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HydrogenDays²⁰²¹

11th International Conference
on Hydrogen Technologies

March 24th–25th, 2021

Program & Abstracts

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Hydrogen Days 2021

Hydrogen on the move



Book of Abstracts
Final Program

Editor: Karin Stehlík

11th International Conference on Hydrogen Technologies
March 24th–25th, 2021

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Dear Colleagues, Ladies and Gentlemen,

Welcome to the Hydrogen Days 2021 conference, specifically to the Book of Abstracts. The book summarizes the contributions that will be presented during the event. The conference edition is now into double digits. The first ten years were characterized by gradual growth from a small local conference of researchers interested in hydrogen as energy vector to a well-established international event. This conference is quite special in a number of aspects, particularly in an effort to disseminate information from the scientific event to the public. All of us involved in the organization hope that this tradition will continue not only in the series of ten consecutive events, but much longer. We also hope that the currently booming interest in hydrogen technologies will persist and a broader implementation of hydrogen technologies will be achieved in the next few years. The motto we have chosen for this year's conference is therefore:

“Hydrogen on the move”.

Traditionally, Visegrad countries and their neighbors have a special place in the program. It has also become customary to welcome to the conference representatives of the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), and Hydrogen Europe Research. The presence of the FCH JU is typically multifaceted. Its representatives will join the event and report the results of the demonstration projects and research activities covering a broad range of technology readiness levels (TRLs), financed within the framework of the FCH JU annual work plan. This year, however, one special aspect will be included. We will focus on the new Framework Program of European Union, i.e. Horizon Europe, and the place of hydrogen research in it. It will consider not only Clean Hydrogen Joint Undertaking, but also the Green Deal initiative of the European Commission.

We all agree that an integral part of the conference, in addition to the technical program, is to provide ample time for networking. This aspect, however, will be this time less pronounced than usual, because due to the ongoing coronavirus pandemic and related restrictions the conference has to go on line. Our motivation is to maintain the information exchange in the field of hydrogen ongoing despite the unfavorable situation. Especially if we consider how exciting the topic of hydrogen has become in the past months.

Finally, I would like to thank you all for your participation and contributions. It is primarily participants and contributors who make the conference stimulating and attractive. Organizers merely try to create an attractive framework and provide everyone with sufficient space to represent their ideas and results of their hard work.

I wish all of us an informative and interesting meeting, despite its on-line virtual form.

Karel Bouzek

Chairman of the Scientific Committee

General Information

Conference

Online 24.–25. 3. 2021
www.hydrogendays.cz

Conference language

The conference language is English. No simultaneous translation will be provided.

Student Award

Thanks to the kind support of HENRY IF SICAV a.s., subfund HYDROGEN 1, two student awards will be given out this year. The STUDENT AWARD for the best student contribution on the conference, from presentations as well as posters, will be announced, which will be awarded with a prize of 25.000 CZK each. HYDROGEN 1 wants to motivate young students in the hydrogen field.

All student contributions will be automatically included in contest for Student Award. Students not wishing to participate are kindly asked to inform the Organising committee at registration committee.

Criteria

Quality of research

- Compliance with ethical standards for publication
- Clear structure and explanation of content
- Poster resp. presentation design
- Ability of student presenter to answer questions.

Students awards will be announced during the closing ceremony on Thursday 25th March, 2021

To participate applicants must:

- be officially matriculated students, including PhD students, at the date of 16 February 2021
- have submitted an abstract
- have uploaded their presentation or poster

The award committee formed by academics and professionals will serve as judges. Scoring rubrics will be used for judging. In the case of same scores the contribution with higher scores in the field of content will be put in first place.

Publication policy

Participants will receive the Book of Abstracts with summaries of lecture and poster contributions presented during the conference. Authors are free to publish their papers at will after the conference. On the basis of authors permission the presentations will be displayed at the Hydrogen Days website after the conference closure.

Contacts

Czech Hydrogen Technology Platform

Hlavní 130
250 68 Husinec-Řež, Czech Republic
www.hytep.cz



Program

Programme at Glance

Wednesday

SESSION 1

Welcome & Plenary Lectures

BREAK

SESSION 2

H₂ Technologies in Different Countries

LUNCH
+ "Virtual Hydrogen Networking Lunch in V4 Countries"

SESSION 3

Development & Deployment in Transportation

BREAK

SESSION 4

Development & Deployment in the Energy Sector

BREAK

SESSION 5

Development & Deployment in Transportation

Thursday

SESSION 1

Cross Cutting & Overarching Issues

BREAK

SESSION 2

Development & Deployment in Transportation
& in the Energy Sector

BREAK

SESSION 3

Development & Deployment in the Energy Sector

LUNCH
+ "Virtual Hydrogen Networking Lunch in V4 Countries"

SESSION 4

Development & Deployment in the Energy Sector

BREAK

SESSION 5

Development & Deployment in the Energy Sector
and Closing Ceremony

Programme

24. 3.

Contribution

Chairperson: Karel Bouzek

- 09:00 **SES1-1: Organizers welcome**
Karel Bouzek / Karin Stehlík
UCT Prague / HYTEP, CZ
- 09:10 **SES1-2: Auspice's welcome**
Karel Havlíček
Ministry of Industry & Trade MIT, CZ
- 09:15 **SES1-3: Auspice's welcome**
Richard Brabec
Ministry of the Environment, CZ
- 09:20 **Auspice's welcome**
Luděk Sosna
Ministry of Transportation, CZ
- 09:25 **Auspice's welcome**
Tomáš Burdych
Ministry of Regional Development, CZ
- 09:30 **Auspice's welcome**
Marek Svoboda
Ministry of Foreign Affairs, CZ
- 09:35 **Sponsor's welcome**
Daniel Jiříčka
ÚJV Řež, CZ
- 09:40 **SES1-4: European Hydrogen Strategy**
Bart Biebuyck
FCH JU, BE
- 09:55 **SES1-5: Importance of Research and Education in H₂ Technologies**
Olaf Jedicke
Hydrogen Europe Research, BE
- 10:05 **SES1-6: Germany's National Hydrogen Strategy: Goals, Next Steps and European Initiatives**
Stefan Kaufmann
Federal Ministry of Education and Research, DE

- 10:20 **SES1-7: The Hydrogen Strategy of the Netherlands and the Implementation Phase**
Rodrigo Pinto Scholtbach
Ministry of Economic Affairs and Climate Policy, NL
- 10:35 **SES1-8: Hydrogen Strategy of the Czech Republic**
Petr Mervart
Ministry of Industry and Trade, CZ
-
- 10:50 **Break**
- Chairperson: Karin Stehlík**
- 11:10 **SES2-1: Ústí Hydrogen Valley**
Martin Mata
Innovation Center of the Ústí Region, CZ
- 11:25 **SES2-2: Smart Specialisation Study on Hydrogen Technologies in Kosice Region**
Maros Halama
TU Košice, SK
- 11:40 **SES2-3: Current Status and Prospects for Development of Hydrogen Value Chain in Sweden**
Vitaliy Tsvyntarnyy
Business Sweden, SE
- 11:55 **SES2-4: Chilean Hydrogen Association (H₂ - Chile) – Promoting a Green Hydrogen Ecosystem**
María Paz de la Cruz
Chilean Hydrogen Association, RCH
- 12:10 Q&A
-
- 12:20 **Lunch**
- Chairperson: Matthias Jahn**
- 13:20 **SES3-1: Decarbonising Freight Transport – The Role of Hydrogen-Based Fuels**
Robert Steinberger-Wilckens
University of Birmingham, UK
- 13:40 **SES3-2: Fuel Cells for Mobile Applications – Technological Approaches Towards Cost Effective Mass Production**
Thomas von Unwerth
TU Chemnitz, DE
- 14:00 **SES3-3: Characterisation of Subassemblies and Fast In-line Quality Assessment in Fit-4-AMandA Project**
Martin Biák
TU Chemnitz, DE
-
- 14:20 **Break**

Chairman: Robert Steinberger-Wilckens

14:40 **SES4-1: Green Hydrogen – a Key Component for CO₂ Emission Mitigation in Industrial Processes**

Matthias Jahn
Fraunhofer IKTS, DE

15:00 **SES4-2: Production of Renewable Hydrogen from Solar Power in Litvínov**

Václav Bystrianský
UniCre, CZ

15:20 **SES4-3: QualyGridS – Standardized Qualifying Tests and Business Cases of Electrolyzers for Grid Services**

Regine Reissner
German Aerospace Center (DLR), DE

15:40 **Break**

Chairperson : Thomas von Unwerth

16:00 **SES5-1: Linde FuelCell – Advantages and Product Overview**

Josef Bartoniček
Linde Material Handling GmbH

16:20 **SES5-2: Fuel Cell Cargo Bicycles for Emission-Free Logistics**

Torsten Knöri
German Aerospace Center (DLR), DE

16:40 **SES5-3: Hydrogen Storages for Flat Box-Shaped Design Spaces in Electric Vehicle Architectures**

Michael Ruf
BMW AG, DE

17:00 **SES5-4: Nanotechnological Approaches as Promising Ways for Effective Hydrogen Storage**

Ivan Saldan
CEITEC, CZ

17:20 **SES5-5: Wrap Up of Day 1**

Karel Bouzek / Karin Stehlík
UCT Prague / HYTEP

25. 3.

Contribution

- 09:00 **SES1-1: Welcome by Chairman**
Václav Bystrianský
- 09:10 **SES1-2: Teaching FCH Technologies in a Masters' Course Across Europe**
Robert Steinberger-Wilckens
University of Birmingham, UK
- 09:30 **SES1-3: The Hydrogen Lab in Görlitz (HLG): a Joint Research Platform**
Maciej Satora
Fraunhofer-Gesellschaft IWU, DE
- 09:50 **SES1-4: Green Hydrogen – Case Studies from Other European Countries**
Martin Dittrich
Bilfinger Tebodin, CZ
- 10:10 **SES1-5: European Hydrogen Backbone – A Dedicated Hydrogen Infrastructure**
Karin Stehlik
NET4GAS, CZ

10:30 Break

Chairperson: Regine Reissner

- 10:50 **SES2-1: Energetic Analysis and Optimization of Decentral Micro Hydrogen Refuelling Stations Using Electrochemical Compression**
Linda Schorer
Research Cluster Electrochemistry, DHBW Mannheim, DE
- 11:10 **SES2-2: New Low Power Modular PEMFC for Transportation Applications operating under Harsh Conditions**
Christophe Kinkelin
Univ. Grenoble Alpes / CEA, FR
- 11:30 **SES2-3: Direct Catalytic Methanation of Carbon Dioxide in Biogas**
Jan Kulas
ÚJV Řež, CZ
- 11:50 **SES2-4: Fiber-like Structure on Proton Exchange Membrane Created by Magnetron Sputtering and Plasma Etching as a Catalyst Support for Water Electrolyzers**
Tomáš Hrbek
Charles University, CZ

12:10 Break

Chairperson: Martin Paidar

- 12:30 **SES3-1: NiFe Anodes for Advanced Alkaline Electrolysis**
Stefan Loos
Fraunhofer Institute for Manufacturing Technology and Advanced Materials, DE

- 12:50 **SES3-2: High Performance Alkaline Water Electrolyser with Highly Porous Non-noble Metal Electrodes Produced by Air Plasma Spraying**
Fatemeh Sanaz Razmjooei
German Aerospace Center (DLR), DE
- 13:10 **SES3-3: Separators for Alkaline Water Electrolysis Based on Porous Polymeric Diaphragms Modified by Graft-Polymerization of Acrylic Acid**
Lubomir Stano
Comenius University in Bratislava, SK
-
- 13:30 **Lunch**
- Chairperson: Martin Biák**
- 14:30 **SES4-1: Evaluation of the Influence of Anion Selective Material and Preparation Method on a Performance of CCM-MEA in Alkaline Water Electrolysis**
Michaela Plevová
University of Chemistry and Technology, Prague, CZ
- 14:50 **SES4-2: Progress in Introducing Membranes into Alkaline Water Electrolysis**
Karel Denk
University of Chemistry and Technology, Prague, CZ
- 15:10 **SES4-3: Aerosol Synthesis of Nanoparticles for Deposition of Catalytic Layers**
Tomáš Němec
Institute of Thermomechanics, Academy of Science, CZ
- 15:30 **SES4-4: Ir-decorated Pt Nanoparticles for Unitized Regenerative Fuel Cell Catalyst**
Lucinda Blanco Redondo
Charles University, CZ
-
- 15:50 **Break**
- Chairperson: Tomáš Němec**
- 16:10 **SES5-1: Experimental Study on the Catalyst Coated Membrane of PEM Electrolyzer**
Amadeu Rocha
University of Porto, PT
- 16:30 **SES5-2: Electrochemical Behaviour of H_3PO_3 in a Pt/H_3PO_4 System at Elevated Temperatures**
Martin Prokop
University of Chemistry and Technology, Prague, CZ
- 16:50 **SES5-3: Epoxy Resin / Graphites Composites for PEM FCs' Bipolar Plates**
Alina M. Darabut
Charles University, CZ
- 17:10 **SES5-4: Closing Ceremony**
Karel Bouzek / Karin Stehlík
UCT, Prague/ HYTEP, CZ

Poster section

Activities of the Joint Programme on Fuel Cells and Hydrogen in EERA

Martin Paidar, Karel Bouzek
UCT Prague, CZ

Electric Bicycle Powered by the Hybrid Energy Source using PEMFC Hydrogen-oxygen Fuel Cells

Andrzej Raźniak, Mateusz Łasica
AGH University of Science and Technology, PL

Hybrid Power Source Involving 2 kW Polymer Membrane Fuel Cell Stack for Supplying Drone

Andrzej Raźniak
AGH University of Science and Technology, PL

Regional Hydrogen Trains on Czech Railways – A Techno-economic Analysis

Federico Zenith
SiNTEF, N

MAMA-MEA: Mass Manufacture of MEAs Using High Speed Deposition Processes

Martin Biák
TU Chemnitz, DE

Indication of Proton Conduction in the $\text{La}_{2-x}\text{A}_x\text{Ni}_{1-y}\text{Fe}_y\text{O}_{4+\delta}$ Cathode Materials for SOFC/SOFC-H⁺

Artem Gilev
Ural Federal University, RU

Material Degradation Testing in Solid Oxide Electrolysis / Fuel Cell

Petra Dvořáková Ruskayová
Research Center Rez, CZ

Solid Oxide Electrolysis / Fuel Cell Loop

Aleš Kejla
Research Center Rez, CZ

Development of an Alkaline Electrolyzer for Storing Electric Power in the Hydrogen Form

Miroslav Kludský, Jiřina Čermáková, Aleš Doucek
UJV Řez, CZ

Nickel Based Electrode as Cathode Catalyst in Alkaline Water Electrolysis

Jana Záchenská, Maroš Ábel, Matilda Zemanová
Slovak University of Technology, SK

NiCoP Cathode Catalyst for Electrochemical Water Splitting: Structural and Electrochemical Characterization

Martin Durovic, Jaromir Hnat, Karel Bouzek
UCT Prague, CZ

Enhanced Photocatalytic H₂ Production from H₂S on Metal Modified CdS-ZnS Semiconductors

Maali Amel Mersel, Lajos Fodor, Otto Horváth
University of Pannonia, HU

Hydrogen Evolution Reaction on CoMo- and MoNi-alloy Modified Nickel Foam Surface

Mateuzs Luba, Mateuzs Kuczynski
University of Warmia and Mazury, PL



Abstracts
Orals

Smart Specialisation Study on Hydrogen Technologies in Kosice Region

^{1,4,6} M. Halama, ² T. Brestovič, ¹ J. Legemza, ³ V. Zeleňák, ⁴ K. Saksl, ⁵ S. Koperdák,
⁶ J. Weiterschutz, ⁶ P. Hegeduš

¹ Technical University of Kosice, Faculty of Materials, Metallurgy and Recycling, Letná 9, Košice, Slovak Republic; tel. +421 556 022 537, e-mail: maros.halama@tuke.sk

² Technical University of Kosice, Faculty of Mechanical Engineering, Vysokoškolská 4, Košice

³ University of P. J. Šafárik, Faculty of Natural Science, Šrobárova 2, Košice

⁴ Slovak Academy of Science, Institute of Materials Science, Watsonova 47, Košice

⁵ Košice Self-government Region, Námestie Maratónu Mieru 1, Košice

⁶ NVAŠ, Slovak National Hydrogen Association, Budyšínska 36, Bratislava

Keywords: hydrogen, transport, storage, safety, education

Hydrogen is among batteries another key renewable vector undergoing considerable attention and consideration at EU level. That is why, group of wide-spectrum authors leading an evidence-based JRC study to discover potential of hydrogen technologies in Kosice Self-Governing Region (KSK) helping the EU reach its environmental goals while boosting local investment in new technologies amongst a diverse set of economic areas. KSK would like to explore further in depth the implications of greater public and private investment in hydrogen as an alternative source of energy, particularly its spill-over effects on regional innovation, education, entrepreneurship and employment. The aim is to detect areas with high deployment of hydrogen technologies across industrial sectors from energy production, transport, storage but also research and development hand in hand with education strongly focused on safety issues. It contain recommendations and alternative scenarios helping KSK to fit unique plans achieving competitive position and to set up policy decisions in future.

Chilean Hydrogen Association (H₂ - Chile) – Promoting a Green Hydrogen Ecosystem

¹ María Paz de la Cruz

¹ Chilean Hydrogen Association, RCH

Keywords: H₂ Chile, green hydrogen, hydrogen strategy, climate change, CO₂ reductions, hydrogen applications, game-changer, pilot projects, renewable potential

The introduction part of the presentation shows what H₂ Chile is, where it is based, who founded the association, why they founded and the current member companies.

The next part is an invitation to think “*why are we talking about green hydrogen*” and all the possibilities it offers to decarbonize each of the productive sectors depending on the final applications. It is also an invitation to think about the new challenges and Game-Changer this molecule can be, allowing the coupling of different sectors that previously worked separately.

The presentation also shows the implications of the Hydrogen Strategies promoted by countries of the European Union to then detail the ambitious Hydrogen Strategy that Chile is promoting.

Finally, some *Green Hydrogen* projects already implemented or in feasibility phase are presented, together with the different activities in which the association is involved.

This presentation aims to show the audience all the desire and potential that Chile as a country has to produce the cheapest *Green Hydrogen* in the world, together with the political commitment to make this happen. Because in H₂ Chile we believe that Hydrogen is the key molecule that allows us to accelerate the energy transition and enable Chile renewable potential to be exported to the world with non-Greenhouse emissions.

Decarbonising Freight Transport – The Role of Hydrogen-Based Fuels

¹ R. Steinberger-Wilckens, ¹ S. Sogbesan, ¹ K. M. Ayodeji, ¹ M. Taylor, ¹ Y. Al-Sagheer

¹ Centre for Fuel Cell and Hydrogen Research, School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK; tel. +44 121 415 8169, e-mail: r.steinbergerwilckens@bahm.ac.uk

Keywords: heavy duty road vehicles, freight transport, SOFC, SNG, zero emissions, CCU, biomass, carbon capture, shipping, aircraft

Transport services have been contributing a growing amount of global emissions in recent years whilst the sectors of industry and households are reducing and retaining their emission levels, respectively. With transport being an indicator and result of global economic development, the reduction of transport impact by both increasing the efficiency of drive trains and reducing vehicle emissions needs to be a main objective of global emissions reductions.

