

MFC Journey by BRUCE LOGAN

My journey into MFCs begins in 1997. After 11 years on the faculty at the University of Arizona my family and I packed up and headed east to start the next chapter in our lives in State College, PA, at Penn State University. At that time much of my current and previous research was mostly driven by opportunities that came along or a natural progression along different topics. With this move to Penn State, I decided to selectively and more intentionally choose new research directions rather than events choosing for me. As I took walks around my new town, thinking about possible new directions for my work I kept noticing all those big American houses sitting snugly warm in the cold snowy winters in State College. I thought about their energy use, magnified by millions of homes, and Richard Smalley's statement that energy supply was the greatest challenge facing humanity. But from my environmental perspective, I began to realize *how we produced the energy that we used was our greatest environmental challenge.*



In 1999 I started working on renewable biological hydrogen production, with a focus on dark fermentation. But I soon became disillusioned with the topic because you could only get 4 moles of H_2 from a mole of glucose, and then you have a waste product with about 2/3 of that starting material (potentially 8 more moles of H_2) that you had to throw away. I thought about coupling hydrogen production to anaerobic digestion, but I lacked enthusiasm for that direction of work. Thus, I sought a new research direction to either solve the issue of how to turn the remaining organic matter into a useful energy source or to develop some new renewable energy technology.

In May of 2002, in one instant, I realized the solution to that desire for a new energy technology, and the direction of my research radically changed. That moment occurred when I saw a poster by Byong Hong Kim, from Korea, at the ASM conference in Salt Lake City. He had shown that *Shewanella* could use a solid substrate for respiration as well as soluble metal oxides. After having spent 11 years at the University of Arizona listening to Bob Arnold and his students discuss their research on soluble iron reduction by *Shewanella*, I realized this ability to convert organic matter into an electrical current using an electrode was a "big thing" if it could be incorporated into fuel cells since no mediators were needed. That evening all I could think of was making a fuel cell using microorganisms. The next day when I returned to Penn State I told one of my PhD students he was working on a new project on making electricity using bacteria. He thought I was crazy. So did my wife. She said she was not a scientist, but water and electricity didn't seem to mix well. After all, you don't throw a toaster in a bathtub.

The US National Science Foundation (NSF) similarly thought my ideas were a bit risky and rejected my first 3-year proposal to make electricity from wastewater. However, they did give me one year of funding to explore this potentially high-risk, high-reward topic. Game on!

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As we began work on MFCs, first with very simple H cells using salt bridges and membranes, I went with the family on a sabbatical in the UK in 2003 at the University of Newcastle, working with Ian Head (who I had collaborated with on a project on perchlorate biodegradation) and Tom Curtis. They gave me some lab space to start a very simple MFC experiment in the basement of the building. As I worked on these reactors people would wander by smirking and muttering something about that crazy American trying to make electricity from poo. They gave me some lab space to start a very simple MFC experiment in the basement of the building. As I worked on these reactors people would wander by smirking and muttering something about that crazy American trying to make electricity from poo. I guess it was good entertainment for all.



Photo 1: Colleagues at the University of Newcastle in 2007: Krishna Katuri, Bruce Logan, Sharon Velasquez-Orta, Beate Christgen, Mirella Di Lorenzo.

While I was at Newcastle in 2003 a paper was published by Willy Verstrate's group at Ghent University on a glucose-fed microbial fuel cell claiming high power. I was thrilled to find another group interested in the topic, but I wondered how I could meet them. Well, as fate had it, I had hired a grad student from Willy's lab a few years previously who indicated that Willy would be happy to host a visit to Ghent should I ever want to go there. So, I took the opportunity to contact Willy and come to the lab on December 4, 2003, and met Korneel Rabaey, a young PhD student who was the researcher leading that microbial fuel cell project. That fateful meeting and my time at Newcastle turned into much professional subsequent correspondence and as well as friendships that have lasted over decades.

Since that 2003 sabbatical I have returned to Newcastle (**photo 1**) and Ghent many times to work with colleagues there as well as elsewhere as we all rushed into defining this new and exciting field. Korneel Rabaey and Uwe Schroder made the big journey from Europe to the US to participate in the very first session on MFCs at the ACS conference in Philadelphia in August of 2004, and you could sense the excitement about this new field at that meeting.

In 2005 I returned to Ghent to participate in a small workshop on MFCs organized at Ghent and to sit on Korneel's dissertation committee which took place on Friday, September 16. That Saturday morning following Korneel's defense and celebration (which included way too much wine and Belgium beer) a small group of us got together to discuss writing a "review" paper on MFCs (**photo 2**). (Actually, the paper was more of an instruction manual for new MFC researchers rather than a review). Of course everyone wanted to participate, but as usual, nobody had time to lead it, so I volunteered (or was voluntold?) to do that. I guess that is what happens when you show up to a meeting late. Initial concerns aside, that paper was very exciting to pull together.

