

Change is in the air

Converting carbon dioxide to more useful — and less harmful — chemicals is a key challenge of our time, and one in which catalysis needs to play a key role.

Converting carbon dioxide into useful chemicals is intuitively attractive not just as a new source of fuels and raw materials, but also as a means of reducing carbon emissions. Unfortunately, it is a challenging process. The energetics of CO₂ reduction can make it difficult to render the procedure economical and, indeed, the process can often become a net carbon producer. In addition to the high energy inputs required, the limited range of products that can be easily accessed and the difficulty in achieving product selectivity are both major hurdles that need to be overcome.

But the opportunities are also great. While the more developed carbon capture and storage (CCS) technologies do promise carbon mitigation on larger scales, they require suitable sites for sequestration and are, by definition, limited to CO₂ storage. CO₂ utilization on the other hand allows for the valorization of a waste resource through the production of fuels, plastics and other organic materials. Additionally, CO₂ utilization can be seen as a possible solution for storing local excesses of electricity caused by variations in supply and demand. Of course, all this assumes the availability of sufficient carbon-free energy, but that is a discussion for another time.

Included in this issue of *Nature Catalysis* you will find some exciting work focusing on the theme of carbon dioxide reduction. Edward Sargent and colleagues report the electrocatalytic production of ethylene from CO₂ using a copper catalyst produced by electro-redeposition. As a precursor to polyethylene, a low-cost route to ethylene that avoids the use of fossil resources is certainly a worthy goal. The results presented show high selectivity for ethylene over other gaseous C₁ products,

which is important in order to avoid costly separations of gaseous mixtures. Insights into the process are just as important, and the use of in situ soft X-ray absorption spectroscopy (in collaboration with the Canadian Light Source) to track the oxidation state of the copper catalyst is one of the highlights of this work.

Included in this issue of *Nature Catalysis* you will find some exciting work focusing on the theme of carbon dioxide reduction.

In a separate report, Haotian Wang, Karen Chan and co-workers also look at copper catalysts for CO₂ electroreduction. In this case, the authors focus on the factors that lead to the formation of new carbon-carbon bonds during the electrocatalytic process. Theory leads them to predict which facets will best achieve the coupling of two bound *CO intermediates — that is, surfaces where the *CO binding is strong enough to allow a sufficient concentration of *CO species to build to increase the likelihood of C-C coupling, but not so strong as to prevent further reaction. An ion cycling method allows the authors to convert copper foil into nanocubes with such facets exposed. And, as visually represented on this month's cover, these cubes do indeed encourage C-C coupling and give excellent selectivity of C₂₊ products.

A different approach to CO₂ reduction is reported by Bert Weckhuysen and co-workers. Hydrogenation of CO₂ is another means to convert CO₂ to more valuable products, and in their work the authors study the hydrogenation to methane

over supported nickel nanoparticles in great detail. A combination of careful synthesis of nanoparticles of a range of sizes and painstaking in situ characterization sheds light on the mechanism of this important process, and shows how the structure sensitivity/particle size controls the mechanism and outcomes of this reaction. The authors propose that these insights could lead to renewed interest in nickel as a Fischer-Tropsch catalyst.

Last, while on this topic, it is worth revisiting some CO₂ valorization work that appeared in our first issue. Guenther Schmid and colleagues showed the efficient electrocatalytic synthesis of carbon monoxide and hydrogen from CO₂ and water, combined with a subsequent fermentation step to convert this mixture into butanol and hexanol (*Nat. Catal.* **1**, 32–39; 2018). Importantly, the system was stable and the cost of products was competitive with commercial sources. It has recently been announced that this work will form the basis of an initial two-year collaboration between Siemens and Evonik on the electrochemical and microbial conversion of CO₂ into alcohols, with a test plant expected in 2021 (www.siemens.com/press/PR2018010135COEN). This vividly demonstrates how fast the field is moving, and how advanced it has become. Not least due to pressing societal needs, the jump from the lab to market has never been smaller.

Many challenges lie ahead, not only technical but also economic. However, with the continuing advances in mechanistic understanding, performance and economics it certainly feels as if a change is in the air. □

Published online: 7 February 2018
<https://doi.org/10.1038/s41929-018-0033-5>