Hf Doping of an Aluminide Bond Coat for Single Crystal Jet Engine Turbine Blades

J. D. Meyer

L.M. He, G. Y. Kim, and W. Y. Lee

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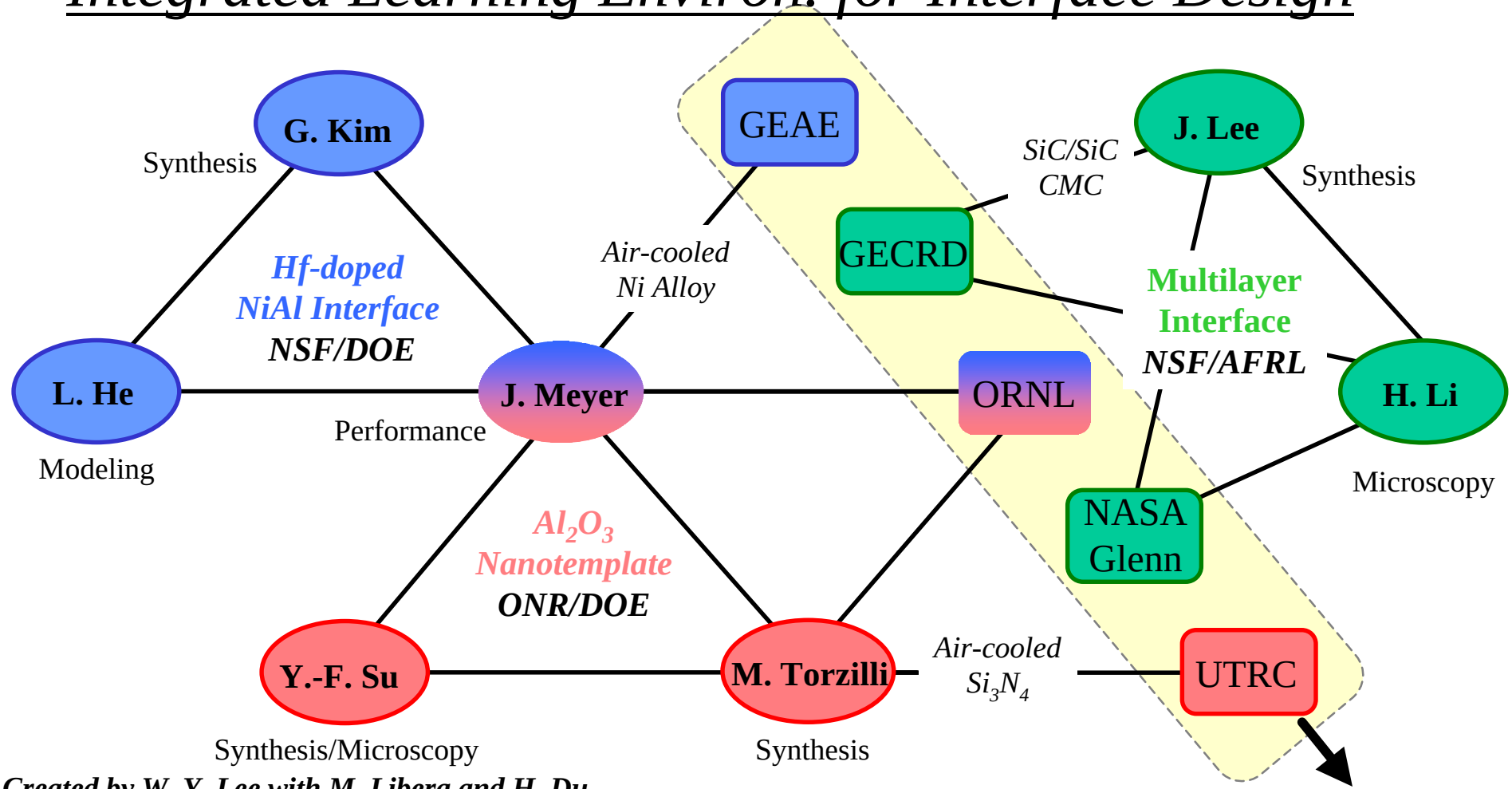
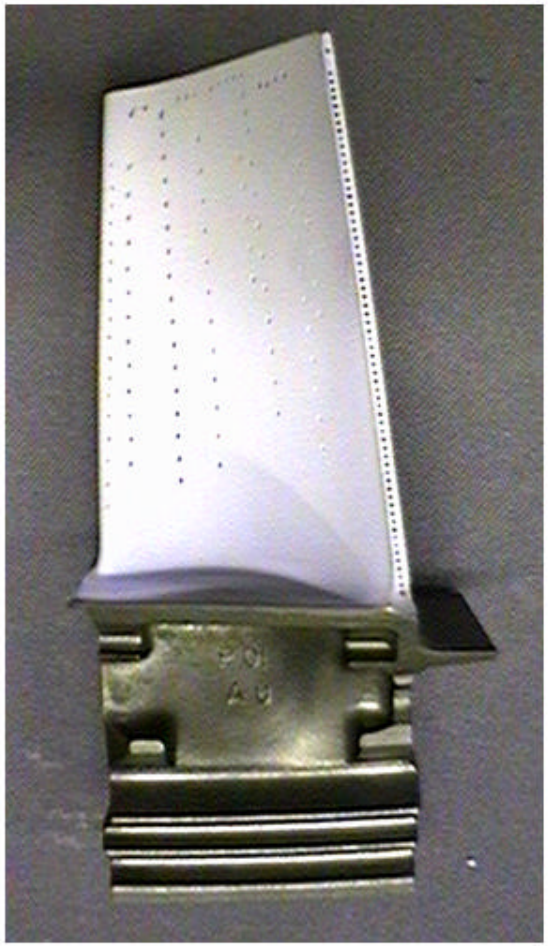
Department of Chemical, Biochemical, and Materials Engineering