Hydrogen is widely seen as 'the' solution to transport emissions. For long-range transport by road, water or air, though, this might not be an option due to limited volume available for on-board storage. Clean hydrogen can be produced from renewable electricity by electrolysis. Nevertheless, the problem remains that the vast majority of current hydrogen is produced by stripping various hydrocarbons of their carbon component (potentially via carbon capture and storage, CCS) and using the resulting 'grey' hydrogen as an energy carrier. Besides from creating a new 'nuclear waste'-type problem of long-term storage of potentially hazardous waste, CCS does not prevent the rapid depletion of fossil energy sources. Insofar, the use of biomass and waste as sources of carbon have to be further investigated, as well as the options of turning carbon into an asset and not releasing it to the atmosphere at all anymore.

This study looks at the options of using renewable hydrogen and biomass carbon to produce methane (synthetic natural gas, SNG), avoiding any release of fossil carbon. In addition, this solution offers all advantages freight transport currently is exploiting with the drive towards methane and especially LNG fuels. SNG uses the current natural gas network and has the potential to gradually take over the existing infrastructure whilst completely decarbonising it.

The use of methane as a fuel for commercial vehicles opens up the door to a number of previously not available options:

- use of high temperature fuel cells (SOFC) in vehicle drive trains,
- use of SOFC-off heat for driving cooling/refrigeration units and air conditioning,
- higher conversion efficiency of fuels due to internal reforming,
- full compatibility to current LNG developments through liquefied SNG,
- facile phasing-in of zero-emission fuels without further investment apart from vehicle conversion to gas propulsion.

Results will be presented on vehicle developments in the three sectors road, maritime and air transport, and on the energy balances and feedstock potential of such a conversion in Europe.

Characterisation of subassemblies and fast in-line quality assessment in Fit-4-AMandA project

^{1,a}M. Biák, ²J. Libra, ^{1,b}T. von Unwerth

¹ Chemnitz University of Technology, Department of Advanced Powertrains, Reichenhainer Str. 70, 09126 Chemnitz, Germany;

^a tel. +49 (0) 371 531 32058, e-mail: martin.biak@mb.tu-chemnitz.de

^b tel. +49 (0) 371 531 23550, e-mail: thomas.von-unwerth@mb.tu-chemnitz.de

² Kolibrik.net, s.r.o., Smetanova 34, 591 01 Žďár nad Sázavou, Czech Republic; tel. +420 777 217 401, e-mail: jiri.libra@kolibrik.net

Keywords: fuel cells, mass manufacturing, automation, PEMFC stack, quality control, single cell, single-cell characterisation

The main objective of the Fit-4-AMandA^[1] project is to build an automated manufacturing line (including in-line non-destructive tests) capable of ramping up the production of PEMFC stacks. To be optimised for automated manufacture, the current design of PEMFC stacks and stack components underwent necessary modifications. Furthermore, a demonstration of the resulting mass-produced stacks is to be performed in real environment, i.e., one of the stacks is to be integrated into a light commercial vehicle and tested in day-to-day operation.

The development of non-destructive quality control tools for the stack-assembly machine is vital to increase yield and reliability of the mass-produced fuel cell stacks. Low throughputs together with high number of faulty produced stacks – every tenth stack is faulty and needs to be reworked – are among the main technical barriers in the fuel-cell stack manufacturing. The goal of Fit-4-AMandA project is to elevate these constraints.

The in-situ diagnostics of single cells with large active areas (>400 cm²) is a part of a validation of the Fit-4-AMandA cell design. These cells are low-voltage (<1 V) power supplies that provide high current (>400 A @ 1 A/cm²). Such a combination poses a challenge for instrumentation in particular the electronic loads used to sink the generated current. One of the solutions to this problem is connecting an auxiliary boost power supply in series with the electronic load and the power supply. A prototype of such electronic load, so-called zero-voltage load, was developed by company Kolibrik according to specification provided by Fit-4-AMandA to be used for testing with the Fit-4-AMandA full-sized single cell with an active area of 409 cm².

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735606.



**FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING**

^[1] Future European Fuel Cell Technology: Fit for Automatic Manufacturing and Assembly (EU project, duration 01 Mar 2017–29 Feb 2020, 36 months). Funding Programme H2020-JTI-FCH-2016-1, Grant Agreement #735606. Website: <http://fit-4-amanda.eu>.

Green Hydrogen – a Key Component for CO₂ Emission Mitigation in Industrial Processes

¹ M. Jahn, ¹ G. Herz, ¹ N. Müller

¹ Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Winterbergstr. 28, 01277 Dresden, Germany; tel. +49 351 2553 7535, e-mail: matthias.jahn@ikts.fraunhofer.de

Keywords: co-electrolysis; CDA, CCU, PtL, steelmaking

The mitigation of CO₂ emissions is a major challenge for modern society and especially the major industrial emitters. In order to sustainably reduce CO₂ emissions, two basic routes are available: carbon direct avoidance (CDA) and carbon capture and utilization (CCU). Both concepts are favorable for different industrial applications. However, even though there are fundamental differences in these two approaches, they both have in common that hydrogen will play an important role in the implementation.

For the steel sector for instance hydrogen has been discussed as a sustainable alternative reducing agent for the production of iron in order to replace fossil fuels, such as coke, coal or methane. A possibility to do so is incorporating CDA concepts into the steelmaking process. One approach in this direction including a solid oxide electrolysis is presented. The concept was modeled and evaluated and is expected to allow for a considerable decrease of CO₂ emissions in steelmaking.

In other industrial sectors CO₂ is an intrinsic part of the process and therefore the formation of CO₂ cannot be avoided. In these cases CCU can be used to mitigate emissions. An exemplary process – the production of lime – will be used in order to demonstrate the advantages of an integration of a Power-to-X process. A corresponding approach will be presented and discussed. Additionally a laboratory-scale plant that is to be scaled up in cooperation with an industrial partner will be introduced.

Production of Renewable Hydrogen from Solar Power in Litvínov

¹V. Bystrianský

¹ ORLEN UniCRE a.s., Revoluční 1521/84, 400 01 Ústí nad Labem, Czech Republic; e-mail: vaclav.bystriansky@unicre.cz

Keywords: hydrogen production, ORLEN UniCRE, renewable hydrogen, decarbonization of chemical industry, alkaline electrolyser

The aim of our project is the construction of a new production plant for renewable hydrogen intended for the decarbonization of the chemical industry and transportation sector in Czech Republic. The production plant under consideration will consist of a renewable energy source – a photovoltaic power plant with a peak output of 52 MWp, specially designed for the needs of a renewable hydrogen production unit – an alkaline electrolyser with a capacity of 20 MW. A significant advantage of the proposed solution is the location of the PV power plant in the immediate vicinity of the chemical plant and the hydrogen unit directly in the plant, where the produced green hydrogen will be used right in the adjacent site of the refinery as feedstock for the modification of conventional fuels.

QualyGridS – Standardized Qualifying Tests and Business Cases of Electrolyzers for Grid Services

¹ R. Reissner, ² M. Bornstein, ³ B. Green, ⁴ L. Abadia, ⁵ C. Bourasseau, ⁵ V. Séguin, ⁶ S. You, ⁷ P. Marcuello, ⁸ V. Clemenz, ⁸ C. Imboden, et al.

¹ German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Pfaffenwaldring 38-40, D-70569 Stuttgart, Germany; tel. +49 711 6862-394, e-mail: reine.reissner@dlr.de

² NEL Hydrogen AS., Norway

³ ITM Power, UK; 3Aragon Hydrogen Foundation, Spain

⁵ CEA, France; 5DTU, Denmark

⁷ IHT, Switzerland

⁸ Hochschule Luzern, Switzerland

Keywords: electrolyser system; electricity grid service; testing protocol; economic analysis

Hydrogen production by electrolysis using electricity from renewable sources is considered an important route for decarbonising transportation and industry as well as long term energy storage. With increasing share of renewable production in the electricity grid more efforts for grid stabilisation are required. This demand provides a chance for electrolyzers to offer their flexibility and thus to create additional revenues. The project QualyGridS develops testing protocols to verify the electrolyzers' capability of performing grid services, tests state-of-the-art electrolyser systems and analyses business cases.

An overview of the most important electricity grid services in European countries is given including their timing and volume requirements. Based on the services Frequency Containment Reserve (FCR), Frequency Restoration Reserve (FRR) and Replacement Reserve (RR) that can be offered by loads in many European countries, this project has developed unified testing protocols that include the variations and uniqueness of the services in different countries. Results applying these testing protocols to state-of-the-art Alkaline Water Electrolyzers (AWE) and PEM Water Electrolyzers (PEMWE) in 10–300 kW size and above are presented. These tests are on the one hand for verifying the applicability of the developed testing protocols and on the other hand for analysing the capability of the electrolyzer systems. It can be shown that with the right setting for the Balance of Plant (BOP) components both PEMWE and AWE exhibit the necessary capabilities for grid services. A submission of the protocols as New Work Item Proposal (NWIP) to the standardisation body is on the way.

Analysing business cases, financial and business logic data for 25 European countries as well as 85 Transmission System Operators' (TSO) grid services, the most promising cases were selected for more detailed analysis. Offering the electrolyzer's flexibility to the grid service markets can reduce the cost of hydrogen at the electrolyzer outlet by up to 10 % at ideal conditions. Sensitivity of the costs is analysed with regard to the electrolyzer system properties and market parameters.

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735485. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and N.ERGHY. The work is also supported by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract No. 17.0009.

Linde FuelCell – Advantages and Product Overview

² J. Bartoníček, ¹ Markus Weinberger, ² Pavel Osička

¹ Linde Material Handling GmbH, Carl-von-Linde-Platz, 63743 Aschaffenburg, Germany;
tel. +49 170 3694502, markus.weinberger@linde-mh.at

² Linde Material Handling Czech Republic Ltd., Polygrafická 622/2, 108 00 Praha 10, Czech Republic;
tel. +420 606 606 593, pavel.osicka@linde-mh.cz

Keywords: fuel cells, material handling, technology, forklifts, intralogistics, warehouse, energy

Linde Material Handling (Linde MH) is a leading global manufacturer of forklift trucks and warehouse trucks, and a solutions and service provider for intralogistics. Linde MH has long been involved in H₂ material handling technology.

Linde Material Handling relies on strong and experienced partners for the development of industrial trucks with fuel cell technology. In our presentation we will focus on real projects that we have realized with our partners in recent years.

For example under the name **“H2IntraDrive”**, a comprehensive study of the economic and technical possibilities was launched in 2013 together with the BMW Group and the Chair of Materials Handling Material Flow Logistics at the Technical University of Munich.

For this purpose, hydrogen-powered forklift trucks were used in the body shop of BMW-i vehicles in Leipzig – for over 20,000 operating hours.

Another example was **‘E-LOG-BioFleet’**, joint project between Linde Material Handling, Fronius International, DB Schenker, OMV, HyCentA Research and Joanneum Research. In one of DB Schenker’s transshipment warehouses in Hörsching, Austria, ten pallet trucks with fuel-cell hybrid drive and the first indoor refueling system for hydrogen in Europe were tested in practice.

With the motto **“Daimler Goes Green”**, Mercedes-Benz is testing the use of forklifts with fuel cell drive. The location is the world’s largest plant for Mercedes Sprinter vans in Düsseldorf.

Linde Material Handling will share experience in the real deployment of hydrogen powered trucks in Europe.

About Linde Material Handling GmbH

Linde Material Handling GmbH, a KION Group company, is a leading global manufacturer of forklift trucks and warehouse trucks, and a solutions and service provider for intralogistics. With a sales and service network that spans more than 100 countries, the company is represented in all major regions around the world. In the 2018 financial year, the Linde MH EMEA Operating Unit (Europe, Middle East and Africa) recorded a total revenue of roughly EUR 3.3 billion, with approximately 11,600 employees. Global sales of Linde trucks amounted to over 135,000 in 2018.

Fuel Cell Cargo Bicycles for Emission-Free Logistics

¹T. Knöri, ²M. Schulze, ³I. Bürger, ⁴T. Maag

¹ German Aerospace Center, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany, Institute of Engineering Thermodynamics; tel. +49-711-6862-8217, e-mail: torsten.knoeri@dlr.de

² Institute of Engineering Thermodynamics; tel. +49-711-6862-456, e-mail: mathias.schulze@dlr.de

³ Institute of Engineering Thermodynamics; tel. +49-711-6862-492, e-mail: inga.buerger@dlr.de

⁴ Institute of Vehicle Concepts; tel. +49-711-6862-298, e-mail: tilo.maag@dlr.de

Keywords: fuel cell, PEM, low temperature, stack, system, cargo pedelec, logistics

Today, 75 % of the Europeans are living in cities. In these urban areas with a high density of population, transportation of goods and services is one of the most important reasons for traffic. Consequently, commercial transport causes 50 % of the emissions and 30 % of the urban vehicle miles.

Many transportation duties in cities or industrial areas could be realized by cargo bicycles at lower costs, often faster and substantially more sustainable than with cars or other transport vehicles. Because of these advantages cargo bikes have received great interest in urban delivery situations, triggered also by the growing transport demand from e-commerce. In combination with micro hubs electric cargo bikes can substitute combustion engine trucks and address the different socioeconomic issues mentioned above.

For commercial application, two different approaches for the electrification of cargo bikes are promising: electro mobility by batteries (accumulators) or by fuel cells (polymer electrolyte membrane fuel cells) depending on the individual application. For duty applications fuel cell technology has many advantages towards batteries: Fast refueling saves time, additional space for replacement accumulators is not required and waste heat can be used for cabin heating in winter. Furthermore, the environmental impact due to manufacturing, life cycle and recycling, is better than in case of batteries. And finally fuel cell powered cargo bikes are the better alternative if high energy capacities are needed e.g. for operations over the whole day, on hilly grounds or with heavy loads.

In the presented projects (FC-REX – Fuel Cell Range Extender and FCCP - Fuel Cell Cargo Pedelec), a modular system is developed based on a liquid cooled PEM fuel cell stack with metallic bipolar plates. This system has a nominal electrical power output of around 350 W, a peak power of 650 W respectively and a 350 (700) bar hydrogen tank.

One drawback of battery or fuel cell powered systems is their inferior performance at low temperatures (sub-zero °C). The cold-start ability of the systems is a special concern, as it reduces their efficiency and their life time. For these reasons, in many electrical systems an additional heater is added for heating up the device in the start-up phase at low temperatures. Due to the required electricity for heating, the range of the vehicle is reduced. For eliminating this disadvantage, the developed fuel cell system is equipped with a metal hydride based pre-heater. This device will not consume hydrogen fuel or electrical energy, but generates adsorption heat to address cold start. Actually, the pre-heater needs less than 60s for increasing the stack temperature from -20 °C to at least 10 °C.

The presentation will give an overview of the complete system, its different components as well as on the status of the validation projects.

Hydrogen Storages for Flat Box-Shaped Design Spaces in Electric Vehicle Architectures

^{1,2}M. Ruf, ¹H.-U. Stahl, ¹K. Kunze, ²S. Zaremba, ³T. v. Unwerth, ²K. Drechsler

¹ BMW AG, Dept. of Hydrogen, Alternative Fuel Tanks, Petuelring 130, 80788 Munich, Germany; tel. +49 89 382 46994, e-mail: michael.g.ruf@bmw.de

² Technical University of Munich, Dept. of Aerospace and Geodesy, Chair of Carbon Composites, Boltzmannstr. 15, 85748 Garching, Germany; tel. +49 89 289 15087

³ Chemnitz University of Technology, Dept. of Advanced Powertrains, 09107 Chemnitz, Germany; tel. +49 371 531 23550

Keywords: hydrogen storage, pressure vessel, box-shaped design space, electric vehicle architectures, volumetric efficiency, carbon composites

Fuel Cell Electric Vehicles (FCEVs) are still a niche product in the global automotive market, although electromobility has already become a worldwide trend. The main reasons from a customer point of view are the high vehicle price of the FCEV compared to Battery Electric Vehicles (BEVs) and the lack of refuelling stations close to their homes or working places. The consequences are low sales and production numbers that do not allow car manufactures to realise economies of scale for development and manufacturing costs.

Today gasoline and diesel cars share the same installation spaces for powertrain components. Likewise it would be very beneficial, if hydrogen drive and battery systems could also share the same vehicle architectures. The integration of both energy systems into the same car body would enable economies of scale and allow flexible production, which could balance demand fluctuations. In most of the current BEVs batteries are integrated in flat box-shaped design spaces within the vehicle underbody. However, large cylindrical pressure vessels are state of the art for hydrogen storage in FCEVs. Thus the major challenge today is the integration of hydrogen storage systems into flat box-shaped design spaces. Furthermore and in order to fulfil customers' cruising range expectations the available design space must be used efficiently.

Therefore two new design solutions for hydrogen pressure vessels are analysed with regard to their volumetric efficiency in a box-shaped design space. Firstly, pressure vessels based on cylindrical elements are investigated. The main challenge here is the connection of the cylindrical main parts as well as stacking them efficiently (Fig. 1, Concept a). The second solution is based on an approximation of the box-shaped design space by the pressure vessel geometry itself. Inner tension struts are used to prevent deformation of the opposite plane surfaces in spite of the high working pressure (Fig. 1, Concept b). The main challenge is the connection of the tension struts and the surrounding wall. Comparative analyses show the potential as well as the technical challenges of both options.

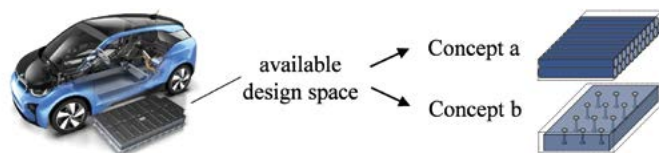


Fig. 1: Integration of hydrogen pressure vessels into battery installation spaces of BEVs (vehicle image for illustration purpose only).

Nanotechnological Approaches as Promising Ways for Effective Hydrogen Storage

¹ I. Saldan

¹ Central European Institute of Technology, Brno University of Technology, Purkyňova 565/123, 612 00 Brno, Czech Republic; tel. +421 951 325 608, e-mail: saldanivan@gmail.com

Keywords: nanostructured hydrides, confinement, catalysis

Almost all solid hydrides with a high hydrogen content (≥ 7.5 wt% H₂) have a thermodynamic stability that does not meet requirements for on-board hydrogen storage. In case of thermodynamic equilibrium ($\Delta G_0=0$), decomposition of MH₂:



under 1 bar of H₂ might be possible at temperature value of ($\Delta H_0/\Delta S_0$)^[1]:

$$\Delta G_0 = \Delta H_0 - T\Delta S_0 = -RT \ln K_{\text{eq}} \quad (2)$$

Very small ΔS_0 value between bulk MH₂ and M (that is not true for nanostructured hydrides) can be neglected while ΔS_0 value of hydrogen to change solid state of matter (hydrogen in MH₂) to gas (H₂ molecules) is calculated as 130.7 J·K⁻¹·mol⁻¹ H₂^[2]. Therefore, to achieve equilibrium pressure value of 1 bar H₂ between 233 and 423 K, ΔH_0 value of MH₂ decomposition should be in range of 30–55 kJ·mol⁻¹ H₂. Unfortunately, these thermodynamic requirements are not found for hydrides with the high hydrogen content. One of the ways to reduce ΔH_0 value was situation where after hydride decomposition a chemical compound MA (not M) might be formed^[3]:



This, so called “destabilized hydrides approach” was considered by group of J.J Vajo and further developed to a mutual chemical reaction between two different type of hydrides^[4].

Enhanced diffusion for MH₂ might be obtained inside a nanoscale void^[5]. When the hydride nanoparticle is embedded in a nanoscaffold, they may stay in the distance of a part of nanometer. Correct physical description of a nanoconfined MH₂-M system must consider the actual situation at the interface of the solids, including the influence of hydrogen pressure and surface interaction of the hydride nanoparticles with the inner wall of the voids. These both aspects may lead to a decrease of the energy parameter through minimizing the excess of surface energy.

