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MOF-based QCM sensor for detecting and discriminating CH_4/CO_2

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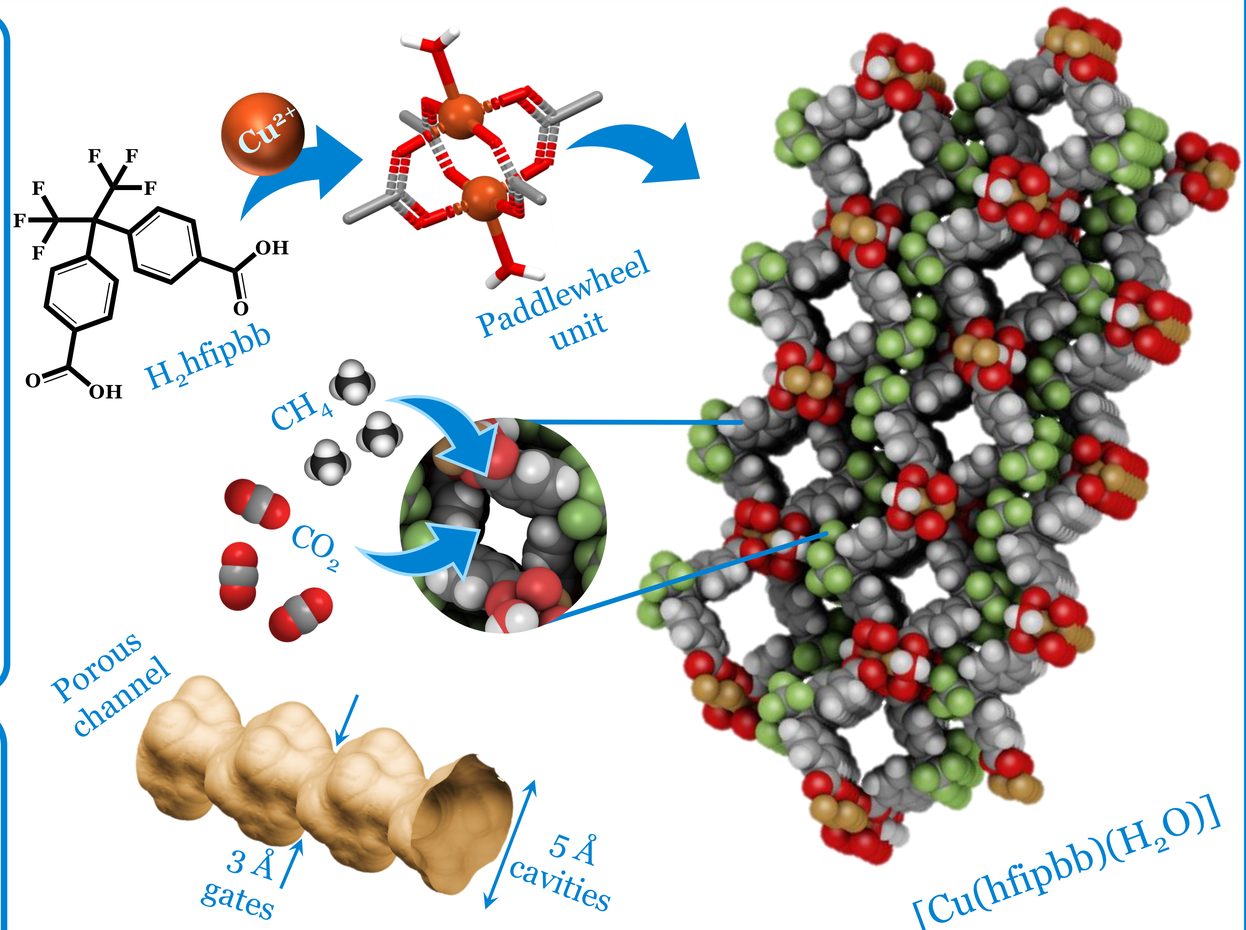
SENSORS & FUNCTIONAL MATERIALS

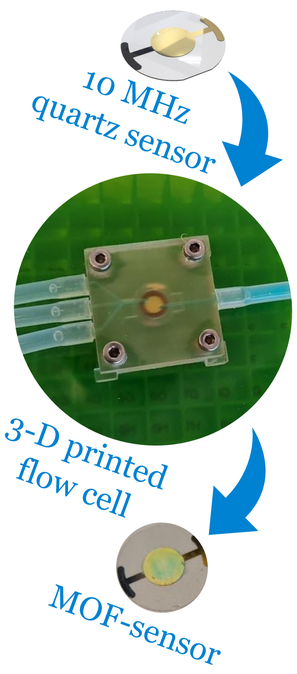
INTRODUCTION

- Among the most overlooked yet urgent environmental concerns is the fugitive emissions of CH_4 and CO_2 from gas pipelines, agriculture sector, wastewater treatment and landfills.[1]
- We have developed a gas sensor based on a metal-organic framework (**MOF**) integrated in a quartz crystal microbalance (**QCM**) as a low-power and cost-effective solution for continuous monitoring of gas leaks.[2]
- [Cu(hfipbb)(H_2O)] is a 2-D MOF with narrow 1-D hydrophobic channels (5Å) connected via smaller gates (3Å) that shows selectivity towards CH4, and CO_2 compared to other atmospheric gases.[3-4]
- Difference in diffusivities of CH_4 and CO_2 into the MOF, enables discrimination based on multiple harmonic response of the QCM.[2]