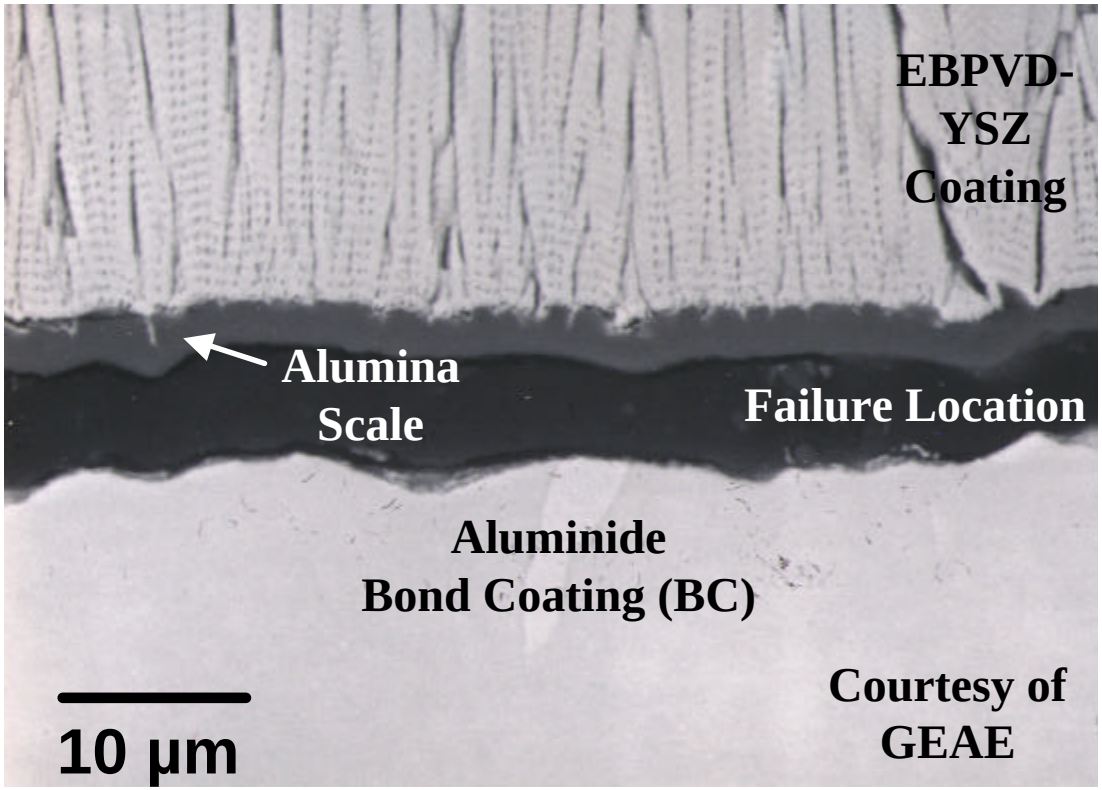
Integrated Learning Environ. for Interface Design



Created by W. Y. Lee with M. Libera and H. Du
The CVD Laboratory
Stevens Institute of Technology
(JDM & WYL, 3/23/2000)

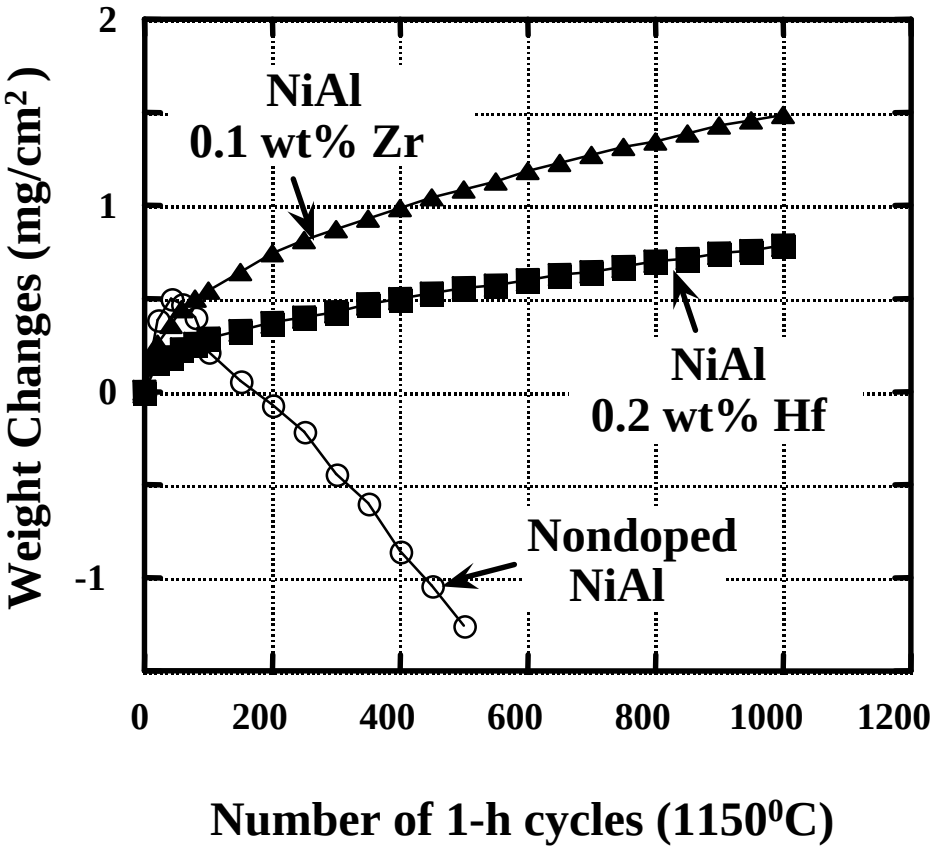
Superior Adhesion Needed for Next Generation TBCs





