Novel Synthesis Routes of Platinum Rare Earth Metal Alloy Nanoparticles as Catalysts for Hydrogen Fuel Cells - DTU Orbit (18/10/2019)

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Hydrogen fuel cells promise to contribute to our future energy landscape by providing clean electricity to stationary and mobile applications. The main challenge of their application is their high cost compared to other energy systems. The main cost is the catalyst that facilitates one of the two main reaction within a fuel cell: The oxygen reduction reaction (ORR). The most active and stable material is platinum in form of nanoparticles, which is a scarce and expensive element. Three approaches are investigated by researchers to reduce its impact on the overall system cost: (1) Replace platinum with non-noble metals, that are cheaper but less active and less stable. (2) Gain control over the shape of the nanoparticles, increasing the share of the higher active platinum facets. (3) Mix platinum with other metals to form alloy nanoparticles with an increased surface activity. In this thesis the latter approach is chosen to obtain novel ORR catalysts. DTU is the leader in the field of establishing rare earth metal platinum alloy nanoparticles as catalyst for the ORR. However, a cheap and scalable synthesis method is lacking so far. The main obstacle is the very negative reduction potential of the rare earths which prohibits the utilization of the common nanoparticle synthesis methods. This thesis discusses and investigates several options of synthesizing PtxY and PtxY nanoparticles by novel synthesis routes.

First, sodium dissolved in liquid ammonia is used as a reducing agent and rapidly mixed with various early transition, rare earth metal salts and platinum on carbon. After an annealing treatment at high temperatures the respective platinum alloy nanoparticles are obtained. However, the size distribution of the nanoparticles does not meet the design criteria of ORR catalysts.

Secondly, the same principle is used by replacing liquid ammonia with a suitable organic solvent. Platinum rare earth metal alloy nanoparticles with an improved particle size distribution are obtained.

Eventually, it is found for the first time that platinum and the respective rare earth metal salts alloy at elevated temperatures in the presence of potassium vapor. This method allows a fairly good control over the phase composition and size distribution of the nanoparticles. The obtained Pt3Y/C and Pt2Gd/C nanocatalysts were electrochemically tested and found to exhibit a higher ORR activity than the responding commercial Pt/C catalyst. The importance of the annealing temperature, precursor stoichiometry and acid leaching is further investigated to complete the understanding the role of the potassium vapor.

This method has the potential to be commercialized and eventually reduce the necessary amount of platinum in fuel cell systems and thus progressing their application and contribution towards a sustainable energy future.

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