NGenE
NEXT GENERATION ELECTROCHEMISTRY
Pioneering research. Originality required.

Next Generation Electrochemistry (NGenE)
Program Summaries

NGenE 2022 group photo II University of Illinois Chicago

7th Program l 2022

presented by University of Illinois at Chicago — Jordi Cabana, Director; George Crabtree, Supporting Director

sponsored by Bio-Logic USA, Gamry Instruments, National Science Foundation
endorsed by The Electrochemical Society (ECS), Materials Research Society (MRS)

The 7th edition of Next Generation Electrochemistry (NGenE) took place at the University of Illinois at Chicago (UIC), June 6-10, 2022. The meeting was held in person for the first time since 2019, after two years of online programming due to the COVID-19 pandemic. 35 advanced graduate students and postdocs and 10 world-renowned experts gathered to discuss the research frontiers in electrochemistry. Our participants joined us from institutions from all over the United States and showcased the growing diversity of our scientific community.

NGenE 2022 was dedicated to the theme *"Electrochemistry for Decarbonization"*.

> *With the aim of arresting the global rise of temperature rise to well below 2°C above pre-industrial levels, decarbonization of all economic sectors by 2050 has become an international goal. This goal requires a suite of technologies for residential grids or transportation and comparably more demanding sectors, such as manufacturing of commodity chemicals or recycling. A stretch goal would be to reach "negative emissions" through capturing and valorizing carbon dioxide already existing in the atmosphere.*
>
> *With the sustained declines in the cost of renewable energy sources, electricity is poised to become sustainable and free of emissions by sidelining the combustion of fossil fuels. This transition unlocks compelling paths where many chemical processes are electrified. Batteries can shift electricity in space for transportation and in time to bridge gaps in supply and demand for the electricity grid and end-users such as buildings. Electrochemistry could replace thermochemistry driven by fossil heat with efficient processes driven by modest voltages at ambient conditions. A poster child is the industrial production of hydrogen via water electrolysis. Green hydrogen could itself become a carbon-free chemical energy carrier to replace hydrocarbons. It is now conceivable that electrochemistry could provide solutions for the industrial production of substances as varied as ammonia, iron and steel, cement, and even plastics, among other products. The program assumes baseline knowledge and prior experience in electrochemistry. NGenE does not ask, "What is electrochemistry?" but instead, "What will electrochemistry become?"*

Lectures by the NGenE faculty provided a high-level overview of the current body of knowledge, which they used to highlight critical gaps preventing transformative advances. They were structured as to promote vigorous discussion driven by the participants, who gladly obliged. The specific focus spanned different applications of electrochemistry targeting the wholesale reduction of emissions, such as direct conversion of CO_2, new technologies with low carbon intensity and the water-energy nexus. The lectures also discussed the most modern approaches to understand electrochemistry, including cutting-edge instrumentation, the rising tide of machine learning and both operando and automated experimentation. The lectures were complemented with a demonstration of cutting-edge tools of *in situ* electron microscopy at UIC.

Grouped in teams, the students were tasked to develop a document and a presentation laying out what they perceived as the most crucial question facing future generations of electrochemists. NGenE pursues training goals beyond pure science, so the group exercise was structured as an opportunity to practice soft skills to distill and communicate important concepts. During the week, the participants were able to network through a combination of social events, a poster session and a discussion of careers in

electrochemistry with electrochemists in different paths, which included NGenE alumni. One of the social events was hosted by the newly created Mid-America Section of the ECS.

Faculty: Kamila Magdalena Wiaderek (Argonne National Lab), Joaquin Rodriguez Lopez (University of Illinois Urbana-Champaign), Brian Ingram (Argonne National Lab), Marta Hatzell (Georgia Tech), Iryna Zenyuk (University of California-Irvine), George Crabtree (UIC/Argonne National Lab), Rajeev Surendran Assary (Argonne National Lab), Papa Pietro (Argonne National Lab), Robert Klie (University of Illinois Chicago), Venkat Srinivasan (Argonne National Lab)

6th Program l 2021

presented by University of Illinois at Chicago — Jordi Cabana, Director; George Crabtree, Supporting Director

sponsored by Bio-Logic USA, Gamry Instruments, National Science Foundation
endorsed by The Electrochemical Society (ECS)

Due to the Coronavirus pandemic, Next Generation Electrochemistry went digital in 2021 and was open to anyone worldwide. Panels featuring electrochemists around the world convened on Zoom with select students admitted directly into the room to engage with presenters.

Inescapable: The Growing Role of Electrochemistry in Society

Recent years have witnessed a boom in research areas leveraging electrochemistry for diverse uses and applications. The sixth annual Next Generational Electrochemistry Workshop—NGenE 2021—showcases the stunning breadth of topics that now depend on advances in electrochemical knowledge. Simultaneously, NGenE 2021 highlights how many unresolved questions cut across possible applications, meaning that progress at a fundamental level can have a widespread technological and social impact.