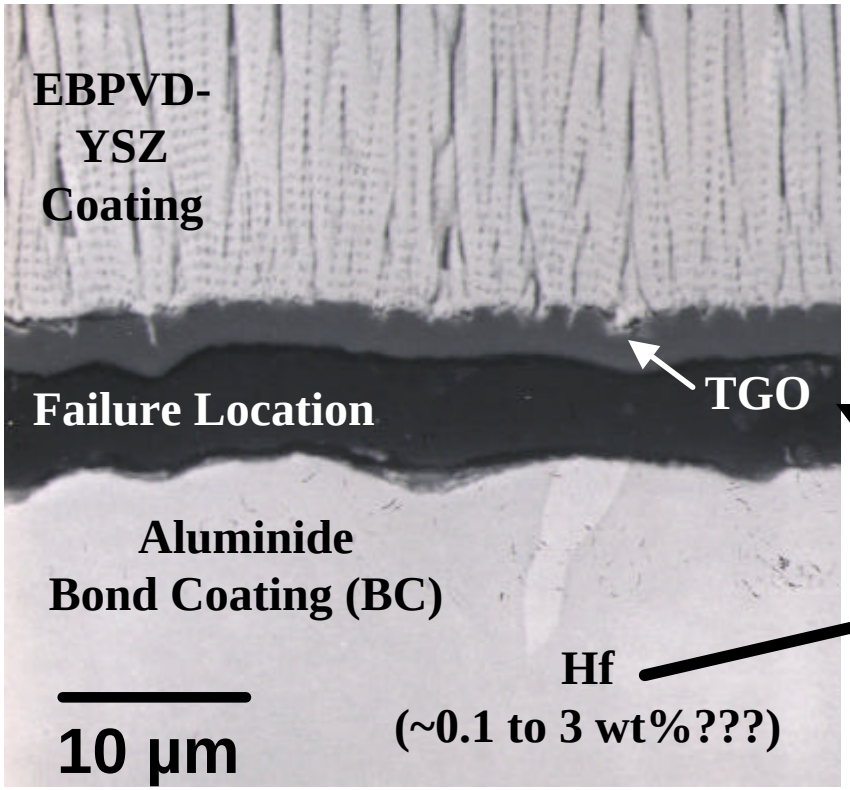
Single crystal Ni super alloy with TBC

"Model" TGO Behavior (Initial Work)



- Cast stoichiometric b-NiAl
  - Pint et al., 1998
- Beneficial effects of Hf
  - TGO growth kinetics
  - Columnar TGO
  - Immobilized sulfur impurity
  - Creep resistance of b-NiAl
- Optimum performance
  - ~0.2 wt% Hf
- Hf solubility in cast b-NiAl
  - Not precisely measured
  - Estimated ~0.1 wt% by Pint

Hf Doping: Rationale and Issues

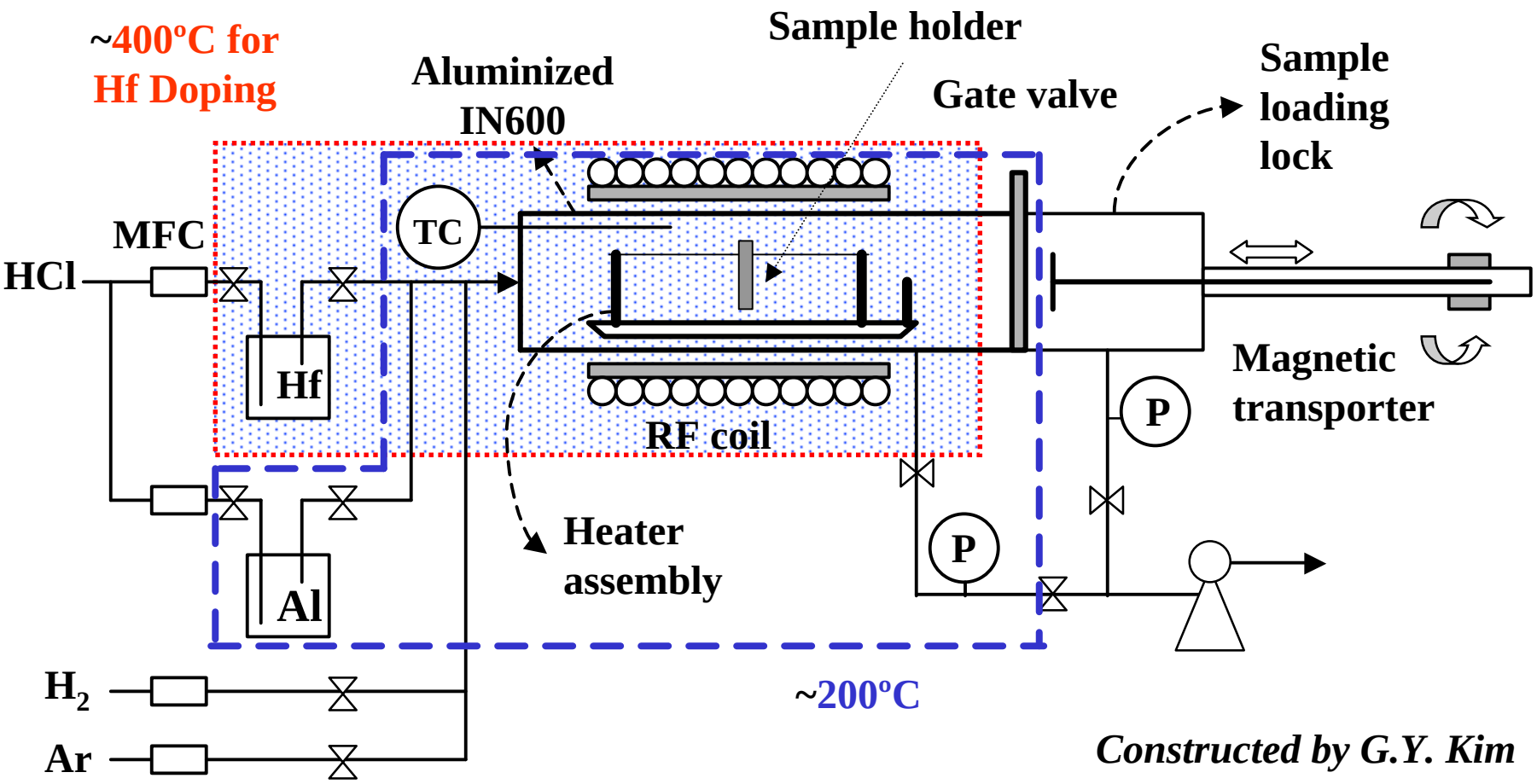


Problems observed in industry

- **Lack of process reproducibility**
- **Inconsistent composition/performance relationships**

