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Published in:
Book of Abstracts. DTU's Sustain Conference 2015

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Acetaldehyde as an intermediate in the electroreduction of carbon monoxide to ethanol on oxide-derived copper

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With implementation of more intermittent renewable energy sources, such as wind and solar power, efficient energy storage technologies need to be developed. In addition, alternative energy carriers to fossil fuels need to be found in order to decrease emission of CO_2 from the transport sector. A highly promising means of doing so would be to hydrogenate CO_2 via electrolysis into fuels, such as methanol or ethanol; as such, it would constitute a carbon-neutral energy carrier.[1] Carbon dioxide could be captured from point sources, such as fossil fuel power plants or by burning biomass.[1] In order to make CO_2 electroreduction feasible for implementation in real devices, an efficient and stable catalyst exhibiting selectivity towards few, preferably liquid, compounds is required. Such a material is yet to be discovered; even so, the field is relatively unexplored. In particular, recent studies have shown that the performance of CO_2 reduction catalysts, in particular copper, can be greatly enhanced by nanostructuring.[2–4]

Our group recently carried out a study on CO reduction on oxide-derived copper (OD-Cu), showing that acetaldehyde is an intermediate product, yielding mechanistic information about the reaction.[5] This compound has not been previously reported for this reaction on OD-Cu, even though it is present in moderate amounts (produced with a Faradaic efficiency of ~5 % at -0.3 V vs. RHE). The reason for this lies within the product detection. It is undetectable in routine NMR spectroscopy measurements, the method-of-choice for many groups in the field, but can be easily detected using headspace-gas chromatography. We hypothesise that the reason for this is that it agglomerates and polymerizes, leading to line broadening in NMR spectra, and precipitation out of solution.

The knowledge that ethanol is produced through acetaldehyde provides us with valuable mechanistic information. Moreover, acetaldehyde is a valuable chemical in its own right. Future work will aim to determine how the catalyst can be engineered to exclusively produce acetaldehyde or ethanol at high kinetic rates with minimal potential losses.

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