MOBILITY & PRODUCTION

Fields of Expertise TU Graz

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Rudolf Pichler,
Mobility & Production
Source: Lunghammer – TU Graz

The visible life of mobility and production has been suffering hard times and we have to acknowledge that the first lockdown in spring turns out not to have been the last one. The short summer in between was immediately used to reopen the laboratories in order to restart the test benches, to reactivate experimental research, to be available again for our students and also to develop new teaching concepts. This is the most wonderful expression of Science, Passion, Technology.

Two months ago, the European Commission reinforced the targets for the European Green Deal and once more Graz University of Technology turns out to be on the right path. Its many years of experience with hydrogen concepts in mobility is going to be further intensified. That is why this issue of TU Graz research presents the latest results of the next generation of fuel cells and hydrogen technologies. To ensure that hydrogen technology really thrives in mobility and comparable applications, multiple challenges still have to be tackled, such as corrosion issues, finding the right framework conditions for obtaining high-purity hydrogen, finding appropriate carrier systems and so on.

In terms of production, last September a milestone in communication standards at Graz University of Technology was able to be achieved. The establishment of a 5G campus private network was finalized at the smartfactory@tugraz. With this installation the research environment for digital production has now got a full playground for working with highest bandwidths and doing tests with upcoming end devices that will help boost production in the fields of productivity, safety and security. At this stage, an open invitation goes out to any interested institution or company to use these facilities for tests or improvements of any kind. Just get in contact with us!

This is only one facet of the spirit of all our institutes in this Field of Expertise. And now please enjoy the fascinating article by our colleague Sebastian Bock.

Sebastian Bock

Research on Next Generation Fuel Cell and Hydrogen Technologies

Due to current efforts being made in the reduction of greenhouse gas emissions and the associated political focus on hydrogen as a clean energy carrier, methods for sustainable hydrogen production and efficient utilization are again in great demand. In the coming years, fundamental and industry-related research as well as innovative ideas are essential to meet the ambitious goals with regard to efficiency, service life and sustainability of the whole process chain. The fuel cells and hydrogen working group is currently focusing on several approaches to tackle these challenges.

EXTENDING DURABILITY OF FUEL CELLS BY REDUCING CARBON CORROSION

The development of clean and noiseless propulsion systems for transport applications is crucial to provide a sustainable, internationally connected economic system. Polymer electrolyte fuel cells (PEFCs) are currently seen as a viable option for use as a power supply in electric vehicles (FCEVs), and achieve high driving ranges in combination with fast refueling, as required especially for commercial vehicles.

However, the main cost driver for current fuel cell stacks in FCEVs is the membrane electrode assembly (MEA), which still contains the precious metal platinum in the electrode catalyst. Increasing the lifetime and platinum-specific efficiency of the electrodes is therefore crucial for the commercialization. A novel concept for the reduction of precious metals through the selective coating of the carbon support material >

Figure 1: Chitosan anion exchange membrane doped with graphene oxide for use in direct alkaline alcohol fuels.
Source: TU Graz / CEET

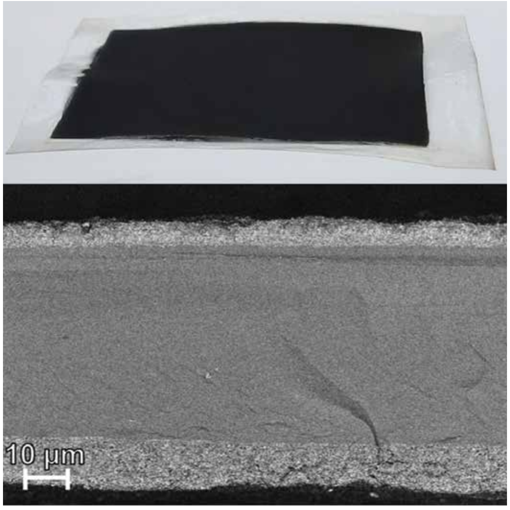

Figure 2: Catalyst-coated membrane and SEM recording of the cross-section.
Source: TU Graz / Grandi

with polyaniline (PANI), a semi-conductive polymer to increase the catalyst lifetime and activity, was recently demonstrated by the working group.

The materials were synthesized in cooperation with international research partners and industry and characterized in the MEA using purposefully designed accelerated stress tests to determine performance over long-term operation. In preliminary tests, the lifetime of the catalyst was increased by +14% in comparison to a state-of the-art Pt/C catalyst. Moreover, at single-cell level a significant increase of the platinum-specific activity of +46% was identified, which consequently enables lower platinum loadings in fuel cell stacks.

An international patent was successfully granted for this innovative concept, for which additional research is scheduled to further enhance the characteristics and preparation method of the PANI-coating and control the material properties in the MEA.

NEW CATALYST SYSTEMS FOR THE SUBSTITUTION OF PRECIOUS METALS

With the development of advanced catalyst systems, liquid fuels such as ethanol will in future also be used in polymer electrolyte fuel cells for a clean energy supply in mobile and stationary applications. Direct ethanol fuel cells promise advantages regarding high performance, low toxicity and environmental friendliness as well as robustness. However, concerning the significantly lower efficiency compared to other fuel cell technologies, such as PEFCs, the development of enhanced catalysts and membrane development is crucial in order to enhance the performance, durability and costs.

