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

By: Yhoshua Wug
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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 off?

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.
Overview

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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 off?

Solution: Dry chemical processing
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 off?

Solution: Dry chemical processing
Dry Chemical Processing

- One concept:
  - a plasma made with $\text{H}_2$ gas produces hydrogen atoms.
  - $\text{a-Si} + \text{H} \rightarrow \text{SiH}_4$; 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$_3$N$_4$ 400nm (MSE= 13.180)

- Al decreases over time.
Results: Al on Si$_3$N$_4$ 400nm (MSE = 13.180)

- Al decreases over time.
- Al$_2$O$_3$ increases over hundreds of hours.
Representation of the changes in a-Si

- Effective medium model
- 3 layer representation
Results: a-Si on Si$_3$N$_4$ 100nm after 100’s hours

<table>
<thead>
<tr>
<th>7 srough</th>
<th>1.600 nm</th>
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</thead>
<tbody>
<tr>
<td>6 sio2_jaw</td>
<td>1.089 nm</td>
</tr>
<tr>
<td>5 ema (a-si_aspnes_cl)/41.2% si</td>
<td>10.489 nm</td>
</tr>
<tr>
<td>4 a-si_aspnes_cl</td>
<td>0.000 nm</td>
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<tr>
<td>3 sin about 109nm</td>
<td>111.700 nm</td>
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<tr>
<td>2 sio2_jaw</td>
<td>1.400 nm</td>
</tr>
<tr>
<td>1 intr_jaw</td>
<td>0.400 nm</td>
</tr>
<tr>
<td>0 si_jaw</td>
<td>10 mm</td>
</tr>
</tbody>
</table>
Results: a-Si on Si$_3$N$_4$ 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$_3$N$_4$ 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$_3$N$_4$ 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 Si₃N₄ 100nm

- SiO₂ 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 Si₃N₄ 400nm (MSE=56.08)

- SiO₂ increases about 0.8nm over 400 hours.
Results: a-Si on Al on Si$_3$N$_4$ 400nm (MSE=56.08)

- EMA increases about 0.2nm over 400 hours
Results: a-Si on Al on Si$_3$N$_4$ 400nm (MSE=56.08)

- SiO increases about 0.7nm over 400 hours
Results: a-Si on Al on Si₃N₄ 400nm (MSE=56.08)

- a-Si component decreases about 0.6nm over 400 hours.
Results: a-Si on Al on Si$_3$N$_4$ 400nm (MSE=56.08)

- Al stays constant over 400 hours.
No aluminum oxide is detected

Sample 170721A

$a = \text{Si on Al on Si}_4\text{N}_3$ 100nm (Al Layer)

$y = 0.1077x + 15.852$

$R^2 = 0.0796$
No aluminum oxide is detected

Barrier layer gradually oxidizes

11.5nm a-Si on 16 nm Al on 100nm Si4N3 on Si

\[ y = 0.1077x + 15.852 \]
\[ R^2 = 0.0796 \]
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

<table>
<thead>
<tr>
<th>Model</th>
<th>Material</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 srough</td>
<td>1.000 nm</td>
<td></td>
</tr>
<tr>
<td>5 sio2 jaw</td>
<td>5.011 nm</td>
<td></td>
</tr>
<tr>
<td>4 ema (a-si_aspes.cl)/69.9% si</td>
<td>11.170 nm</td>
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<tr>
<td>3 a-si_aspes.cl</td>
<td>0.000 nm</td>
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<tr>
<td>2 al2c3.cl</td>
<td>1.703 nm</td>
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</tr>
<tr>
<td>1 al_palik_g</td>
<td>100000000.000 nm</td>
<td></td>
</tr>
<tr>
<td>0 si_jaw</td>
<td>10 mm</td>
<td></td>
</tr>
</tbody>
</table>

Generated and Experimental

- Model Fit
- Exp E 60°
- Exp E 65°
- Exp E 70°
- Exp E 75°
- Exp E 80°

Photon Energy (eV) vs. Ψ in degrees
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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