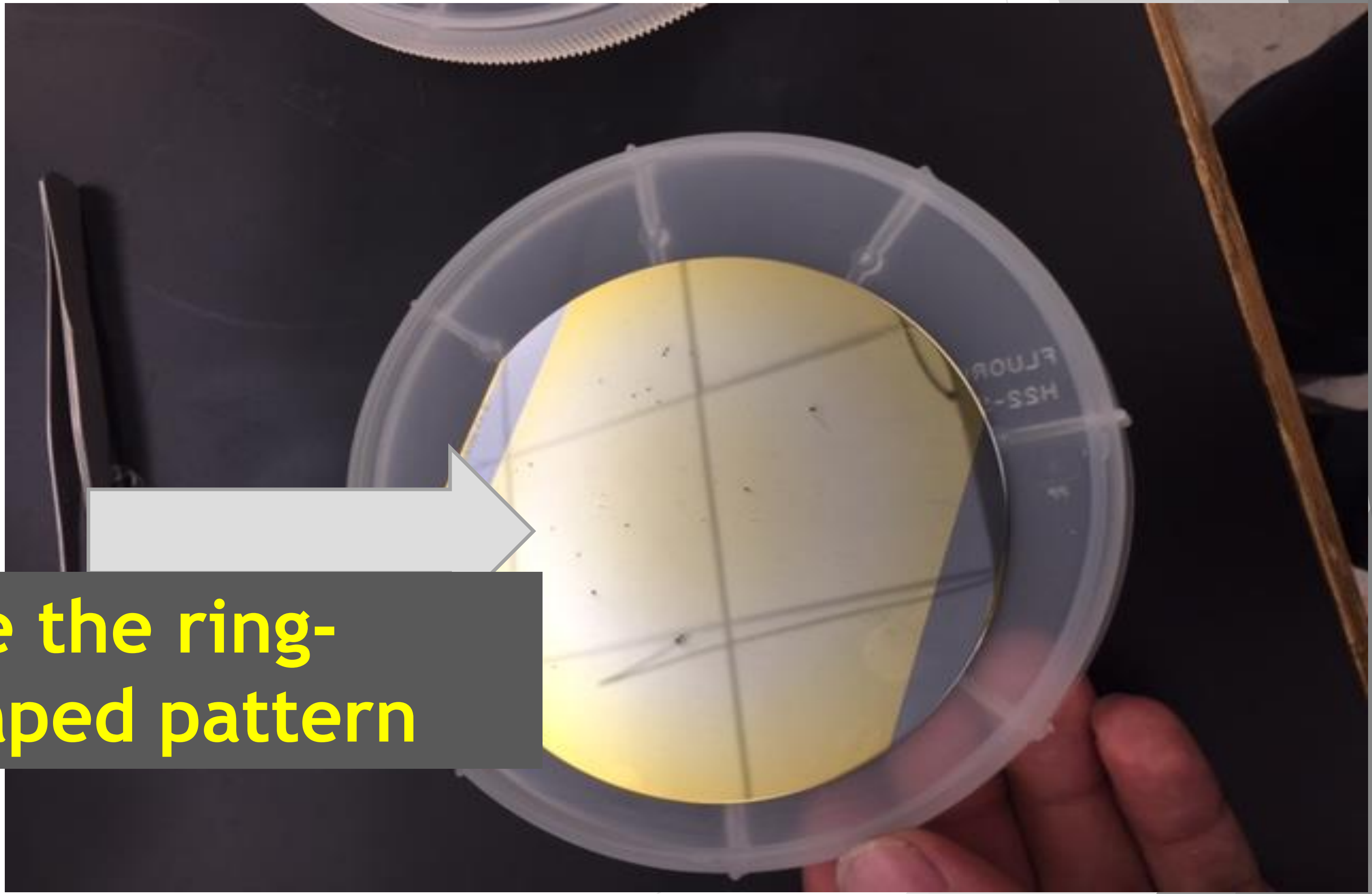

11.5nm a-Si on 16 nm Al on 100nm Si4N3 on Si
Thickness (nm)
18
16
14
12
10
8
6
4
2
0
-0.5
0
0.5
1
1.5
2
2.5
3
Log(t) in hrs.
y = 0.1077x + 15.852
R² = 0.0796
No aluminum oxide is detected
Barrier layer gradually oxidizes
Al
a-Si
"a-Si"
"SiO"
Linear (Al)

SPIE103

Results: 1st Dry Chemical experiment- yes, there is etching…..

