Devising Metal-Organic Framework Technology for Scalable Direct Air Capture of CO2

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Human activity and fossil fuel consumption continue to increase the atmospheric carbon dioxide (CO2) content to extraordinary levels, compounding the greenhouse-gas effect and driving global warming. This poses an urgent need for sustainable technologies that reduce CO2 pollution levels: namely, ones for direct air capture of CO2 from ambient air (DAC). This project aims to scale up, and industrially optimize, the metal-organic framework NbOFFIVE-Ni-1 for use in a novel DAC and utilization system. To accomplish this, new techniques for synthesis and purification of the nanoporous metal-organic framework NbOFFIVE-Ni-1 were employed to elevate its CO2-uptake performance, as reported in the existing literature. Then, the compaction pressure for pelletizing the powdery product into a large-scale, reactor-compatible form was optimized. The integrity of the framework structure was monitored via powder X-ray diffraction, and carbon dioxide adsorption measurements examined the effect on uptake performance after pelletizing. The shape and size of the pellets were then optimized for space-efficiency and surface-area-to-volume ratio. After optimized conditions were found, a two-kilogram reactor-system prototype of NbOFFIVE-Ni-1 was designed and built, and an effective batch-process system for filtering carbon dioxide from polluted atmospheric air was devised. This prototype was then tested for cyclability and adsorption-desorption performance. This validated it as direct air capture technology that is favorable for large-scale implementation, verifying that it will significantly contribute towards carbon-negative solutions and meeting the U.S.'s net zero emissions goal by 2050.

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