Improved Catalyst Selectivity and Longevity Using Atomic Layer Deposition

WBS 2.1.10.1

Argonne National Laboratory, Forge Nano, Honeywell UOP

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Christopher L. Marshall, Chemical Sciences and Engineering Division,
Argonne National Laboratory

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Overview

Project Title: Improved Catalyst Selectivity and Longevity Using Atomic Layer Deposition

Timeline:

Project Start Date: 05/01/2018

Budget Period End Date: 04/30/2020

Project End Date: 04/30/2020

Project Budget and Costs:

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$1,600,000	$512,320	$2,112,320	24.3%
Approved Budget (BP-1&2)	$1,600,000	$512,320	$2,112,320	24.3%
Costs as of 3/31/19	$666,306	$210,286	$882,284	23.8%

AMO MYPP Connection:

- Developing an advanced propylene manufacturing catalyst that outperforms conventional market-leading catalysts
  - Higher activity and better selectivity at reduced temperatures
- Supporting AMO goal
  - Reducing the life-cycle energy consumption required to manufacture light olefins by 50% in 10 years.

Barriers and Challenges:

- Catalysts lose effectiveness due to sintering of metals
- Manufacturers normally address this activity by increasing the catalyst temperature
- Eventually the catalyst must be removed and replaced

Project Team and Roles:

- **Argonne National Laboratory**
  - Project Management
  - Catalyst Evaluation
    - Activity and Selectivity
- **Forge Nano**
  - Catalyst overcoating and scale Up
- **Honeywell UOP**
  - Catalyst Synthesis, Process Verification, Life Cycle Analysis

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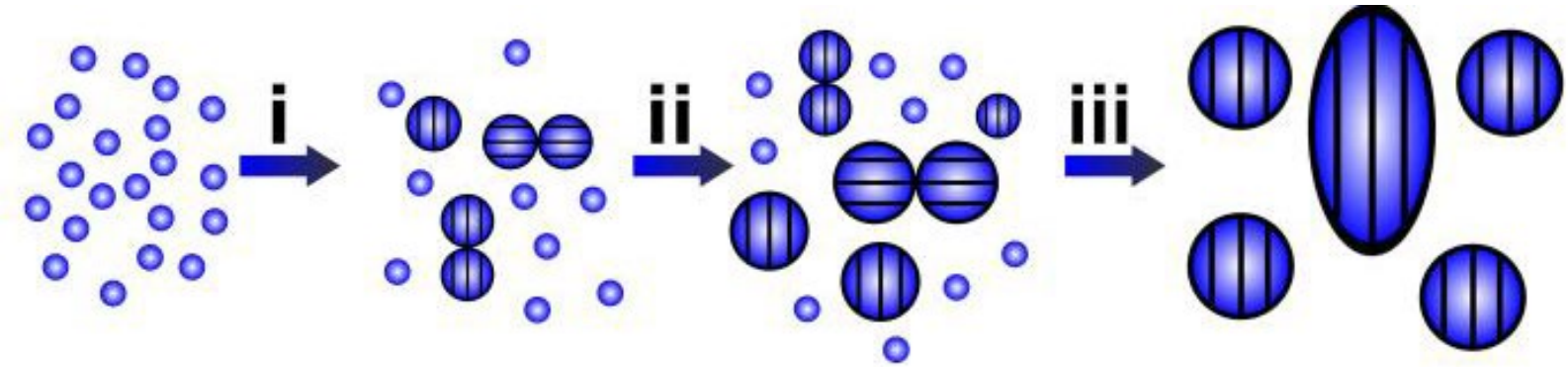
Project Objectives

Sintering (Aging)

- Loss of active surface area from the prolonged exposure to high temperatures.
- Commercial catalysts lose surface area and hence activity via a process called sintering.
- In most cases the remedy for sintering is:
  - Increase reactor temperature **(energy inefficient)**
  - Remove spent catalyst and replace with new material. **(expensive and leads to loss in productivity)**



Project Objectives

ANL and its partners Honeywell UOP (UOP) and Forge Nano (FN) are applying protective layers using Atomic Layer Deposition (ALD) to inhibit metal sintering of commercial Pt-based PDH catalysts to extend usable lifetime.

- Improve the efficiency of the catalytic reaction to reduce the energy required for the process.
- Larger energy savings would result from an improvement in selectivity.
    - Undesirable chemical byproducts that require high energy consumption processes for separation and removal from the product stream.
- Activity and selectivity are both degraded by sintering.

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Technical Innovation 1

Improved Catalyst Selectivity and Longevity :

- Catalyst deactivation costs the chemical industry billions of dollars in lost revenue
- Imperfect selectivity in catalytic transformations engenders the use of large, costly separation processes to remove unwanted impurities.