Superior TGO Adhesion

CVD Reactor Designed for Short-time Experiments



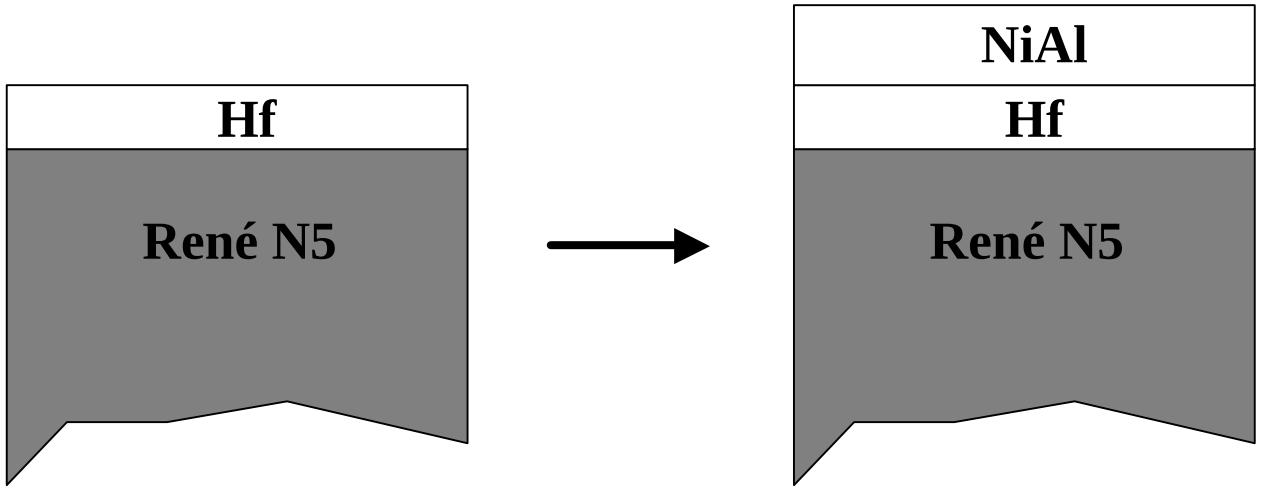
First Approach: Sequential Doping Procedure