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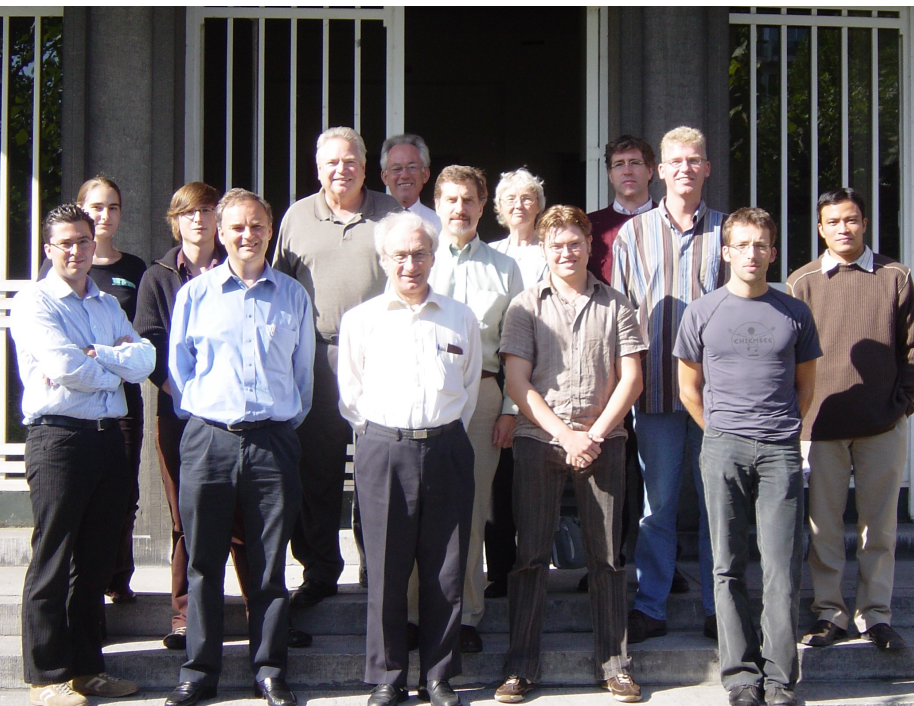


Photo 2: The group at Ghent University on Sept 17, 2005. Front row: Korneel Rabaey, Jurg Keller, Willy Verstrate, Rene Rozendal, Uwe Schroder. Second row: Liesje De Schampelaere, Peter Aelterman, Greg Zeikus, Bruce Logan, Gertjan Euverinck, Hai Te Pham. Back row: Dennis and Fraeda Hawkes (Glamorgan colleagues) and Bert Hamelers

We all learned a lot, and it was fun yet challenging to write the article given the relatively short period of time for the field, made doubly challenging we had to coordinate the writing with researchers around the world (EU, UK, US and Australia). And remember, this was way before Zoom! In the end, we were quite proud of the final product, and it received a good response. That paper, “Microbial fuel cells: methodology and technology”, by Bruce E Logan, Bert Hamelers, René Rozendal, Uwe Schröder, Jürg Keller, Stefano Freguia, Peter Aelterman, Willy Verstraete, and Korneel Rabaey, went on to be my most highly cited paper (likely true for the others as well) with over 7000 citations to

date (according to Google Scholar). Thanks everyone for reading it and citing it! Following that experience, I embarked on writing and publishing my book on MFCs.¹

As the MFC community grew we got tired of having sessions at conferences like ACS that charged us huge registration fees and gave us nothing but a meeting room with a pitcher of water. In 2007 I took a chance and organized the first MFC conference at Penn State with the support of the National Science Foundation. We filled the room to capacity, and for a very modest registration fee, we wined and dined well and got to enjoy the lovely Penn State campus. That tradition of bringing researchers together through volunteer work, while enjoying a high-quality event and low conference costs, has continued forward for all our conferences to date.

In the next years after 2007 we had many conferences and the community grew from just a focus on the “MFC” and a few microbes, to all sorts of bioelectrochemical systems and their associated technologies and microorganisms. Thus, on September 15, 2011, at a lunch meeting at Spats Cafe and Speakeasy Restaurant in downtown State College, PA, a group of us decided to form our own non-profit society to run our conferences and build the community. Most of the attendees of that lunch included people who became founding board members. You can still find the photo of this group on the ISMET website: <https://is-met.org/history/>. (The quality of the photo reminds me how much digital photographs have improved since then).