The use of ALD to inhibit metal sintering will avoid these issues and generate several benefits:

- Improved catalyst lifetime >100% due to a reduction in deactivation rate.
- Higher catalytic reaction selectivity and reduced energy required
- Validation and acceptance of atomic layer deposition as a scalable catalyst manufacturing technique.

BES sponsored Energy Frontier Science Center (EFRC)

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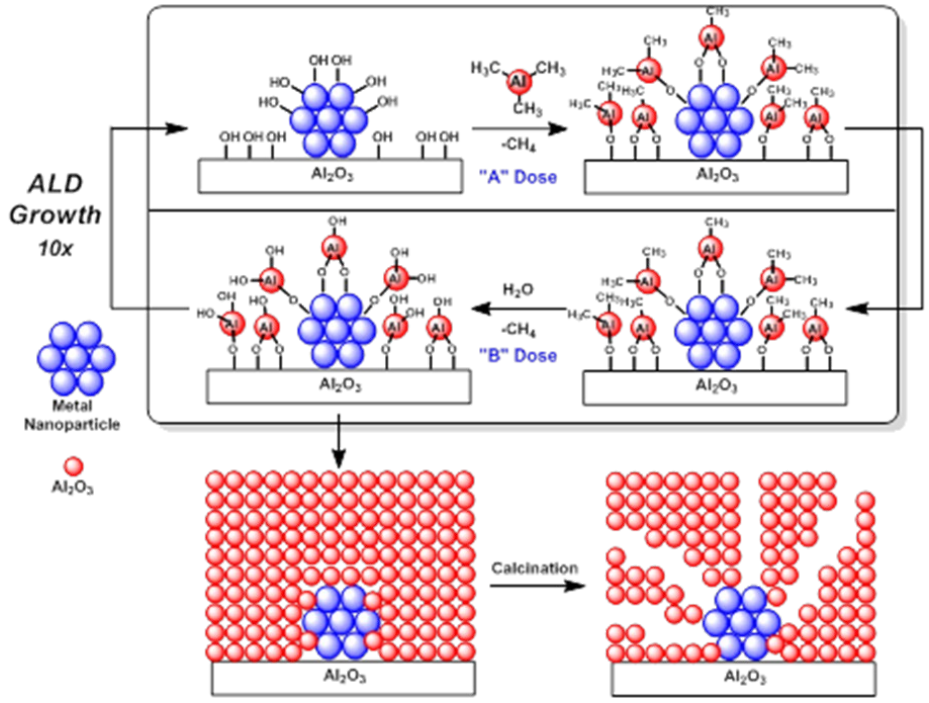
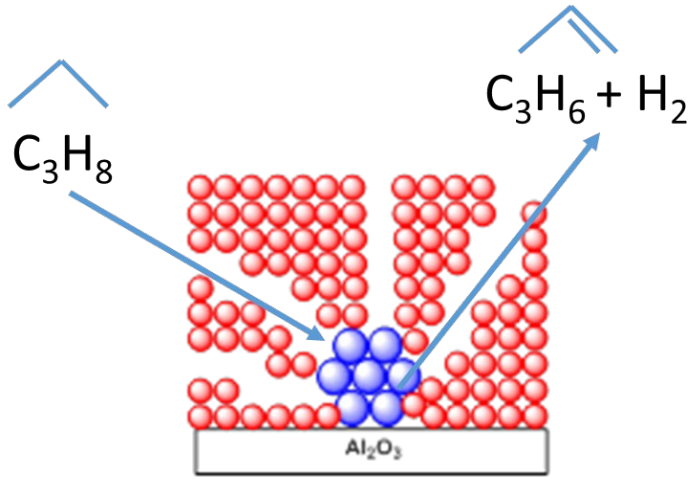
Technical Innovation 2

Improved Catalyst Selectivity and Longevity :

- ALD overcoating prevents sintering of the active catalytic metal.
- ALD overcoating improves the selectivity to olefin
  - avoiding coke formation.
- New technology from FN could make ALD useful for large volume applications such as catalyst manufacturing.





- Retain/Improve Productivity
- Reduced Metal Sintering

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Technical Approach 1

- Test the ALD overcoating
  - Several metal oxides (Al_2O_3 TiO_2) and metal oxide loadings
  - Different surface areas.
  - Improved catalyst
    - Longevity, selectivity
- Potential project risks and unknowns
  - Ability to scale up ALD to the volumes required for use in the refining and chemical industry.
  - Understanding of the fundamental impact of ALD based Al_2O_3 and TiO_2 overcoating on catalyst performance in the formed materials under study.
  - Changeover costs in the market, necessitating drop-in ready catalysts

