



Acceleration of heterogeneous catalysis through dynamic resonance (2019-226)

A method to dynamically vary binding rates to drastically increase rate of chemical reactions involving heterogeneous catalysts.

Technology No. 2019-226

IP Status: PCT Patent Application Filed

Applications

- Chemical reactions involving heterogeneous catalysis

Key Benefits & Differentiators

- Drastically higher reaction rate with minimal energy input
- Temporal control of reaction rate
- Allows continuous modulation and optimization of reaction rate
- Drives catalytic reactions to new steady states different from equilibrium

Catalytic resonance to improve reaction rate

Researchers at the University of Minnesota have developed a new method for increasing chemical reaction rates by dynamically varying the electronic properties of a catalyst. Specifically, this method involves perturbation of catalyst properties as a function of time to vary the binding energy of one or more of the surface species. By varying the binding energy of substrates - to these surfaces at frequencies in the resonance frequency range, **the reaction rates can be increased from 10x to over a million times faster than conventional catalysts at static conditions.** Heterogeneous catalysts including metals, metal oxides, and microporous materials such as zeolites or metal-organic frameworks (MOFs) can be enhanced in overall activity when operated under such dynamic oscillatory conditions. Chemistries that can be accelerated via dynamic catalysis and oscillatory surface energy include ammonia synthesis, NO_x reduction, hydrogen electrolysis, oxidation of alkanes, dehydration of alcohols to olefins, oxygen reduction, oxygen evolution, and hydrogenation.

Improving performance by dynamically varying binding energy

Heterogeneous catalysis is an integral component of many industrial processes that manufacture food, materials and energy. Performance of catalysts for most industrial processes are limited by a maximum theoretical limit called the Sabatier maximum (also called the "volcano peak"). The dynamic approach discussed here permits catalyst performance as much as a million times faster than this theoretical limit while enhancing selectivity. This method creates a dynamic catalytic active site that changes on the time scale of the turnover frequency of the reaction, evolving over the catalytic cycle, providing an optimal energetic environment for each step and the overall progression of the reaction sequence. In other words, a single active site can be modulated to alternate between ideal characteristics for reactant adsorption, surface reaction, and product desorption.

Phase of Development

TRL: 3-4

Pilot scale demonstration and characterization in lab scale experiments.

Desired Partnerships

This technology is now available for:

- License
- Sponsored research
- Co-development

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Publications

- **The Catalytic Mechanics of Dynamic Surfaces: Stimulating Methods for Promoting Catalytic Resonance.** ACS Catalysis (2020)
- **Catalytic resonance theory: superVolcanoes, catalytic molecular pumps, and oscillatory steady state.** Catalysis Science & Technology (2019)
- **Catalytic resonance theory: parallel reaction pathway control.** Chemical Science (2020)
- **Principles of dynamic heterogeneous catalysis: surface resonance and turnover frequency response.** ACS Catalysis (2019)
- **Resonance-Promoted Formic Acid Oxidation via Dynamic Electrocatalytic Modulation.** ACS Catalysis (2020)

Researchers

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