Will Fuel Cells be a Widespread Product in 20 Years?

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The world is becoming aware of an upcoming energy crisis; most of the worldwide energy demand is still satisfied using fossil fuels (whose availability is limited), while renewables still account only for a small portion. The use of fossil fuels results in greenhouse gas emissions but most of the CO₂ emitted is a result of an inefficient conversion and distribution of energy. Therefore, in addition to increasing the use of renewable energy, there is an urgent need to develop highly efficient energy conversion, storage and distribution systems. A technology that has a potential in this respect is fuel cells.

Polymer Electrolyte Membrane Fuel Cells (PEMFCs) are one type of fuel cells, which typically operate in a low temperature regime (~60 –120°C) and use hydrogen as fuel, noble metals as catalysts and Nafion™ as electrolyte. Their power density typically reaches high values of ~1.5 kW/kg. Even though the concept and development of PEMFCs is fairly advanced, market penetration is still low. Obviously, there are important issues related to PEMFCs which hinder a broader commercialization. Some of those are: (a) Low efficiency at high power densities; (b) Use of hydrogen which is only a secondary energy carrier; (c) Requirement of large amounts of noble metal; (d) Durability and lifetime of the system.

The first issue is low efficiency at high power density of current PEMFCs. Typical electric power densities are ~1 W/cm² at 0.7 V. That accounts for a voltage efficiency of ~50%–connected with a release of waste heat of almost 0.5 W/cm²–while the overall system efficiency is even lower.

The second issue relates to the fuel hydrogen. The advantage of using hydrogen in PEMFCs is that water is the only reaction product. Hydrogen, however, is only a secondary energy carrier which is currently produced by e.g., reforming of natural gas. Hydrogen could be produced by regenerative sources but those are only insufficiently available, probably for many decades to come.

The last two issues refer to the current material systems used in PEMFCs. Pt supported on Carbon (Pt/C) is commonly used in PEMFCs and in order to achieve desirable power densities high amounts of noble metal are required. Even though Pt possesses a high catalytic activity, it is of limited supply and thus of a high price. Carbon is commonly used as support material since it is inexpensive with a sufficiently high electronic conductivity and high availability. Carbon, however, is one of the reasons of a reduced lifetime of the PEMFC system because of its instability especially on the cathode.

What are possibilities? It is known that the power output in the high voltage regime is controlled by electrocatalytic properties. Most of the losses can be attributed to the slow kinetics of the oxygen reduction reaction. In order to achieve a high power, high efficiency system, it is necessary to identify and develop highly active catalyst materials that could push the power output up to ~1 W/cm² at 0.85 –0.9 V. Pt and C have been studied as candidates for many years but they do not seem to offer a solution. Up to now, no catalyst/support system has been found that would be able to overcome these problems. Researchers should focus at identifying novel material systems, both for catalysts and supports, which would replace Pt and C.

Another beneficial aspect for PEMFC systems would be that—in addition to hydrogen—alternative fuels, such as bio-derived alcohols, can be directly converted. Direct methanol fuel cells are a starting point but the current status is not satisfying; Large amounts of catalyst, complicated two phase flow on both electrodes, an electrolyte with high water and alcohol permeability, low power density, low efficiency. Bio-ethanol as a fuel may be an attractive candidate. It can be produced from cellulosic biomass, has a high energy density, is non-toxic, and it is liquid which allows using the current fuel infrastructure. Research should aim at identifying highly active catalysts towards ethanol oxidation and oxygen reduction and also find electrolytes with low alcohol permeability which can also operate at elevated temperatures. A fuel cell with a direct conversion of various fuels would be advantageous.

In this cover page future targets that should be set in order to achieve a high power, high efficiency device at reasonable are envisioned. This can broaden the commercial potential of fuel cells. Over the years, there are envisioned success in improving the power density and at the same time reduce the amount of catalyst necessary. But the goals need to be set higher and high-risk, high-profit solutions are required that can drastically improve the current PEMFCs status. If one believes that we have performed enough research for PEMFCs then the reality is obviously different—• we are just in the middle of it, hopefully not at the beginning.

So, develop a fuel cell that does not need materials of limited supply, that is able to convert various fuels of renewable sources, that is able to provide an electric power density of 1 W/cm² at a cell voltage of 0.9 V –this is my vision.

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