Rapid, Room Temperature Synthesis of a Biomass-Derived, Recyclable Copper Metal-Organic Framework Utilizing Automation for CO_2 Capture

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1. Introduction

Atmospheric CO_2 levels are increasing at an alarming rate, and materials to effectively capture CO_2 are crucial. Ideal candidates must have high capacity for CO_2 uptake (>2 mmol/gram of adsorbent) as well as fast sorption kinetics, selectivity, recyclability, thermal stability, all whilst being relatively low cost and fast to produce.[1] Metal-Organic Frameworks (MOFs) are porous materials synthesized from a combination of an inorganic (metal) building block and organic linker which form an extended network structure. MOFs have been shown to be very promising sorbents for CO_2 capture and can meet several of these desired criteria. A particularly groundbreaking example is the zinc-based MOF CALF-20 (CALF = Calgary Framework), which is highly selective for CO_2 even at 40% relative humidity.[2] Oftentimes, the synthesis of MOFs requires toxic chemicals, harsh conditions, and fossil fuel-derived resources, particularly as linkers, in their syntheses. CALF-20 can be prepared using water/methanol or ethanol at scale, which is safer and more environmentally favourable in comparison to other high-performing MOF-based CO_2 sorbents.

Inspired by this work, we aimed to create biomass-derived MOFs[3] to reduce the dependence on petrochemicals using greener synthetic conditions, with the goal of meeting several of the outlined properties for an efficient CO_2 sorbent. Furthermore, to address issues of production, we integrated an automated platform into our discovery to accelerate our MOF synthesis and optimization.

2. Our Approach

We synthesized a novel copper (II) MOF, TORF-1 (TORF = Toronto Framework-1) using a linker containing 100% bio-derived carbon under green synthesis conditions in only 5 minutes. Copper was selected for its abundance and relatively low toxicity compared to many heavy metals commonly used in MOF syntheses.

Utilizing our automated platform, we demonstrated a low-cost, entry-level accessible platform for those wishing to enter the high-throughput experimentation space. We were able to rapidly identify and optimize synthetic conditions for our target MOF (Fig.1).

Our work demonstrates the potential of this workflow to rapidly identify, synthesize and screen numerous MOFs towards CO_2 capture utilizing bio-derived linkers. TORF-1, our preliminary material met our goals achieving a CO_2 capture (~2 mmol/g). Furthermore, our MOF is able to be recycled and reformed rapidly, outlining its promising applications.

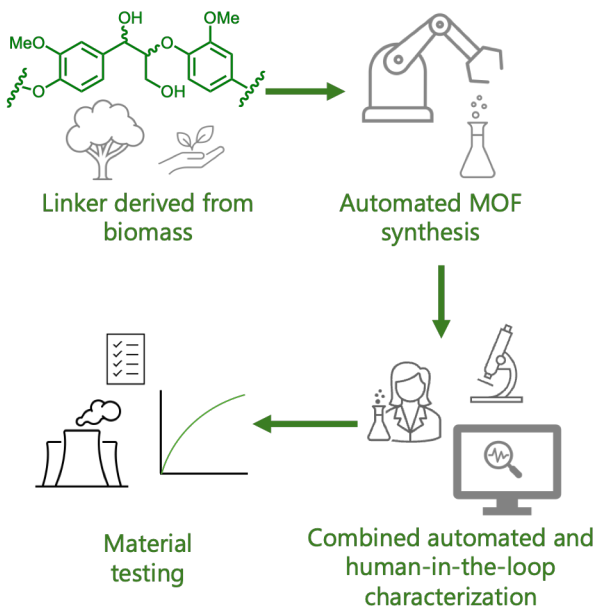

Fig. 1. Workflow for the synthesis of novel biomass-derived metal-organic frameworks.

3. Future Work

We will continue to use this platform to further screen MOFs implementing biomass-derived linkers as well as integrating automated

characterization, and machine learning into the loop to optimize our materials .

References

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