New technique demystifies the behavior of catalysts in fuel cells

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Real-time XAFS experiment for polymer electrolyte fuel cells at UEC/NEDO beamline BL36XU @SPring-8

In autumn 2014 Toyota Motor Corporation announced the start of the commercial sales of the 'Toyota Mirai'—the world's first commercially available hydrogen fuel-cell vehicle.

"This announcement was the culmination of decades of research on polymer electrolyte fuel cells (PEFCs)," says Professor Yasuhiro Iwasawa, head of the Innovation Research Center for Fuel Cells at the University of Electro-Communications, Tokyo. "Toyota's hydrogen fuel cell vehicle is one example of the potential applications of fuels cells for generating 'green energy'. However, there is still a lot of fundamental research required in order to benefit from the ultimate potential of PEFCs. In particular, our understanding of the chemical reactions governing the generation of electricity from fuel cells is still incomplete. Specifically, the atomic structure, reactions mechanisms, and degradation mechanisms of fuel cell catalysts are still a black box."

With this background, Iwasawa and colleagues have constructed a unique 80 meter beamline at the SPring-8 synchrotron facility at Harima Science Park City, Hyogo Prefecture, Japan, as part of an approximately US$26 million national NEDO project to develop X-ray absorption fine structure (XAFS) spectroscopy to probe the behavior of catalysts in fuel cell.

"Our XAFS beamline enables in-situ and real time measurements with high time and spatial resolution, and importantly, under conditions used for operational fuel cells," explains Iwasawa. "Such XAFS measurements are only possible with our beamline. It is truly unique."

Lab. members near the BL36XU hutches

Notably, the UEC-Tokyo SPring-8 XAFSs beamline (BL36XU) was built to study nanoparticle catalysts in the cathode inside the membrane electrode assembly (MEA) during power generation. The beamline enables time and spatial XAFS measurements with a time resolution of 100 microseconds, spatial resolution of 200 nm, and depth resolution of one micron.

Recent highlights of research being conducted by Iwasawa and colleagues includes the direct mapping of the degradation of platinum (Pt) nanoparticle catalysts in PEFCs by nano-XAFS with a beam size of 570×540 nm^2 or 228×225 nm^2. More specifically, the researchers, succeeded in the two-dimensional mapping of Pt species in electrode catalyst membranes and in the identification of dissolved species and preferential sites using the nano- XAFS with the highest spatial resolution reported to-date. XAFS showed the selective oxidation and dissolution of the Pt nanoparticles as four-coordinate Pt^2+-O^4 in the 2-3 μm region around the boundary between the cathode catalyst layer and the electrolyte membrane and around micro-crack boundaries.

"These findings are expected to enable engineers to design and develop 'experiment based knowledge' electrode catalysts for the next generation of fuel cells for applications including cars and electricity generation systems for homes," says Iwasawa. "We welcome researchers from all over the world to join us in our research with our beamline at SPring-8 on in-situ analysis of PEFCs."

More information: O. Sekizawa et al, *J. Phys.*: Conf. Ser. 430, 012020, (2013). DOI: 10.1088/1742-6596/430/1/012020

S. Takao, et al, "Mapping Platinum Species in Polymer Electrolyte Fuel Cells by Spatially Resolved XAFS Techniques," *Angew. Chem. Int.* Ed., 53, 14110 (2014). DOI: 10.1002/anie.201408845