Mirror Coatings with Atomic Layer Deposition: Initial Results

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What is ADL?

Atomic Layer Deposition:
a method to deposit a uniform coating on a substrate,
one atomic layer at a time,
with complete control over that layer,
for an unlimited number of layers,
for almost any atomic species in the periodic table.

It is widely used in the semiconductor industry.

It has not yet been used to coat astronomical mirrors.

Why use ADL for mirrors?

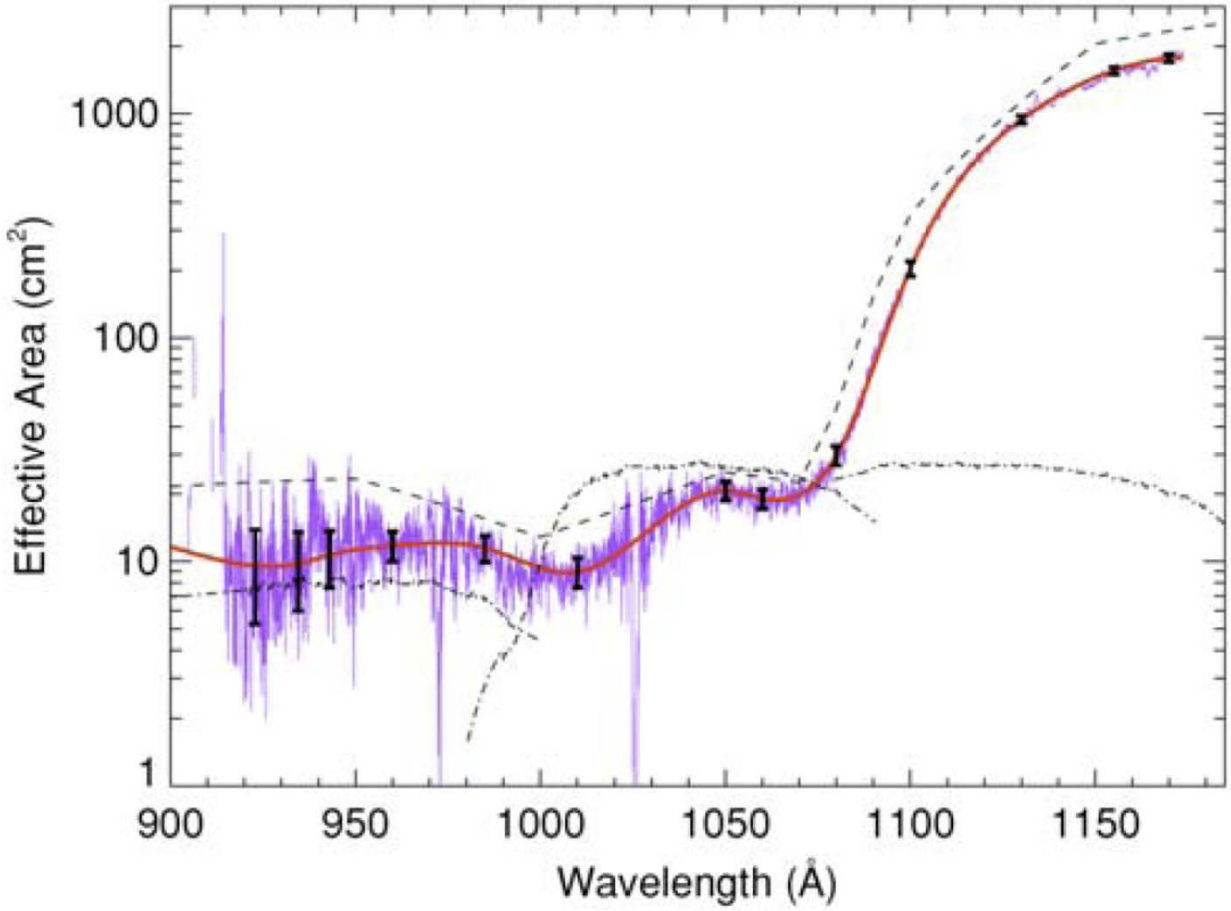
ALD layers are atomically compact,
without conventional coating's column-like structures,
therefore possibly more mechanically robust,
and probably more impervious to water and oxygen.

ALD is done in a small chamber of size D*D*ΔD,
not a conventional chamber of size D*D*2D.