The abbreviated program was held June 14-16 and resulted in a published paper, „NGenE 2021: Electrochemistry Is Everywhere" (ACS Energy Lett. 2022, 7, 368–374). The program included the following panels:

Can electrochemistry replace thermochemistry in industry? — With Marta Hatzell (Georgia Tech)**,** Khartish Mathiram (MIT)**,** Dan Steingart (Columbia U.)**,** Iryna Zenyuk (UC Irvine)

Frontiers in electrocatalysis — With Feng Jiao (U. Delaware)**,** Aleksandra Vojvodic (U. Pennsylvania)**,** Jenny Yang (UC Irvine)

Frontiers in solvation science applied to electrochemistry — With Nitash Balsara (UC Berkeley/LBNL), Kristin Persson (UC Berkeley/LBNL), Donald Siegel (U. Michigan)

Frontiers in neuroelectrochemistry — With Christy Haynes (U. Minnesota), Janine Mauzeroll (McGill U.), Mei Shen (U. Illinois Urbana-Champaign)

Frontiers in our understanding of local effects in electrochemistry — With Nina Balke (ORNL/North Carolina State U.), Joaquín Rodríguez-López (U. Illinois Urbana-Champaign), Debra Rolison (Naval Research Laboratory), Reza Shahbazian-Yassar (U. Illinois at Chicago)

Ask me anything about batteries — With Venkat Srinivasan (ANL)

Frontiers in corrosion —With Santanu Chaudhuri (U. Illinois at Chicago), Adrien Couet (U. Wisconsin-Madison), Jason Hattrick-Simpers (NIST)

Publishing electrochemical research — With Prashant Kamat (U. Notre Dame/ACS Energy Letters), Janine Mauzeroll (McGill U./Journal of the Electrochemical Society), Shelley Minteer (U. Utah/ACS Au), Alexandra Stephan (Cell Prss/Joule)

Career Panel — WIth Debra Rollison (Naval Research Laboratory)**,** Iryna Zenyuk (UC Irvine), Prashant Kamat (U. Notre Dame/ACS Energy Letters), Jenny Yang (UC Irvine), Shelley Minteer (U. Utah/ACS Au),

Kharthish Mathiram (MIT), Marta Hatzell (Georgia Tech), Christy Haynes (U. Minnesota), Janine Mauzeroll (McGill U./Journal of the Electrochemical Society), Alexandra Stephan (Cell Publishing/Joule), Donald Siegel (U. Michigan), James Noël (ECS Education Committee/Western University)

5th Program l 2020

presented by University of Illinois at Chicago — Jordi Cabana, Director; George Crabtree, Supporting Director

sponsored by Bio-Logic USA, Gamry Instruments, National Science Foundation
endorsed by The Electrochemical Society (ECS)

Due to the Coronavirus pandemic, Next Generation Electrochemistry went digital in 2020 and was open to anyone worldwide. Panels featuring electrochemists around the world convened on Zoom with select students admitted directly into the room to engage with presenters.

Diversity in Electrochemistry II

Electrochemistry is central to fields as varied as energy storage, water treatment and neuroscience. However, the concepts that underlie the research barriers in this field are often similar, meaning that they can be traced back to a core challenge in electrochemistry. In turn, the knowledge of electrochemistry developed for one field could offer clues for new research directions in other fields. NGenE 5.0 aims both to foster cross-pollination of ideas from seemingly different fields linked by electrochemistry and to identify fundamental challenges that transcend fields, pointing at research directions with potential for very broad impact. Faculty will present both our current gaps in understanding of important electrochemical processes in different sub-disciplines, and emerging strategies to add detail with the highest possible chemical, temporal and spatial definition. They will lay out a series of critical unresolved questions that must become the priority of the next generation of electrochemists, motivating their importance through experience and future societal needs. Emerging approaches to probe and model electrochemical phenomena will naturally become a focus of the lectures.

The abbreviated program was held June 22-23 and included the following panels:

Frontiers in Energy Storage
Batteries are now an innovation worthy of a Nobel Prize. But, are we done making them better? What fundamental questions remain in electrochemistry that impede further meaningful advances? What are the limits that can be reached with electrochemical energy storage?

With Stan Whittingham (Binghamton University), Héctor D. Abruña (Cornell University), George Crabtree (Argonne National Laboratory, University of Illinois at Chicago), Clare Grey (Cambridge University)

Integrating computational and experimental approaches at the electrochemical frontiers
Many frontier challenges in electrochemical research are becoming too large for a single approach to solve them. It is increasingly important to create feedback loops between computational and experimental methods, and integrate their power wherever possible. But this goal is easier said than done. This panel will promote a dialog between disciplines that are very often walled off. What kind of experimental inputs would models benefit from? How could experiments and characterization be best guided by computations? Can computational analysis directly be integrated into data analysis of experiments?

