Atomic Layer Deposition for Enhanced Reactivity and Stability of Biomass Conversion Catalysts

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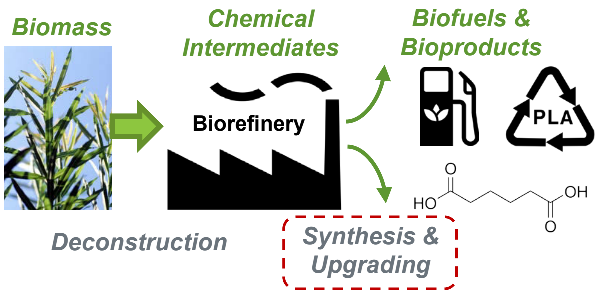
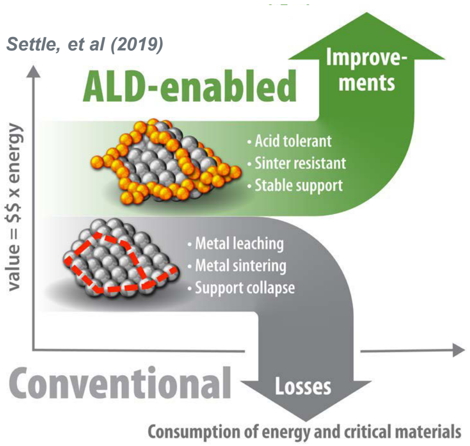
Chemistry Challenges of Biomass Conversion



- *Synthesis & Upgrading requires robust and economical catalytic processes*
- *Harsh process conditions (temperature, acidity, H_2/O_2, high moisture) impose significant barriers*
- *Thin metal oxide coatings via atomic layer deposition (ALD) developed for next-gen heterogeneous catalysts*

Application of ALD Coatings

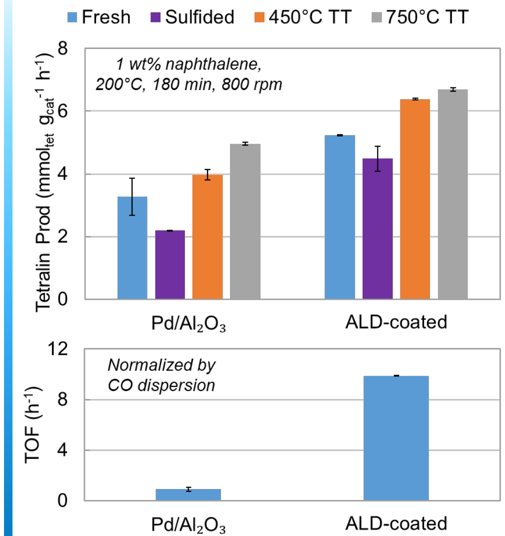


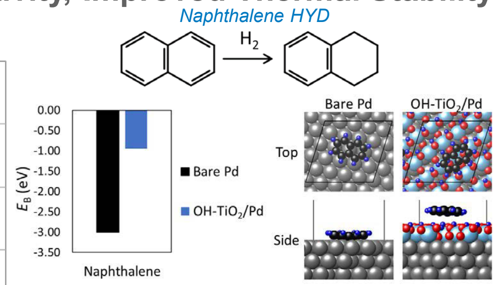
TiO_2 and Al_2O_3 ALD overcoats applied to supported Pd catalysts for hydrogenation reactions

Goal 1: ***Improve catalyst stability***

Goal 2: ***Scalable ALD synthesis***

TiO_2 ALD: Increased Activity, Improved Thermal Stability and Sulfur Tolerance

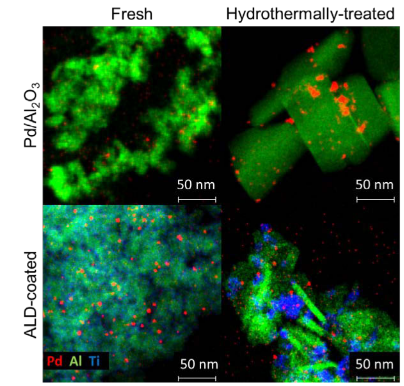




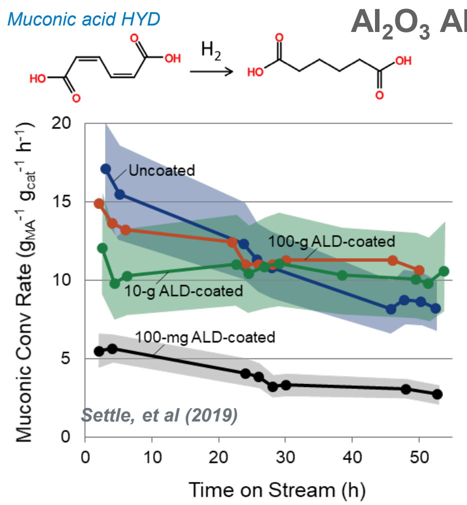
- *Activity substantially increased by addition of ALD overcoat; TiO_2 surface affects reactant binding to Pd*
- *ALD-coated catalyst retained 86% of initial activity after exposure to sulfur*
- *Activity increased following oxidative thermal treatments*
- *ALD overcoat improves hydrothermal stability*

Effects of 15 h 200°C hydrothermal treatment

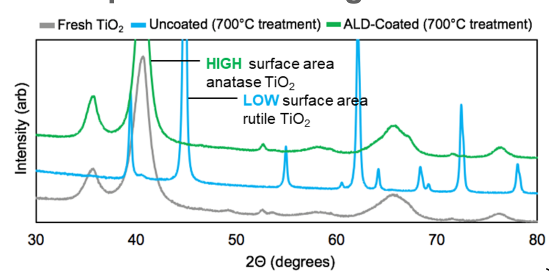
Catalyst	BET_{init} ($m^2\ g^{-1}$)	BET_{final} ($m^2\ g^{-1}$)	% change BET
Uncoated (Pd/Al_2O_3)	112	19	-83%
ALD-coated	110	81	-26%



Al_2O_3 ALD: Improved Leaching and Thermal Stability

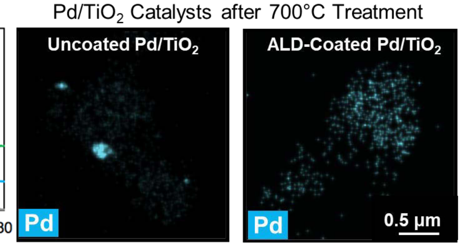


- *Al_2O_3 ALD overcoat improves stability in muconic acid conversion to adipic acid, an important bioproduct*
- *Improvements demonstrated with ALD fabrication at multiple scales*



>9x greater surface area retention than uncoated TiO_2 powder

Pd/TiO_2 Catalysts after 700°C Treatment



>80% loss of surface area | <25% loss of surface area

Pd leaching during Muconic Acid HYD

Catalyst	Leaching (Pd ppm)	Leaching Rate ($\mu g_{Pd}\ h^{-1}$)
Uncoated (Pd/TiO_2)	1.4 ±0.7	0.32
100-mg ALD-coated	0.3 ±0.1	0.07
10-g ALD-coated	0.08 ±0.04	0.02
100-g ALD-coated	0.05 ±0.01	0.01

Conclusions and Future Outlook

- *ALD-enabled catalysts show superior performance vs. conventional catalysts in hydrogenation reactions*
- *Observed leaching and stability benefits maintained upon ALD synthesis scale-up*
- *Ongoing work focused on improving leaching resistance in oxidative environments*

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