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Doped Zeolite for Tunable Oxygen Separation and Pumping

Background

Oxygen (O2) sorption materials can be used as a means for either producing a low partial pressure of oxygen (PO2) environment for chemical processes or in the production of O2 rich gas (>21 %) from leaner O2 gas streams (O2 composition < 21% down to PO2 < 10 Pa or lower). Oxygen removal and O2 enrichment are critical processes in many industrial applications, such as chemical looping, thermochemical fuel generation, partial oxidation processes such as of methane, and O2 production. Current mechanical oxygen pumping equipment is energy intense and does not provide any separation properties.

Current O2 separation techniques such as cryo-distillation have high cooling energy requirements and do not pump. A recent solution to these problems was the application of bulk materials for chemical-looping-based O2 separation. These bulk materials, such as perovskites, require elevated operating temperatures (>250 °C) to facilitate oxygen exchange with the bulk. Although this has changed the energy form required to drive the process from electricity to heat, the high operating temperatures still incur a large thermodynamic energy penalty compared with operation at room temperature. As such, there is a need for materials to separate and pump O2 with greater efficiency than traditional materials and processes.

Invention Description

Using high-surface-area porous materials and the sorption/desorption process, researchers at Arizona State University have developed doped zeolites to simultaneously separate and pump O2. In the system, O2 adsorbs to the zeolite even at low (1 Pa) pressures, separating the O2 from the surrounding gas, if present. In the second pumping step, the temperature is increased, driving thermal O2 desorption and thus regenerating the material to restart the cycle. The O2 desorption pressure depends on the temperature, meaning that a higher final PO2 can be achieved by increasing the desorption temperature. Conventional zeolites are incapable of performing this action as O2 does not adsorb in its pores. However, zeolite O2 adsorption is enabled by the inclusion of dopants (such as transition metals and semi-metals) with high-energy electron density. The number of dopant sites governs the pumping capacity, while dopant type can be used to engineer desired pumping strength—i.e., the lowest PO2 from which O2 can be extracted—and the temperature and PO2 during release.

Potential Applications

- Oxygen removal and enrichment
- Chemical looping
- Partial oxidation of methane
- Solar hydrogen production

Benefits and Advantages

- Bypasses the high cost and inefficiencies associated with cryogenic distillation and mechanical alternatives
- Achieves oxygen adsorption at low pressures
- Requires much lower operating temperatures compared to perovskite methods
- Dopant selection allows tunability of operating temperatures, pressures, and pumping strength

Related Publication: Substituted ALPO-5 Zeolites as Promising O2 Sorption Pump Materials: A Density Functional Theory Study

Research Homepage of Professor Christopher Muhich