ALD offers the possibility of controlling reflectance
and phase shift, by selecting the species in each layer.

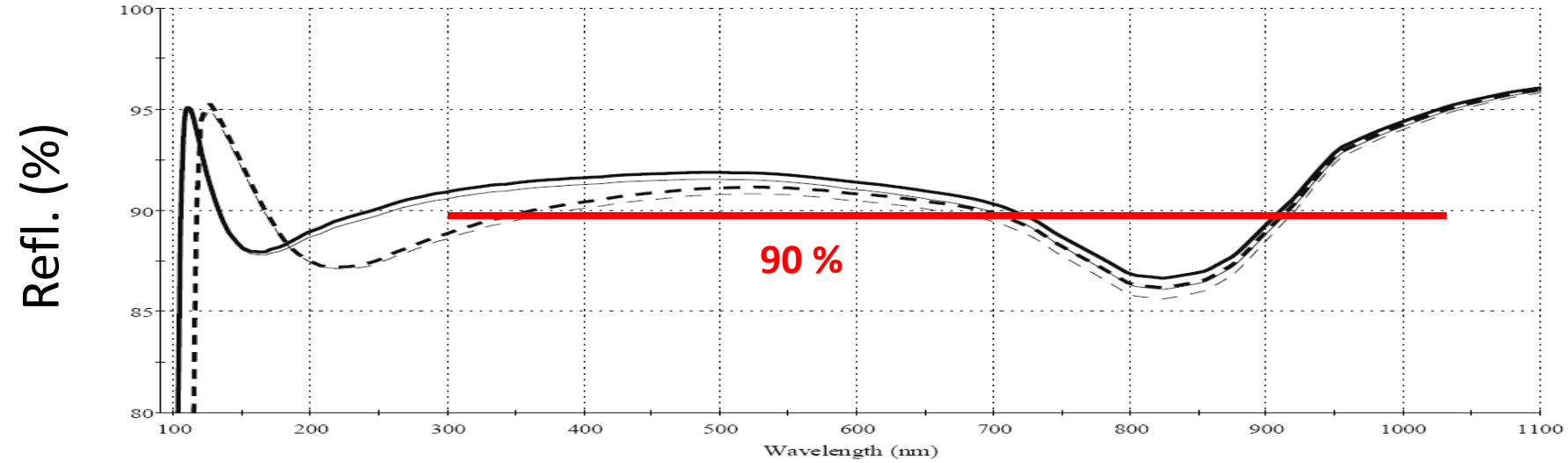
ALD allows a joint UV-exoplanet mission, with
high-reflec. In UV, & small S-P phase shift in visible.

