University of Southampton Partner Portrait

CO_2EXIDE – CO_2-based electrosynthesis of ethylene oxide

Partner portrait and research highlights

Click here to view the CO2EXIDE SOTON's partner film

Within the EU-funded H2020 CO_2EXIDE project, the University of Southampton (SOTON) is responsible for the design of the electrocatalysts for the carbon dioxide reduction reaction to ethylene, and for the water oxidation reaction to hydrogen peroxide. The University of Southampton is additionally spearheading the optimisation of the operating conditions for electrolysis and enhancing the overall stability of the proposed electrocatalysts.

The SOTON CO_2EXIDE research team is comprised of the following individuals:

Principle Investigator: Prof Carlos Ponce de León, Head of the Energy Technology Research Group (ETRG), Faculty of Engineering and Physical Sciences

Principle Investigator: Prof Ling Wang, Head of the national Centre for Advanced Tribology at Southampton (nCATS), Faculty of Engineering and Physical Sciences

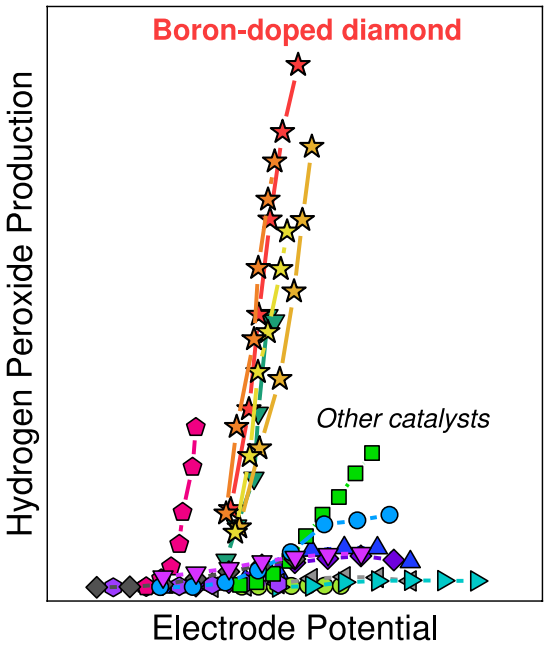
Electrochemical CO_2 reduction catalyst fabrication: Prof Pui Ki Leung

Electrochemical CO_2 reduction measurements Dr Samuel C. Perry; Prof Pui Ki Leung

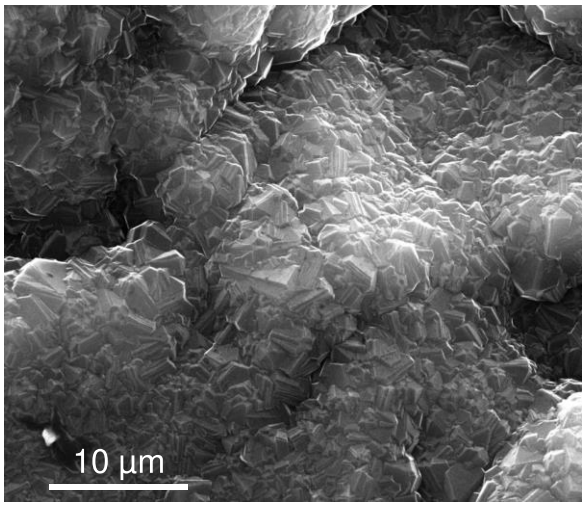
Electrochemical H_2O oxidation measurements: Sotirios Mavrikis (PhD-student)

Additional research assistance by more than ten undergraduate and graduate engineering students at SOTON.

Research Results



Surface of boron-doped diamond



Performance of tailored boron-doped diamond (BDD) microfilms introduced by SOTON compared to other reported electrocatalysts in the literature for the WOR to produce H_2O_2

SOTON has successfully carried out studies on the carbon dioxide reduction reaction (CO_2RR) to produce ethylene (C_2H_4) using hydrophobic coatings on the copper-based cathodes that can increase the efficiency of the CO_2RR, while also stabilising the electrode for improved conversion over time. Indeed, the cathodes loaded with a small amount of the hydrophobic particles (0.01 mg cm^{-2}) recorded a 2.5-fold increase in the efficiency of the reaction, reaching a peak value of approximately 50%.

