Energy researchers invent error-free catalysts

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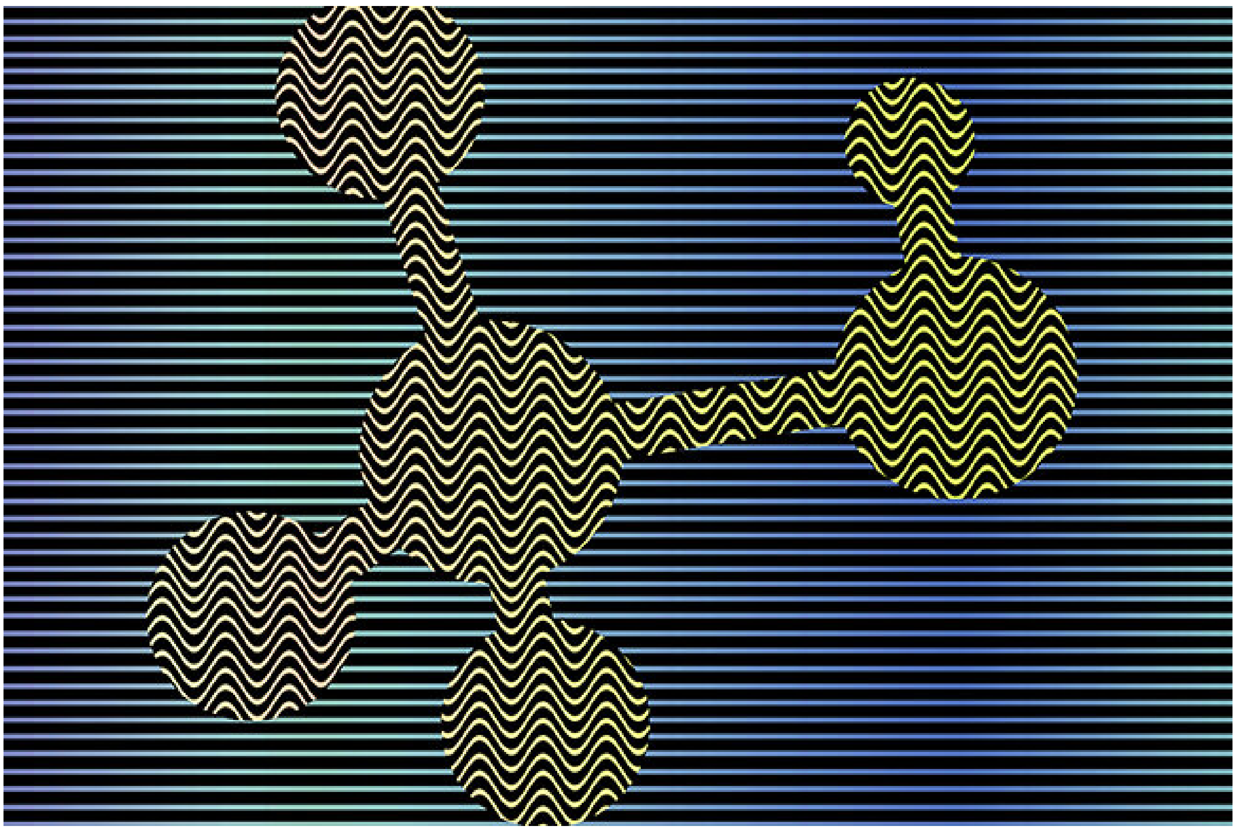

Researchers at the Catalysis Center for Energy Innovation invented catalyst technology that can accelerate chemical reactions using waves. The groundbreaking technology can be incorporated into hundreds of industrial chemical technologies to reduce waste by thousands of tons each year while improving the performance and cost-efficiency of materials production. Credit: Ardagh et al., Catalysis Center for Energy Innovation

A team of researchers from the University of Minnesota, University of Massachusetts Amherst, University of Delaware, and University of California Santa Barbara have invented oscillating catalyst technology that can accelerate chemical reactions without side reactions or chemical errors. The groundbreaking technology can be incorporated into hundreds of industrial chemical technologies to reduce waste by thousands of tons each year while improving the performance and cost-efficiency of materials production.

This research is published in *Chemical Science*, the premiere journal of the Royal Society of Chemistry.

In chemical reactions, scientists use what are called catalysts to speed reactions. A chemical reaction occurring on a catalyst surface such as a metal will accelerate faster than undesirable side reactions. When the primary reaction is much faster than every other side reaction, then the catalyst is good at selecting for the most valuable products. The side reactions are errors in chemistry control, and they result in significant generation of wasted material and economic loss.

Researchers at the Catalysis Center for Energy Innovation funded by the U.S. Department of Energy had a breakthrough when they realized they could design a new class of catalysts that greatly accelerated the primary surface reactions using waves. When the applied wave frequency and amplitude match up with characteristics of the primary chemistry, then that reaction becomes thousands of times faster than all other side reactions. The catalyst at these wave conditions essentially stops making any errors to side products.

"All chemical reactions have natural frequencies, like strings on a piano or a guitar," said Paul Dauenhauer, the lead author of the study and a Professor in the Department of Chemical Engineering and Materials Science in the University of Minnesota's College of Science and

Engineering. "When we find that right frequency of a desired catalytic reaction, then the catalyst becomes almost perfect—the wasteful reactions almost completely stop."

The discovery has particular significance for the production of key chemicals in the energy, materials, food, and medical industries. The most important chemicals are manufactured at massive industrial scale such that even well-developed catalysts form some side products, generating thousands of tons of waste per year.

The researchers were able to broadly explain the relationship between different types of chemistries and the frequencies of surface waves that control catalyst errors.

"A molecule on a surface can go down several energy pathways, but the oscillating catalyst can almost completely control which pathway the molecule selects, including preventing molecules from moving along undesired energy conduits on the catalyst surface," said Alex Ardagh, the first author of the research paper and a postdoctoral research scholar at the University of Minnesota.

The discovery of highly selective, error-free catalysts builds on the previous development of dynamic catalytic theory developed by the same group. Conventional catalysts that exhibit optimal control over catalytic reactions have surface energies specific to a particular chemistry. However, the newer dynamic catalysts that change like a wave, oscillate binding energy between both stronger and weaker than the conventional surface energy.

"The transition from conventional to dynamic catalysts will be as big as the change from direct to alternating current electricity," said Professor Dionisios Vlachos, a professor at the University of Delaware and director of the Catalysis Center for Energy Innovation. "This has the potential to completely change the way we manufacture almost all of our most basic chemicals, materials, and fuels."

More information: Matthew Alexander Ardagh et al, Catalytic Resonance Theory: Parallel Reaction Pathway Control, *Chemical Science* (2020). DOI: 10.1039/C9SC06140A

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