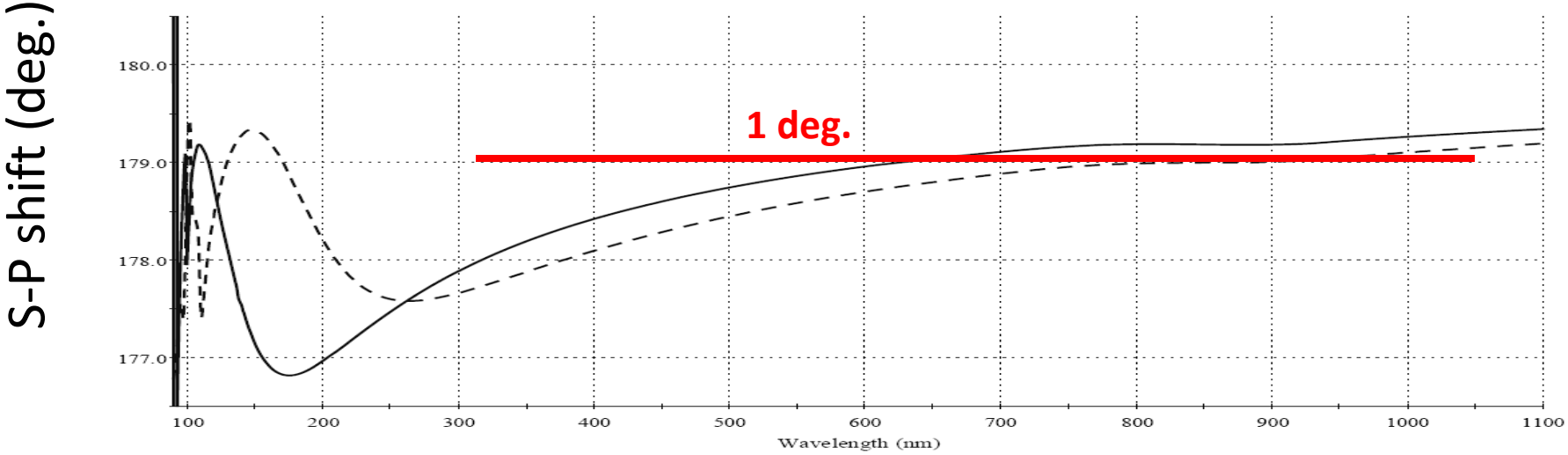
Current UV coatings: example



Effective area of GALEX telescope in VUV, only a few percent at $\lambda < 110$ nm.

Calc. reflec. & phase shift: MgF_2/Al and LiF/Al



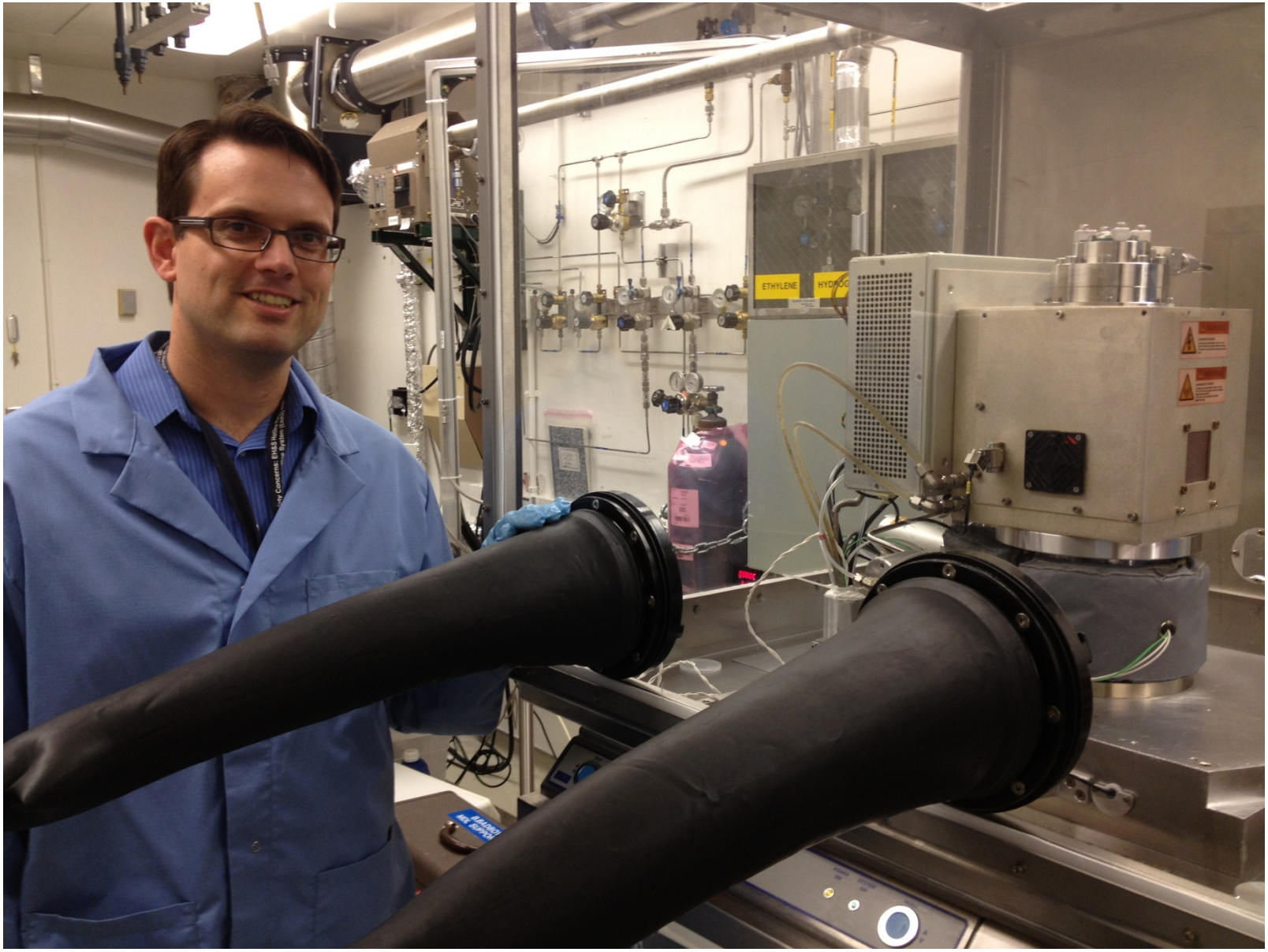


How does ADL work?

