1. Hydrogen in aerospace applications

Timeline of hydrogen (H₂) within aerospace:

- 1783 – First hydrogen balloon flight
- 1954 – Hydrogen peroxide Sikorsky Helicopter
- 1966 – Hydrogen batteries in satellite (NTS-2)
- 1988 – First hydrogen aircraft prototype (Tu-155)
- 2011 – EADS/AIRBUS A380 first flight

Conventional storage methods: Compression or liquefaction.
Problem: Low H₂ densities and high investment costs.
Possible Solution: Physisorption onto a porous material.

BUT: Each additional kg sent into space costs ~ $ thousands!

2. Materials

Desired properties of solid adsorbent:
- Light
- Robust
- High surface area
- Large pore volume
- Good cycle life

Metal-organic framework (MOF) chosen for study:

\[ \text{NH}_2\text{-MIL-101(Al)} \] [SBU*: 634.04 g mol⁻¹]

\[ \text{c.f. heavier analogue [1]}: \]

\[ \text{NH}_2\text{-MIL-101(Cr)} \] [SBU*: 712.37 g mol⁻¹]

([*Secondary Building Unit])

Synthesis of \( \text{NH}_2\text{-MIL-101(Al)} \) [2]

3. Characterization of the MOF

Comparison of analogues BET surface areas:

- \( \text{NH}_2\text{-MIL-101(Al)} \) : 2540 m² g⁻¹
- \( \text{NH}_2\text{-MIL-101(Cr)} \) : 1298 m² g⁻¹

Max. hydrogen uptake at 77 K:

- \( \text{NH}_2\text{-MIL-101(Al)} \) : 3.82 wt%
- \( \text{NH}_2\text{-MIL-101(Cr)} \) : 2.66 wt%

Thermogravimetric analysis of \( \text{NH}_2\text{-MIL-101(Al)} \) (ramp rate - 5 °C min⁻¹)

- Indicates guest solvent removal between 80-200 °C.
- Reveals interesting thermal degradation steps.

4. Ongoing work

As seen in the figure below:
- Lighter analogue shows increased H₂ uptake.
- Removal of amine from \( \text{NH}_2\text{-MIL-101(Cr)} \) increases H₂ uptake.
- Potential for even higher uptake from removal of amine from \( \text{NH}_2\text{-MIL-101(Al)} \)?

Comparison of hydrogen excess isotherms for MIL-101 analogues at 77 K

5. Summary

- \( \text{NH}_2\text{-MIL-101(Al)} \) has greater BET surface area and H₂ uptake than the heavier Cr analogue.
- Removal of the NH₂ group from \( \text{NH}_2\text{-MIL-101(Al)} \) may result in very promising hydrogen uptake.
- Good initial results, but more materials need to be studied for potential commercial use.