Reduction of standard dehydrogenated state enthalpy and surface energy contribution for nanostructured hydrides will be discussed as a promising way to developed hydrogen storage materials for practical application in fuel cells.

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Teaching FCH Technologies in a Masters' Course Across Europe

¹ Robert Steinberger-Wilckens, ² Aravind Purushothaman Vellayani, ³ Massimo Santarelli, ⁴ Yegor Brodnikovskiy, ⁵ Lars N. Cleeman, ⁶ Karel Bouzek, ⁷ Jan Van herle, ⁸ Jean-Luc Delplancke, ⁹ Ioan Iordache, ¹⁰ Florence Druart, ¹¹ Vladimir Molkov, ¹² Olaf Jedicke

¹ University of Birmingham, B15 2TT, UK; tel. +44-121-415-8169, e-mail: r.steinbergerwilckens@bham.ac.uk

² TU Delft/Hanze Universiteit Groningen

³ Politecnico di Torino

⁴ KPI Kyiv

⁵ DTU

⁶ VSCHT Prague

⁷ EPFL

⁸ Universite Libre de Bruxelles

⁹ UPB Bucharest

¹⁰ INP Grenoble

¹¹ Ulster University

¹² KIT Karlsruhe

Keywords: FCH education, training, continuous professional development, MSc, university course

As the fuel cell and hydrogen technologies (FCHT) industry gradually emerges into the markets, the need for trained staff becomes more pressing. Up to the year 2030, it is estimated, around 300,000 trained staff will be required, made up of trained workers, technicians, engineers, and scientists. It can be expected that many university and college graduates will chose employment in this growing industry, but many already employed staff will need to be re-trained, too. Nevertheless, currently practically no educational programmes exist in Europe that would be able to train this human resource. The project TeachHy, funded by the European Commission through the FCH JU, specifically addresses the supply of undergraduate and graduate education (BEng/BSc, MEng/MSc, PhD etc.) in fuel cell and hydrogen technologies (FCHT) across Europe.

12 European universities have teamed up to develop an MSc course and the supporting material. This 'blended learning' TeachHy MSc course can be delivered through a wide network of universities across Europe who have subscribed to the project. Any university being able to offer 20 to 30 % of the course content locally in face-to-face teaching, can draw on the other 70 to 80 % to be supplied by the project via an online platform. Alternatively, the teaching material can be implemented on the university learning management system (LMS) platform. This will allow any institution to participate in this European initiative with a minimised local investment. TeachHy2020 is offering solutions to accreditation and quality control of courses, and supports student and industry staff mobility by giving access to placements. Universities from outside the EU can also participate in the scheme.

Learning materials for Continuous Professional Development (CPD) will be derived from the TeachHy course material. This also entails translation of the course material into several European languages, in order to allow communication on FCH technologies possible in all EU countries. TeachHy will also offer educational material for the general public (e.g. MOOC's), build a business model to continue operations post-project, and as such act as a single-stop shop and representative for all matters of European university and vocational training in FCHT.

The Hydrogen Lab in Görlitz (HLG): a Joint Research Platform

¹ S, Schmidt, ¹ H. Hilse, ¹ M. Satora, ¹ A. Garcia-Sanchez

¹ Fraunhofer Institute for Machine Tools and Forming Technology (IWU).
Technology Fraunhofer Plastics Technology Center Oberlausitz, Theodor-Körner-Allee 6 02763 Zittau, Germany;
tel. +49 3583 54086-0, e-mail: sebastian.schmidt@iwu.fraunhofer.de

Keywords: hydrogen production, clean energy, hydrogen applications, electrolysis, digitalization, mobility applications, hydrogen storage, hydrogen transmission and distribution

Energy transition is one of the greatest challenges of our time. Resources must be conserved and the potential of regenerative energies must be used effectively. This requires viable alternative options to the fossil energy sources currently still in use. This is where the usage of hydrogen technology offers an excellent opportunity.

These objectives are accompanied by equally challenging change processes, both technological and social. On 15 July 2019, the Free State of Saxony, Siemens AG and the Fraunhofer-Gesellschaft signed a letter of intent to strengthen the location in the long term and support the structural change in Lusatia. The Görlitz Innovation Campus was established for this purpose. The aim of this pact is to attract further technology and industrial companies, start-ups and research institutes. The focus is on digitalisation, automation, energy technology and innovative material and production technologies.

The result is the Fraunhofer Hydrogen Lab Görlitz (HLG), a joint research platform at Siemens Innovation Campus. Its aim is to develop innovative solutions along the hydrogen value chain. Here, the HLG benefits from the synergy effects of the research competences of the Fraunhofer Institute for Machine Tools and Forming Technology (IWU) and the Fraunhofer Institute for Microstructure of Materials and Systems (IMWS), as well as further industrial and university partners.

The research focuses on hydrogen production, storage and the use of hydrogen in mobile and stationary fuel cells for mobility and for supplying neighbourhoods and industrial sites. This includes in particular testing and development of electrolyzers, hydrogen storage and fuel cells (mobile and stationary), as well as CO₂-neutral industrial processes. Among other things, the focus on electrolysis production and the establishment of a certification centre for hydrogen technologies will open up new possibilities for expansion and development in situ.

The main difference with other hydrogen centres is the focus on research and not just production, although the expected power is between 12 and 15 MW.

Therefore, the targeted transfer of technology and know-how to the region will contribute significantly to strengthening Lusatia's competitiveness and creating new jobs.

Green Hydrogen – Case Studies from Other European Countries

¹ M. Dittrich, ¹ M. Kloda

¹ Bilfinger Tebodin Czech Republic, s.r.o., Prvního Pluku 224/20, 186 00 Praha 8;
tel. +420 724 518 622, e-mail: martin.dittrich@bilfinger.com

Keywords: hydrogen, green hydrogen, renewables, electrolysis, hydrogen transportation, hydrogen compression, power to gas, power to mobility, hydrogen product chain engineering, Bilfinger Tebodin

Bilfinger is a leading international industrial service provider for the process industry. The group covers the entire value chain of projects and industrial plants from consulting, engineering, manufacturing, assembly and plant expansion to turnarounds and maintenance. Also includes environmental technologies and digital applications.

Bilfinger has a comprehensive portfolio of products and services to support its industrial customers to reach their sustainability goals and meet climate change targets.

From mature activities like Hydro power, District Heating or Flue Gas Cleaning to new areas such as Green Hydrogen, Carbon Capture Utilization & Storage (CCUS), Power/Waste-to-X or Energy Efficiency, Bilfinger is constantly developing its capabilities to better serve its customers throughout the entire value chain and move from hard to abate emissions.

As the trend of abating emissions is getting stronger, more cities, countries and industries are leaning towards the green sources of the energy and they are starting with their own studies about achieving the goal of the abating emissions. Green hydrogen produced by electrolysis and renewable source of energy is one of the way.

Bilfinger spots an increasing trend in the demand for the feasibility studies related to the green hydrogen production all around the Europe. A few projects have positive investment decisions or are even in execution.

Bilfinger has experience with many hydrogen projects from all around the Europe. This includes the projects related to Power to gas, Power to mobility and Power to hydrogen applications.

One of the most interesting projects is the conceptual design of the big green hydrogen production offshore island in the North Sea. This concept study was made in three variants for 2; 5 and 20 GW of offshore wind capacity connected to it, together with 3D model for this island.

One of the key factors in the hydrogen production chain is the hydrogen transport infrastructure including the safety of such infrastructure. Among other projects, Bilfinger has the experience from large-scale compression station study for approx.

1 GW electrolysis production capacity. Bilfinger also participates in the project, which develops the solution for transporting the hydrogen embedded into liquids (e.g. LOHC).

European Hydrogen Backbone – A Dedicated Hydrogen Infrastructure

¹ K. Stehlík

¹ NET4GAS, s.r.o., Na Hřebenech II 1718/8, 140 21 Prague 4, Czech Republic; e-mail: karin.stehlik@net4gas.cz

Keywords: european hydrogen backbone, hydrogen transport, hydrogen strategy, gas for climate, safe and reliable energy transition

Hydrogen plays a major role in the plans of the European Commission in the transition to a net zero-emission EU energy system. The European Hydrogen Strategy and Energy Integration Strategy, both published on July 8th, 2020, describe the scale-up of hydrogen already before 2030. To make full use of the potential of hydrogen, future places of supply and demand need to be well-connected. In this contribution the vision of the European Hydrogen Backbone EHB is presented, which has been developed by eleven European gas infrastructure companies from 9 European countries.

The companies Enagás, Energinet, Fluxys Belgium, Gasunie, GRTgaz, NET4GAS, OGE, ONTRAS, Snam, Swedegas and Teréga, supported by Guidehouse, describe a network, which is gradually emerging between mid-2020 and 2040. Firstly, connecting centres of H₂ production and demand, by 2040 the foreseen hydrogen network reaches 23,000 km, of which 75 % will consist of converted natural gas pipelines and 25 % represent new pipeline stretches. This will result in two parallel gas transport networks: a dedicated hydrogen and a dedicated (bio)methane network. This hydrogen infrastructure can be, in the same way as the natural gas network, used for large-scale and long-distance hydrogen transport, also enabling hydrogen imports.¹

Physical properties of hydrogen and natural gas differ from each other requiring component adaption and operation optimisation, when changing the transported commodity to hydrogen. For the purposes of this study, the hydrogen backbone is defined to consist of transmission pipelines, compressor stations, control valves, and gas metering stations. The total investment costs for the 2040 European Hydrogen Backbone are expected to range from €27 to €64 billion. These costs have to be seen in the overall context of European energy transition and time horizon of this study until 2040.

The hydrogen infrastructure supposed in this study represents a critical piece in the puzzle to achieve the objectives European Green Deal. In order to create a European hydrogen backbone, development is still necessary in many aspects. Therefore, is EHB an open initiative open all interested stakeholders to join in the thinking.

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Energetic Analysis and Optimization of Decentral Micro Hydrogen Refuelling Stations Using Electrochemical Compression

¹ L. Schorer, ¹ S. Schmitz

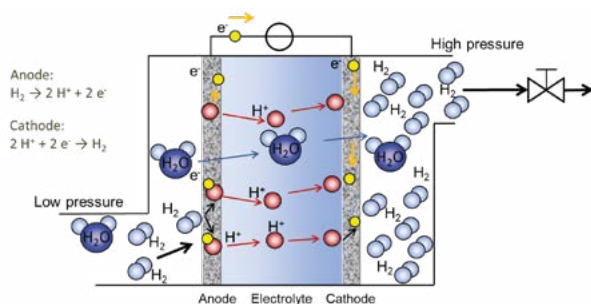
¹ DHBW Mannheim, Research Cluster Electrochemistry, Handelsstrasse 13, 69214 Eppelheim, Germany; tel. +49 621 4105 1821, e-mail: linda.schorer@dhbw-mannheim.de

Keywords: electrochemical hydrogen compression, renewable energy, polymer electrolyte membrane, decentral hydrogen refuelling, hydrogen pumping

Hydrogen car mobility is currently facing a chicken-egg-dilemma. On the one hand the number of hydrogen refuelling stations is quite low and their prices are still very high. On the other hand, the number of cars is increasing very slowly because of the missing stations.

Smaller decentral stations in the proximity of renewable energy production sites could solve the dilemma. Comparable to the loading of battery electric vehicles using the electricity of roof installed photovoltaics power plants a hydrogen storage and refuelling system reduces the grid load even more, because hydrogen is a long-term storage and the storable capacity only depends on the tank size.

Today several electrolyser and tank products are commercially available. The compressor whereas is usually a mechanical one with a low efficiency producing heat, noise and maintenance. At bigger hydrogen refuelling stations the compressor is responsible for half of the installation costs and for most of the failures. An alternative, making decentral hydrogen refuelling a suitable application, is the electrochemical hydrogen compressor (EHC). Using the PEM-technology (polymer electrolyte membrane) like PEM fuel cell and PEM electrolyser the EHC requires the same conditions and can therefore be easily integrated into the PEM system. Significant cost reductions with increasing production numbers will be achieved by using the same materials and components.



The working principle of the EHC is quite simple. An external voltage source forces the hydrogen molecules at the anode to split into electrons and protons. Like in a fuel cell the protons are using ionic transport mechanisms to move to the cathode, where they recombine with the electrons to diatomic hydrogen. This process leads to hydrogen pumping to the cathode side, where a pressure increase is achieved. As the compression is only driven by electrochemistry, it is a noiseless and clean procedure, fitting perfectly to a decentral refuelling solution.

In the presentation results from the EHC measurements and the energetic analysis will be shown.

New Low Power Modular PEMFC for Transportation Applications operating under Harsh Conditions

¹ C. Kinkelin, ¹ J-P. Poirot-Crouvezier, ¹ S. Germe, ¹ P. Martin, ¹ B. Morin, ¹ L. Rouillon, ¹ P. Bazin,
¹ E. Pinton

¹ Univ. Grenoble Alpes, CEA, LITEN, DEHT, F-38000 Grenoble, France; tel. +33 4 38 78 27 83, e-mail: christophe.kinkelin@cea.fr

Keywords: PEMFC, low power, modular stack, harsh conditions, transportation

The majority of low power PEMFC systems (typically a few kW and below) rely on the open cathode technology. Advantages of these systems are a reduced balance of plant and thus a low weight. On the other hand, the volumetric and thermal integration of such systems in the application can be challenging since they are bulky, the allowed ambient temperature range is generally restricted from 0°C to 35°C, and their durability is generally low.

In order to address the applications where open cathode technology is too restrictive, a new concept of modular fuel cell stack was developed. Ability to operate under extreme temperatures and improvement of the durability are provided by the liquid cooling and the closed cathode architecture. The base element of this modular stack consists of a new metallic bipolar plate design featuring a small active area, a reduced pressure drop and an optimized distribution of reactants and coolant inside the stack. The modular fuel cell is made up of a variable number of individual stacks combined with a variable number of cells per stack and common lightweight end plates. This allows to adapt the volumetric shape of the fuel cell to a given application (e. g. UAV or cargo bike). The end plates are designed to electrically interconnect the individual stacks in order to reach the required voltage range. A dedicated balance of plant was developed for this low power fuel cell. Optimal operating parameters of the system were selected using a proprietary code. The system was assembled, put into service and first tests were performed.

Direct Catalytic Methanation of Carbon Dioxide in Biogas

^{1,2}J. Kulas, ²L. Polák, ²A. Doucek

¹ University of Chemistry and Technology, Department of Gaseous and Solid Fuels and Air Protection, Technická 5, 166 28 Prague 6, Czech Republic; tel. +420 266 172 480, e-mail: kulasj@vscht.cz

² Department of Hydrogen Technologies, ÚJV Řež, a. s., Hlavní 130, Husinec - Řež, Czech Republic

Keywords: catalytic, methanation, biogas, upgrading, biomethane

With the growing pressure to reduce carbon dioxide emissions there are rising efforts to reduce natural gas emissions. One of the ways to reduce natural gas emissions is to substitute natural gas with biomethane, i.e. biogas upgraded to natural gas quality. Biogas upgrading to biomethane is generally realized via carbon dioxide separation. Catalytic methanation can serve as an alternative pathway to upgrade biogas to biomethane quality. Catalytic methanation is a reaction of hydrogen and carbon dioxide in which they are converted into methane and water. Hydrogen needed for the reaction can be produced via water electrolysis from surplus electrical energy. This contribution is focused on the use of catalytic methanation to facilitate upgrading of biogas, where biogas serves as the source of carbon dioxide needed for the methanation reaction. Catalytic methanation of biogas provides the benefit of a one-step process of biogas upgrading along with the possibility to store surplus electrical energy from renewable sources. Four model gases were tested at 0.55 MPa overpressure with the use of a nickel catalyst. The first model gas served to determine activity and selectivity of the used catalyst. This gas consisted of a stoichiometric ratio of hydrogen and carbon dioxide (4:1). The other three gases consisted of hydrogen and carbon dioxide in a stoichiometric ratio of the methanation reaction and methane in various ratios to carbon dioxide.

Fiber-like Structure on Proton Exchange Membrane Created by Magnetron Sputtering and Plasma Etching as a Catalyst Support for Water Electrolyzers

¹T. Hrbek, ¹P. Kůš, ¹Y. Yakovlev, ¹Y. Lobko, ¹J. Nováková, ¹V. Matolín, ¹I. Matolínová

¹ Charles University in Prague, Faculty of Mathematics and Physics, Department of Surface and Plasma Science, V Holešovičkách 2, 180 00 Prague, Czech Republic; tel. +420 951 552 325, e-mail: alexrthm@gmail.com

Keywords: PEM electrolyzer, oxygen evolution reaction, magnetron sputtering, plasma etching, thin-film catalyst

Currently growing popularity of solar and wind power plants lead to high demands on reliable and scalable systems, which would be capable of storing the energy during the overproduction periods and releasing it while it is deficient. The interesting alternative is a hydrogen economy concept. The concept is based on the storing of produced electrical energy in the form of chemical energy, specifically in the form of H₂. Thus, it is possible to create a large amount of H₂ in times of overproduction and consequently use it for multiple purposes – conversion back to electricity by fuel cell in times of electricity deficit, direct injection into the existing natural-gas network, use in a chemistry or metallurgy, etc. Regardless of which pathway for H₂ is ultimately chosen, the key inseparable technology necessary for the concept of hydrogen economy to function remains the water electrolysis. Proton exchange membrane water electrolyzer seems to be very promising concept of electrolyzer. However, there are still challenges which need to be dealt with. Especially the need of reducing the amount of iridium used on the anode side of the electrolyzer. It is currently the only sufficiently active catalyst which withstands the aggressive conditions during the oxygen evolution reaction (OER). Reducing Ir loading through its dispersion over the catalyst support, a method adopted from fuel cell industry, is not trivial since it is hard to find inexpensive, corrosion-resistant and conductive material in form of nanoparticles.

In this work we present a way how to obtain a better utilization of used iridium, which can effectively lead to the reduction of the amount of used iridium. Presented approach consist of combination of plasma etching in argon-oxygen atmosphere and sputtering of CeO_x. Sputtered CeO_x works as a masking element which can hinder the etching procedure on same spots of the membrane. This effect then leads to creation of fiber-like structures with a high surface. Those structures then can work as a support of used catalyst which is durable and does not add unnecessary ohmic resistance to the system. Our study comprises characterization of the modified PEM morphology, electrochemical active surface area determination via rotating disk electrode and in-cell PEM-WE performance testing, including electrochemical impedance spectroscopy.

NiFe Anodes for Advanced Alkaline Electrolysis

¹ S. Loos, ¹ P. Junghanns, ¹ C. I. Bernäcker, ¹ T. Rauscher, ¹ T. Weißgärber, ¹ L. Röntzsch

¹ Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Branch Lab Dresden, Winterbergstraße 28, D-01277 Dresden, Germany; tel. +49 351 2537-301, fax: +49 351 2537-399

Keywords: alkaline electrolysis, OER, NiFe-oxyhydroxides, powder metallurgy, porous electrodes

The conversion of solar and wind power into chemically stored energy is a key to reduce the CO₂ emissions that result from the burning of fossil fuels. If powered by renewable energy, alkaline water electrolysis provides an environmentally friendly source of hydrogen as an alternative fuel. The anodic water oxidation is pivotal in water splitting for hydrogen production and in general for any attractive technological route towards sustainable fuel production and contributes significantly to the cell voltage.^[1] Therefore the development of effective and stable electrodes is crucial and of high scientific, as well as technological, interest.