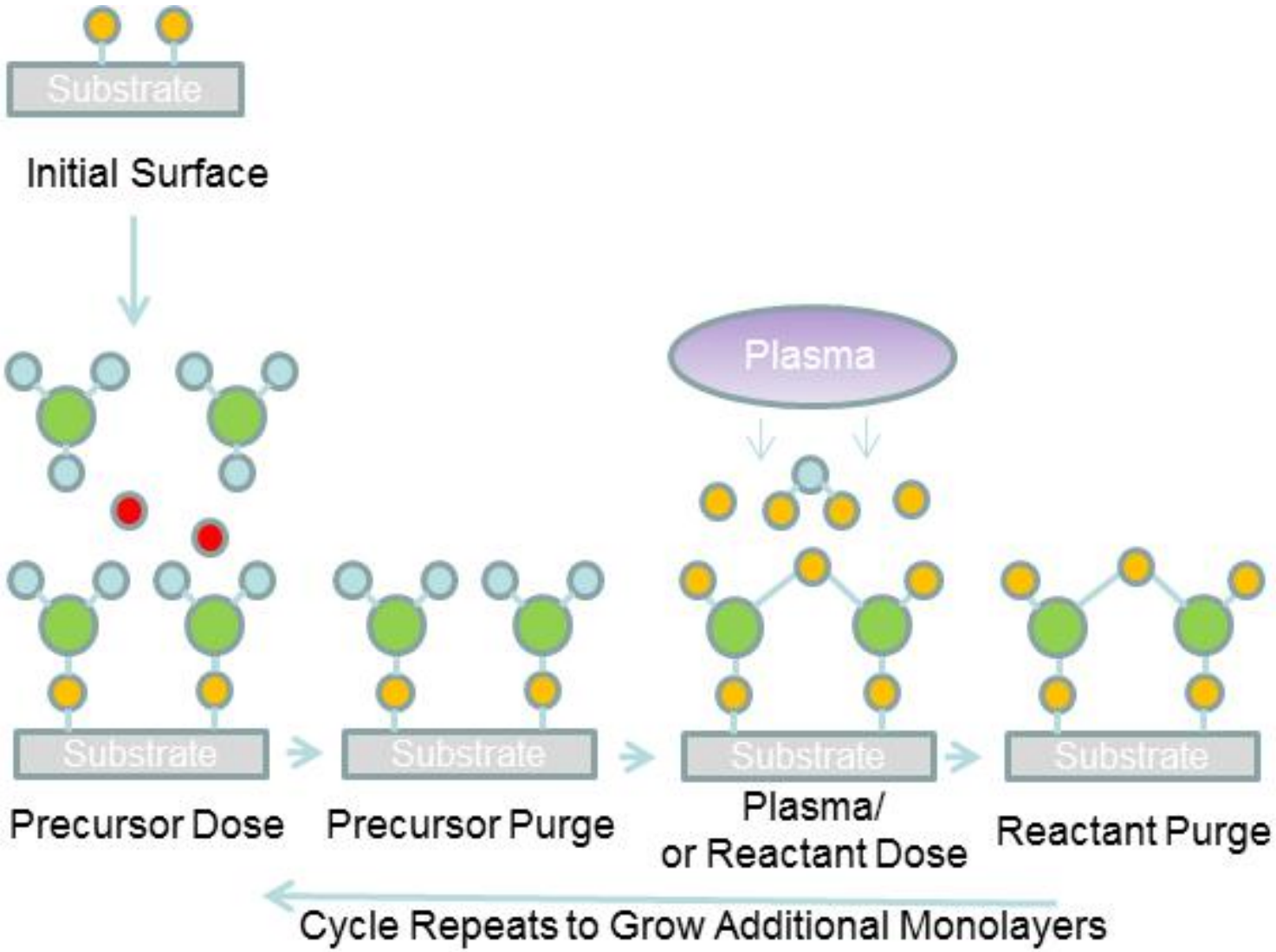
Pump, warm substrate, clean surface,
open valve to reactant 1, close valve, pump,
open valve to reactant 2, close valve, pump,
repeat.