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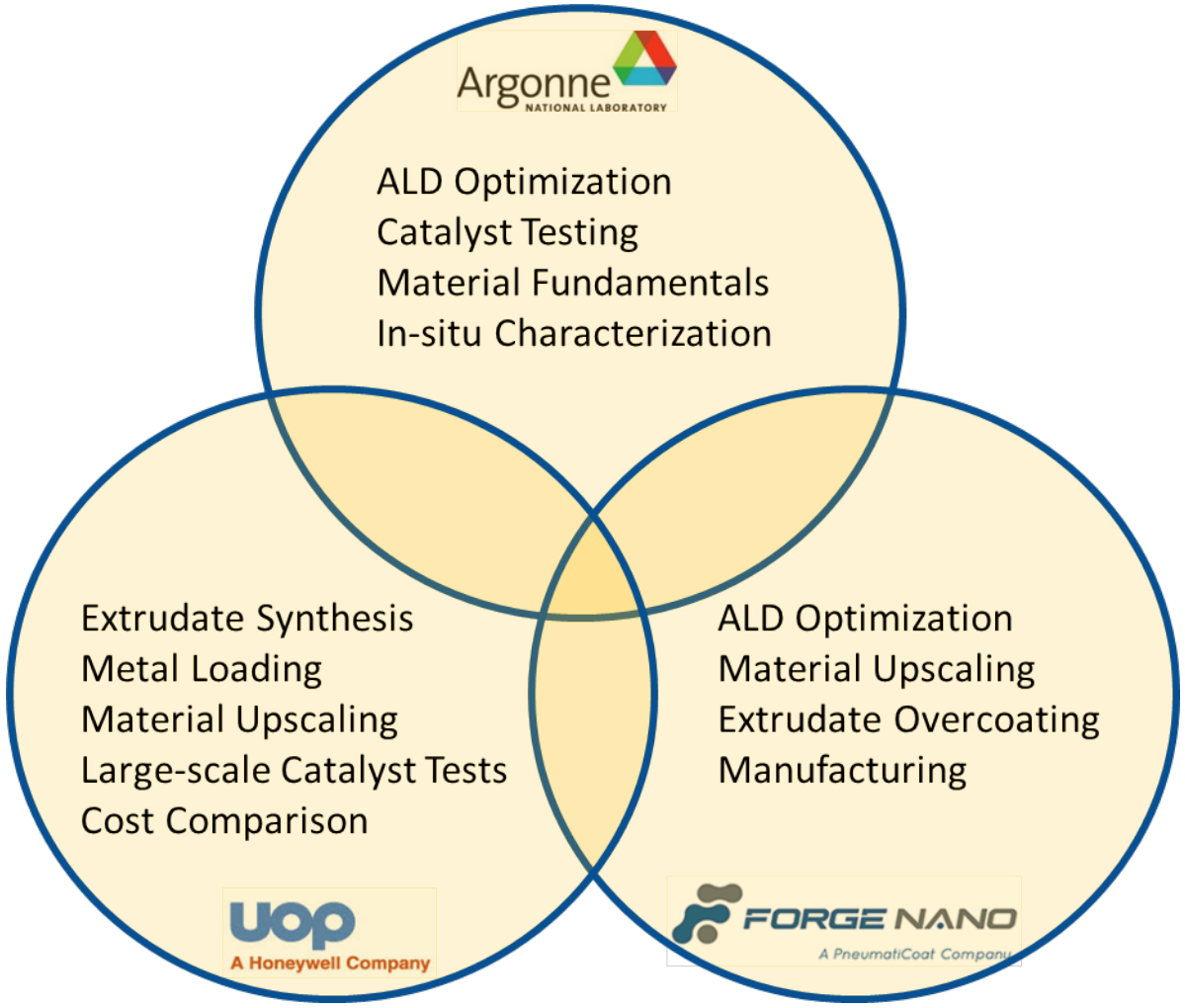
Technical Approach & Project Roles



Results and Accomplishments

Demonstrated

- Overcoating applied to wide variety of catalysts
  - including %Pt and surface areas
- Al_2O_3 overcoats optimized
  - Works effectively at all SA levels tested
  - Little to no effect on catalyst selectivity
- Calcination opens active sites
- Overcoating covers some of the active Pt sites
- Steaming used to simulate long term deactivation.

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Milestones

- Two-year project spanning 3FY began in 2018.
- Lab-scale synthesis of base catalysts and determination of penetration depth of ALD precursors into the formed materials using TiO_2 overcoatings (2018).
- Understanding of catalytic effectiveness of Al_2O_3 and TiO_2 ALD overcoating and down selection of process variables (2019).
- Scaled-up production of selected ALD overcoated catalysts in large quantities. Performance validation of the scaled-up coatings and techno-economic analysis of scaled-up process (2020).

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Transition

- Technical readiness (TR) level
  - Start (May 2018)
    - TR3 Research to Prove Feasibility
  - Project end (April 2020)
    - TR6 Technology Development

- Patent filing underway
- Intellectual property licensing will be explored.

Develop infiltration strategies and optimize process conditions & coating loadings at the 1g scale

Make instrumentation modifications to enable chemistry on extrudates at scale

Scale to: 1 kg batches

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