Recently, a combination of iron and nickel oxyhydroxides has been found to be among the most promising electrocatalysts (low overpotential at reasonably high current densities) for water oxidation in alkaline medium,^[2] including sea water electrolysis.³ NiFe oxyhydroxides are by far more active than the corresponding Ni-only and Fe-only catalysts, but the details of the Ni-Fe synergism are still unclear.

The talk will focus on different synthetic routes in order to prepare stable and active electrodes for alkaline water oxidation such as galvanic deposition, cyclic electrochemical treatment in KOH and powdermetallurgical modification of nickel foams with iron and NiFe alloys. Those kind of porous electrodes exhibit large electrochemical active surface area and enable operation in zero gap electrolyzers.

Electrochemical characterization will include Tafel slopes, turn over frequencies and analysis of the electrochemical active surface area. Especially the degradation of such anodes at technological relevant conditions will decide about the deployment in real-life electrolyzers. The results were obtained using 30 wt.-% KOH at 60 °C as electrolyte.

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High Performance Alkaline Water Electrolyser with Highly Porous Non-noble Metal Electrodes Produced by Air Plasma Spraying

¹ R. Reissner, ¹ L. Wang, ¹ F. S. Razmjooei, ¹ A. Ansar, ¹ G. Schiller, ¹ A. S. Gago, ¹ K. A. Friedrich

¹ German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Pfaffenwaldring 38-40, D-70569 Stuttgart, Germany; tel. +49 711 6862-394, e-mail: regine.reissner@dlr.de

Keywords: alkaline electrolysis; electrodes; nickel; plasma spraying; AEM-electrolysis

Highly porous Raney® type Nickel (Ni) noble metal-free electrodes coated on top of metallic substrate were developed for conventional alkaline water electrolysis (AWE) as well as alkaline anion exchange membrane water electrolysis (AEMWE) to achieve high performance. The coating was applied by atmospheric plasma spraying (APS) which is an industrial coating process for the large-scale application.

Commercially available alkaline water electrolysers still suffer from low operational current densities and are not optimised for intermittent operation. To overcome this limitation DLR developed highly porous APS Raney® type Ni coatings for anode and APS Mo-doped Raney® type Ni coatings for cathode to achieve a full cell performance of above 0.5 A cm⁻² at 1.8 V at 70 °C with Zirfon® separator and stability in on-off operation cycles. Compared to uncoated electrodes, the electrode coatings prove an overvoltage reduction on the cathode side of 250–300 mV and on the anode side of 130–150 mV at a current density of 0.5 A cm⁻² at 70 °C, which is primarily due to the high porosity and high electrochemical surface area of the coating. The electrodes are presently tested in a 100 kW, 20-cell alkaline electrolyser at the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW).

The avenue to achieve performances similar to proton exchange membrane water electrolysis (PEMWE) and stability comparable to conventional AWE is the integration of thin anion-exchange membranes (AEM) and low concentration of KOH with our developed electrodes. Recently, AEM stability and conductivity have been gradually improved, now being either commercially available or available within research collaborations. Electrode packages with the same Raney® type Ni coatings were tested at 60 °C and in low concentrated KOH solutions (0.1 to 1.0 M) as well as high concentrations (6.0 M) using different AEMs and demonstrate a significant technological progress ^[1,2]. The cell operated in 1.0 M KOH exhibits a current density of 0.4 A cm⁻² at 1.80 V demonstrated for 100–150 h of operation which is very close to conventional AWE ^[2]. By modifying the anode even a highest current density of 1 A cm⁻² at 1.80 V is demonstrated ^[1] which is in the range of industrial PEM systems.

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Separators for Alkaline Water Electrolysis Based on Porous Polymeric Diaphragms Modified by Graft-Polymerization of Acrylic Acid

¹ L. Staňo, ¹ M. Stano, ¹ M. Kuťka, ¹ P. Ďurina, ² K. Mosnáčková

¹ Comenius University in Bratislava, Faculty of Mathematics, Physics and Informatics; Dep. of Experimental Physics, Mlynská dolina F2, 842 48 Bratislava, Slovakia

² Polymer Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 845 41 Bratislava, Slovakia; tel. +421 910 418 197, e-mail: lubomir.stano@fmph.uniba.sk

Keywords: alkaline water electrolysis, membrane separator, acrylic acid, grafting

Production of green hydrogen by alkaline water electrolysis in connection with intermittent renewable power sources sets high requirements on inter-electrode separator membranes. While high electric conductivity is required for efficient operation at high power loadings and for compact electrolyzer design, low permeation of hydrogen and oxygen is required to suppress their mutual cross-contamination, especially at low power loadings.

We report on investigation of porous polymeric diaphragms with hydrophilic surface modification achieved by low-pressure plasma activation followed by graft polymerization of acrylic acid (AAc). In this process, coating of the porous diaphragm can be achieved in its whole cross-section. The grafted AAc becomes intensively solvated in aqueous KOH solution, creating an ion-conductive environment supported by the structure of the porous substrate. This environment also hinders penetration and precipitation of product gas bubbles in the separator structure.

The separators were characterized in terms of electrolytic resistance in four-contact configuration and by measurement of hydrogen and oxygen purity produced in a lab-scale (12.5 cm²) cell as a function of cell current density. Electrical conductivity was enhanced substantially with increasing grafting degree (GD) of acrylic acid. Specific electrical resistance as low as 20 mΩ cm² was achieved with polyethersulfone diaphragm used as the substrate. In addition, increasing GD reduced considerably the diffusion of H₂ dissolved in the electrolyte, reflected by increasing product gas purity. In terms of overall performance, the ratio of H₂ diffusion flux density to separator conductivity decreased with increasing GD for all types of studied substrates. This confirmed the positive effect of AAc grafting on the crucial separator properties.

Acknowledgement

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Evaluation of the Influence of Anion Selective Material and Preparation Method on a Performance of CCM-MEA in Alkaline Water Electrolysis

¹ M. Plevová, ¹ J. Hnát, ² J. Žitka, ¹ M. Paidar, ¹ K. Bouzek

¹ University of Chemistry and Technology, Prague, Dep. of Inorganic Technology, Technická 5, 166 28 Prague 6, Czech Republic; tel. +420 220 444 009, e-mail: plevovam@vscht.cz

² IMC CAS, Heyrovského nám. 2, 162 06 Prague, Czech Republic

Keywords: alkaline water electrolysis, non-Pt catalyst, catalyst coated membrane, hydrogen production

Alkaline water electrolysis (AWE), using energy from renewable sources, is the suitable technology for producing pure hydrogen as a means of energy storage. However, flexibility, safety and efficiency of this process are limited due to the use of highly concentrated KOH as liquid electrolyte. Liquid electrolyte is needed because of an inorganic diaphragm, which is used as an electrode separator. Efficiency of the system is low due to high overpotential as AWE electrolyzers typically operate at a cell voltage of 1.8–2.0 V, much higher than the thermoneutral voltage (1.48 V) of water splitting. But, compared to the other technologies, AWE has relatively low capital expenses because of the use of abundant materials. This technology can be improved by replacing the diaphragm with a dense anion selective polymer membrane and the overpotential can be decreased by utilization of catalysts. Moreover, the catalyst can be applied directly onto the membrane surface (CCM). In this arrangement, better contact between the membrane and the catalyst is achieved, which leads to higher utilization of the catalyst and thus a thinner layer can be applied. This approach is already being used in proton-exchange membrane water electrolysis but in an alkaline environment, suitable polymeric material able to withstand the operation conditions is missing.

In this work, we use different preparation methods and substrates to evaluate their influence on the performance of CCM in AWE. Block copolymer polystyrene-ethylene-butylene-styrene (PSEBS) in the bare form and functionalized with 1,4-diazabicyclo[2.2.2]octane (DABCO) functional groups is used as an anion selective material. NiCo₂O₄ and NiFe₂O₄ are used as anode and cathode catalysts, respectively. Load of the catalyst is 2.5 mg cm⁻². Catalyst to binder ratio was determined to be 93/7 and the optimal catalyst particle size was 200 μm. As a preparation method we chose air brush spraying and computer-controlled air brush spraying at elevated temperature. When the bare PSEBS was used as a substrate for CCM, it was immersed in DABCO solution for a week to ensure the functionalization of the membrane as well as the binder in the catalytic layer. When the functionalized membrane was used, the immersion lasted only 24 hours. Performance of the prepared CCMs was tested in the form of the load curves under the AWE conditions with different concentrations of KOH at 50 °C. Electrochemical impedance spectroscopy (EIS) was used to evaluate the resistances of the system and SEM was used to observe the morphology of the layers. The obtained results show good reproducibility of both preparation methods, sufficient stability of all the tested samples and also the possibility of using the non-functionalized membrane, which should allow us to use higher temperature in the preparation process.

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Progress in Introducing Membranes into Alkaline Water Electrolysis

¹ K. Denk, ¹ J. Hnát, ² J. Žitka, ¹ M. Paidar, ¹ K. Bouzek

¹ University of Chemistry and Technology, Prague, Dep. of Inorg. Technology, Technická 5, 166 28 Prague 6, Czech Republic; tel. +420 220 444 008, e-mail: denkk@vscht.cz

² IMC CAS, Heyrovského nám. 2, 162 06 Prague, Czech Republic

Keywords: alkaline water electrolysis, stack, DABCO, anion-selective membrane, diaphragm

Alkaline water electrolysis (AWE) is one of the electrolytical ways of hydrogen production. Because AWE does not require use of rare platinum-type metals, the capital cost is lowered thus making it perspective. Furthermore, substitution of the usually used inorganic diaphragm with an anion-selective membrane enhances efficiency, safety and flexibility of the process which can lead to possible connection with renewable sources of energy. This connection would make the process of hydrogen production and subsequent storing suitable for future energy management.

In AWE with diaphragm, high concentrations of the electrolyte (25–30 wt. % KOH) and high temperatures (70–80 °C) are required. These conditions are needed because the diaphragm is porous and only the solution present in the pores is responsible for conductivity which is low due to the small diameter of the pores. Another disadvantage of the porosity is that the pressure must be kept the same in all electrode chambers to prevent driving the gas through the pores with subsequent production of a flammable mixture of hydrogen and oxygen.

These disadvantages can be solved by introducing anion-selective membranes. Membrane alkaline water electrolyser (MAWE) can be built in the zero-gap configuration which decreases the ohmic resistance of the apparatus, allowing the use of lower electrolyte concentrations and temperatures, thus increasing energy efficiency. Furthermore, the membrane serves as a hydraulic separator which does not allow to pass the gasses through due to pressure changes. It also lowers the diffusion of gas through the separator, which in turn allows using lower current densities thus making the process more flexible.

In this work, a MAWE stack consisting of nickel-foam electrodes and nickel-sheet current collectors is used. The separators used were one type of anion-selective membrane and one inorganic diaphragm. The membrane was made of poly(styrene ethylene butylene-styrene) (PSEBS) functionalized by 1,4-diazabicyclo[2.2.2]octane (DABCO) and the diaphragm was commercially used Zirfon Perl®. The active area of each cell was 78.5 cm². Potassium hydroxide was used as the electrolyte in different concentrations (1, 5, 10 and 15 wt. %).

Linear sweep voltammetry was used to obtain the load curves to assess the performance of the stack. Gas flow meter was used to calculate current efficiency by comparing the real gas flow rate with the theoretical one. Using gas chromatography, gas purities were obtained.

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Aerosol Synthesis of Nanoparticles for Deposition of Catalytic Layers

¹T. Němec, ¹J. Šonský, ¹J. Gruber

¹ Institute of Thermomechanics of the Czech Academy of Sciences, Dep. of Electrical Engineering and Electrophysics, Dolejškova 5, 182 00 Praha 8, Czech Republic; tel. +420 266 053 152, e-mail: nemec@it.cas.cz

Keywords: spark discharge generator, catalyst nanoparticles, hydrogen fuel cells, gas diffusion electrode, electrochemically active surface area

We use an aerosol-based nanoparticle synthesis process to produce metallic nanoparticles for applications in catalysis. The method is based on a spark discharge generator (SDG), which allows us to evaporate a solid metal rod and to mix the metallic vapor with a carrier gas to achieve a rapid condensation of metallic vapors. Platinum nanoparticles of 5 nm average diameter can be produced at a production rate of grams per day by a typical SDG. Direct deposition of the SDG nanoparticles on a gas diffusion layer enables us to make gas diffusion electrodes for hydrogen fuel cells in a simple one-step process.

The gas diffusion electrodes utilizing the SDG platinum catalyst nanoparticles were used to prepare membrane electrode assemblies (MEA) by a standard hot-pressing procedure. The performance of MEAs was measured in a laboratory fuel cell with a 5 cm² active area. Reference MEAs were prepared by a conventional blade-coating process of the catalyst ink (using Pt/C HiSpec 3000 catalyst) onto a gas diffusion layer, followed by the hot-pressing step. By using the standard Nafion HP membrane in both cases, we were able to directly compare the performance of the SDG catalyst layer vs. the reference blade-coated catalyst layer under real-world fuel cell operating conditions. Moreover, cyclic voltammetry has been employed to characterize the electrochemically active surface area of the two types of catalytic layers. The SDG catalytic layers show promising performance results and may represent a viable alternative to commercial electrodes for hydrogen fuel cell applications.

Ir-decorated Pt Nanoparticles for Unitized Regenerative Fuel Cell Catalyst

¹ L. Blanco Redondo, ¹ V. Matolín, ¹ Y. Lobko

¹ Charles University, Prague, Dep. of Surface and Plasma Science, V Holešovičkách 2, 180 00 Prague 8, Czech Republic; tel. +34 680 16 82 65, e-mail: lublare93@gmail.com

Keywords: PEM regenerative fuel cell, cathode catalyst, polyol method, iridium, platinum

The challenge of slowing down the climate change and ensuring the worldwide energy supply requires the progress in using renewable energy sources. This imminent global power shift has focused the attention on the hydrogen technologies such as the Unitized Regenerative Fuel Cell (URFC). It is an electrochemical device that can operate alternately as a fuel cell (FC, to produce electricity) or water electrolyser (WE, to produce hydrogen). However, the way of developing an efficient and durable unit is still opened. Oxygen electrode in URFC is a limiting component due to the complicated and slow kinetics of the oxygen reduction reaction (ORR) and oxygen evolution reaction (OER) that take place there. Moreover, there is not a common material that catalyses these reactions: the most suitable materials for the ORR and OER are the costly noble metals platinum and iridium, respectively. In this study Pt nanoparticles decorated with Ir have been produced by polyol method. Briefly, the Pt precursor has been reduced at elevated temperature in ethylene glycol (EG) to form Pt nanoparticles. After that, the Ir precursor dissolved in EG has been introduced into the synthesis flask and reduced on the surface of the existing Pt cores. In addition, polyvinylpyrrolidone (PVP) has been added as capping agent to prevent agglomeration and to decrease the average particle size. In order to study the activity of the bimetallic nanoparticles, commercial pure Pt, Ir and a mechanically prepared mixture of both metals have been used as reference. The samples have been characterized via Rotating Disk Electrode (RDE) technique, X-Ray Photoelectron Spectroscopy (XPS), and Transmission Electron Microscopy (TEM). Ir-decorated Pt nanoparticles ($\text{Pt}_x\text{Ir}_{100-x}$) with various compositions ($\text{Pt}_{15}\text{Ir}_{85}$ and $\text{Pt}_{50}\text{Ir}_{50}$) have been prepared, and the results show that the nanoparticles with a Pt:Ir ratio 50:50 display the best results. The activity towards the ORR is comparable with pure Pt nanoparticles and the OER activity is slightly lower than pure Ir nanoparticles.

Experimental Study on the Catalyst Coated Membrane of PEM Electrolyzer

¹ A. Rocha, ¹ R. B. Ferreira, ¹ D. S. Falcão, ¹ A. M. R. Pinto

¹ Transport Phenomena Research Center (CEFT), Dep. Chemical Engineering (DEQ), Faculty of Engineering of University of Porto (FEUP), Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; tel. +351 917074813, e-mail: amadeu@fe.up.pt

Keywords: power-to-gas, proton-exchange membrane water electrolysis, catalyst coated membrane, electrochemical characterization, electrocatalyst

With the increasing share of intermittent renewable energies in the energy market, it is of great importance to develop technologies capable of coordinating power supply with power demand^[1]. Hydrogen produced by water electrolysis (WE) is regarded as a sustainable energy vector to balance the electrical grid. Proton-exchange membrane (PEM) WE systems produce high purity hydrogen, operate dynamically fast, have high energy density and efficiency, and do not emit greenhouse gases. These features have been driving R&D in PEM WE as it makes the technology suitable for Power-to-gas systems^[2].

The performance of a PEM WE device is highly dependent on its catalyst coated membrane (CCM). This component is composed of a polymeric membrane, which acts as an electrolyte, coated with the electrocatalysts for the WE half-reactions. The membrane blocks the produced hydrogen and oxygen at both electrodes while allowing the protons to migrate from the anode to the cathode. Different commercial options exist for CCMs. The most used material for membrane is Nafion, a perfluorosulfonic acid ionomer, and state of the art catalysts include IrO₂ and IrRuO_x at the anode and Pt at the cathode^[3].

In this communication, results obtained with several commercial CCMs will be presented. Features such as the membrane thickness, the CCM supplier and catalyst type and loading will be investigated. The CCMs will be assessed through electrochemical in-situ characterization techniques in a commercial electrolyzer. These tests will comprise I-V curves to assess the electrolyzer general performance, electrochemical impedance spectroscopy to quantify the different overvoltages (ohmic, activation and concentration), cyclic voltammetry to compare the CCMs electroactivity and linear sweep voltammetry to measure the crossover of hydrogen gas through the membrane.

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Electrochemical Behaviour of H_3PO_3 in a $\text{Pt}/\text{H}_3\text{PO}_4$ System at Elevated Temperatures

¹ M. Prokop, ¹ T. Bystron, ¹ M. Paidar, ¹ K. Bouzek

¹ Institute of Chemical Technology, Prague, Dep. of Inorganic Technology, Technická 5, 166 28 Prague 6, Czech Republic; tel. +420 220 444 272, e-mail: prokopm@vscht.cz

Keywords: HT PEM FC, H_3PO_4 , H_3PO_3 , platinum, electrochemical oxidation

High temperature fuel cell with a proton-conductive polymer electrolyte membrane (HT PEM FC), operating with H_2 as a fuel and O_2 as an oxidant, represents a promising device for highly efficient cogeneration of electric and heat energy. Its operating temperature of 120 to 180 °C greatly improves the resistance of Pt catalyst against poisoning by CO and makes heat energy utilisation feasible. However, at the same time it is necessary to utilise H_3PO_4 as a proton conductive media in the membranes. Presence of H_3PO_4 has several negative effects on the activity and durability of Pt catalyst. They include adsorption of H_2PO_4^- on a Pt surface, dissolution of Pt and subsequent redeposition of Pt ions leading to the decrease of the Pt surface area and reduction of H_3PO_4 to phosphorus impurities. Exact nature of these impurities and their electrochemical behaviour is still a matter of a debate with very small background available in the literature. One of the identified impurities is H_3PO_3 , the major product of H_3PO_4 reduction by hydrogen on a Pt surface.

In order to understand processes taking place during HT PEM FC operation, mechanism of H_3PO_3 formation and oxidation on a Pt electrode has to be examined first. This comprises voltammetric studies performed in concentrated H_3PO_4 at elevated temperatures. Such an aggressive, melt-like environment brings numerous complications to experimental setup and requires a modification of standard techniques, especially in terms of Pt surface area determination. Accordingly, the goal of this work is to describe electrochemical behaviour of H_3PO_3 on a bulk Pt electrode in H_3PO_4 electrolyte at elevated temperatures and reveal mechanism of its adsorption and oxidation.

