

Carbon Dioxide Activation Center 2018 - HIGHLIGHTS

About the center

The Carbon Dioxide Activation Center (CADIAC) was established in 2015 by Prof. Troels Skrydstrup and Prof. Kim Daasbjerg at Aarhus University in collaboration with two outstanding international groups headed by Prof. Melanie Sanford at the University of Michigan, USA, and Prof. Matthias Beller at the Leibniz Institute for Catalysis, Germany. Two younger associates, Assoc. Prof. Nina Lock and Assoc. Prof. Anders T. Lindhardt, are also part of the research activities. The goal of the research center is to explore new methods for the activation of carbon dioxide eventually providing sustainable solutions for the exploitation of this molecule as a valuable reagent to high-value chemicals of industrial importance. The highlights of the published work from CADIAC for the year 2018 and start of 2019 are described below.

Single copper sites enhance the activity of nitrogen-doped carbon for CO₂ reduction

Copper is an important Earth-abundant transition metal, which has shown the ability to convert CO₂ into a variety of carbonaceous products but, unfortunately, at low selectivity. Downsizing Cu metal to single copper sites may result in improved activity for CO₂ reduction, but this has not been well studied yet. In a work to be submitted, CADIAC scientists have demonstrated that incorporation of single copper sites significantly enhances the activity of nitrogen-doped carbon for CO₂-to-CO conversion in aqueous medium, and it occurs with a high selectivity at a low overpotential.^[1] Experimental characterization and density functional theory calculations have been performed to identify the configurations of the active single copper sites. Most surprisingly, the origin of the activity enhancement could be assigned to a Cu(III) species coordinated to two nitrogen and two carbon atoms in a *cis*-configuration.

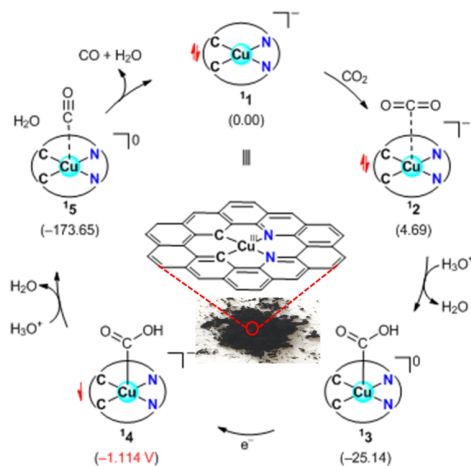


Figure 1: Computed CO₂ reduction mechanism using single copper catalyst in a carbon matrix.

Applying CO₂ for Carbon Labeling of Aliphatic Amides

In a recent study published in *Chemistry, A European Journal*, CADIAC members report on a new late-stage carbon isotope-labeling technique, which exploits CO₂ as the origin of the isotope label. Carboxamides represent an important chemical constituent of many pharmaceutically active compounds and therefore they represent a logical target for isotope labeling. However, attempts to exploit previous techniques for the isotope-labeling of benzamides with aryl-palladium complexes to aliphatic amides resulted in fast β -hydride elimination when the corresponding alkyl-Pd complexes were prepared. As such, the CADIAC scientists developed a new class of pincer nickel complexes, which proved successful for the desired purpose.^[2] The corresponding Ni(II)-alkyl complex underwent fast insertion

with ¹³C-labeled carbon monoxide generated from ¹³C-SilaCOgen, itself formed from ¹³C-carbon dioxide. Subsequent introduction of an amine then provided the corresponding carbon isotope-labeled amide in good yields. Particularly exciting is the possibility to exploit this technique for the isotope-labeling of peptides and proteins which will be a future objective of this project.

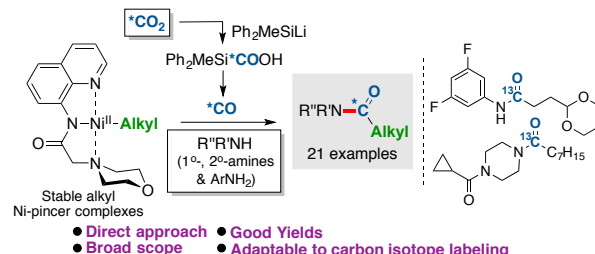


Figure 2: An approach to the carbon isotope-labeling of aliphatic carboxamides exploiting carbon dioxide.

Transformation of Carboxylic Acids to Biaryls

One of the many exciting spin-off projects coming from CADIAC chemists was published in *Nature* in 2018 from the Sanford group. In this work, carboxylic acids were transformed to acid fluorides, which in turn were exploited for base/fluoride-free Suzuki couplings for the effective generation of biaryls.^[3] Such structural motifs are of high interest for the pharmaceutical industry for drug development programs. Particularly remarkable in this work is the mildness of the reaction conditions.

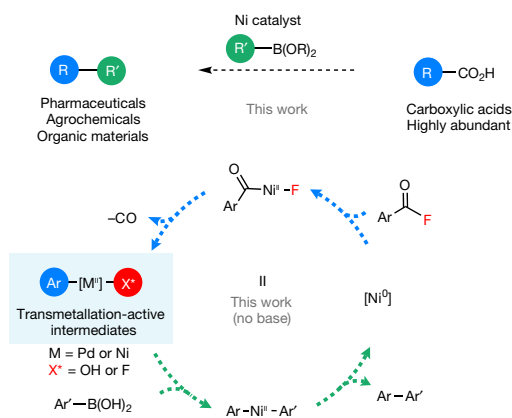


Figure 3: The development of a new catalytic protocol for the Ni-catalyzed cross coupling of aryl carboxylic fluorides with aryl boronic acids.

References

- [1] Hu, X.-M.; Sundararajan, M.; Hval, H. H.; Pudasaini, B.; Dalgaard, K. J.; Welter, E.; Bremholm, M.; Pedersen, S. U.; Skrydstrup, T.; Baik, M.-H.; Daasbjerg, K. Single Copper Sites Enhance the Activity of Nitrogen-Doped Carbon for Electrochemical CO₂ Reduction. *Manuscript submitted*.
- [2] K. T. Neumann, A. S. Donslund, T. L. Andersen, D. U. Nielsen, and T. Skrydstrup, "Synthesis of Aliphatic Carboxamides Mediated by Nickel NN₂-Pincer Complexes and Adaptation to Carbon-Isotope Labeling" *Chem. Eur. J.* **2018**, 56, 14946.
- [3] C. A. Malapit, R. Bour, C. E. Bringham, and M. S. Sanford, "Base-free nickel-catalysed decarbonylative Suzuki-Miyaura coupling of acid fluorides", *Nature* **2018**, 563, 100.