With Don Siegel (University of Michigan), Perla Balbuena (Texas A&M), Mike Toney (Stanford Linear Accelerator Center), Andrew Gewirth (University of Illinois at Urbana-Champaign)

“Frontiers in electrochemistry at the water/energy nexus”
Access to clean water is a vital tenet of a healthy society. Yet climate change and increases in consumption of energy place severe pressures on the water supply. How can emerging technologies based on electrochemistry contribute to producing clean water that is safe to drink? What fundamental barriers in electrochemistry must be addressed for these technologies to have a meaningful impact?

With Jelena Radjenovic (Institut Català de Recerca de l’Aigua, Spain), David Jassby (University of California, Los Angeles), Brian Chaplin (University of Illinois at Chicago), Douglas Call (North Carolina State University)

“Frontiers in organic electrochemistry”
Electrochemical driving forces are a powerful means to reach chemical states extremely far from equilibrium. They have opened up new routes toward sophisticated modifications of organic compounds. What are the opportunities in the area of organic electrochemistry? How far are we in our ability to control carbon bonds with electrochemistry? What new knowledge is urgently needed for leaps in our current ability?

With Song Lin (Cornell University), Kevin Moeller (Washington University-St Louis), Shelley Minteer (University of Utah), Phil Baran (Scripps Research Institute)

4th Program l 2019

presented by University of Illinois at Chicago — Jordi Cabana, Director; George Crabtree, Supporting Director

sponsored by Bio-Logic USA, Gamry Instruments, National Science Foundation

endorsed by The Electrochemical Society (ECS), Materials Research Society (MRS)

The 4th edition of Next Generation Electrochemistry (NGenE) took place at the University of Illinois at Chicago (UIC), June 3-7, 2019. During NGenE 2019, 37 advanced graduate students and postdocs and 9 world-renowned experts gathered to discuss the research frontiers in electrochemistry. Lectures by the NGenE faculty provided a high-level overview of the current body of knowledge, which they used to highlight critical gaps preventing transformative advances. The specific focus of the lectures spanned applications of electrochemistry in a variety of variety of scientific fields, from batteries to the detection of neurological processes. The overarching message to the students was that solving certain fundamental questions could impact a notable number of very diverse fields, thus creating opportunities for cross-pollination of approaches between fields. The lectures also discussed the most modern approaches to understand electrochemistry, which were complemented with demonstrations of cutting-edge tools such as UIC's *in situ* electron microscopy, and a one-day visit to facilities at Argonne National Laboratory. During the week, the participants were able to network through a combination of social events, a discussion of careers in electrochemistry and a poster session. Grouped in teams, the students were tasked to develop a document and a presentation laying out what they perceived as the most crucial question facing future generations of electrochemists.

Faculty: Héctor D. Abruña, Paul A. Fenter, Shelley Minteer, Joaquin Rodriguez Lopez, Reza Shahbazian-Yassar, Mei Shen, Donald Siegel, Dan Steingart

3rd Program l 2018

presented by	University of Illinois at Chicago	Jordi Cabana, Director George Crabtree, Supporting Director
partners with	Argonne National Laboratory	
sponsored by	Bio-Logic USA, Gamry Instruments, National Science Foundation	
endorsed by	The Electrochemical Society (ECS), Materials Research Society (MRS)	

The 3rd edition of Next Generation Electrochemistry (NGenE) took place at the University of Illinois at Chicago (UIC), June 4-8, 2018. During NGenE 2018, 39 advanced graduate students and postdocs and 8 world-renowned experts gathered to discuss the research frontiers in electrochemistry. The theme of this edition was *"Electrochemistry in Motion"*. Lectures by the NGenE faculty provided a high-level overview of the current body of knowledge, highlighting critical gaps in mechanistic understanding of important electrochemical processes which prevent transformative advances. They subsequently charted possible paths forward involving innovative approaches, with an emphasis on creating "movies" of the underlying reactions as they happen, at the highest possible chemical, temporal and spatial definition. The lectures were complemented with demonstrations of cutting-edge tools such as UIC's *in situ* electron microscopy, and a visit to facilities at Argonne National Laboratory.

NGenE is centered on its participants, who lead discussions of the contents of each lecture, and are encouraged to vigorously probe existing concepts. During the week, the participants also conducted a project in teams of four or five. Their charge consisted of identifying a frontier fundamental question under the umbrella of *"Electrochemistry in Motion"*, with an established connections to the lectures in the program. They subsequently developed a research plan to answer this question using the most modern and upcoming methods, inspired by their existing knowledge and new understanding developed during the summer institute. At the end of the week, the NGenE participants summarized their project in a presentation to their peers and the faculty, who provided feedback. The lively discussions and stimulating atmosphere of the workshop produced many creative and engaging proposals. The program was closed with a career panel moderated by the NGenE organizers, where students had the opportunity to explore future professional prospects in the area of electrochemistry, driven by the experience of the current generation.