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Epoxy Resin / Graphites Composites for PEM FCs' Bipolar Plates

¹ A.M. Darabut, ¹ Y. Lobko, ¹ V. Matolin, ¹ Y. Yakovlev

¹ Charles University, Faculty of Mathematics and Physics, Dep. Of Surface and Plasma Science, V Holešovičkách 747/2, 180 00 Prague 8, Prague, Czech Republic; tel. +420 221 912 733, e-mail: alinadarabut@gmail.com

Keywords: polymer composites, carbon fillers, electrical conductivity, percolation threshold, PEM FCs

Fuel cells (FCs) have been used as a technology for alternative power sources (hydrogen, methane, etc.) either in stationary or mobile applications. The proton exchange membrane FCs (PEM FCs) is favorable considering due to its high-power density, low operating temperature and zero emissions.

The bipolar plates (BPs), as an important component of the PEM FCs, must conduct electricity, provide a gas flow field, remove heat, etc. Also, its weight is approximately 80 % of the FCs and its price about 45 %. As a result, different types of bipolar plates have been investigated such as metal BPs, graphite BPs and polymer composites' BPs. The last type is one of the most promising owing to the high chemical resistance, high electrical and thermal conductivity, acceptable mechanical properties, lightness, etc.

The polymer composites' BPs are formed from polymer matrix and electrically conductive fillers (carbon, metal, metal oxides particles). The high amount of the fillers provides proper conductivity of the BPs, but, at the same time, it can be mechanical defects of the materials. For this reason, it is essential to find an optimal amount of fillers to reach the possible highest conductivity, but do not reduce the mechanical properties of the BPs. The progress of the conductivity versus the filler load normally presents an S-shaped dependency with three parts (dielectric, transition and conductive). From this plot, it is possible to obtain the critical filler content, also named percolation threshold (ϕ_c), for each composite.

In this study, the issue of preparation carbon-polymer composite BPs based on epoxy resin is tackled. Both commercial natural/synthetic graphite and thermal expanded graphite obtained in the laboratory are used as fillers. The dependence between electrical conductivity and filler content will be shown through the percolation threshold. As a consequence, the percolation threshold of different composites is also analysed.



Poster section

Activities of the Joint Programme on Fuel Cells and Hydrogen in EERA

¹ M. Paidar, ¹ K. Bouzek

¹ University of Chemistry and Technology, Prague, Dep. of Inorg. Technology, Technická 5, 166 28 Prague 6, Czech Republic; tel. +420 220 443 802, e-mail: paidarm@vscht.cz

Keywords: fuel cell and hydrogen, eera, implementation plan, hydrogen europe research

The European Energy Research Alliance (EERA) is the largest energy research community network in Europe. It brings together around 250 research centres and universities across 30 European countries. The main aim is to coordinate and accelerate research towards energy sustainability. To reach targets of Paris Agreement, it is necessary to support research of low-carbon technologies. EERA research activities are based on 17 joint research programmes (JPs) covering whole range of low-carbon energy technologies. JP Fuel cell and Hydrogen (FC&H) covers all activities related to hydrogen use as an energy vector. JP-FC&H consist of 7 sub-programmes (SP). Each of SPs focuses to the specific topic, as e.g. materials development and testing, mathematical modelling, systems design, hydrogen production, handling and storage. The main activity of JP-FC&H consists in preparation of JP FCH Implementation Plan for 2018–2030. It represents a convincing and concrete action plan towards effective and large-scale implementation of FC&H technologies by 2030 and beyond. JP-FC&H collaborates with Hydrogen Europe Research in identifying long-term research activities enabling hydrogen technologies to reach breakthrough crucial for their commercialisation. Main attention is paid to the technologies at TRL 2-5. The idea of transfer chain and position of EERA within is as follows:



By participating in the JP-FC&H of EERA, members can influence European priorities of research in the field of energy. Information exchange and activities coordination represent excellent background for future collaboration and for forming successful consortia applying for collaborative research grants. Due to the joint workshops and meetings organised in collaboration with of the EERA JPs, strong interdisciplinary collaboration across the boards of traditional frameworks is supported as well.

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Electric Bicycle Powered by the Hybrid Energy Source using PEMFC Hydrogen-oxygen Fuel Cells

¹ M. Nowobilski, ¹ K. Kukliński, ¹ K. Kobiela, ¹ M. Łasica, ¹ L. Miałkos, ¹ M. Wójcik, ¹ D. Pietrasz, ¹ B. Nowak, ¹ P. Żurek, ¹ P. Nieczaj, ¹ M. Dudek, ¹ A. Raźniak

¹ AGH University of Science and Technology, Kraków, Faculty of Energy and Fuel, al. Mickiewicza 30, 30-059 Kraków, Poland; e-mail: razniak@agh.edu.pl

Keywords: polymer membrane fuel cell, hydrogen, hybrid energy source

The purpose of the paper is to present the research results of the student project entitled Hybrid energy sources, consisting of the Li-Pol battery pack and the PEMFC 500W fuel cell stack built and integrated in the electric bicycle. This project was implemented by the Fenec Student Scientific Group from the Faculty of Energy and Fuels of the AGH University of Science and Technology in Krakow.

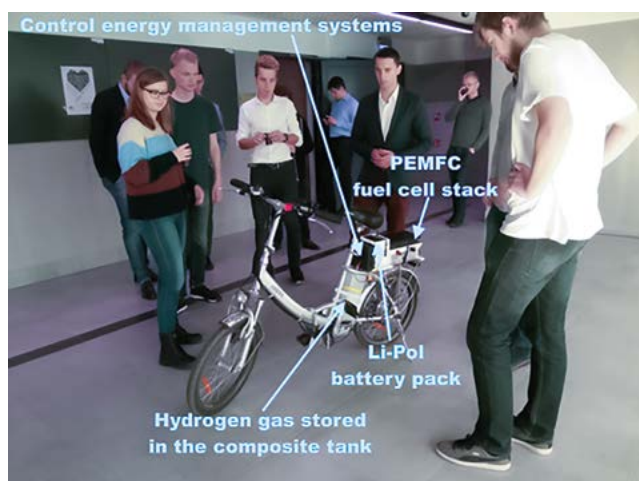


Fig. 1:
The Photo of electric bicycle powered by the hybrid energy source using PEMFC hydrogen-oxygen fuel cells

As part of the research project, the project was developed the hybrid energy source (consisting of the Li-Pol battery pack and the 500 W PEMFC fuel cell stack) to power the electric bicycle was made. The energy source was built in the electric bicycle with the hydrogen supply system (hydrogen gas stored in the composite tank with a capacity of 1 l). Control and measurement and energy management systems were built for the hybrid energy source. The hybrid energy source built (the battery pack plus the PEMFC fuel cell stack) was tested on the stationary station. The current-voltage dependencies for batteries, fuel cell stack and hybrid energy source under a different electrical load were determined. The analysis of hydrogen consumption was performed for given working conditions. The hybrid source was integrated in the electric bicycle, electric tests of the energy source were performed during test drives in the area with a different elevation profile. Energy consumption profiles were determined, which were correlated with topographic conditions of the area using GPS. On the basis of the conducted research, it was found that the use of the hybrid energy source will allow the extension of the electric bicycle range to 100 km, compared to power supply only by the electrochemical battery with a range of 40 km.

Hybrid Power Source Involving 2 kW Polymer Membrane Fuel Cell Stack for Supplying Drone

^{1,2}M. Dudek, ^{1,2}A. Raźniak, ^{1,2}B. Lis, ^{1,3}T. Siwek, ¹W. Kalawa, ³D. Uhl, ⁴J. Wesoł, ³K. Śmierciak

¹ AGH University of Science and Technology, Kraków, Faculty of Energy and Fuel, al. Mickiewicza 30, 30-059 Kraków, Poland; e-mail: razniak@agh.edu.pl

² AGH University of Science and Technology, Center of Energy, str. Czarnowiejska 36, 30-059 Kraków, Poland

³ UAVS Poland Sp.z o.o.

⁴ AGH University of Science and Technology, Kraków, Faculty of Mechanical Engineering and Robotics, al. Mickiewicza 30, 30-059 Kraków, Poland

Keywords: polymer membrane fuel cell, drone, hydrogen, prediction of flight time

The purpose of the work is to present the results of the project „The Increase of flight time of Unmanned Aerial Vehicle by Using Hybrid Power Source Implemented in Scientific and Industrial Consortium UVAS Ltd. and The AGH Energy Centre in Krakow.” The scope of the work mainly included tasks concerning: i) determination of energy demands, taking into account different operation phases and missions of unmanned aerial vehicle, ii) development of a hybrid model of energy source for powering a drone of multi-rotor construction, iii) development of an algorithm for managing of hybrid energy source built from an electrochemical battery (Li-Pol) and stack of PEMFC fuel cells of a power of 2 kW, iii) development of a system of hydrogen gas storing and dispensing with a mobile filling station of high-pressure composite tanks, iv) integration of hybrid energy source in drone platform and test in stationary conditions as well as during the flight.

As a result of the research performed in the project, energy consumption profiles of a drive unit on an engine test bench and during flight were determined. The emphasis was given to the analysis of energy efficiency of the constructed hybrid unit (battery and fuel cells) for different mission of drone. The increase of time of flight was obtained compared to only batteries power source.



Fig.:
1 The Photo of drone supplied by hybrid power source (battery and hydrogen-air PEMFC stack) during flight.

Regional Hydrogen Trains on Czech Railways – A Techno-economic Analysis

¹ F. Zenith, ² K. Stehlík, ³ L. Polák

¹ SINTEF, P.O. Box 4760 Torgarden, NO-7465 Trondheim, Norway; tel. +47 40 00 51 00

² Czech Hydrogen Technology Platform, Hlavní 130, 250 68 Husinec-Rez, Czech Republic; e-mail: karin.stehlik@hytep.cz

³ ÚJV Rez, a.s, Hlavní 130, 250 68 Husinec-Rez, Czech Republic

Keywords: hydrogen mobility, GHG emission reduction, SINTEF, techno-economic analysis, regional railways

The objective of this project is to analyse the Czech railways and locate areas where hydrogen train technology would be a preferred technical, economic and environmental solution compared with other train technologies. This study will examine and collect initial data especially from the non-electrified railways where diesel train are operated. Through the methodology and software developed by SINTEF, the analysis will generate techno-economic analysis and make a comparison ranking of train technologies solution between diesel, battery, hydrogen and hybrid trains. The results will allow to identify preferred areas with a beneficial technological, economic and environmental outcome by deploying low-emission trains for replacing future decommissioned diesel trains on non- electrified railway.

This study will contribute to the application of new technologies in the field of transport and increase the competitiveness of the Czech Republic. This project also aims to support the preparation of results for new strategic plans, deployment of hydrogen technologies and reduction of GHG emission.

MAMA-MEA: Mass Manufacture of MEAs Using High Speed Deposition Processes

^{1,a}V. Buday, ^{1,b}M. Biák, ^{1,c}T. von Unwerth

¹ Chemnitz University of Technology, Department of Advanced Powertrains, Reichenhainer Str. 70, 09126 Chemnitz, Germany;

^a tel.: +49 (0) 371 531 39362, e-mail: vladimir.buday@mb.tu-chemnitz.de

^b tel.: +49 (0) 371 531 32058, e-mail: martin.biak@mb.tu-chemnitz.de

^c tel.: +49 (0) 371 531 23550, e-mail: thomas.von-unwerth@mb.tu-chemnitz.de

Keywords: PEM fuel cells, MEA, CCM, roll-to-roll mass manufacturing, additive layer deposition process, automation, quality control, single cell, PEMFC stack, characterisation

The aim of MAMA-MEA^[1] is to develop an innovative additive layer deposition process that integrates all the main CCM components (membrane, catalyst layers, sealing) in a single continuous roll-to-roll manufacturing process for the PEM fuel cell industry.

A key project objective is an increase in the manufacturing rate of over 10 times compared to the state-of-the-art process, whilst also increasing material utilisation to 99 %, and the product quality, and thus yield, to over 95 %.

Overall, sealed CCM direct materials and manufacturing costs will be reduced by up to 58 % in the new CCMs. The project will also conduct comprehensive ex-situ characterisation and in-situ fuel cell performance and durability testing and provide an engineering design of an ALM sealed CCM production line, including quality control methodologies.

The project harnesses advanced deposition techniques from the coating and printing industry. To achieve this a consortium encompassing academia, SMEs and industry, will take the concept of additive layer deposition, already at MRL3, to deliver and demonstrate an MRL6 level process design utilising a verified EU supply chain and consistent with the MAWP.

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 779591.



^[1] MAMA-MEA: Mass Manufacture of MEAs Using High Speed Deposition Processes (EU project, duration 01 Jan 2018–30 Jun 2021, 42 months). Funding Programme H2020-JTI-FCH-2017-1, Grant Agreement #779591. Website: mama-mea.eu.

Indication of Proton Conduction in the $\text{La}_{2-x}\text{A}_x\text{Ni}_{1-y}\text{Fe}_y\text{O}_{4+\delta}$ Cathode Materials for SOFC/SOFC-H⁺

¹A. R. Gilev, ¹E. A. Kiselev, ¹K. S. Sukhanov, ¹V. A. Cherepanov

Ural Federal University, Institute of Natural Sciences and Mathematics, Dep. of Physical and Inorganic Chemistry, Lenin av., 51, Yekaterinburg 620000, Russia; tel. +7(343)2517927, e-mail: artem.gilev@urfu.ru

Keywords: La₂NiO₄, cathode, crystal structure, conductivity, impedance spectroscopy

The K_2NiF_4 -type $\text{La}_2\text{NiO}_{4+\delta}$ showed moderate performance as a cathode material in oxygen-ion conducting solid oxide fuel cells (SOFCs)^[1], as well as in proton-conducting SOFCs (SOFCs-H⁺)². This oxide is stable under moist air and is considered to be a proton-blocking material^[1,3]. However, on the contrary to cobalt-, iron- and manganese-based perovskites, it shows water insertion at temperatures $T < 400^\circ\text{C}$ ^[3]. The aim of this work was to study the effect of humidity on the crystal structure and transport properties of the $\text{La}_{2-x}\text{A}_x\text{Ni}_{1-y}\text{Fe}_y\text{O}_{4+\delta}$ (A=Ca, Sr; $x=0.5, 0.6$; $y=0.4, 0.5$) oxides in order to disclose proton conductivity in these materials.

The $\text{La}_{2-x}\text{A}_x\text{Ni}_{1-y}\text{Fe}_y\text{O}_{4+\delta}$ complex oxides were synthesized by a citrate-nitrate technique followed by a series of high-temperature treatments at 1100°C . Then, the powders were pressed into rectangular bars and sintered at 1350°C in air. X-ray diffraction (XRD) results revealed that all obtained samples were single phase. High-temperature XRD (HT-XRD) was performed at 100, 300 and 500°C . The conductivity was measured by a four-probe method in the range of $25\text{--}1000^\circ\text{C}$ in air. The symmetric cell for impedance spectroscopy measurements was made by deposition of the studied powders on the $\text{Ce}_{0.8}\text{Sm}_{0.2}\text{O}_{2-\delta}$ pellet followed by sintering at 1150°C for 1 h in air. The impedance spectra were recorded from 300 kHz to 1 MHz with a signal amplitude of 20 mV using a two-electrode configuration at 500, 550, 600, 650 and 700°C . All measurements were performed in dry and humidified air.

HT-XRD results for $\text{La}_{2-x}\text{A}_x\text{Ni}_{1-y}\text{Fe}_y\text{O}_{4+\delta}$ revealed that the increase in air humidity led to elongation in the La/A-O₂ bond length, while the Ni/Fe-O₁ one remained unchanged. This phenomenon, most pronounced at 300°C , indicated that water could be inserted in the rock-salt layer without any effect on the oxidation state of Ni/Fe. The conductivity decreased with increasing air humidity at $T < 600^\circ\text{C}$ demonstrating the maximum decrease in the range of $250\text{--}400^\circ\text{C}$. At least 5 contributions can be identified in the impedance spectra, 4 of which increased in the humidified air (charge transfer through the electrolyte/electrode interface was almost unchanged). Most notable increase in resistance was observed for the charge transfer process in the electrode material and for the contribution associated with surface exchange phenomena. The effect of humidity on the conductivity exponentially increased with the increase in the unit cell volume of $\text{La}_{2-x}\text{A}_x\text{Ni}_{1-y}\text{Fe}_y\text{O}_{4+\delta}$. In this way, the obtained results clearly indicated the possibility of proton conduction in these materials.

The study was funded by the Russian Science Foundation, project № 19-73-00008.

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Material Degradation Testing in Solid Oxide Electrolysis / Fuel Cell

¹ P. Dvořáková Ruskayová, ¹ A. Toháčková, ¹ M. Šilhan

¹ Research centre Řež, Division of Research and Development in Energy, Hlavní 130, 250 68 Husinec-Řež, Czech Republic; tel. +420 266 173 353; e-mail: petra.ruskayova@cvrez.cz

Keywords: high temperature, fuel cell, electrolysis, hydrogen, solid oxide

One reason, why to study high temperature solid oxide electrolysis is its capability of reverse mode (electrolysis - fuel cell). This phenomenon enables to use the technology for energy storage. It can operate both as an electric power generator, but also as a hydrogen generation unit when the electric energy is abundant. Fuel cell is a clean and potentially low-emission way to produce electric energy and heat. Generally, fuel cells are a prospective source of power for industry, households or the transportation sector. Germany is currently european leader in hydrogen technologies. There is almost 1 000 fuel cell-based micro-cogeneration units and over 300 hydrogen vehicles in Germany. The hydrogen infrastructure in Czech Republic is currently in development.

Our hydrogen research group is involved in hydrogen technologies research, focusing mainly on development and deployment of high temperature solid oxide electrolysis / fuel cells (SOEC/SOFC) and their synergies with GEN IV nuclear reactors. This work is concerned with degradation of the cell's materials and its mechanisms. Understanding of degradation processes is important in order to improve the cell's durability and efficiency. Results of the experiments were obtained using SOEC/SOFC cell test rig which contains the cell with 16 cm² operating area. The cell can operate in two modes, either as high temperature fuel cell or in mode of high temperature electrolysis.

As for observing the structural changes on the surfaces of fuel cell's materials the Scanning Electron Microscopy was used. Energy-Dispersive X-Ray Spectroscopy can analyse the changes in elementary composition and characterize the degradation of materials in the fuel cells.

Solid Oxide Electrolysis / Fuel Cell Loop

¹ A. Kejla, ¹ M. Šilhan

¹ Research centre Řež, Division of Research and Development in Energy, Hlavní 130, 250 68 Husinec-Řež, Czech Republic;
e-mail: ales.kejla@cvrez.cz

Keywords: experimental loop, high temperature, solid oxide, fuel cell, electrolysis, hydrogen

Research centre Řež is involved in hydrogen technologies research, primarily in solid oxide electrolysis / fuel cells (SOEC/SOFC) and subsequent deployment in the energy sector.

First results obtained by the SOEC/SOFC experimental loop are presented. The loop is designed as heat recuperation experimental device using excess heat from helium cooled nuclear reactor of Generation IV. Helium here is replaced by air with comparable energy properties. The loop is intended to be operated during long term experiments either in high temperature electrolysis or fuel cell mode with a 1 kWe electrolysis power.

First experimental results are presented. Analytical methods, as SEM, or Energy-Dispersive X-Ray Spectroscopy, were employed to characterize the material degradation.

