

Breaking the bottlenecks in electrochemical ammonia synthesis

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Ammonia underpins global food production and is gaining prominence as a carbon-free energy carrier, yet its industrial manufacture via the Haber–Bosch process accounts for roughly one per cent of global CO₂ emissions. An electrochemical alternative operating at ambient temperature and pressure could decentralise production, reduce energy demand and align ammonia synthesis with renewable electricity supply.^[1,2]

Herein I will provide a personal account of recent progress and remaining challenges in electrochemical nitrogen reduction. To date, among solid electrodes, only lithium- and calcium-based systems in organic electrolytes have been unequivocally demonstrated to reduce nitrogen to ammonia.^[3,4] However, the current performance of these systems leaves considerable room for improvement.

To address this challenge, our research employs a multidisciplinary approach combining electrochemical methods, cryo-electron microscopy, infrared spectroscopy, electrochemical mass spectrometry, time-of-flight secondary ion mass spectrometry (TOF-SIMS), X-ray photoelectron spectroscopy (XPS), surface enhanced infrared absorption spectroscopy (SEIRAS), and density functional theory (DFT).

We elucidated the roles of various components in the process, including the choice of cations, salts, electrolytes, proton donors electrode structure and composition.^[5-9] Building on this understanding, we propose pathways to achieve improved performance.

Bio:

Ifan Stephens is a Professor of Electrochemistry at Imperial College London. His research focuses on enabling large-scale electrochemical energy conversion for fuels and chemicals, key to the energy transition.

He has published extensively on oxygen evolution, CO₂ reduction, nitrogen reduction, and battery degradation. His work on H₂O₂ electrosynthesis led to the HPNow spinout, which he co-founded. His awards include the MIT Peabody Visiting Associate Professorship (2015), ERC Consolidator Grant (2021-2025), RSC John Jeyes Award (2021), Clarivate Highly Cited Researcher (2022–present), and RSC Geoffrey Barker Medal (2024).

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