Can Enzymes Help Address the Climate Crisis?

Humanity is facing a climate crisis, with our fossil fuel consumption driving an unsustainable increase in global temperatures. While electrification can replace many applications of fossil fuels, the chemicals industry requires carbon neutral or even negative feedstocks, and some transport methods such as air travel mean the energy density of a chemical fuel is still required. In the last 30 years electrochemical CO_2 reduction has emerged as an approach to make fuels and chemicals, allowing the potential to remove CO_2 from the atmosphere or prevent its release at source. Nature however beat humanity by millenia, using the calvin cycle to turn CO_2 into biomass.

We can take advantage of nature's hard work by using enzymes as catalysts in semi-artificial systems, combining these uniquely performing catalysts with state-of-the-art porous electrode materials to directly reduce CO_2 to value added products such as formic acid using renewable energy. The selectivity and activity of enzymes means they are ideal model catalysts that can guide the design of synthetic systems. However, they must be in an environment that is close to their optimal to operate efficiently, with small changes in properties such as pH drastically affecting their activity. By optimising their local environment using finite element modelling, the rates of fuel formation can be drastically (>18×) increased.[1] This talk will also discuss the crucial role of CO_2 hydration kinetics on the local pH and CO_2 concentration using the enzyme Carbonic Anhydrase co-immobilised with Formate Dehydrogenase[2] and how this contrasts with more common heterogeneous CO_2 reduction which does not possess the unique properties of enzymes. Finally I will demonstrate how this approach can be extended to low CO_2 concentrations, taking inspiration from the natural carboxysome to develop a system where Formate Dehydrogenase and Carbonic Anhydrase are co-immobilised in a nanoconfined structure to improve low CO_2 concentration utilisation(fig. 1),[3] learning from nature to improve our ability to convert CO_2 into valuable fuels and chemicals

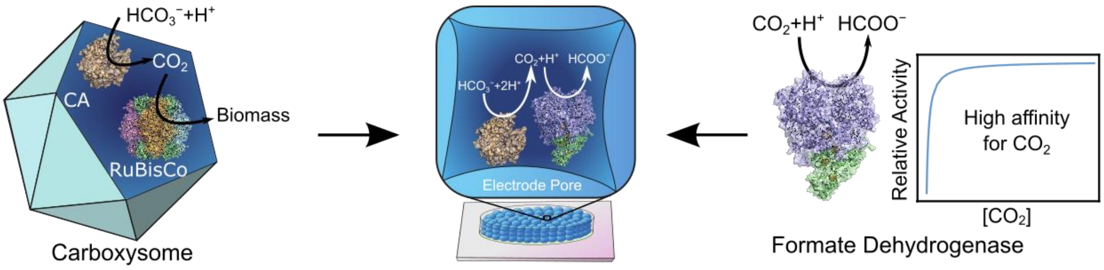

Figure 1: *Carboxysome inspired utilisation of low CO_2 concentrations*

References

[1] E. E. Moore, S. J. Cobb et al., *Proc. Natl. Acad. Sci. USA* **2022**,*119,* e2114097119
[2] S. J. Cobb et al., *Nat. Chem.* **2022**, *14,* 417 – 424
[3] S. J. Cobb et al., Angew. Chem. Int. Ed.,**2023** *e202218782*