Development of an Alkaline Electrolyzer for Storing Electric Power in the Hydrogen Form

^{1,2} M. Kludský, ¹ J. Čermáková, ¹ A. Doucek

¹ ÚJV Řež, a. s., Hlavní 130, Řež, 250 68 Husinec, Czech Republic

² University of Chemistry and Technology, Prague, Technická 5, Dejvice, 166 28 Prague 6, Czech Republic; tel. +420 601 315 842, e-mail: miroslav.kludsky@ujv.cz

Keywords: alkaline hydrolysis, electrolyzer, hydrogen, energy storage

One way how to store electric power is to use hydrogen as a storage medium. The production of hydrogen via electrolysis can take advantage of times of low electricity demand and can be converted back to electricity during high demand with the use of a fuel cell. This variation in electricity demand is typical for distribution grids with a high share of renewables. This work dealt with the development of an alkaline electrolyzer with a polymer membrane, which uses less expensive catalyst materials instead of noble metal catalysts which are used in PEM (proton-exchange membrane) electrolyzers. The catalyst used in the electrolyzer is nickel in the form of a nickel foam, the electrolyte is a up to 30 % potassium hydroxide solution and Fumasep FAAM-75-PK with a thickness of 75 μm supplied by Fumatech is used as the polymer membrane. In our case, the own membrane PSEBS CB DMS was synthesized, which increased the efficiency of the electrolyser. The alkaline electrolyzer was tested and verified in a pilot plant in order to characterize its properties. We assume that the electrolyzer could partially replace the batteries in households that produce electricity from renewable sources, e. g. solar panels and thus store it in the form of hydrogen. Therefore, the experiments were carried out at room temperature and at a maximum overpressure of 7 Bar. Our development of the alkaline electrolyzer will continue towards a reversible fuel cell that is capable of operating both in the alkaline electrolyzer mode and in the alkaline fuel cell mode. The main innovative element of the alkaline reversible cell in the electrolyzer mode compared to the membrane-type alkaline cell is the design of the electrodes, which does not need separate electrolytes for the cathode and anode sections.

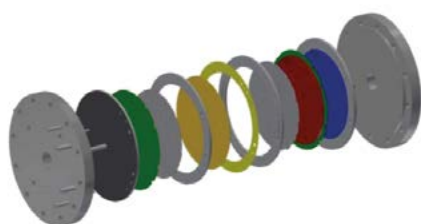


Fig. 1: A cell of the electrolyzer.

Nickel Based Electrode as Cathode Catalyst in Alkaline Water Electrolysis

¹ J. Záchenská, ¹ M. Ábel, ¹ M. Zemanová

¹ Institute of Inorganic Chemistry, Technology and Materials, Faculty of Chemical and Food Technology, Slovak University of Technology, Radlinského 9, 812 37 Bratislava, Slovak Republic; tel. +421 259 325 450, e-mail: jana.zachenska@stuba.sk

Keywords: 3D electrodes, Ni and Ni-W coatings, zero gap electrolyser, alkaline water electrolysis, load measurements

For its catalytic properties, platinum electrode is still the best electrode for hydrogen evolution reaction (HER). However, its high cost is the main reason for the research of its substitution^[1]. One of promising materials are nickel and nickel alloys^[2]. Most of the reported electrode materials were two dimensional (2D) structures. Increase of catalyst surface area is an essential point of effective HER^[3].

In this work, nickel and Ni-W alloys coatings were tested as possible cathode catalysts for alkaline water electrolysis. The coatings were prepared by direct and pulse current electrodeposition. Nickel-based metallic nanocoatings were deposited on the 2D steel mesh and 3D nickel foam. Optimal parameters, such as time, current density and electrode distance of electrodeposition were studied to obtain homogenous coatings on the substrate. Prepared coatings were investigated by the means of SEM, XRD, EDX and XPS. Electrochemical measurements were performed in three electrode cell configuration in 1 M KOH solution by the chronopotentiometry, potentiodynamic polarization and cyclic voltammetry. Load and stability measurements of prepared nickel-based coating were tested in zero gap alkaline water electrolyser. As electrolyte, solution of 10 wt.% KOH was used.

It was found that the coatings prepared on nickel foam were superior to the coatings on the steel mesh. This can be explained by bigger active surface area. Load and stability measurements showed better results for Ni-W coatings. The reason is the higher number of active sites due to the tungsten content.

Acknowledgement

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NiCoP Cathode Catalyst for Electrochemical Water Splitting: Structural and Electrochemical Characterization

¹ M. Durovic, ¹ J. Hnat, ¹ K. Bouzek

¹ University of Chemistry and Technology, Prague, Dep. of Inorganic Technology, Technická 5, 166 28 Prague 6, Czech Republic; e-mail: durovic@vscht.cz

Keywords: electrolysis, hydrogen, phosphides, cathode, electrocatalyst, alkaline environment

Water electrolysis, in combination with renewable energy sources, has come to the forefront of interest during the last decade because of its ability to efficiently convert excess electrical energy into chemical energy of hydrogen. On an industrial scale, the most well-established route is that of alkaline water electrolysis (AWE). However, since this technology was originally designed for long-term stable operation, the above-mentioned combination with renewable energy sources places new demands on the process. Hence, in recent years significant research activity has focused on different aspects of AWE with the aim to increase its efficiency and flexibility. One of the important, and thus most widely investigated, topics in this field is to find an inexpensive electrocatalyst with high stability in an alkaline environment and good catalytic activity for the hydrogen evolution reaction (HER).

In this work, NiCoP catalyst was synthesized by cathodic electrodeposition on Ni substrate in a deposition bath ($\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$) at 24 °C. The effect of (i) the deposition solution composition and (ii) the current density (-100, -75, -50, -25 mA cm^{-2}) on the catalyst activity, composition and morphology was determined by several analytical and electrochemical methods, such as TEM, SEM-EDS, Tafel analysis, cyclic voltammetry, electrochemical impedance spectroscopy etc. The structural characterization showed that multiple phases are formed during the electrodeposition. The catalyst composition is not dependent on the current density but can be adjusted by the deposition solution composition. The electrochemical studies suggest excellent catalytic activity of the material for HER in an alkaline environment.

Financial support by the Technology agency of the Czech Republic (TK02030103) and specific university research (MSMT No 21-SVV/2020) is gratefully acknowledged.

Enhanced Photocatalytic H₂ Production from H₂S on Metal Modified CdS-ZnS Semiconductors

¹ M.A. Mersel, ¹ L. Fodor, ¹ O. Horváth

¹ Research Group of Environmental and Inorganic Photochemistry – Center for Natural Sciences – Faculty of Engineering – University of Pannonia – 8200, Egyetem u. 10 – Veszprém, Hungary;
tel. +36 20 486 8213, e-mail: sam003miloo@gmail.com,
tel. +36 20 495 4082, e-mail: lajos@almos.uni-pannon.hu,
tel. +36 70 247 1061, e-mail: horvath.otto@mk.uni-pannon.hu

Keywords: H₂S, photoactivity, photocatalytic H₂ production, ammine complexes, CdS-ZnS

Photocatalytic H₂ production by H₂S decomposition is regarded to be an environmentally friendly process to produce a carbon-free energy through direct solar energy conversion. For this purpose, sulphide-based materials, as photocatalysts, were widely used due to their excellent solar spectrum responses and high photocatalytic activity. The loading of proper co-catalysts that are based on cheap and earth-abundant materials on those semiconductors was shown to play an important role in the improvement of their efficiency.

In this research, CdS-ZnS composite was studied because of its controllable band gap and excellent performance for H₂ evolution under visible light irradiation. The effects of the modification of this photocatalyst with different types of materials and the influence of the preparation parameters on its H₂ production activity were investigated.

The CdS-ZnS composite with an enhanced photocatalytic activity for H₂ production was synthesized from ammine complexes. Two types of modification were used: compounds of Ni-group metals (NiS, PdS and Pt) were applied as co-catalyst on the surface of CdS-ZnS semiconductor, while NiS, MnS, CoS, Ag₂S and CuS were used as dopant in the bulk of the catalyst. It was found that 0.1 % of noble metals didn't remarkably influence the photocatalytic activity, while the modification with 0.5 % of NiS was shown to be more efficient in the bulk than on the surface. The modification with other types of metals results in a decrease of the rate of H₂ production, while the co-doping seems to be more promising. The preparation parameters (such as the amount of ammonia to form the ammine complexes, the order of the preparation steps together with the hydrothermal treatment) were also found to highly influence the rate of H₂ production. SEM, EDS and DRS analyses were made to reveal the structure of the most efficient photocatalysts. Moreover, the detection of the conduction band electron on the surface of the catalyst was also investigated.

The excellent photoactivity of the CdS-ZnS catalysts with and without modification encourages further investigations to enhance the hydrogen generation by optimization of the reaction conditions.

Hydrogen Evolution Reaction on CoMo- and MoNi-alloy Modified Nickel Foam Surface

¹ M. Łuba, ¹ M. Kuczyński

¹ Department of Chemistry, Faculty of Environmental management and Agriculture, University of Warmia and Mazury in Olszyn, Łódzki Square 4, 10-727 Olsztyn, Poland; tel. +48 660 673 274, e-mail: mateusz.luba@uwm.edu.pl, tel. +48 507 708 114, e-mail: mateusz.kuczynski@uwm.edu.pl

Keywords: hydrogen evolution reaction; electrocatalysts; molybdenum; nickel; cobalt; Ni foam; electrochemical impedance spectroscopy

This poster reports on the influence of the CoMo and MoNi alloy deposits' on a hydrogen evolution reaction (HER). Kinetics of the HER were studied at room temperature in 0.1 M NaOH solution for surface-activated Ni foam, CoMo- and NiMo-modified Ni foam materials for the cathodic overpotential range of -100 to -400 mV. Surface modification of Ni foam base material was made via electrochemical deposition. The exchange current-density values, the charge-transfer resistance for the HER and other electrochemical parameters for examined catalyst materials were obtained by means of a.c. impedance spectroscopy and Tafel polarization techniques. Significance of employed deposition methodology of such-obtained Ni foam/CoMo alloy particles was discussed in detail by means of SEM/EDX spectroscopy analysis.



CZECH HYDROGEN
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CONTENT

HYTEP

MEMBERS

- 1 C-Energy Planá s. r. o.**
- 2 CDV – Transport Research Centre (CDV)**
- 3 Chart Ferox, a. s.**
- 4 CHEMINVEST s. r. o.**
- 5 CYLINDERS HOLDING a. s.**
- 6 Czech Technical University in Prague (CTU)**
- 7 DEVINN**
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- 9 ENVISAN-GEM, a. s., environmental services**
- 10 GREEN REMEDY**
- 11 HYDROGEN 1**
- 12 Hyundai Motor Czech s. r. o.**
- 13 Institute of Thermomechanics of the CAS**
- 14 LEANCAT**
- 15 OKK Koksovny, a. s.**
- 16 ORLEN Unipetrol Group**
- 17 Research Centre Řež**
- 18 SOLEK HOLDING SE**
- 19 ŠKODA ELECTRIC a. s.**
- 20 ŠKODA JS a.s.**
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HYTEP – Czech Hydrogen Technology Platform is a grouping of commercial, scientific, research and educational entities active in the field of hydrogen technologies and related fields, with 27 members.

HYTEP was initiated by the Ministry of Industry and Trade of the Czech Republic in 2007.

HYTEP enables effective involvement

of its members in national and european institutions with the aim to increase national competitiveness in the field of power engineering technologies.

HYTEP supports effective communication

between different entities, effective cooperation in dealing with projects of research, development and innovation, as well as activities within the framework of the implementation of hydrogen technologies into all concerned industries.

HYTEP defines, represents, defends

and promotes the legitimate common interests of its members in order to create a suitable environment for the application of modern technologies in sustainable energy development.

HYTEP organizes international conferences

on hydrogen technologies in Central Europe. HYTEP also organized the World Hydrogen Technology Convention WHTC 2017 and brought, for the first time, a big hydrogen event to the Czech Republic and Central Europe. HYTEP also organizes every year in spring the international conference Hydrogen Days.

HYTEP is an association open to other businesses

and entities that are actively engaged or wish to engage in the issues of innovative power engineering technologies; for those, who want to participate in the Czech Republic's involvement in research, development, and application of hydrogen technologies and other supporting activities in the area of clean energy technologies.



Czech Hydrogen Technology Platform

Husinec-Řež 130

250 68 Husinec - Řež

Czech Republic

Tel.: +420 723 252 557

E-mail: info@hytep.cz

www.hytep.cz

MEMBERS



CZECH HYDROGEN
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C-Energy Planá s. r. o.

C-Energy Planá s. r. o. is a producer and supplier of energy made in highly efficient cogeneration units; at the same time, the company utilizes its state-of-the-art technologies to provide ancillary services supporting grid stability and security with a minimum impact on the environment.

C-Energy Planá is a member of the C-Energy Group – a holding that operates and develops ecological and highly efficient power plants. The mission of C-Energy Group is to set trends in utilization and operation of state-of-the-art and ecological power generation technologies. That is why the group has spent more than 2 billion Czech crowns in the modernization of the power plant in Planá nad Lužnicí since 2012. Nowadays the plant ranks among the most modern power generation facilities in Central and Eastern Europe.

Currently there are 6 Rolls Royce gas CHP units (4x9.25 MWe and 2x11.5 MWe). There is a 0.6 MWe photovoltaic power station combined with a battery energy storage system (BESS) featuring 4 MWe capacity and 2.5 MWh output. The BESS was the largest one in the Czech Republic at the time its operation was launched, and C-Energy Planá was the very first power plant to test and utilize a BESS to provide ancillary services in the electric grid. Besides, the plant includes a 26 MWe steam turbine which underwent a general overhaul in 2015 resulting in increased efficiency of the unit. At the same time, two modern grate firing boilers with fluid technology elements were installed in Planá; nowadays lignite combined with biomass are combusted in the boilers. C-Energy Planá is planning to modify the existing boilers to make 100 % biomass burning possible.

C-Energy's long-term goals include further reduction of emissions, specifically the CO₂ emissions, by increasing the share of biomass combustion. The company also investigates other CO₂ reduction strategies, while primarily focusing on hydrogen technologies.



C-Energy Planá s. r. o.

Průmyslová 748

Planá nad Lužnicí

391 02 Sezimovo Ústí II

Česká republika

Tel.: +420 380 071 800

E-mail: info@c-energy.cz

www.c-energy.cz



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Transport for future

CDV – Transport Research Centre (CDV) is a public research institution, established according to the law 341/2005 Coll. on public research institutions, and the only one research body under the Czech Ministry of Transport.

CDV provides research, expertise and services in all transport fields for both public and private sectors.

Through its research focus, CDV – Transport Research Centre, covers the key needs of transport development in the Czech Republic at national, regional and local levels.

CDV has been involved for a long time in research of impacts of transport on the environment. One of the main activities in this area deals with the production of emissions by transport, which has been under enormous pressure since 2017. We see the huge potential to meet ambitious goals in accordance with sustainable development policy, the National Action Plan on Clean Mobility, and also in terms of meeting the energy demands of society in general, in the introduction of hydrogen technologies in the transport sector. In this context, it is necessary to address issues not only of a technical nature but also in terms of social acceptability, identification of psychological and sociological barriers, conceptual and strategic documents aimed at developing “hydrogen transport” (including development of filling station infrastructure in accordance with road and rail transport demands, in international, national and regional level) etc. Our aim is to support the natural introduction of innovative and environmentally friendly technologies without negative market distortions with adverse social and environmental impacts.

CDV has been involved a long time as well in the issue of alternative drives. In terms of hydrogen drives, CDV, for example, has prepared a Feasibility Study for the Application of Hydrogen in Public Transport in Karlovy Vary, which was used in several outputs in the international project Green urban transport systems (GUTS).



Transport Research Centre (CDV)

Líšeňská 33a

636 00 Brno

Czech Republic

Tel.: +420 541 641 711

E-mail: cdv@cdv.cz

www.cdv.cz/en

Chart Ferox, a. s.

Chart Ferox, Inc., is globally recognized for the design, manufacture and supply of highly engineered cryogenic equipment and systems for the storage, transportation and distribution of liquefied gases, including oxygen, nitrogen, argon, hydrogen, carbon dioxide and hydrocarbons, especially liquefied natural gas (LNG), and hydrogen as well.

Located in Děčín, Czech Republic, Chart Ferox is the principal European operation of Chart Industries, Inc., (Nasdaq: GTLS), which has global coverage through multiple facilities throughout the US and in China, Italy, Germany, France, the UK, India, Australia and the Americas.

Chart Ferox product portfolio includes a complete range of state of the art vacuum insulated cryogenic tanks, from the smallest standard packaged gas cylinders right through to the world's largest shop built units. In 2012, the first HT 1000 with a storage capacity of 1 million liters was designed, manufactured and installed in Norway. Today these vertical and horizontal tanks are almost a standard product and incorporated into many of Chart's modular turnkey technical solutions for satellite regasification units, automotive and marine fueling stations and multifunctional storage terminals for liquefied natural gas.

Transportable and distribution solutions include intermodal ISO containers, tanks, road trailers, rail cars and semi-trailers that facilitate transport of liquefied gases by road, rail and water.

Storage and distribution of hydrogen, hydrogen as a fuel

Chart Inc. has produced more than one hundred of cryogenic hydrogen storage tanks for liquid hydrogen. In most cases these tanks are part of hydrogen refueling stations for forklifts.

Chart Ferox, a. s. for example manufactured hydrogen storage tanks for the Ariane space program, supplied to Kourou, French Guyana. Currently, the company offers storage tanks, ISO containers and semitrailers for liquid hydrogen. Company designed marine fuel systems as well and received approval of the concept.



Chart Ferox, a. s

Ústecká 30

405 30 Děčín 5

Czech Republic

Tel.: +420 412 507 111

E-mail: ferox-sales@chartindustries.com

www.chart-ferox.cz



Innovation. Experience. Performance.®

We make your projects delivered on time!

CHEMINVEST was founded in 1995 in Litvínov, Czech Republic, as a subsidiary of Chemopetrol Group a. s., but its foundations were laid in 70's. Due to this fact our history is strongly connected with chemical industry.

Our originally designing and engineering company has become a strong EPC contractor with an ability to satisfy the most demanding customers. Our sales were 264 mil. CZK in 2017 and we had ca. 50 employees at that time.

Our Services

- Designing and Engineering Activities
- CAPEX Project Management
- EPC Projects
- Client Representation

Areas of Expertise

- Chemical Industry
- Traffic Constructions
- Long Distance Pipeline Constructions
- Power Engineering
- Water Constructions

CHEMINVEST and Hydrogen

We consider hydrogen as one of the most promising clean energy sources of the future. We want to be involved in general use of the hydrogen and focus on designing and constructing the hydrogen operating units including the infrastructure for FC engines.



CHEMINVEST s. r. o.

Gorkého 1613

Horní Litvínov

436 01 Litvínov

Czech Republic

Tel.: +420 417 639 739

E-mail: management@cheminvest.cz

www.cheminvest.cz

CYLINDERS HOLDING is a Czech company that has been continuously developing and producing seamless steel pressure cylinders since 1905.

We are a manufacturer of seamless steel pressure cylinders and vessels for hydrogen with a pressure range from 200 up to 1050 bar and we also realize solutions of product applications for hydrogen storage and transport in modular units (hydrogen virtual pipelines). We are constantly growing thanks to our own research and development.

CYLINDERS HOLDING a. s.

- is a global producer with the largest share in the European steel cylinder market. The company's export targets all the continents. In selected territories, the holding builds not only a market position but also new production facilities.
- is the only company that is capable to produce seamless steel hydrogen pressure vessels up to 1000bar by using method of reverse extrusion.
- builds its future on the principles of the circular economy, i.e. on the ability to use primary production waste and using modern technologies to produce a suitable and environmentally friendly product without it. Mobile and virtual gas pipeline systems developed by Cylinders Holding confirm that there are comfortable, environmentally friendly and economical top-quality solutions that reduce the burden on our planet.



