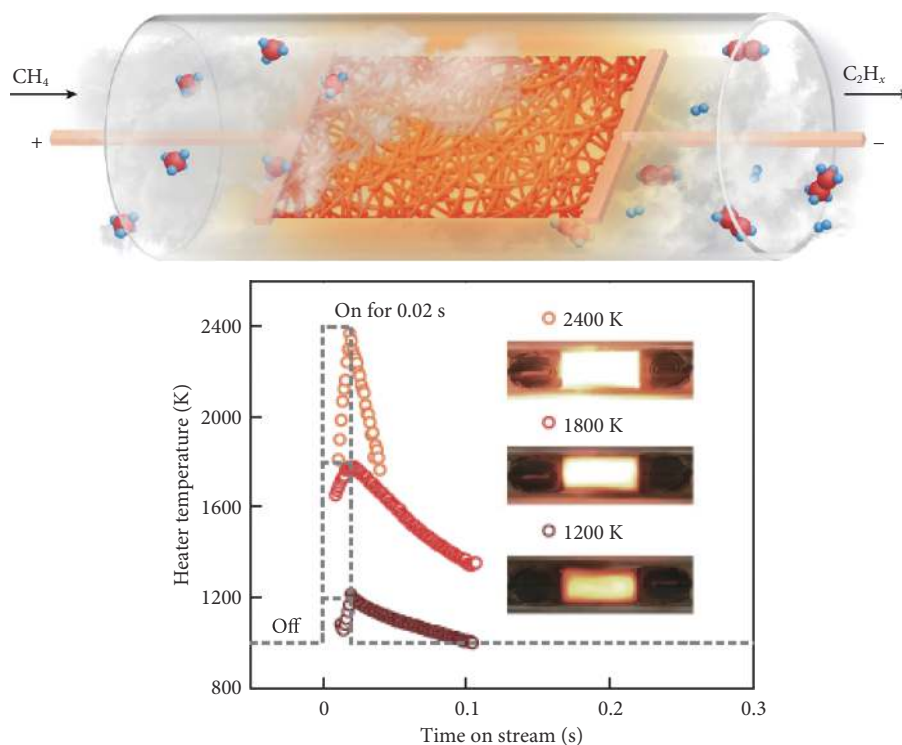


Programmable heating and quenching for non-equilibrium thermochemical synthesis

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Conventional thermochemical syntheses by continuous heating under near equilibrium conditions face critical challenges in improving the synthesis rate, selectivity, catalyst stability and energy efficiency, owing to the lack of temporal control over the reaction temperature and time, and thus the reaction pathways.

As an alternative, Dong with authors from the University of Maryland, University of Delaware, Princeton University, Johns Hopkins University, and Peking University recently presented a non-equilibrium, continuous synthesis technique that uses pulsed heating and quenching (for example, 0.02 s on, 1.08 s off) using a programmable electric current to rapidly switch the reaction between high (for example, up to 2,400 K) and low temperatures. The rapid quenching ensures high selectivity and good catalyst stability, as well as lowers the average temperature to reduce the energy cost. This work has been published in *Nature* 605 (2022) 470–476 as a front cover.



Using CH₄ pyrolysis as a model reaction, the programmable heating and quenching technique leads to high selectivity to value-added C₂ products (>75% versus <35% by the conventional non-catalytic method and versus <60% by most conventional methods using optimized catalysts). The technique can be extended to a range of thermochemical reactions, such as NH₃ synthesis, for which we achieve a stable and high synthesis rate of about 6,000 μmol·g_{Fe}⁻¹·h⁻¹ at ambient pressure for >100 h using a non-

optimized catalyst. This study establishes a new model for highly efficient non-equilibrium thermochemical synthesis.

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