10 min

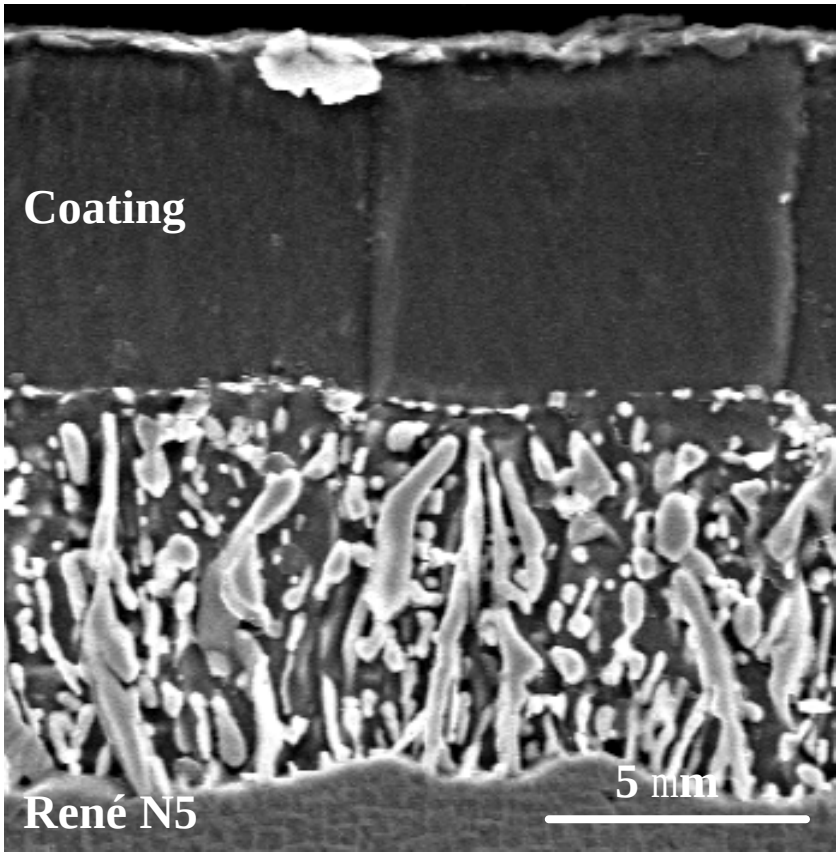
$HfCl_4 + H_2$

20 min

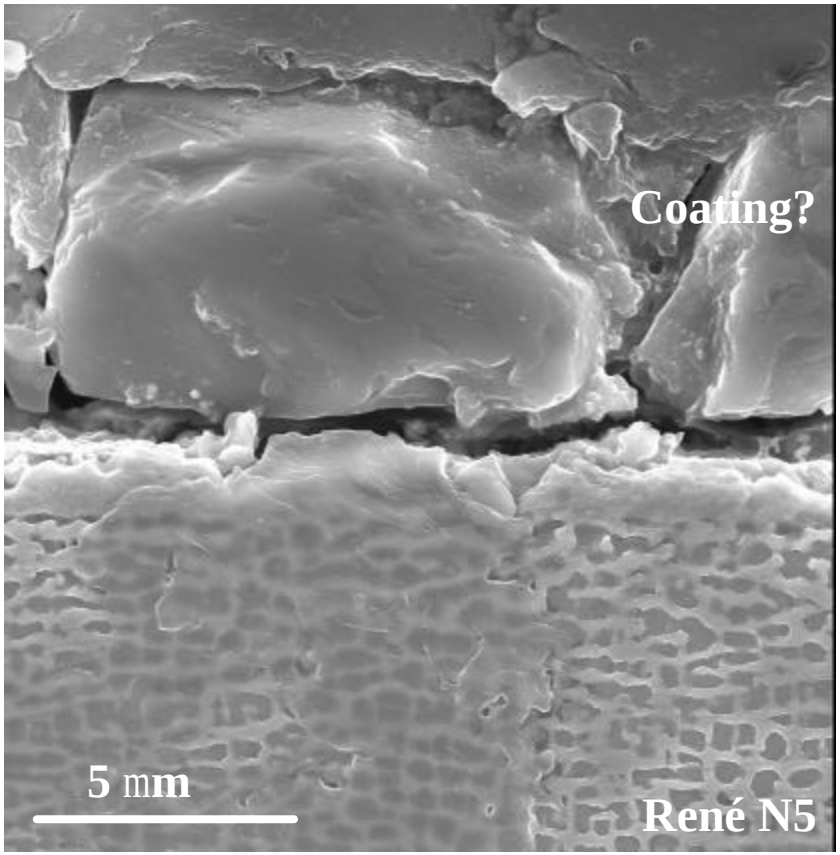
$AlCl_3 + H_2$



Result: Change in Microstructure was not Desirable



No Hf : columnar structure



With Hf: discontinuous structure

Second Approach: Continuous Doping Procedure

20 min

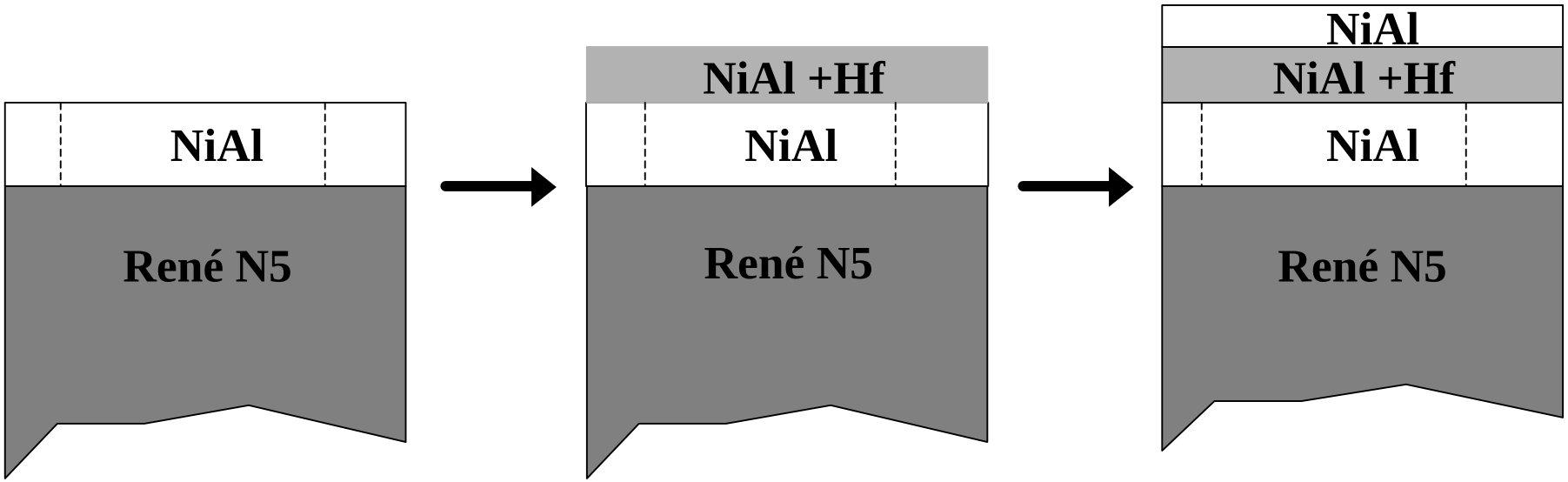
$AlCl_3 + H_2$

15 min