CYLINDERS HOLDING a. s.

Výstavní 81/97

703 00 Ostrava - Vítkovice

Czech Republic

Tel.: +420 595 953 350

E-mail: cylinders@cylinders.cz

www.cylinders.cz



**Cylinders
Holding**

Czech Technical University in Prague (CTU)

The Czech Technical University in Prague is one of the biggest and oldest technical universities in Europe. It was founded on the initiative of Josef Christian Willenberg on the basis of a decree issued on January 18th, 1707 by Emperor Josef I.



CTU currently has eight faculties (Civil Engineering, Mechanical Engineering, Electrical Engineering, Nuclear Science and Physical Engineering, Architecture, Transportation Sciences, Biomedical Engineering, Information Technology) and about 21,000 students.

The aim of the faculty is a top pedagogical and scientific Czech workplace recognized at home and abroad. The Faculty actively participates in the harmonization of the European Education and Research Area in order to be compatible with the European system, attractive for the listeners and to meet the needs of the society.

The departments of the Faculty of Mechanical Engineering are located in Prague - Dejvice, in a historic building on Charles Square, Horská Street and Julisce. Since the academic year 2003/04, a newly-deployed workplace was established in Sezimovo Ústí. The faculty also has several training centers. Currently, there are 32 professors, 78 associate professors, 175 lecturers and assistants at the faculty at 14 institutes and two research centers, who also make significant contributions to research and development projects. The Faculty also participates in the activities of other research centers, cooperates with the Academy of Sciences of the Czech Republic, the Academy of Engineering of the Czech Republic, the Association of Research Organizations, the Union of Industry and Transport, the Association of Manufacturers of Engineering Technology, a number of large, medium and small industrial companies such as Siemens, Porsche, Škoda Auto, The Hydrosystem Olomouc and many others.

International cooperation in education takes place in several ways. In addition to the mobility of students and academics under contracts, this is mainly about scientific, research and pedagogical activities connected with participation in scientific and professional seminars and conferences, especially in the EU countries. International R&D cooperation is implemented through direct links to individual EU programs or other international programs. At the Faculty of Mechanics, it is also possible to study in English. This teaching is designed for our and foreign students and is greatly supported by regular purchases of foreign study literature.

The Czech Technical University in Prague

Zikova 1903/4

166 36 Prague 6

Czech Republic

Tel.: +420 224 351 111

E-mail: cvut@cvut.cz

www.fs.cvut.cz



DEVINN s. r. o.

Who we are:

We are a Czech development company. We work in the heart of the Czech automotive industry, in Mladá Boleslav. We mainly focus on smart innovative solutions, which we implement starting from the initial phase of the preliminary development up to the production and prototype testing. We are developers in the area of alternative-fuel passenger cars. We execute lighting tests, tests of cable harnesses, tests of control units and tests of other automotive electronics.

We engage in development of:

- alternative fuel / electric mobility
- energy storage systems
- lights and lighting for cars
- electrical systems and electronics of cars
- race cars
- custom-made production of flood lights

Hydrogen technologies at DEVINN:

We are engaged in the development and the application of efficient hydrogen systems for use in energetics and in the future automotive industry.



DEVINN s. r. o.

Domicile:

DEVINN s. r. o.

Skřivánčí 4769/38, 466 01 Jablonec n. N.

Czech Republic

Development center:

DEVINN s. r. o.

Koněvova 134, 293 01 Mladá Boleslav

Czech Republic

E-mail: info@devinn.cz

www.devinn.cz

Energy financial group a. s.

The investment corporation Energy Financial Group focuses on projects aimed at energy production from renewable sources. We develop projects of ecological energy production, contributing to research and development of new technologies and cooperation with leading universities. Our vision is to promote the responsible waste management of in the Czech Republic and contribute to the development of the energy segment, which will be environmentally friendly.

Our motto:

We do not inherit the earth from our ancestors, we borrow it from our children.
Antoine de Saint-Exupéry

We are dealing with:

- BDW energetic use
- Developing ideal biogas practices
 - By membrane separation of biomethane from biogas
 - Biological methanization of carbon dioxide from biogas
- Cooperating with universities in further research and development
- Purchase, collection and sorting of the energetically usable of biodegradable waste (BDW)

We operate:

- Biogas station energetically utilizing BDW: EFG Rapotín BPS
- Company producing biomethane from biogas: EFG Rapotín upgrading
- Company building biogas stations: EFG Engineering
- The central BDW depot and sorting facility: EFG Kralice na Hané
- Collecting company equipped with technology for the BDW collection: EFG Waste logistic

EFG and hydrogen technology

In hydrogen technology, we are particularly interested in P2G technology, mainly in connection with the project of the biogas station of the EFG Rapotín BPS.

P2G technology is perceived as a suitable addition to this project where the produced biogas is further processed by membrane separation. The result is separation of biomethane from carbon dioxide and other substances. Our next aim is to utilize the waste carbon dioxide in the new project of carbon dioxide methanization.

We are actively interested in its methanisation by biological means.



Energy financial group a. s.

Jihlavská 1558/21

140 00 Prague 4 - Michle

Czech Republic

Tel.: +420 608 424 545

E-mail: sekretariat@ef-group.cz

www.ef-group.cz



**ENERGY FINANCIAL
GROUP**

ENVISAN-GEM, a. s.

is a specialized company with a focus on providing services in waste management, remediation of environmental damage, environmental protection and special applied microbiology. The company has gained a lot of experience in these fields and has a wide range of technical and technological backgrounds.

The company provides comprehensive services for business/industrial waste management in the South Bohemian region.

Since 2016, the company has started research and development in electricity storage and hydrogen technologies, specifically with the focus on alkaline systems.

ENVISAN-GEM, a. s. services

- Ecological Consulting
- Waste collection and disposal
- Optimization of waste management
- Soil and water analysis
- Remediation of environmental damage
- Applied microbiology

ENVISAN-GEM, a. s. and hydrogen

In our innovation center, we focus on environmental research and technology transfer. Our company joined a consortium to develop electrolyzer powered by renewable energy in 2016. Follow-up projects are directed towards the conversion of hydrogen back into electricity and hydrogen storage.



ENVISAN-GEM, a. s.

Hůry 149

373 71 Hůry

Czech Republic

Tel.: +420 602 270 809

E-mail: info@envisan.cz

www.envisan.cz

ENVISAN GEM
geologie | ekologie | mikrobiologie

GREEN REMEDY is a private company developing a complex design of Hydrogen Economy to cover the entire spectrum of its usage and applications.

We believe in the future of hydrogen as an alternative to carbon energies and one of key energy carrier in near future.

GREEN REMEDY is working on a project for complex implementation of hydrogen economy, which aims to create a system to enable hydrogen technologies to be used in the full spectrum of its options – power storage, clean mobility, electricity production, etc. The key benefit will be innovative and entrepreneurial joining of the technologies that are now still in different stages of development or commercialization into a functionally optimized whole, with the widest use of IT technology.

GREEN REMEDY Goals

The goal is to produce a model system of hydrogen management using hydrogen technologies in connection with a solar power plant and hydrogen storage in a real-world environment to demonstrate the potential of hydrogen technology in the following areas:

- Accumulation of surplus electricity into hydrogen
- Utilization of stored energy in hydrogen as
 - a back-up power supply for power generation in the event of a power failure
 - for system services of the transmission system (peak alignment)
 - as a fuel for a passenger hydrogen car (later also hydrogen bus) – a general solution to hydrogen pumping station and pure mobility
- Data collection from the entire system and it's evaluation for continuous optimization of the system

The Model of Hydrogen Management System

The Model of Hydrogen Management System will serve to verify the functionality of the system, optimize it, and help create a kit that will be commercially available as a "modular" solution.



GREEN REMEDY, s. r. o.

Cyrilská 7

602 00 Brno

Czech Republic

Tel.: +420 603 536 812

E-mail: hydrogen@greenremedy.cz

www.greenremedy.cz



WE HAVE EXPERIENCE IN HYDROGEN SINCE 2007.

HYDROGEN1 is a fund of HENRY IF SICAV joint stock company. Its main strategy are investments into renewable energy sources and technologies for production, distribution and use of hydrogen in industry and transport. HYDROGEN1 belongs to the category of funds based on the principles of "Socially Responsible Investment". Two of the fund's founders are also founding shareholders of United Hydrogen Group Inc. (UHG), which in 2019, as the only private company in the world, completed and launched production of liquid hydrogen in Charleston, Tennessee, USA. HYDROGEN1, along with UHG, successfully realized this \$ 40 million investment, which resulted in the merger with the world leader in hydrogen technologies, PLUG POWER Inc.

Socially responsible investments pay off

We are pleased that our investments are helping to save the environment for future generations and through HYDROGEN1, each of our investors contributes to it. Our goal is, of course, to create value for our investors. And we are glad that we are doing well, from the establishment of the fund from June 2019 to December 2020 we have created profit on invested capital of 370 %.

Our experience

Our advantage is more than 13 years of experience with hydrogen technologies and business and flexibility and speed of decision-making in projects. After successful exit of our USA projects, we are focusing on the EU and Czech markets. Hydrogen is the future of transportation and energy, and today we are at the beginning of this revolution equipped with experience, know-how and capital.

Our energy

For us, hydrogen is a synonym of energy. Hydrogen is a key element of change that can preserve our freedom of movement and to provide us with the energy we need for our daily living, all without unwanted emissions. And we and our team give OUR maximum energy to make this change happen and we ourselves participate in the creation of projects and their development.



HENRY IF SICAV a.s. subfund HYDROGEN 1

Headquarters: International Busines Center
Pobřežní 620/3, 186 00 Praha 8

Czech Republic

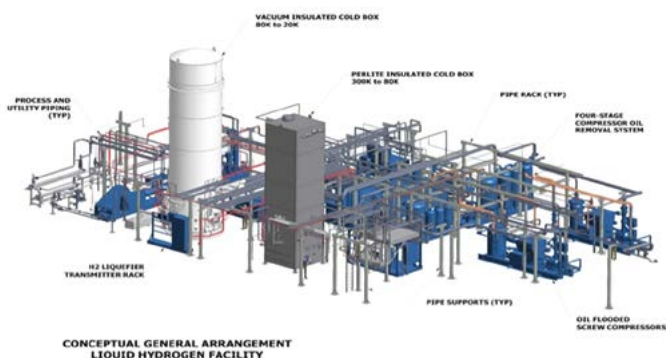
Offices: Štěpánská 621/34

110 00 Praha 1

Czech Republic

E-mail: ladislav.ornst@hydrogen1.cz,
roman.horak@hydrogen1.cz

www.hydrogen1.cz



Hyundai Motor Czech s.r.o. is the brand's importer for the Czech Republic.

Hyundai Motor Czech s. r. o. is the Czech brand representation of South Korean car manufacturer Hyundai, one of the most important automotive brands on the Czech market. One of the brand's goals is a responsible attitude towards the environment, clearly visible in the company's effort in offering a wide range of electrified or fully electric models and other solutions for sustainable mobility.

- One of the company's manufacturing plants is located in Nošovice in Frýdecko-Místecko region, where popular models such as i30 and Tucson are being made, as well as Kona Electric, the first fully electric model with a Czech origin.
- The complete portfolio includes compact models i10 and i20, one of the most popular Czech models i30, efficient Ioniq, crossovers Bayon and Kona, or SUVs Tucson and Santa Fe.
- The portfolio also includes Hyundai Nexo, a fully electric vehicle powered by a fuel cell, which is the first hydrogen passenger car registered with Czech registration signs.
- In the beginning of 2021 Hyundai boasts a dealer network consisting of 51 branches all over the country.



Hyundai Motor Czech s. r. o.

City West, Siemensova 2717/4

155 00 Praha 13

Czech Republic

Tel.: +420 800 800 900

E-mail: info@hyundai.cz

www.hyundai.cz

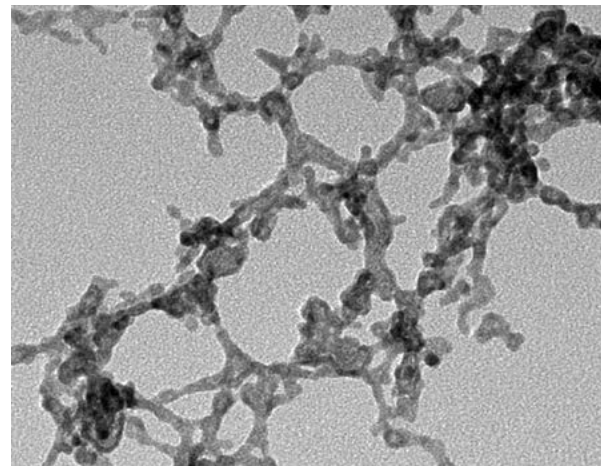


Institute of Thermomechanics of the Czech Academy of Sciences

The Institute of Thermomechanics of the Czech Academy of Sciences is a public research institution focusing on basic and interdisciplinary research in applied physics, particularly fluid dynamics and thermodynamics, dynamics and vibrations in solid bodies and mechanical systems, impact and waves in solids, ultrasound methods for studying mechanical properties of solid materials, electrical engineering and electrophysics.

The Institute of Thermomechanics has several branches across the Czech Republic. Although the Institute is focused primarily on basic research, it maintains extensive collaboration with large industrial companies as well as dynamic and technology-oriented SMBs. Our research has a strongly interdisciplinary character and is relevant to mechanical, power and environmental engineering, biomechanics and electrical engineering.

In the field of hydrogen technologies, the Institute focuses on the development of methods of synthesis and deposition of metal nanomaterials using the principle of aerosol synthesis by spark discharge. We use nanopowders synthesized from the platinum-group metals (such as platinum, iridium, palladium, ruthenium) and their mixtures to produce catalytic layers for PEM hydrogen fuel cells and electrolyzers, and we characterize their performance and durability. Our research in this area is motivated by the use of hydrogen technologies for energy storage.



Institute of Thermomechanics of the CAS

Dolejšková 1402/5

182 00 Prague 8 - Libeň

Czech Republic

Tel.: +420 266 052 021

E-mail: secr@it.cas.cz

www.it.cas.cz/en

A Fuel Cell Technology Company

Our first interest was a new “lean cat-alyst”, then we moved on to R&D new versions of complete PM fuel cells for various applications. Out of need to properly test these FCs, we started to develop and sell our own sophisticated testing stations. We also develop an H₂ generator, a UPS and a forklift. We are LEANCAT.

We innovate

Leancat is a small innovative company, founded thanks to a close cooperation between the Department of Surface and Plasma Physics at the Faculty of Mathematics and Physics, Charles University in Prague, and a Czech technology group JABLOTRON. The founder and co-owner of the company, Professor Vladimír Matolin, gathered around him a team of enthusiastic and dedicated young researchers and technicians who are trying to transform the theoretical knowledge from the field of hydrogen technology into meaningful products.

We produce

We manufacture professional and fully customized test stations for hydrogen fuel cells up to 10 kW. We have also started with H₂ generators and UPSs for industrial and residential applications, single cells and custom-made mixing stations for technical gases. With company Belet a. s. we are preparing the first Czech hydrogen-powered forklift.

We love hydrogen

We are trying to absorb everything interesting in the field, and we are moving fuel cells forward.

We go worldwide

For example, we supplied test stations to the European Synchrotron Radiation Facility (ESRF) in Grenoble, to Hochschule Rhein-Waal (GER) or Manchester University (UK). You will also find our equipment in prestigious institutes in China and India.



LEANCAT s. r. o.

Registered seat:

U Přehradý 3204/61

466 02 Jablonec n. N.

Czech Republic

R&D lab / production:

U Pergamenky 1145/12

170 00 Prague 7

Czech Republic

Tel.: +420 603 892 678

E-mail: info@lean-cat.com

www.lean-cat.com



LEANCAT
FUEL CELL TECHNOLOGY

OKK Koksovny, a. s.

OKK Koksovny, a. s. is the largest European producer of foundry coke. Foundry coke that we produce has been enjoying the reputation of a top European quality product for long time. OKK Koksovny, a. s. offers a broad range of cokes for foundry and metallurgical production, special metallurgy, heating and other purposes. Other products include chemicals, which are formed in high-temperature coal carbonisation. OKK Koksovny, a. s. is a significant member of the Czech Coke-Making Society.

OKK Koksovny, a. s. (hereinafter referred to as "OKK" or the "Company") operates one production plant – the Svoboda Coking Plant, where 4 coke oven batteries are in operation. The Company produces about 700 kt of coke annually by the so-called thermodynamic conversion of coking coal without air access – coking. In this process, foundry, blast furnace, heating and technological sorts of coke were produced, divided further according to grain size and qualitative features in accordance with the market requirements.

The major production programme of OKK Koksovny, a. s., is the production of coke – a raw material required not only for iron and cast iron production, but also for a number of other industries. We produce coke virtually from all kinds of cokeable coal.

Foundry and blast furnace coke

Its technological properties must ensure the conditions for the production of cast iron and insulating materials based on basalt or glass fibres. Blast furnace coke is used mainly as an oxidising-reducing agent in blast furnaces. It creates a supporting structure within a blast furnace, which ensures counter flows of gas and liquid products of the blast furnace process in the production of pig iron.

Technological coke.

It includes: O1 – Nut coke¹, O2 – Nut coke², Hr – Breeze, Pr – Dust. The first two kinds are often called heating cokes with respect to their prevailing purpose of use, i.e. as cheap and ecological fuel for heat production and water heating in households, companies, particularly there where remote distribution of heat and gas is not possible. Due to its low content of ballast and sulphur in the ratio to the calorific value (26 MJ/kg) it is an ecological fuel complying with the strict limits for the content of pollutants, the so-called air emissions.

Chemical products

They are coking by-products obtained from coke oven gas. These include tar, benzole, ammonium sulphate, solid sulphur and technically pure coke oven gas. Tar and benzole are important raw materials for further processing in the chemical industry, ammonium sulphate is used in agriculture as a fertiliser and technically pure coke oven gas is reused to heat coke oven batteries and about 45 % for electricity and heat production.

Coke oven gas contains about 55 % of hydrogen. Hence the idea of separating hydrogen from gas for further use, in particular for propulsion of vehicles and, in particular, city buses in Ostrava.

Ecological activities

Air protection along with the development of safe and healthy working conditions for the employees belongs among the highest priorities of the Company.



OKK Koksovny, a. s.

Koksární ulice 1112

702 24 Ostrava-Přívoz

Czech Republic

Tel.: +420 596 292 230

E-mail: okk@koksovny.cz

www.koksovny.cz



Fuelling your success.

The ORLEN Unipetrol Group is the largest refinery and petrochemical company in the Czech Republic. It focuses on crude oil processing and on the production, distribution and sale of vehicle fuels and petrochemical products – particularly plastics and fertilisers. In all these areas, it belongs among the critical players on the Czech and Central European market.

The ORLEN Unipetrol Group encompasses refineries and production plants in Litvínov and Kralupy nad Vltavou, Paramo with its Mogul brand in Pardubice and Kolín, Spolana Neratovice, and two research centres in Litvínov and Brno.

Unipetrol also includes a network of Benzina ORLEN filling stations in the Czech Republic and Slovakia. With 419 filling stations, Benzina ORLEN is the largest chain in the Czech Republic. Since its entry in 2019 to Slovakia, Benzina ORLEN has been one of the fastest-growing chains and currently has 20 stations in its network.

In 2005, ORLEN Unipetrol became a member of the ORLEN Group, the largest crude-oil processor in Central Europe. ORLEN Unipetrol employs more than 4,800 people. In addition to its business development, ORLEN Unipetrol is proud to be a socially responsible corporation. Therefore, it pays an equal amount of attention to initiatives, focusing on the cultivation and support of sustainable development, education, local communities, and the environment.