On October 22, 2011, we sent out an email announcing the official formation of ISMET that was signed by the inaugural board of directors: Bruce Logan, Korneel Rabaey, Lars Angenent, Leonard Tender, Xia Huang, Cesar Torres, Ashley Franks, Haluk Beyenal and Uwe Schroder. To make us legal, so we could conduct financial transactions, we had to file our organization with the US government. Thus, on December 12, 2011, I plunked down \$2000 (theoretically a loan, but I wasn’t sure!) to pay a lawyer to draft the legal ISMET bylaws that would establish us as a not-for-profit and get the group going. That initial payment allowed us to get a bank account, collect membership dues, and start the financial side of our organization. It was a bit of a risk, but eventually,

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the organization paid back the loan, and ISMET has continued to be a solvent organization ever since then.

The MFC and ISMET journey since those early years has been amazing. I cannot begin to call out all the wonderful students and researchers in my laboratory over the years, and the many visitors from other countries including the UK, EU, South America, Mexico, China, and Korea. But the funding I received from KAUST in 2007 for my research and our collaborations and helping to launch their new campus in 2007 was truly a career changing grant! There was also the International Francqui Chair funding for my sabbatical at Ghent in 2013, as well as many collaborations with colleagues at Harbin Institute of Technology, Tsinghua, and many other universities that gave me opportunities over the years to give talks and have fruitful discussions all around the world in many diverse locations. When I travel, I really love to see my “academic family”, or those people that were former students, collaborators, visitors, or postdocs in my lab (**photo 3**). And the journey goes on. I continue to meet new researchers taking on research topics that span bioelectrochemistry and technologies, including things I only dreamed of like establishing pathways of direct electron transfer to methanogens (which many said did not exist), and engineering new capabilities into electroactive microorganisms, as well as improving technologies and going on creative adventures in all sorts of new bioelectrochemical research directions.

My current journey continues to build upon the motivation that got me into this MFC field back in the late 1990's: a desire to address the environmental consequences of energy production through education and by helping to develop solutions to climate change. Now I am spending lots of time working on effective ways to discuss and communicate energy use and carbon emissions both on a personal level as well as in terms of global emissions. See my book on “Daily Energy Use and Carbon Emissions”,² and if you get motivated to teach a course in this area, I am happy to share all my course notes, as well as problems, quizzes, and solutions. I know that ISMET researchers will play important roles in both technology and education climate solutions to enable policy changes that are needed to prepare the world for the new challenges of climate change in our collective and global future.

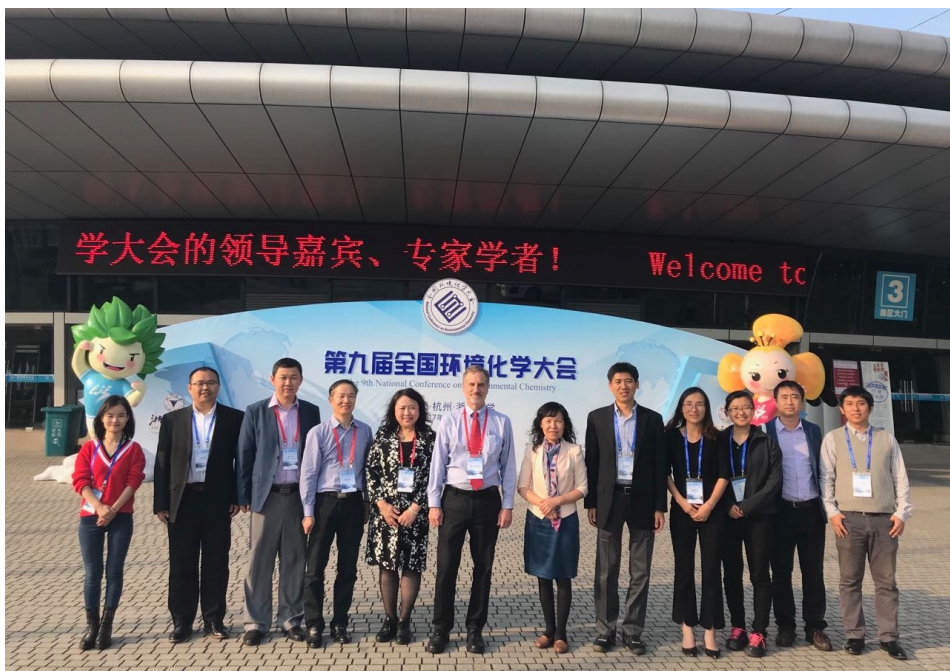


Photo 3: Getting together with friends and colleagues at the 9th National Conference on Environmental Chemistry (9th NCEC) at Zhejiang University, Hangzhou City, China, October 19 - 22, 2017. Left to right: Dan Sun, Weihua He, Feng Zhao, Shaoan Cheng, Yujie Feng, Bruce Logan, Xia Huang, Jason Zhiyong Ren, Huijie Hou, Jia Liu, Xu Wang, Xin Wang.

References

1. Logan, B. E., *Microbial fuel cells*. John Wiley & Sons, Inc., 2008.
2. Logan, B. E., *Daily energy use and carbon emissions*. John Wiley and Sons, Inc., 2022.

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