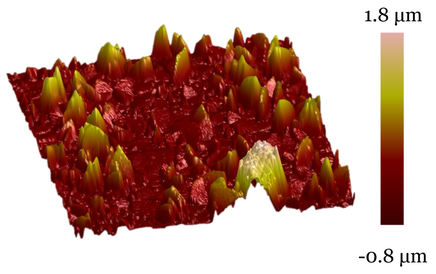


SYNTHESIS

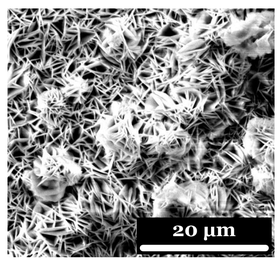
- Thin films of the MOF are directly grown on the gold electrode of 10 MHz quartz resonators via layer-by layer flow synthesis.
- First, a layer of thiol linker (16-mercaptohexadecanoic acid) is dip coated on the gold electrode.
- A peristaltic pump is used to alternate flows of ethanolic solutions of Cu^{2+} and the linker on the sensor in a custom-designed multi-channel flow cell.
- Powder X-ray diffraction confirms that the MOF-sensor film matches the calculated structure.
- Scanning electron microscopy shows disc-like crystals forming clusters.
- Atomic force microscopy shows average roughness features of ~1 µm