$HfCl_4 + AlCl_3 + H_2$

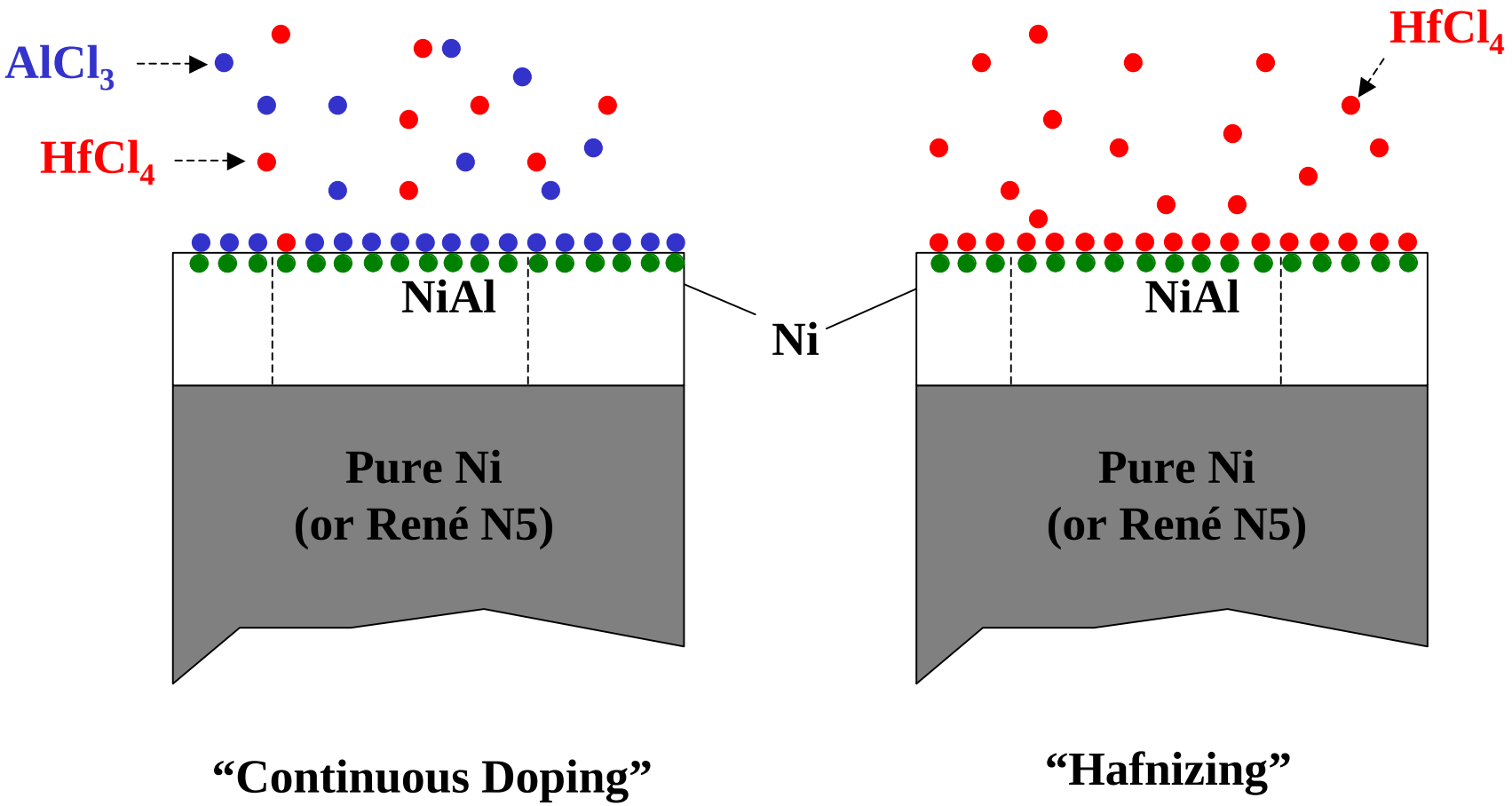
10 min

$AlCl_3 + H_2$



$$\left(\frac{HfCl_4}{AlCl_3} = 0.02 \sim 1.88\right)$$

Result: Absorption of $HfCl_4$ is a Rate Limiting Step

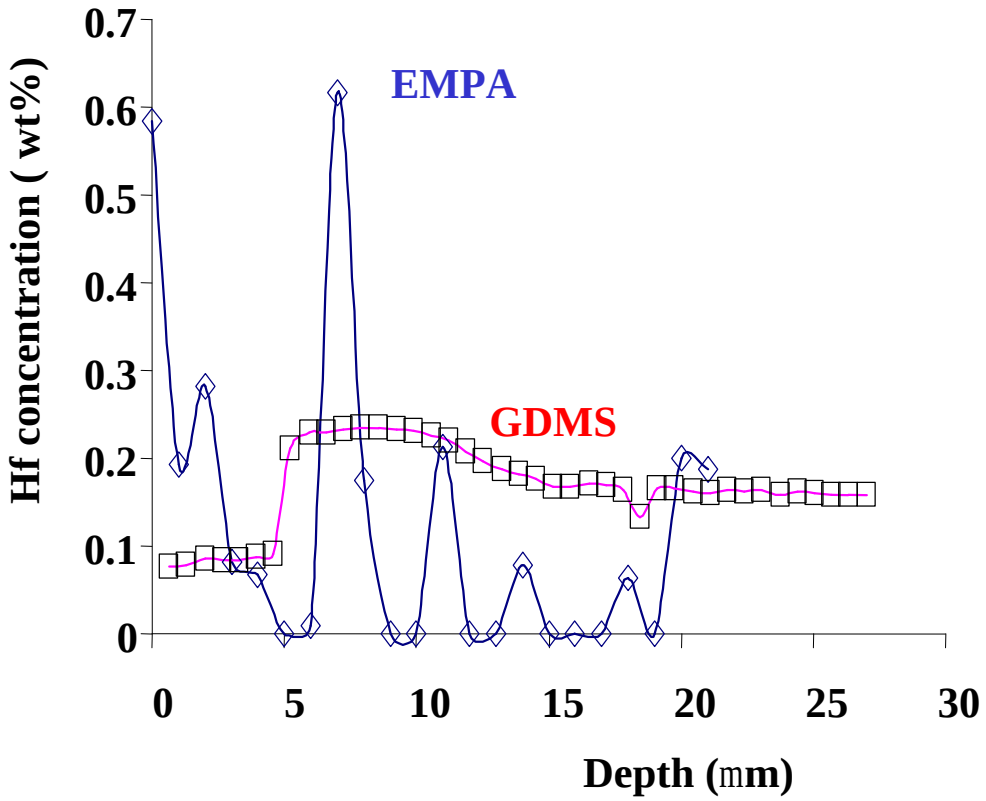


"Continuous Doping"

"Hafnizing"

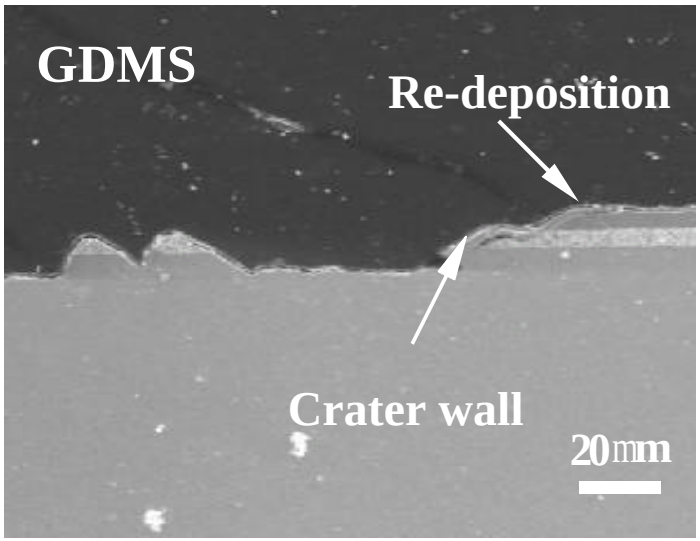
Hf Conc. And Dist. Measured by GDMS & EMPA