In the ongoing project, the performance of the membranes is improved by adding functionalized graphene oxide (GO) to new anion-exchange membrane composite materials by using simple papermaking and coating procedures. The properties of graphene oxide, such as a large surface area, high electrical conductivity, corrosion resistance and the ability to be chemically modified, make the material interesting as a carbon support. Moreover, graphene is very cost-effective compared to other carbon supports as it can be produced from common graphite. Special methods for doping the membranes with GO are proposed to further increase the ionic conductivity as well as their chemical, thermal and mechanical stability and reduces the ethanol crossover in the cell.

The synthesized and advanced functionalized graphene-based electrode materials are now used for the development of novel membrane electrode assemblies (MEAs), an evaluation of the influence of production parameters and cell design on the performance of MEAs and their final characterization on cell level.

Figure 3: Synthesis of corrosion-resistant carbon supported catalyst for PEM fuel cell electrodes.
Source: TU Graz / Grandi

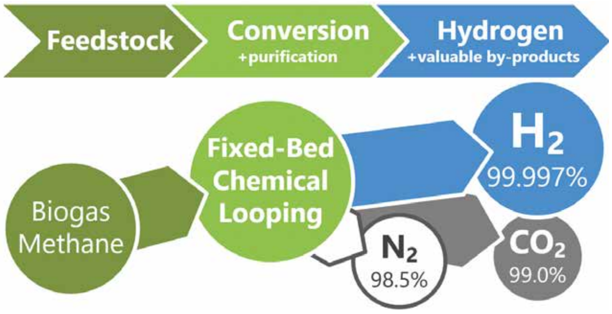

Figure 4: High-purity hydrogen production through chemical looping with pure carbon dioxide and nitrogen sequestration.
Source: TU Graz / Bock

ADVANCED OXYGEN CARRIER FOR THE PRODUCTION OF HIGH-PURITY HYDROGEN

Besides research on electrochemical cells, the research group focuses on the development of chemical looping hydrogen, a process formerly known as the steam iron process. In this process, the production of high-purity hydrogen is made possible by the ability of iron oxides to act as an oxygen transmitter between its reduction with reductive gases and its reoxidation by steam. In the latter, the binding of the oxygen atom from water in the iron oxide results in the release of pure hydrogen.

The challenge lies, among others, in the optimization of suitable thermally and chemically stable metal oxides. The strongly fluctuating, high process temperatures in the range of 600-1200°C as well as the constant chemical transformation by the incorporation and removal of oxygen in the metal lattice permanently induces structural changes and phase transformations. The addition of high-melting inerts such as aluminium oxide, silicon oxide or zirconium oxide is inevitable to preserve the mechanical integrity and oxygen exchange capacity of the metal oxides, in order to obtain long-term stable materials for later industrial applications.

Recent research focused in particular on the improvement of the preparation route for oxygen carriers regarding their mechanical integrity and oxygen capacity. The results indicated that the pre-treatment of the applied materials, often highly prioritized in the literature, had less influence in the long run compared to the chemical composition and the process conditions. Also, the oxidation state of the applied oxygen carrier was identified as significantly influencing the mechanical strength of the porous pelletized materials, which hence determines the preferred oxidation state during storage.

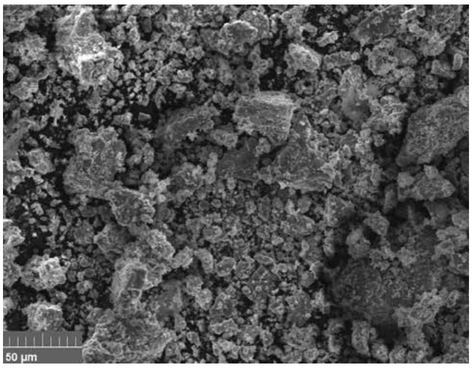

Figure 5: SEM recording of porous oxygen carrier with aluminum oxide as inert stabilizer.
Source: TU Graz / Grandi

The use of other metal oxides as a chemical intermediate to separate oxidizing media from the fuel has also been proposed for other high-temperature processes in the field of fuel conversion, such as biomass combustion for heat generation or synthesis gas production from biomass or hydrocarbon reforming. The advantage of such processes is to easily separate air as the oxidizing media stream from the combustibles by phase separation and hence enable the production of nitrogen-free product gas streams. The research group is currently involved in the Bio-Loop project in cooperation with, among others, BEST Research and TU Wien, to also develop and enhance such oxygen carriers also for future biomass-focused applications.

As presented in the above-mentioned applications, further fundamental and industry-related research in cutting-edge fuel cells and hydrogen technologies at research organisations is essential to find solutions for future commercial applications. Innovative ideas will hence further strengthen the position of Austrian research and industry in the economically important field of mobility technologies also in combination with future fuel cell technologies.

Sebastian Bock
recently completed his dissertation on the development of chemical looping technologies for high-purity hydrogen production and is currently a post-doc researcher in the fuel cells and hydrogen working group at the Institute of Chemical Engineering and Environmental Technology. The co-authors Sigrid Wolf and Maximilian Grandi are PhD students in the working group.