Time: about 1 second per step,
so a few thousand seconds per coating.

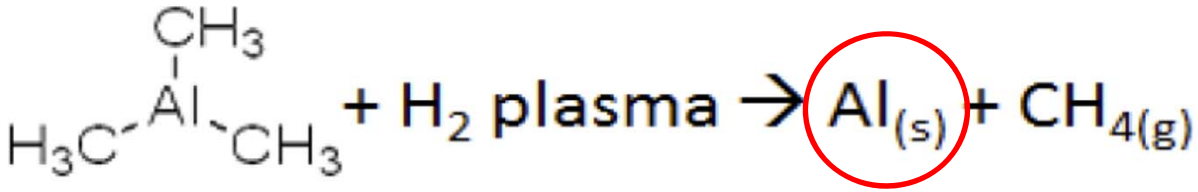
Frank Greer with apparatus in glove box

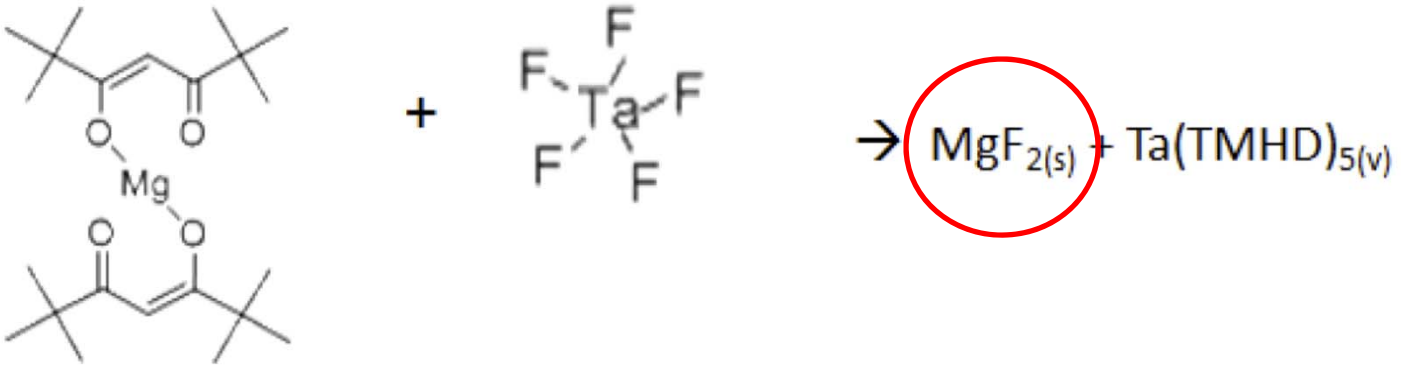


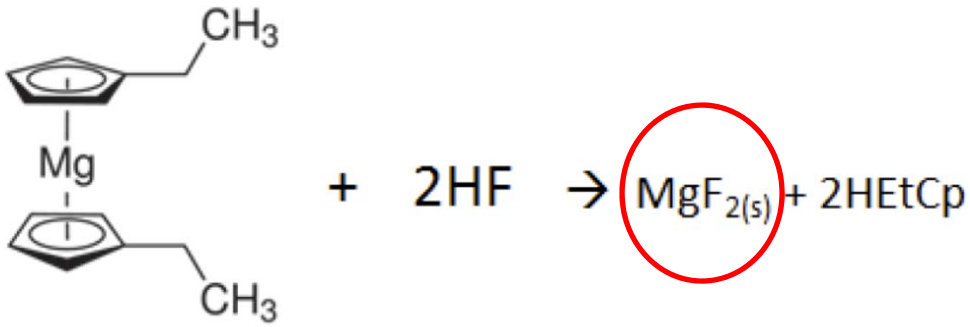
ALD steps


Substrate
Initial Surface
Plasma
Substrate
Substrate
Substrate
Substrate
Precursor Dose
Precursor Purge
Plasma/
or Reactant Dose
Reactant Purge
Cycle Repeats to Grow Additional Monolayers