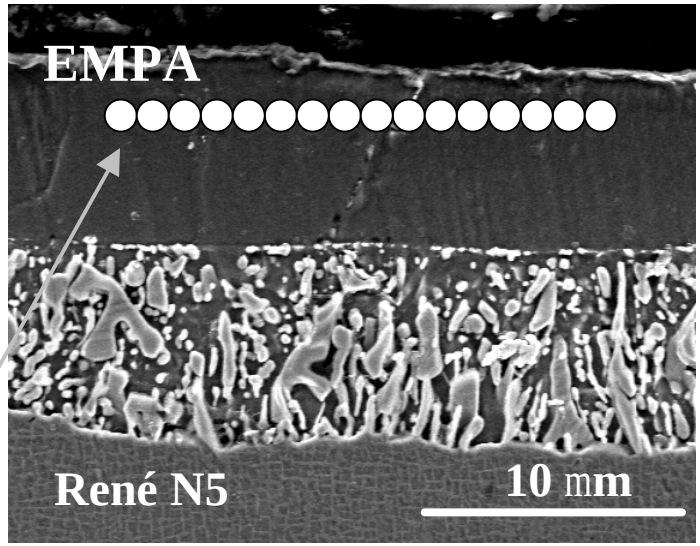
Limit of techniques reached!



$P_{HfCl_4}/P_{AlCl_3} = 0.6$

line scan





Evaluation of Processing Approaches

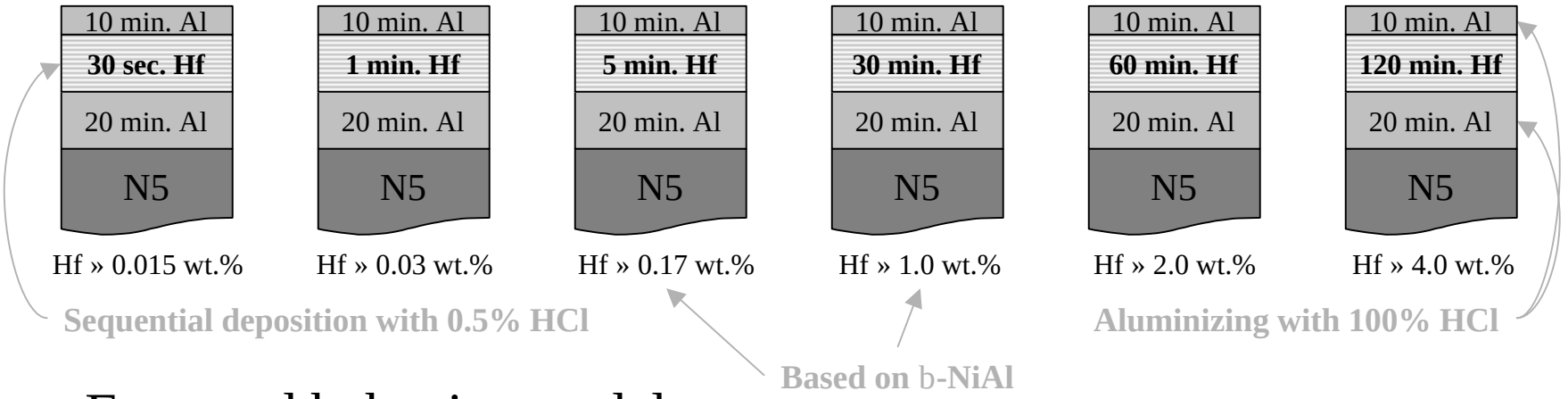
- First approach (sequential doping) resulted in an undesirable microstructure—deposition time may have been too long

- Second approach (continuous doping) resulted in coatings with a desirable microstructure, but Hf concentrations too low to measure with state of the art techniques!

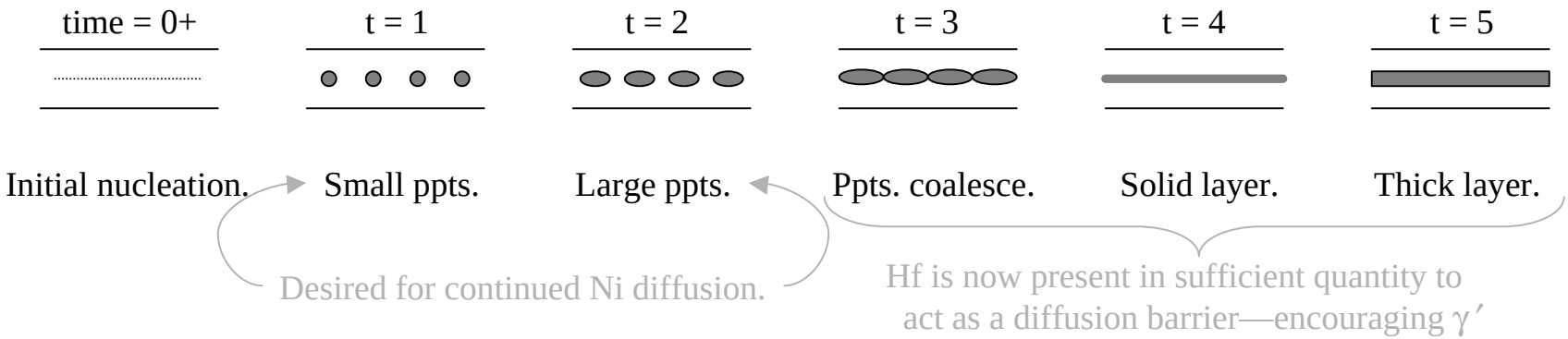
- A combination of the two would seem to be the only option remaining: the only way to deposit a suitable amount of Hf is by the first approach, but it must be done in many small layers, such that the desired microstructure is maintained

