Functional Materials and Nanotechnology

Development of Durable Ceramic Electrocatalyst Support Materials for Proton Exchange Membrane Fuel Cells

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Introduction

Proton exchange membrane fuel cells provide a clean and efficient way of converting the chemical energy of a fuel, typically hydrogen, into electrical energy for use in any kind of operation.

In the membrane electrode assembly the hydrogen fuel is split into protons and electrons at the anode, the latter of which go into an electrical circuit. Protons travel through the ionically conductive membrane to the cathode side, where they react with oxygen and the electrons to produce water.

Low durability and high material costs impede the full scale commercialization of proton exchange membrane fuel cells. As part of the UpCat project, this PhD project is dedicated to the development of catalyst supports of high stability and activity that may in the future replace conventional materials.

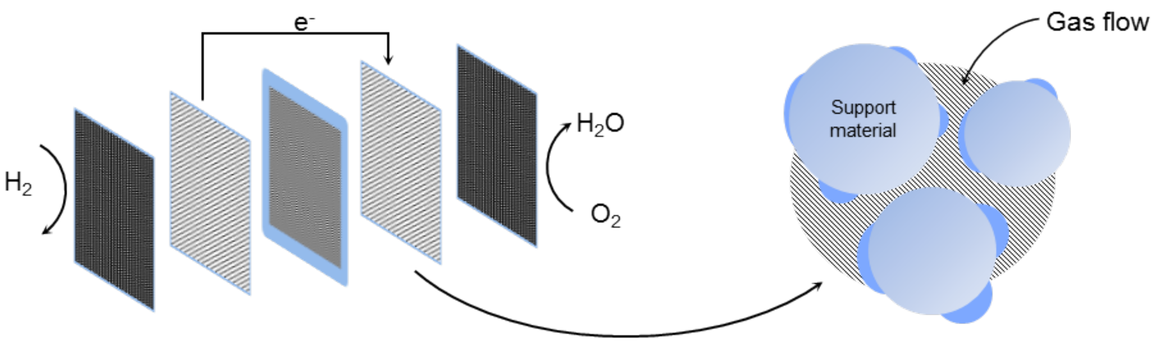

Illustration of the main components of the membrane electrode assembly: gas diffusion layers, catalyst layers and the proton exchange membrane.

Structure of the catalyst layer, consisting of platinum particles attached to a support material, typically carbon. A support material with specific properties is required in order to increase platinum dispersion and gas flow, increasing efficiency and reducing platinum loading.

Background

Harsh operating conditions of fuel cells as well as goals to optimize efficiency result in specific requirements for the properties of catalyst support materials. These can be summarized as [1]:

- High surface area
- High electrical conductivity
- Suitable porosity to facilitate gas flow
- High stability under fuel cell conditions

Ceramic catalyst supports generally exhibit extremely good stability but low surface area; therefore, specific materials with tailor-made properties are needed in order to create a catalyst support that meets all of these requirements. Certain ceramic materials currently being investigated show great potential as future catalyst supports.

Tungsten Carbide Support Materials

The Initial focus of this PhD is on the synthesis of nanoparticle, phase-pure tungsten carbide (WC) produced by a self-propagating high-temperature synthesis. The synthesis utilizes the heat energy generated from a highly exothermic solid-state reaction in order to facilitate the formation of tungsten carbide from carbon black and a tungsten precursor [2]. The effect of the carbon precursor can be investigated by testing different high surface area carbon black materials.

Produced materials are analyzed by a wide array of characterization methods, including particle size, X-ray diffraction methods, and thermogravimetry. These materials can be platinized and then further analyzed electrochemically by cyclic voltammetry or impedance spectroscopy.

References

[1] E. Antolini, E.R. Gonzalez, Ceramic materials as supports for low-temperature fuel cell catalysts, Solid State Ionics. 180 (2009) 746–763.

[2] I. Borovinskaya, T. Ignat'eva et al., Preparation of tungsten carbide nanopowders by self-propagating high-temperature synthesis, Inorg. Mater. 40 (2004) 1043–1048.

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