Faculty: Karena Chapman, Anne Co, Andrew Gewirth, Sossina Haile,Joaquin Rodriguez Lopez, Amin Salehi-Khojin, Reza Shahbazian-Yassar, Chris Wolverton

2nd Program l 2017

presented by	University of Illinois at Chicago	Jordi Cabana, Director George Crabtree, Supporting Director
partners with	Argonne National Laboratory, Northwestern University, University of Chicago;	
sponsored by	Bio-Logic USA, Gamry Instruments, National Science Foundation	
endorsed by	The Electrochemical Society (ECS), Materials Research Society (MRS)	

The 2nd edition of Next Generation Electrochemistry (NGenE), a weeklong summer research institute on the frontiers of electrochemistry, took place at the University of Illinois at Chicago (UIC), June 26-30, 2017. During NGenE2017, 37 advanced graduate students and postdocs and 9 world-renowned experts gathered to discuss the research frontiers in the study and understanding of electrochemical interfaces. Lectures by the NGenE faculty provided a high-level overview of the current body of knowledge, while highlighting critical gaps that need to be overcome for transformative advances. The lectures subsequently charted possible paths forward involving innovative approaches. The lectures were complemented with demonstrations of cutting-edge tools such as UIC's *in situ* electron microscopy, and visits to large scale user facilities at Argonne National Laboratory.

NGenE is centered on its participants, who are encouraged to lead discussions of the contents of each lecture, and challenge existing notions. During the week, the participants also conducted a project in teams of four or five. Their charge consisted of identifying a frontier fundamental question within one of two broad topics of interest in electrochemical interfaces. They subsequently developed a research plan to answer this question using the most modern and upcoming methods, inspired by their existing knowledge and new understanding developed during the summer institute. NGenE faculty provided mentoring during hour-long sessions of project discussion. At the end of the week, the NGenE participants summarized their project in a presentation to their peers and the faculty, who acted as reviewers. The lively discussions and stimulating atmosphere of the workshop produced many creative and engaging proposals.

Faculty: Anne Co, Andrew Gewirth, Sossina Haile, Nenad Markovic, Joaquin Rodriguez Lopez, Reza Shahbazian-Yassar, Junko Yano, Henry White, Perla Balbuena

1st Program l 2016

presented by	University of Illinois at Chicago	Jordi Cabana, Director George Crabtree, Supporting Director
partners with	Argonne National Laboratory, Northwestern University, University of Chicago;	
sponsored by	Bio-Logic USA	
endorsed by	The Electrochemical Society (ECS), Materials Research Society (MRS)	

The inaugural edition of Next Generation Electrochemistry (NGenE), a weeklong summer research institute on the frontiers of electrochemistry, took place at the University of Illinois at Chicago (UIC), June 13-17, 2016. The program welcomed 22 advanced graduate students and postdocs and 13 world-renowned experts to address the research frontiers of electrochemistry and the application of innovative strategies to address them.

The inaugural program focused on concepts for the generation, conversion, and storage of energy. Experts presented high-level lectures related to the current body of knowledge, highlighting critical gaps in the frontier that need to be explored and surpassed for transformative advances. Vigorous student-driven discussions followed each lecture. The lectures were complemented with demonstrations of cutting-edge tools such as UIC's *in situ* electron microscopy, and visits to large scale user facilities at ANL, such as the Advanced Photon Source.

Participants were challenged to identify a frontier fundamental question in electrochemistry and to develop a proposal to resolve their chosen frontier issue using the most modern and upcoming methods. They worked in teams of four or five to develop their own critical and original thinking, with faculty providing mentoring during hour-long sessions of project discussion. They presented their innovative solutions to their peers and the faculty, who acted as reviewers. The lively discussions and stimulating atmosphere of the workshop produced many creative and engaging proposals As hoped for, after the conclusion of the program, continuing interactions between faculty and students have materialized.

Plans for NGenE 2017 are underway. The organizing team seeks input from key players in the community to shape the critical features of our program, focusing on fundamental aspects of electrochemical science. While the scientific emphasis will evolve, NGenE will maintain an overlapping roster of faculty from year to year as it builds a continuity of challenges and opportunities in electrochemistry. The research projects will be refined to target fundamental challenges at the frontier of electrochemistry and original, innovative approaches to overcoming them.

Faculty: Perla Balbuena, Bruce Dunn, Joseph Dura, Andrew Gewirth, Sossina Haile, Nenad Markovic, Linda Nazar, Phil Ross, Daniel Scherson, Carlo Segre, Henry White, Kang Xu