Dose "Level" Determination Exp. (0.5% HCl)

- Determine maximum dose level while maintaining precipitates

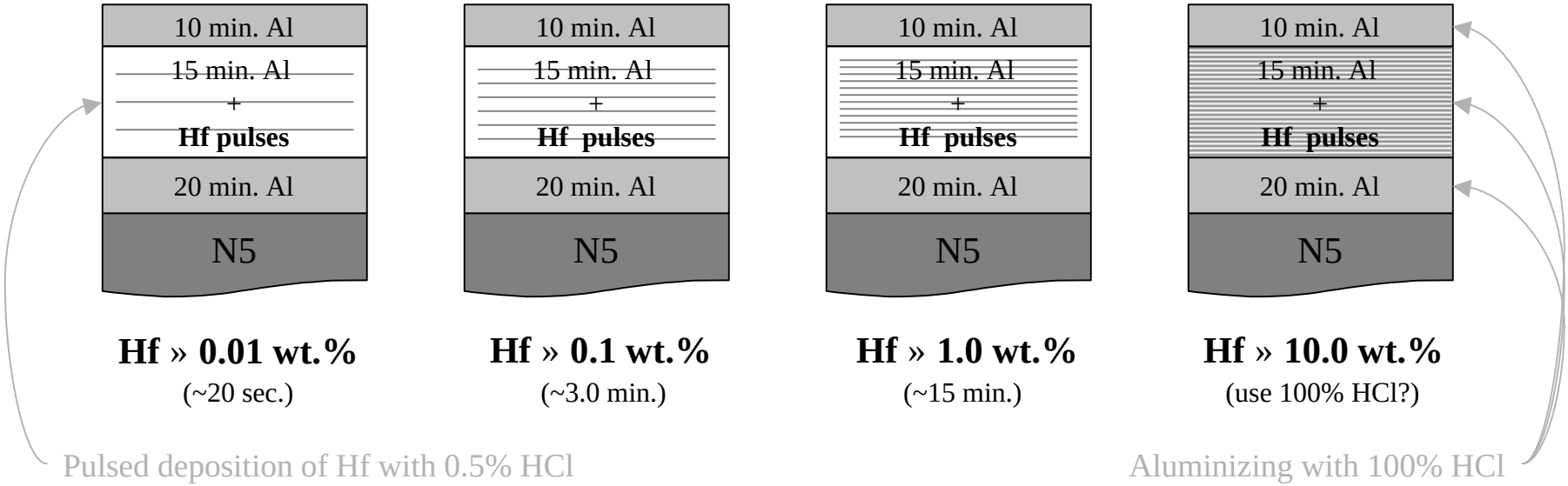


- Expected behavior model:



Dose Distribution Experiment

- Create four coatings over the desired range of Hf concentrations for eventual TBC coating and FCTing



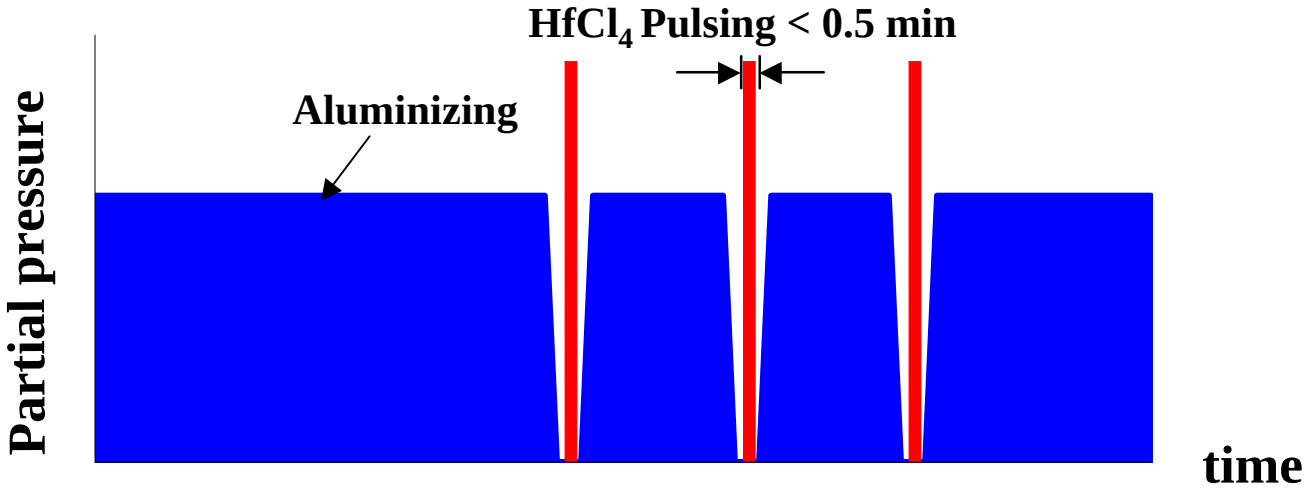
- Pulse frequency calculations are based on
  - 15 minutes of aluminizing → 3μm NiAl
  - Optimal thickness determined in previous “dose level” experiment

Refinement of Procedure Based on GEAE Data

- Internship at GEAE this summer will make use of their large experience and data base
- Statistical analysis of GEAE coating characterization data to estimate the ideal frequency/distribution of Hf *(summer plan)*
- Based on trends observed in the GEAE coating samples, we can tailor our deposition process to produce a more viable coating for testing

How to Synthesize Coatings with 0.01 to 3 wt% Hf?

0.01 wt%Hf



0.10 wt%Hf