



Arthur Shih
Postdoctoral Fellow
Northwestern University

Electrifying Ammonia Synthesis

Monday July 10th

Lecture 4:00-5:00 p.m. | Physics/Astronomy
Auditorium (PAA) A110

Reception 5:00-6:00 p.m. | Benson Hall Lobby



Bio

Dr. Arthur Shih (he/him) grew up surrounded by diesel engines and farmland – in Indiana at the overlap of the rust and corn belts. He is passionate about developing clean technologies for the economic production and transport of chemicals and energy. As a postdoctoral scholar at Northwestern University in Sossina M. Haile's group, his research is focused on electrifying ammonia synthesis. Previously, he studied water electrolysis with Marc T.M. Koper at Leiden University and the reduction of toxic NO_x emissions from diesel engines with Fabio H. Ribeiro at Purdue University. Throughout his career, he has co-organized several sessions at AIChE and is currently on the editorial board for the Department of Energy's Frontiers in Energy Research Newsletter. As an educator, Arthur strives to eliminate barriers to learning. During his undergraduate at the University of Michigan, he worked with H. Scott Fogler on interactive modules for web version of the textbook Elements of Chemical Reaction Engineering. At Northwestern University, he is active in a learning community through the Inclusive STEM Teaching Project. He is also a co-organizer of the Context, Connections, and Community Symposium (C3S), an initiative by the Northwestern ChBE Anti-Racism Diversity, Equity and Inclusion (ARDEI) Committee to highlight the impactful research of scholars from historically excluded backgrounds to an audience of local companies and organizations. As a fun aside, his favorite molecule is ethanol because it looks like a dog.

Abstract

Ammonia (NH₃) is a critical global resource for fertilizers and chemical intermediates and can also serve as an easily transported hydrogen vector in support of a green hydrogen economy. An electrochemically driven process generates high chemical potential of reactant species allowing us to circumvent pressurization of the system. Thus, electrochemical NH₃ synthesis would reduce capital costs, decrease energy consumption, and enable NH₃ synthesis at smaller scales than the incumbent high-pressure approach (the Haber-Bosch process).

Intermediate-temperature ($T \sim 250^\circ\text{C}$) systems are advantageous over low-temperature aqueous ($T < 80^\circ\text{C}$) and high-temperature solid oxide ($T > 600^\circ\text{C}$) systems as it confers faster reaction kinetics than low-temperature systems and preserves more favorable thermodynamic conversions than high-temperature systems. Cesium dihydrogen phosphate (CsH₂PO₄) solid acids is our electrolyte of choice since they can readily conduct protons at 250°C. Thus, we fabricated electrochemical reactors with molybdenum oxynitride at the cathode and platinum nanoparticle catalysts at the anode, separated by a CsH₂PO₄ electrolyte layer. As expected, NH₃ is produced at the cathode and no NH₃ is produced at the anode. We also find that NH₃ is produced at almost the same rate in the absence of N₂, indicating that molybdenum oxynitrides do not readily utilize N atoms from N₂, but rather from lattice N. Insights from these results serve as a starting point to devise strategies to further utilize the benefits of solid acid electrolytes for intermediate-temperature electrochemical ammonia synthesis.