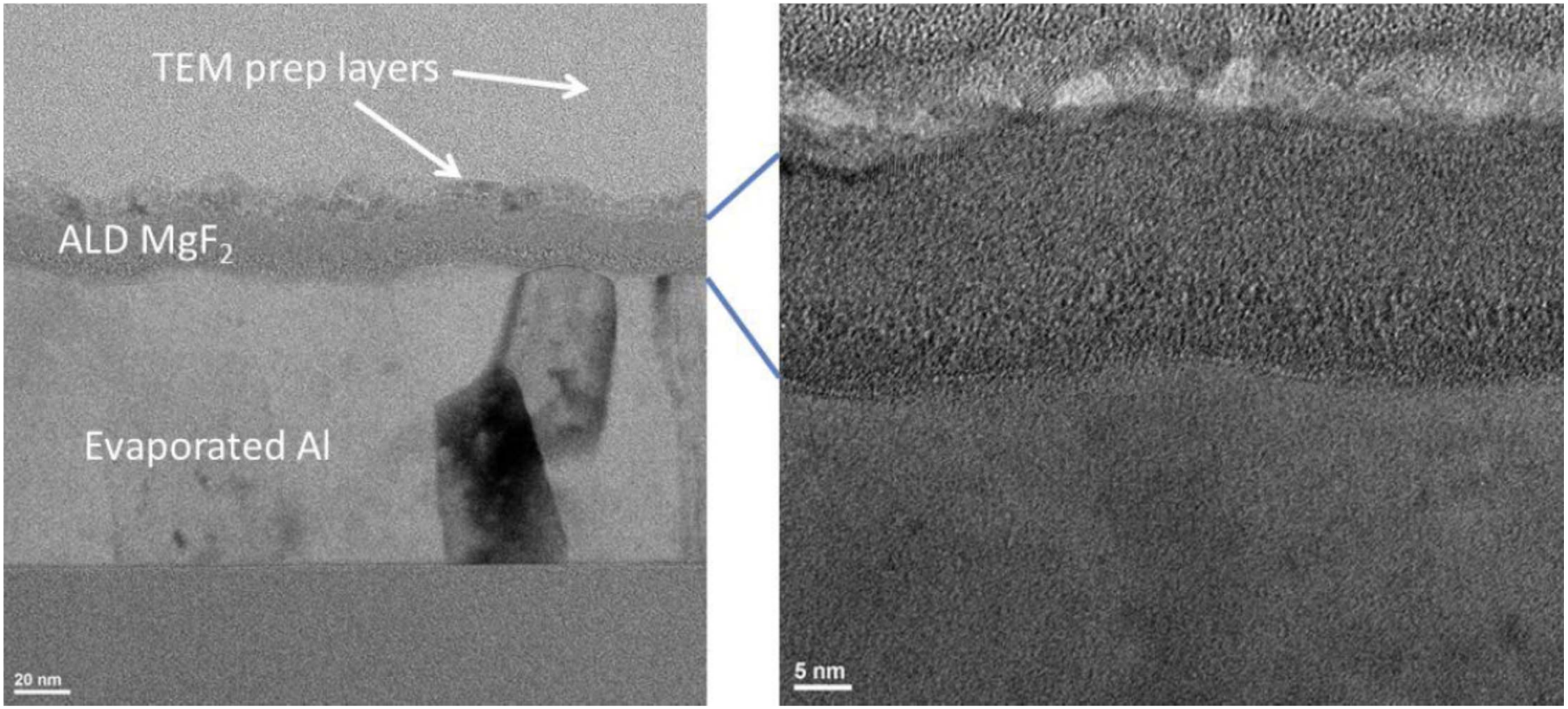
Examples


CH3
Al
H3C
CH3
+ H2 plasma → Al(s) + CH4(g)