Placed coated wafer sample on cathode is sputter chamber. Used H_2 as the working gas.

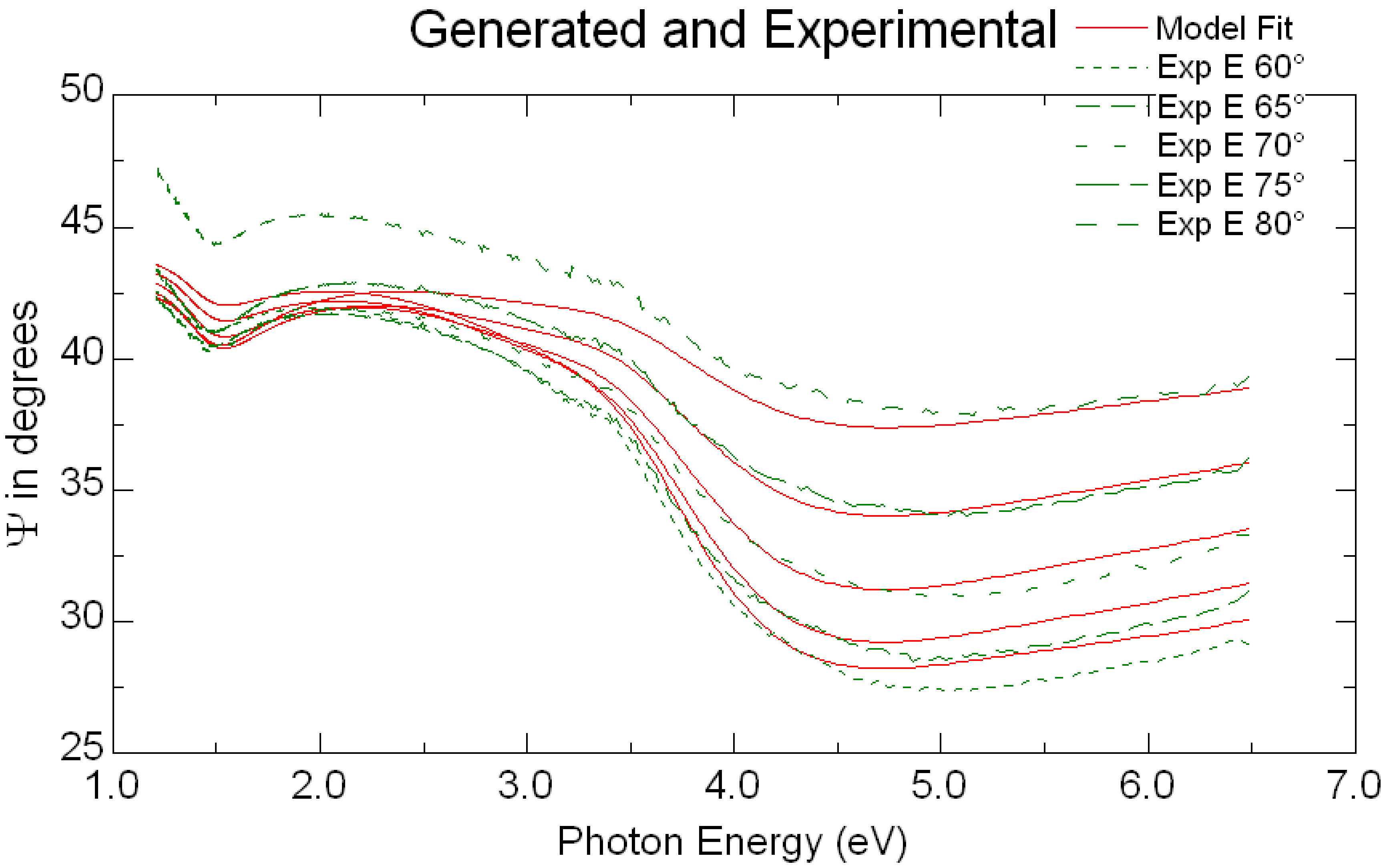
See the ring-shaped pattern



Dry Chemical Etching Process- attempt- could not be modelled

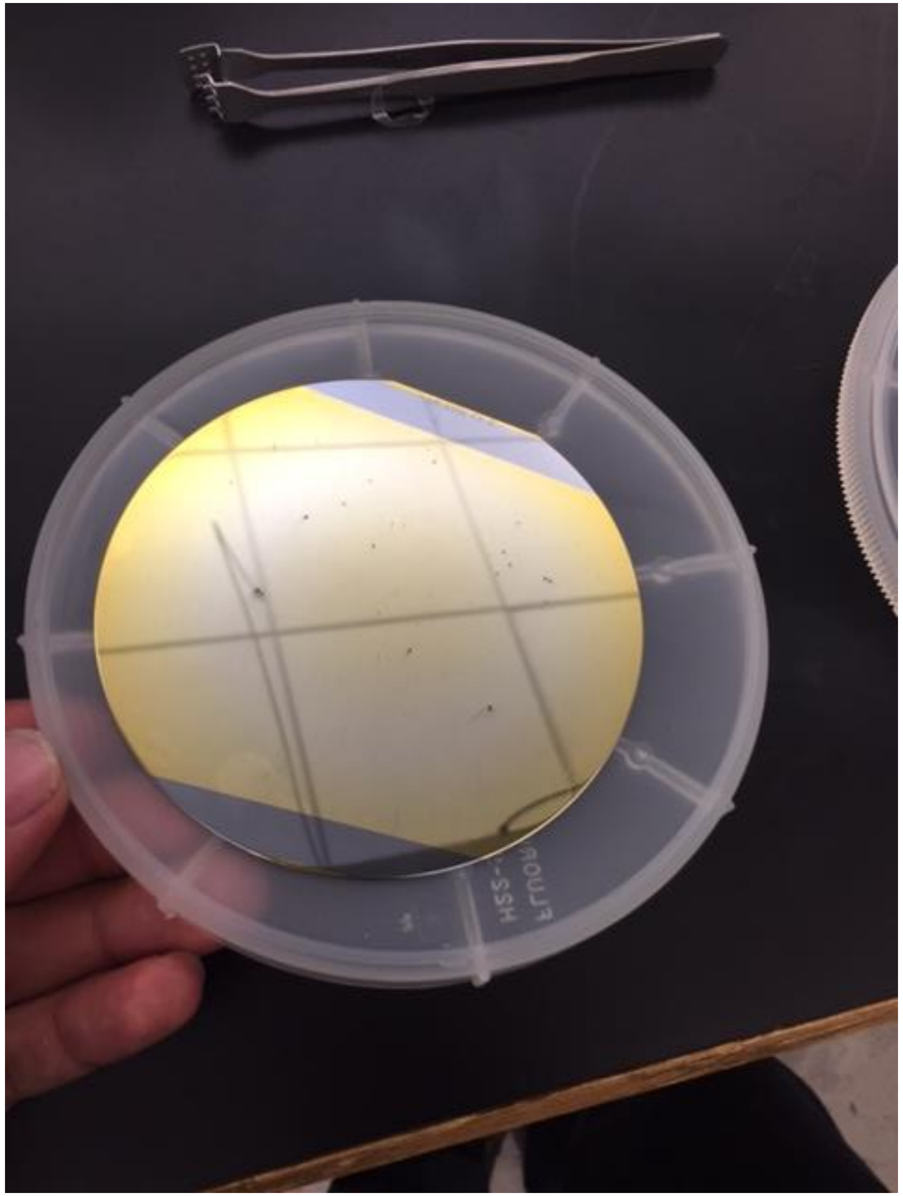
nodel ema with a-si aspnes and sio palik and al

6 srough	1.000 nm
5 sio2_jaw	5.011 nm
4 ema (a-si_aspnes_cl)/69.9% si	11.170 nm
3 a-si_aspnes_cl	0.000 nm
2 al2o3_cl	1.703 nm
1 al_palik_g	100000000.000 nm
0 si_jaw	10 mm



Dry Chemical Processing- summary

- Model after dry chemical processing did not work.
- Large MSE and unrealistic layers thicknesses.
- Ring made by the etching process.



Conclusion

- a-Si blocks the oxidation of Al from the data obtained
- Dry Chemical Process removes the a-Si protective layer
- We do not know if it roughens the Al layer
- More data needs to be taken from more samples
- Samples should be measured on the same place every time to obtain better data

Acknowledgements

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