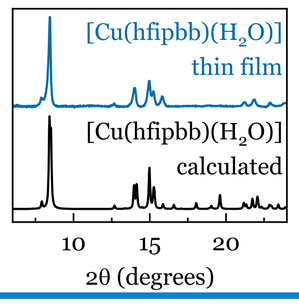
AFM



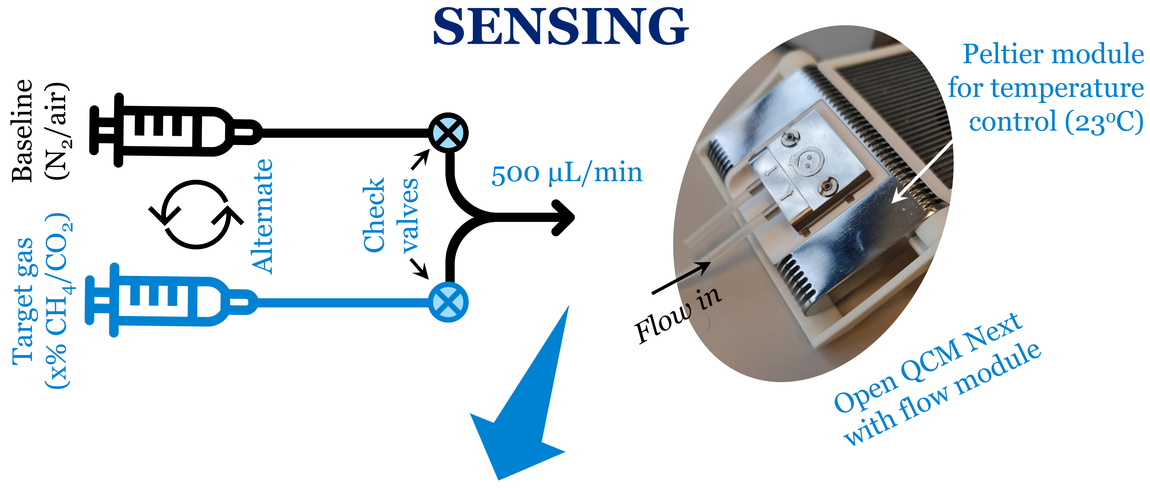
SEM



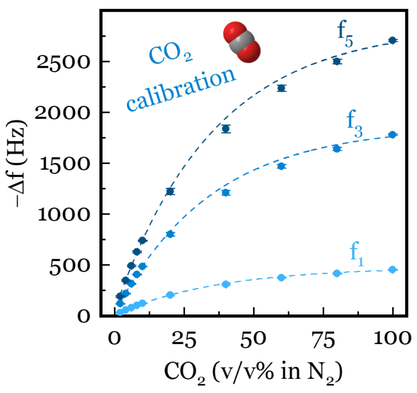
XRD

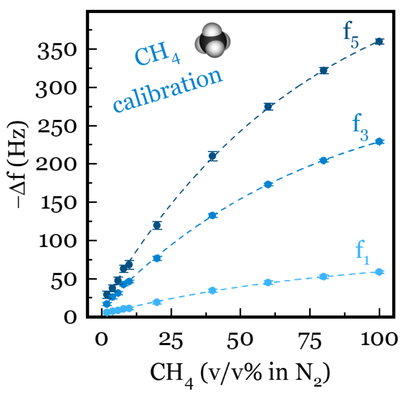


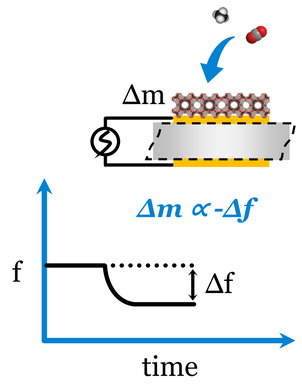
SENSING



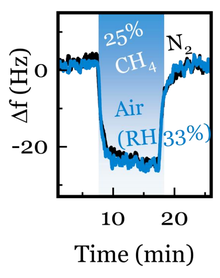
Sensor calibration



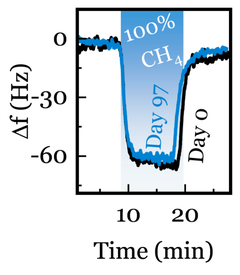




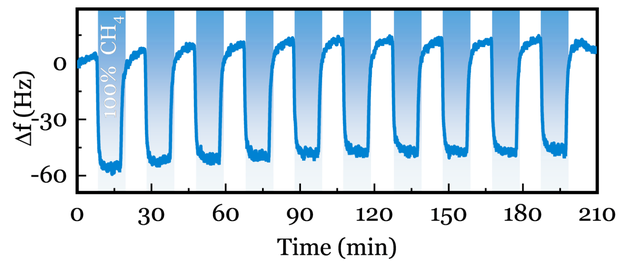
Humidity resistant



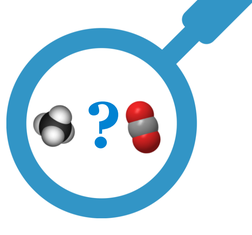
Robust

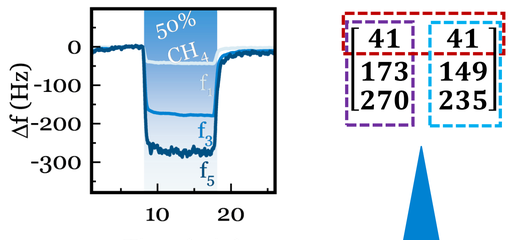


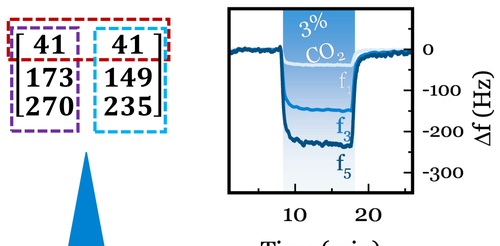
Cycling and regeneration

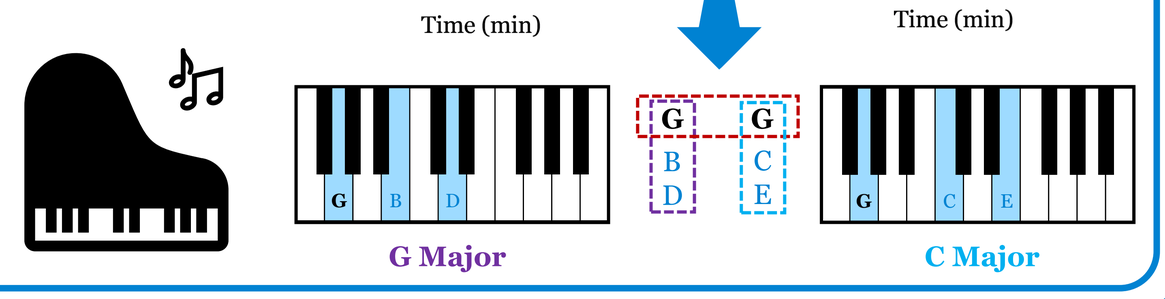


Discrimination









OUTLOOK

- **MOF-based sensor.** Detects a range of concentrations of CH_4 and CO_2 (1-100 v/v% in N_2) with a limit of detection ~0.4%.
- **Analyte discrimination.** Enabled via frequency deviation of multiple harmonics.
- **Practicality.** The sensor shows a regenerative response. It works in air (under various humid conditions) at standard atmospheric conditions.
- **Robustness.** Stable for months when stored at atmospheric conditions.
- **Future work.** Multivariate analysis to quantify responses from CH_4/CO_2 mixtures. Testing new MOFs for this application.

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