For the water oxidation reaction (WOR) to generate hydrogen peroxide (H_2O_2), SOTON is using boron-doped diamond (BDD) as a productive and stable catalyst material. By modifying the BDD microfilms in close collaboration with the Friedrich–Alexander University Erlangen–Nürnberg, and enhancing the carbonate (K_2CO_3) supporting electrolyte, SOTON has achieved the highest H_2O_2 production rates to date for the WOR (**see image above**).

SOTON's research accomplishments and contributions to the CO_2EXIDE project have led to numerous peer-reviewed publications, a list of which can be found below.

- Review Article: "*Electrochemical synthesis of hydrogen peroxide from water and oxygen*", **2019**, published in Nature Reviews Chemistry, https://doi.org/10.1038/s41570-019-0110-6
- Research Article: "*Boron-Doped Diamond Electrocatalyst for Enhanced Anodic H_2O_2 Production*", **2020**, published in ACS Applied Energy Materials, https://doi.org/10.1021/acsaem.0c00093
- Review Article: "*Developments on carbon dioxide reduction: Their promise, achievements, and challenges*", **2020**, published in Current Opinion in Electrochemistry, https://doi.org/10.1016/j.coelec.2020.04.014
- Research Article: "*Polymers with intrinsic microporosity (PIMs) for targeted CO_2 reduction to ethylene*", **2020**, published in Chemosphere, https://doi.org/10.1016/j.chemosphere.2020.125993

- Review Article: "*Recent Advances in Electrochemical Water Oxidation to Produce Hydrogen Peroxide: A Mechanistic Perspective*", **2020**, published in ACS Sustainable Chemistry and Engineering, https://doi.org/10.1021/acssuschemeng.0c07263
- Research Article: "Hydrophobic thiol coatings to facilitate a triphasic interface for carbon dioxide reduction to ethylene at gas diffusion electrodes", **2021**, published in Faraday Discussions, https://doi.org/10.1039/D0FD00133C
- Research Article: "*Effective Hydrogen Peroxide Production from Electrochemical Water Oxidation*", **2021**, published in ACS Energy Letters, https://doi.org/10.1021/acsenergylett.1c00904

SOTON will continue to develop copper-based gas diffusion electrodes with hydrophobic layers to further improve the efficiency of the CO_2 reduction reaction to produce C_2H_4. SOTON will also dive deeper into the coating properties of BDD, and the influence of aqueous K_2CO_3 solutions on the WOR, to optimise the operating conditions for H_2O_2 electrosynthesis in the demonstrator unit for ethylene oxide (C_2H_4O) production, that will be assembled at AGH University of Science and Technology in Krákow, Poland.

The University of Southampton (SOTON), one of the leading universities in Britain, was founded in 1952 and is a member of the prestigious Russell Group of UK Universities and the World Universities Network (WUN), comprising 19 research-intensive institutions spanning 6 continents. WUN-led activities, much collaborative research takes place with research-led academic institutions and commercial organizations across Europe, the USA and the rest of the world.

The Energy Technology Research Group (ETRG) is a multidisciplinary team engaged in cutting-edge technologies and their mainstream applications. Our activities are supported by world class computing and experimental facilities. Research Areas Facilities: Fuel cells and redox flow batteries, Batteries and Energy Storage systems, Clean Combustion Technology, CFD modelling, CO_2 sequestration, Vehicle Dynamics and Control, Hybrid and Electric Vehicles, Enhanced Oil & Gas Recovery, Materials, Tribology and Surface Engineering, Nanostructured Materials for Energy Applications, Cryogenics and Superconductivity.

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