TEM characterization of highly active and stable PEM fuel cell nanoparticle catalysts

S Selve¹, F Hasché², M Oezaslan², D Berger¹, P Strasser²

¹. TU Berlin, Zentraleinrichtung Elektronenmikroskopie (ZELMI), Berlin, D-10623, Germany.
². TU Berlin, Institute for Chemistry, Berlin, D-10623, Germany.

soeren.selve@tu-berlin.de
Keywords: fuel cell, nanoparticle, catalyst

The requirements of polymer electrolyte membrane fuel cells (PEMFC) to solve the increasing energy demands are low material cost, high activity and durability [1-3]. Therefore, a multitude of new and improved catalysts have been developed over the last decades. In particular, bimetallic nanoparticle catalysts show enhanced performance of the rate-limiting oxygen reduction reaction compared to pure platinum nanoparticle catalysts [4]. Moreover, the support material plays an important role for the improvement of the catalysts stability. Oxidation resistance of the support material is one point of concern [5-6]. Nanoparticle size, shape and chemical composition stability under operation conditions are further challenges, in order to maintain a steady performance of the fuel cell [7].

The transmission electron microscopy (TEM) is an important tool to study the morphological and compositional changes of electronanocatalysts before and after the operating conditions. As an imaging method with a high lateral resolution, the TEM complements typical non-imaging characterization methods like XRD and provides information about, for example the precise localization of the PEM fuel cell nanoparticle catalysts or their crystal structure.

The present work investigates the behaviour of nanoparticles with different chemical compositions on various support materials, including high surface area materials (for example multi walled nanotubes, Vulcan XC 72R, mesoporous nitrogen doped carbon) before and after several test cycles. For example, Figure 1 clearly shows differences of the distribution of particles on the support material before and after testing just as larger particle sizes after the test cycles [4].

High catalytic yields can only be achieved if the nanoparticles are attached to the surface of the support material. Especially at nanotube support materials it occurs that particles are deposited on the inner surface of the tube reducing the catalytical efficiency. To verify whether particles are inside or outside of a nanotube is further part of this work. Figure 2a shows a dark field micrograph that was used for faster finding and easier determination of the platinum nanoparticles. The detailed Figure 2b shows a multi walled carbon nanotube and a groove, marked by an arrow, that we interpret as nanoparticle migration within the tube.

References

[1] Departement of Energy, Table 3.4.12 Technical Targets; Electrocatalysis for Transportation Application, Department of Energy – Multi Year Research and Development Plan (2007)

[8] We kindly acknowledge the Exzellenzcluster “Unicat” for the financial support of the TEM.

**Figure 1.** TEM bright field micrographs of carbon supported PtCu3 nanoparticle catalyst
   a) as synthesized - high distribution of particles on the support
   b) after electrochemical testing - less and larger particles [4]

**Figure 2.** Pt migration within multi walled carbon nanotube – TEM micrograph for Pt/MWCNT after electrochemical "lifetime" potential cycling (0.5-1.0V vs RHE, 10000cycles)
   a) dark field TEM micrograph
   b) bright field TEM micrograph [5]