Ultra-sensitive gas sensors made from electrochemically synthesised metal-organic frameworks

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1. Introduction

Why do we need high sensitivity gas sensors?

- **Security applications** such as detection of trace explosive vapours in airports [2]
- **Pollution** and greenhouse gas monitoring
- **Medical diagnostics** such as exhaled breath analysers to screen for diseases like diabetes [1]

What are Metal-Organic Frameworks?

Metal-Organic Frameworks, **MOFs**, are typically 3D **porous lattice** structures comprised of metal nodes joined by organic molecules, but we are interested in MOFs that are **2D** and **electrically conductive**.

How do metal-organic frameworks work as gas sensors?

When gases get **trapped** in their **pores**, the **electrical resistance** of a conductive MOF changes. This change can be measured using a simple circuit to form a **sensing response**.

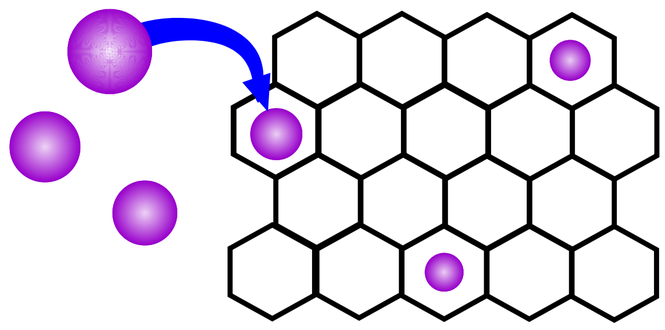
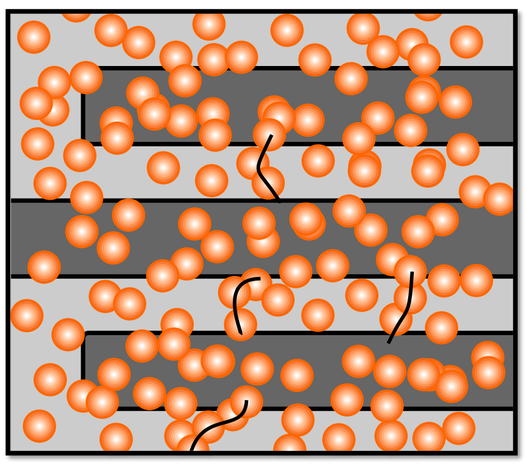
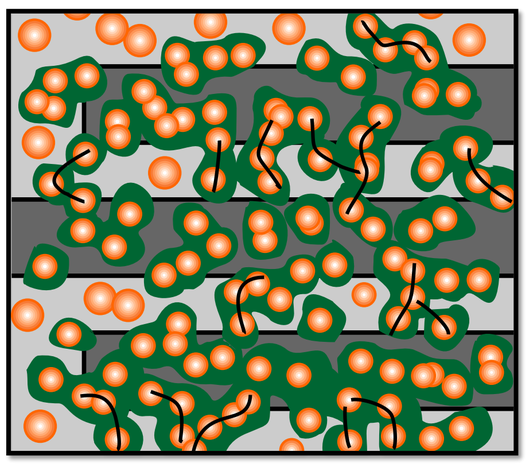


Figure 1: Schematic representation of gas molecules (purple) being trapped in the pores of a 2D framework (black).

2. Novel Synthesis Method

Copper **nanoclusters** are deposited onto a pattern of interdigitated electrodes. Some nanoclusters form bridges across the insulating gaps between electrodes. These bridges are shown as black lines in the right hand diagram.

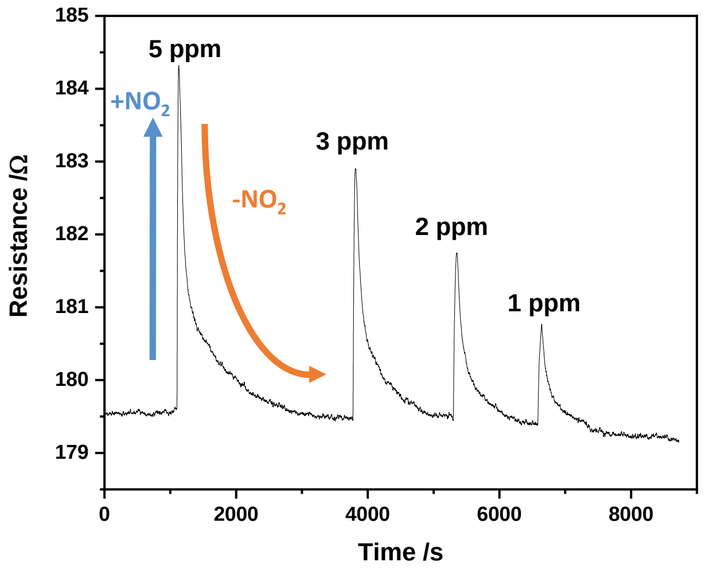




By applying an **electrical potential** and submerging the electrodes in a solution of **organic molecules**, conductive MOFs, (shown in green) grow out from the nanoclusters. This creates new routes for current flow through the MOF.

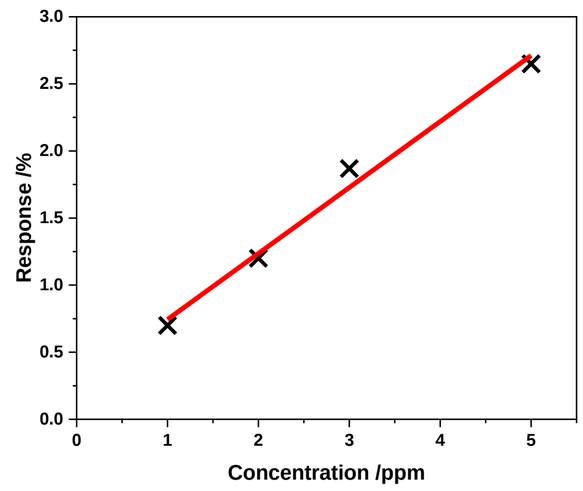
This process forms a ready-to-use **sensor** for ammonia and nitrogen dioxide gases.

3. Results



The resistance of the sensors are measured as they are exposed to parts per billion concentrations of NO_2 gas for 60s.

The sensing responses are reversible and have magnitude proportional to the gas concentration. Extrapolation of the calibration plot (right) can be used to find the limit of detection for the sensor.



The calculated limit of detection for this sensor is 64 ± 5 ppb.

4. Summary

- This new method of electrochemically growing $Cu_3(HHTP)_2$ MOF produces the MOF in-situ on the electrodes required for sensing. The result is a ready-to-use sensor able to detect NO_2 gas in the parts per billion concentration range.
- The method overcomes problems such as the coffee-ring effect and high contact resistance that are encountered with other synthesis methods.

Engineering and Physical Sciences Research Council

1. Andrysiewicz, W. *et al*. *Electron. Mater. Lett.* **16**, 146–155 (2020). 2. Lefferts, M. J. *et al. Analyst.* **146,** 2186-2193 (2021)