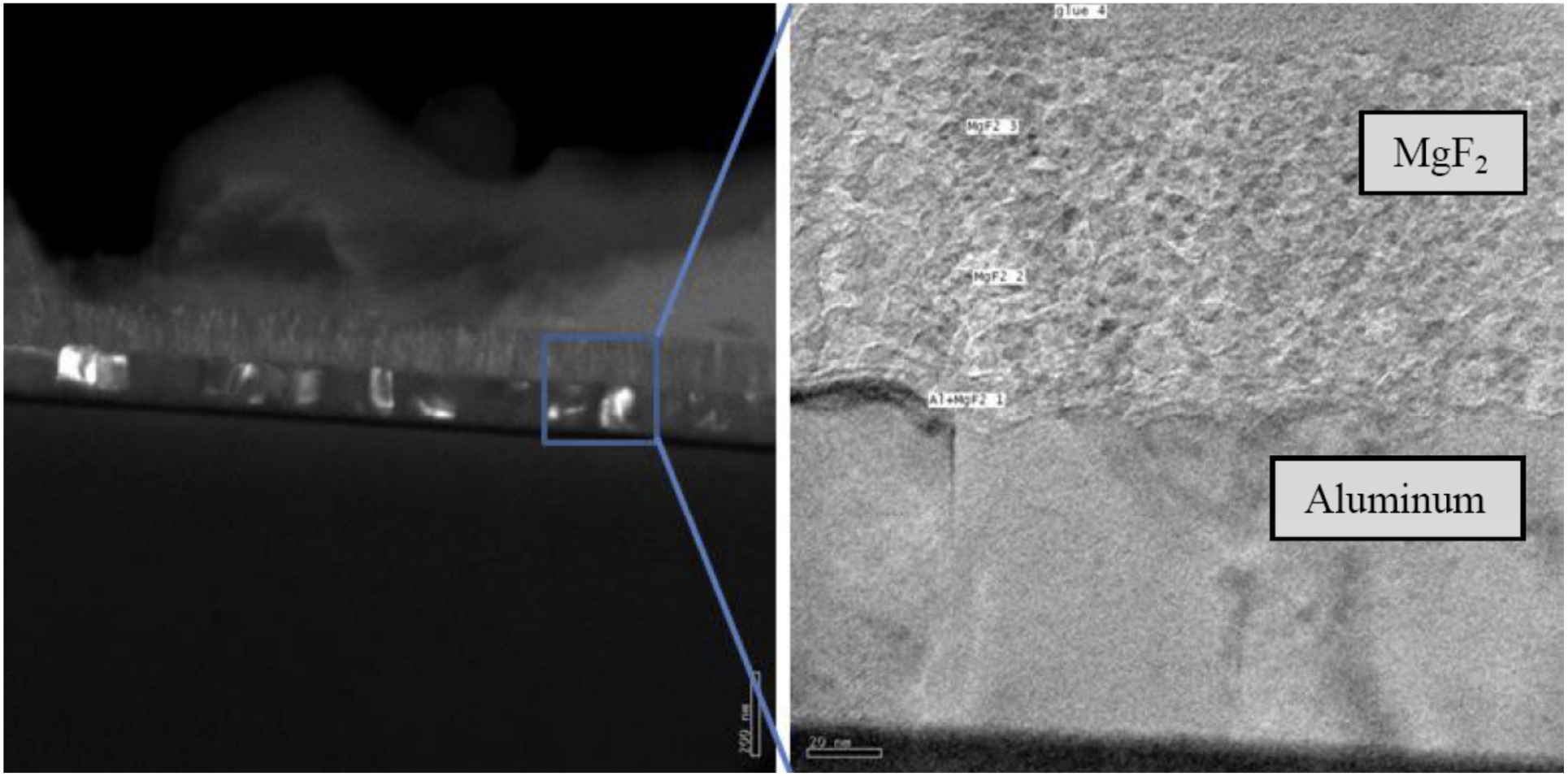

O
O
Mg
O
O
+
F
F
Ta
F
F
F
→ MgF2(s) + Ta(TMHD)5(v)


CH3
Mg
CH3
+ 2HF → MgF2(s) + 2HEtCp

Results: TEM of ALD MgF_2 + E-beam Al



Results: TEM of COTS MgF_2 + Al



Lessons learned

ALD is simple, as hoped, but with caveats.

The ALD apparatus we use is not optimal;
a new one is on order.

Chemistry knowledge is necessary.

Surface cleaning is important.

Future work

Measure current samples with ellipsometry,
to determine thickness and index values.

Use better ALD machine.

Explore range of substrates and coatings.

Seek higher UV reflectance & lower visible phase shift.