MPIE Placement

Armourers & Brasiers Non-Technical Report

Daniel Varley — Queens' College, Cambridge

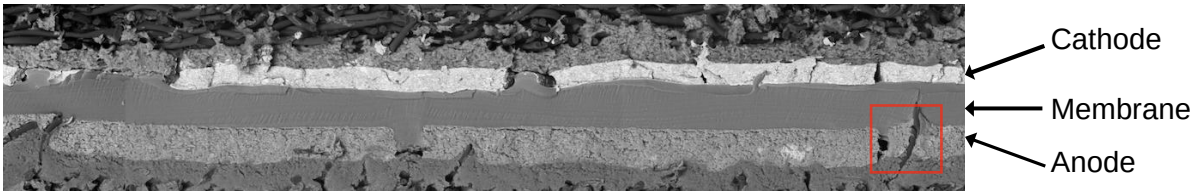

Rhine tower

If you were to ask 18-year-old me how I was planning to spend my 2016 summer, I doubt the answer would have included two months in a research institute based in Germany. Nevertheless, after almost two years into my Natural Sciences degree, I was set on specialising in Materials Science and wanted to do something productive with my summer. After strong recommendations from my Part IB supervisor and older students, I applied to the Max Planck Institut für Eisenforschung (MPIE) — located in Düsseldorf, Germany — for an eight-week placement. I chose Germany not only for MPIE, but also because I had never before visited the country and was keen to learn about the culture while trying to pick up some of the language basics. I knew that most people at the institute could speak English, but in order to help with everyday tasks such as shopping and travelling, I actually started an online language course a couple of weeks before my placement so that I could hit the ground running. This really helped me to pick up German more quickly from the people around me.

My research was concerned with the degradation of fuel cells. More specifically, I investigated samples of high-temperature polymer electrolyte membrane fuel cells (HT-PEMFC) produced by a fuel cell technology company; it was part of a collaboration project between the company and my supervisor, Katharina, who is working towards her PhD thesis. The particular HT-PEMFCs that I investigated, fuelled by hydrogen and oxygen, are intended for electricity and heat generation in homes. The main focus of my project was the way in which the components forming the membrane electrode assembly (MEA) changed in terms of their physical structure and elemental composition.

The first week of my placement largely involved settling in and getting to grips with the techniques needed for my work. I was given an introduction to the operation of a JEOL JSM 6490 scanning electron microscope (SEM) such that I could do everything from sample loading to image collection and energy dispersive X-ray spectroscopy (EDX) to final venting, without any supervision. Indeed I also learned how to prepare samples for the SEM. Obviously it was also very important for me to understand the data collected so I spent a great deal of time reading journal articles and review papers relating to mechanisms of HT-PEMFC degradation.

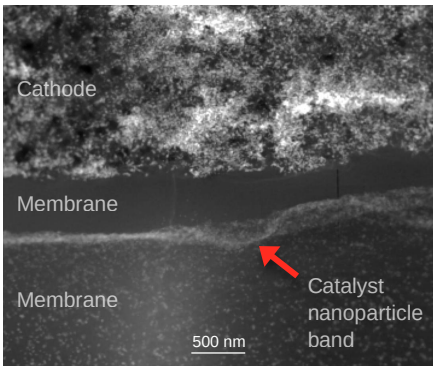
The different MEAs varied in terms of their electrode catalyst composition and membrane material, in addition to the range of durations for which each had been operated. For each MEA, I prepared SEM samples and collected approximately 50 images along the cross section. With a great deal of dragging around in PowerPoint, these images were put together to form a long strip of SEM images as shown in the image below (only one tenth of a strip is shown for clarity). Funnily enough it was only after I had spent hours doing this for each MEA that I discovered a computer program that could do this automatically. From these cross sectional strips, the thickness of each component (cathode, membrane and anode) could be measured and compared across different



A strip of five SEM images from an MEA's cross section (scale bar omitted for the sake of confidentiality).

MEAs. Other qualitative observations, such as the occasional protrusion of the outer-layer fibres (highlighted above) in the membrane, were made. Although fibres sticking through the electrodes would cause serious problems for the fuel cell, I found that they mostly occurred on the side of the MEA cut by the scalpel; so, their appearance was probably due to sample preparation.

Alongside my own SEM work at the micrometer scale, I learned a lot while shadowing Katharina during transmission electron microscopy (TEM) at the nanometre scale; this included aspects of sample preparation using focussed ion beam (FIB) lift-out methods which I found extremely interesting. On top of the examination of the migrating catalyst, we found a fascinating phenomenon concerning catalyst nanoparticles (including platinum) migrating from the anode, through the membrane and collecting at an arbitrary distance close to the cathode.



The research group — Nanoanalytics and Interfaces — consisted of about 10 people (pictured below) mostly working towards their PhDs. Their collaborative nature was very welcoming and supportive; they often helped each other and there were even occasions on which I explained some materials science (including how to use phase diagrams) to those from different scientific backgrounds. Only about half of them were German while others came from China, Sri Lanka and Iran. Aside from working, we often gathered for '*Kaffee und Kuchen*' (or 'Coffee and Cake' — a particularly popular afternoon pairing in Germany) and even had a group outing to a climbing park (you can see me holding on for dear life in the image below) before playing mini golf (I won). Midway through the placement I found myself in Munich with Katharina for an informal meeting with the fuel cell company; after presenting and discussing my data, there was time to explore some of the main sights including the impressive *Neues Rathaus* (New Town Hall) shown below.



Aside from the fun I had with colleagues, I spent a lot of time with the 30 people in my large flat-share; they were mostly German with a few from France, Italy, Spain and even one from Scotland. I loved my time in that flat, there was a large communal kitchen and living room so there were always people to cook with or just relax with after work. Being around so many Germans gave me a great insight into their culture — especially the food: every weekend they made brunch for the whole flat which introduced me to lots of new foods such as *weißwurst* (white sausage). They could all speak English but largely conversed in German — the exposure really helped my learning and towards the end I could often get the gist of their conversations. It was very common for several of us to go out on the weekends: we went out to the old city for birthday parties, played more mini golf (I won again) and had a great time at the annual *Kirmes* (funfair) .

Düsseldorf was a great city to be living in. I was just a 10-minute tram ride from the *Altstadt* (Old City) with all the main restaurants, shops and the river Rhein. It was very easy to get around with the excellent public transport system, although I did find myself walking most places. Overall I had such an enjoyable summer. I learned so much from the group at MPIE, especially Katharina, and it's made me rather excited to continue studying materials in Part II. If you're reading this because you are deciding whether to apply for a CaMPUS placement then I can't recommend it enough. My

language learning, practical and analytical skills and even my culinary talent showed huge improvements. Any reasons for pre-application hesitation disappeared after just a few days of being there. Thank you so much to everyone in my MPIE research group and the organisers of the scheme in the Materials Science department who made my summer an unforgettable one. I'm also exceptionally appreciative to Queens' College and The Worshipful Company of Armourers and Brasiers for the generous funding, without which my summer would not have been possible.