Main products

- diesel
- automotive gasoline
- aviation fuels (jet)
- motor and fuel oils
- LPG
- petrochemicals (ethylene, propylene, C4 fractions, benzene, butadiene)
- plastics (polyethylene, polypropylene)
- asphalts
- ammonia

ORLEN Unipetrol and hydrogen

ORLEN Unipetrol, as a traditional hydrogen producer, sees the future in this gas through gradual replacement of conventional fuels in transport. We produce hydrogen mainly in the Litvínov refinery. Approximately half of the hydrogen produced is used for the production of ammonia, feedstock for the production of fertilizers. The other half is used for hydrocracking of vacuum distillates and hydrotreating of motor fuels. At the same time, we are engaged in a project for the efficient production of so-called green hydrogen from alternative sources, ie without a carbon footprint, for example by electrolysis of water using electricity obtained from photovoltaic cells installed at our refineries or directly at filling stations. In 2021, we plan to open hydrogen filling stations at two existing Benzina filling stations, in Litvínov and in Prague in Barrandov. This will be followed by the installation of hydrogen racks at gas stations in Brno and Pilsen. We are involved in platforms that support the development of the use of hydrogen, and we discuss with governmental and non-governmental institutions and automotive manufacturers the possibilities of introducing hydrogen into passenger and public transport and the transport of goods.



ORLEN UNIPETROL

Milevská 2095/5

140 00 Prague 4

Czech Republic

Tel.: +420 225 001 444

E-mail: info@orlenunipetrol.cz

www.orlenunipetrol.cz, www.benzina.cz

Social media: ORLEN Unipetrol, Benzina, Mogul



Research Centre Řež focuses on research, development and innovations in the field of power generation, especially (but not only) nuclear.

Research Centre Řež is part of the ÚJV Group, owned by ÚJV Řež, a. s. and is knowledge-oriented organization which is – thanks to its unique research infrastructure – the largest complex research centre in Central Europe. The combination of research reactors, technological experimental loops, hot cells and material laboratories at one site is really exceptional.

Two nuclear research reactors and experimental loops simulating operation parameters of PWR, BWR, SCWR, MSR; hot cells; severe accidents laboratories (e.g. cold crucible, LOCA device); material laboratories; microstructural and microchemical laboratories; NDT laboratories.

Within the field of hydrogen technologies, the focus is on its production by high-temperature electrolysis for co-generation applications. For this purpose, a dedicated loop was developed, as well as a test bench. The test bench serves for testing of different single cells for research and development. High-temperature electrolysis loop is used for a demonstration of hydrogen production via co-generation and testing of system components.



Research Centre Řež

Hlavní 130

250 68 Husinec - Řež

Czech Republic

Tel.: +420 266 173 181

E-mail: cvrez@cvrez.cz

www.cvrez.cz



Centrum výzkumu Řež s.r.o.

Research Centre Řež

SOLEK HOLDING SE

SOLEK HOLDING SE is an energy company established in 2010, providing business in renewable energy sector. With a focus on solar power, it develops, builds, owns, operates and maintains power plants across the European and Latin American continents. Its activities are most widespread in Chile; other localities of successfully realized photovoltaic projects include the Czech Republic, Slovakia and Romania. As part of its business strategy, the expansion goes also to new markets, such as Cyprus.

Since its establishment, SOLEK HOLDING SE completed more than twenty projects over 100 MW of installed capacity. Other 260 MW from tens of photovoltaic power plants are currently under development and construction. Its mission to build 500 MW of installed capacity should be reached in 2023.

For the first decade, SOLEK HOLDING SE performed primarily as a developer, when solar power plants around the Chilean capital Santiago successfully sold to the Canadian "Carbon Free", the American "Arroyo Energy Group" and the French investors "Reden Solar". Today, its current business strategy is not only to design and build photovoltaic plants, but also to take a position as an active owner and operator. In particular, the investment instruments are used for financing activities, such as the corporate bonds programme with a stable income, successfully placed in the market.

SOLEK HOLDING SE is headquartered in Prague, Czech Republic, with subsidiary offices in Chile, Cyprus, Hungary, Romania, Greece and Colombia. The founder, majority owner and CEO of SOLEK HOLDING SE is Zdeněk Sobotka, a Czech entrepreneur and solar energy visionary.



SOLEK HOLDING SE

Voctářova 2449/5

180 00 Praha 8

Czech Republic

Tel.: +420 722 931 678

E-mail: solek@solek.com

www.solek.com



ŠKODA ELECTRIC a. s. – Clean energy

Škoda Electric as a part of Škoda Transportation group is a leading world manufacturer of public transport vehicles and electric traction equipment. Škoda Electric is a stable, strong and experienced European company, which guarantees quality, reliability and long-term cooperation. It continues in the tradition of the Škoda Works in Plzeň, which dates back 160 years.

The company prioritises the use of cutting-edge technology for its modern urban public transport and rail vehicles. It invests an average of 5 % of its annual turnover in the development of new products.

The company employs around 800 people, more than 200 of whom are specialists in technical development, projects and construction

ŠKODA ELECTRIC and product

- Manufacturing of electric drives and traction motors for railway applications and mining vehicles
- Manufacturing of trolleybuses and electric buses
- Vehicle modernization and maintenance

ŠKODA ELECTRIC and goals

- Our goals are to support clean energy in transport and to contribute to the sustainable development of society

ŠKODA ELECTRIC and fuel cell technology

- In 2009, Škoda, in cooperation with ÚJV Řež, a. s., has developed a prototype of the first fuel cell bus in the Czech Republic called TriHyBus.



ŠKODA ELECTRIC a. s.

Tylova 1/57

312 00 Plzeň

Czech Republic

Tel.: +420 378 181 155

E-mail: electric@skoda.cz

www.skoda.cz



ŠKODA JS a.s.

The Power of Nuclear Engineering

We are one of the leaders of the nuclear power industry in Europe. We are part of its history and we pass on our knowledge and experience from one generation to the next. We are a team of experts working with advanced technologies and our three pillars – engineering, production and service – provide a wide range of activities within the lifecycle of a nuclear power plant. We constantly innovate and push ourselves and nuclear engineering forward.

Over the past sixty years, ŠKODA JS a.s. has participated in the construction of nuclear power plants not only in the Czech Republic and Slovakia, but also in Hungary, Bulgaria and Germany.

Activities of ŠKODA JS a.s.

Engineering, production and service for VVER, RBMK, PWR, and BWR nuclear power plants and for research reactors.

In the field of high-pressure gases, ŠKODA JS a.s. has, among other things, many years of experience with controlled removal of hydrogen generated in the primary circuit of nuclear power plants.

ŠKODA JS a.s. also has significant references in the field of supply of pressure vessels for the chemical industry. Already in 2005, we delivered the first chemical reactor for the production of ammonia.

In the field of hydrogen technologies, ŠKODA JS a.s. focuses on the use of hydrogen in power industry, production of hydrogen using renewable sources and accumulation of energy in hydrogen.



ŠKODA JS a.s.

Orlík 266/15

316 00 Plzeň

Czech Republic

Tel.: +420 377 535 400

Fax: +420 377 524 755

E-mail: info@skoda-js.cz

www.skoda-js.cz



ŠKODA JS a.s.

The Czech Gas Association (CGA) brings together businesses, scientific, research and educational institutions, and experts operating in the gas and related industries.

The CGA follows up on the traditions established in 1919 by the Czechoslovak Gas and Water Association and it is a founding member of the International Gas Union (IGU) (1931). The CGA's mission is to work for the benefit of the Czech gas industry's professional interests and needs; help to raise its levels of expertise; and represent the Czech gas industry at the international level.

The CGA is a member of the IGU, Eurogas, Marcogaz and NGVA Europe, i.e. major international gas associations. The CGA facilitates the transmission of gas industry information from these associations, and through its activities in their bodies and structures represents the Czech gas industry at the international level.

The CGA paves the way for broad-ranging exchanges of information in the Czech gas industry. It uses such information for drafting and commenting on international and national legislation and technical regulations; it is a partner of the Czech Office for Standards, Metrology and Testing in the harmonisation of the national technical legislation with the relevant EU regulations. In this respect, the CGA also works with the Chamber of Commerce of the Czech Republic.

In pursuing its mission, the CGA also operates in technical education, organising international conferences and a number of technical training courses for both its members and outside experts.

The CGA supports and actively promotes increased use of natural gas, biomethane and SNG as green fuels that can be utilised most efficiently.



The Czech Gas Association

U Plynárny 223/42

140 00 Prague 4 - Michle

Czech Republic

Tel.: +420 222 518 811

E-mail: cpsvaz@cgoa.cz

www.cgoa.cz

ID data box: aef3es5

University of Chemistry and Technology, Prague

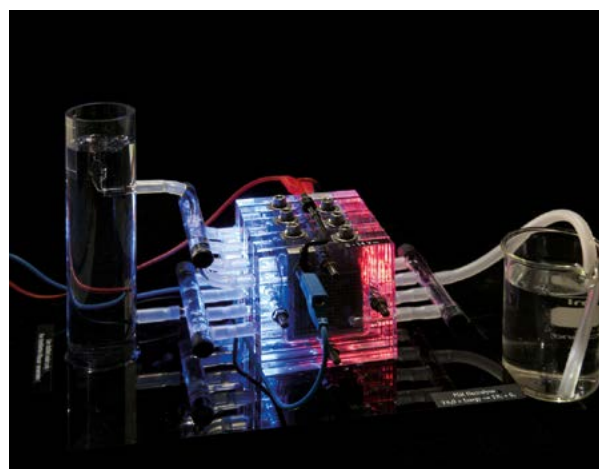
The University of Chemistry and Technology, Prague (UCTP) is a typical research university, providing a top-class education in the fields of chemistry, materials chemistry, biochemistry and related technologies. It is one of the largest educational and research establishments in these fields in Europe.

UCTP closely collaborates with the industrial sector and is committed not only to the publication of the results achieved, but also to their practical implementation. Research activities conducted at UCTP have the advantage of a robust infrastructure consisting of a technical library, central laboratories equipped with state-of-the-art equipment, as well as a publishing house specialising in chemistry and related fields. Besides the permanent staff, the students of PhD and MSc programmes are intensively involved in the research activities.

The broad range of specialisations includes "Hydrogen and membrane technologies" which trains specialists to operate, maintain and develop hydrogen-related technologies. The establishment of this program was motivated by the UCTP tradition of following and supporting the philosophy of sustainable development. This also covers renewable energy production, conversion and storage.

The Technical Electrochemistry research group responsible for carrying out this program has many years of experience in fuel cell and hydrogen research. Its current research activities cover the fields of material (catalyst, membranes, etc.) development and testing, cell set-up and optimisation as well as system design. The focus is on low-temperature PEM and alkaline systems and also SOFC/SOEC systems. The unique advantage of our research is the direct connection between experimental work and mathematical modelling. The mathematical modelling laboratory uses a broad portfolio of software tools (MatLab, COMSOL, Fluent, ASPEN plus, etc.) to understand and describe fundamental phenomena as well as to design the related technologies.

The UCTP research activities in the field of hydrogen technologies are currently funded by national bodies (Grant Agency of the Czech Republic, Technology Agency of the Czech Republic, Ministry of Industry and Trade of the Czech Republic and Ministry of Interior of the Czech Republic) as well as by the European Union. On the European level, the support of research and development in the field of hydrogen technologies is provided exclusively by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU). UCTP is the only member representing the Czech Republic in FCH JU. It is a member of the Hydrogen Europe Research (former N.ERGHY) grouping.



UCT Prague

Technická 5

166 28 Prague 6 - Dejvice

Czech Republic

Tel.: +420 220 444 145

E-mail: info@vscht.cz

www.vscht.cz



UCT PRAGUE

The ÚJV Řež namely is technical-engineering and design capacities, applied research, and technological equipment for safe and reliable energy, industry or nuclear medicine.

One of the key tasks of ÚJV Řež is to support the safety and reliability of nuclear power plants in the Czech Republic and worldwide. Current clients from all over the world include power plant operators, regulatory bodies, industrial technology investors, radioactive waste producers and nuclear medicine facilities.

ÚJV Řež and services

They are primarily focused on the safe and efficient operation of energy sources, in particular nuclear sources, fuel cycle chemistry, and complex services in the management of radioactive and other waste products. In the field of design and engineering offer a comprehensive set of services to support their activities, from feasibility assessments to the realization of investment projects. In nuclear medicine, we are involved in the development, production, and distribution of radiopharmaceuticals and the construction and operation of positron emission tomography (PET) centers.

ÚJV Řež and research projects

Research and development projects of the company are devoted, for example, to 4th generation nuclear reactors, small modular reactors, material research or use of nanotechnologies for energy and industry.

ÚJV Řež and Hydrogen Technologies

The onset of hydrogen technologies in the Czech Republic is closely connected to the Řež project of hydrogen bus – TriHyBus, a system of storing surplus energy from solar panels in hydrogen or the Power - Box 180 W portable power source prototype with a hydrogen element.

ÚJV Řež and International Cooperation

Active participation in several international organisations and cooperation on major multilateral projects enables NRI Řež / ÚJV Řež to remain at the top of European services in energy and industry.



ÚJV Řež, a. s.

Hlavní 130, Řež

250 68 Husinec

Czech Republic

Tel.: +420 266 172 000

Fax: +420 220 940 840

E-mail: ujv@ujv.cz

www.ujv.cz



NUCLEAR
RESEARCH
INSTITUTE

Energy Research Center

The Energy Research Center (ERC) at Technical university of Ostrava is a specialized workplace dealing with research and development (R&D) activities primarily in the field of energy. Since 2002 ERC has become an independent HE university institute. One of the principles of ERC's functioning is the systematic building of partnerships with enterprises and the conduct of research activities for the needs of industrial practice.

Part of ERC is an accredited, authorised and notified testing laboratory for measuring heat'n' technical quantities and emission of pollutants in waste gases (including continuous measurement of mercury concentration), and testing of energy devices.

Improvement of technical level of energy devices

- Investigation of a characteristics of energy processes and technologies
- Increase of energy transformation and equipment efficiency
- Reduction of negative impacts of fuel combustion on the living environment

Use of alternative fuels, RES and waste energy

- Characterization and use of solid alternative fuels (SAF)
- R&D equipments for use of SAF
- Use of biomass for cogeneration, photovoltaic production of electric energy
- Production of liquid 2nd-generation biofuels by the Fischer-Tropsch synthesis

Hydrogen energy

- The issues of fuel cells
- Operational characteristics of hydrogen production due to RES
- Storage and reuse of hydrogen
- Comprehensive hydrogen infrastructure for homes and transport
- Hydrogen storage and its utilization for network management

Safety in power engineering and industry

- Identification of risks related to the use of alternative fuels
- Modeling tools for explosions of fuel-air mixtures
- Analysis and experimental verification of limits of flammability and explosiveness, determination of explosion parameters
- Problematics of nanoparticles

Cooperation with industrial partners is oriented on

- Elaboration of energy studies (ES), energy audits (EA), energy assessment (EA) and building energy use intensity certificates (EUI)
- Energy monitoring and optimization (Energoguard), energy management
- Monitoring of renewable resources (SunnyGuard)
- Complete projection and design engineering in energy
- Accredited emissions measurement, authorised testing of boilers
- Consulting and implementation of EN ISO 50 001



VSB – Technical University of Ostrava

Energy Research Center

17. listopadu 15/2172

708 33 Ostrava-Poruba

Czech Republic

Tel.: +420 597 324 285

E-mail: vec@vsb.cz

vec.vsb.cz



ASSOCIATED MEMBERS



CZECH HYDROGEN
TECHNOLOGY PLATFORM

— SINCE 2007 —

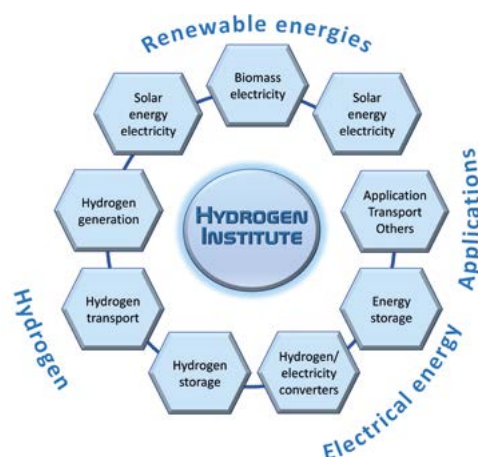
Hydrogen Institute CZ, s. r. o.

is a company with more than 15 years of history. The company's activities are directed to several areas. Nuclear power, hydropower, power plants and more have been dominant in the past. Creating models of structures and systems, expert analyzes, analyzes of commercial processing of natural gas, LPG, solving projects in the field of renewable energy sources and preparation of documentation were other dominant areas of the company.

Hydrogen Institute CZ focuses on research and development of components of the energy chain for the conversion of „Environmental Energy“ into electrical energy using renewable energy sources.

Research into hydrogen technologies and components is a current issue. Hydrogen production, transport and storage of hydrogen, development of fuel cells as a converter of hydrogen energy to electricity with the support of new promising technologies, research of materials for fuel cells are currently solved research and development areas.

Hydrogen Institute CZ currently includes other areas of research, development and development. Operating conditions of small hydropower plants in the still unresolved area of operation under non-standard conditions for better use of energy potential of water flow, use of hydrogen in connection with LPG and CNG, electricity storage – „energostorage“ are the main tasks.



Hydrogen Institute CZ

Žatecká 16/8

110 00 Prague 1

Czech Republic

Tel.: +420 602 121 140

E-mail: info@hydrogenin.cz

www.hydrogenin.cz

PRAŽSKÁ PLYNÁRENSKÁ (Prague's Gas Supplier)

The company Pražská plynárenská (Prague's Gas Supplier), has been for a long time one of the most important domestic suppliers of energy. Reliably supplies almost 420 thousand supply points. Although the history of Pražská plynárenská is inseparably linked with Prague and the roots of the gas industry can be traced back to 1847, today the company is a reliable supplier of energy and related customers services throughout the Czech Republic. It deals with natural gas and electricity.

To the company's main priorities belong comfortable customer service, energy security and a wide range of exclusive services, often unique in the Czech Republic. Pražská plynárenská supports environmental friendly energy use by ecological and efficient technologies, especially the use of natural gas and electricity in transport.

Pražská plynárenská is working on a long-term and systematic strategy to enable the use of alternative drive systems, which reduce greenhouse gas emissions, noise and operating costs and thus contribute to improving the lives of citizens.



PRAŽSKÁ PLYNÁRENSKÁ

Národní 37/38

110 00 Prague 1 - Nové Město

Czech Republic

Tel.: +420 800 134 134

E-mail: callcentrum@ppas.cz

www.ppas.cz

R&T ČR, s. r. o. – True Partner in Pressure

R&T ČR s. r. o. is a trading company operating on the market since 1998 as the member of Rév Group which represents the renowned company Luxfer Gas Cylinders in Central and Eastern Europe. An important component of the product range are alternative fuel cylinders including CNG and Hydrogen. The company offers complete Hydrogen systems for all major forms of transportation, including buses and heavy trucks, and offers cylinders and bundles for Hydrogen transport and storage.

The company R&T ČR focuses on the import and sale of quality high-pressure aluminium, composite and steel cylinders for industrial and special gases, which achieve exemplary record for dependability and safety in a variety of industry applications.

The company is committed to giving its customers the opportunity to contribute to reducing earth pollution by supporting new innovative fuel technologies. The use of CNG or Hydrogen in transportation provides a cost-effective solution that can help reduce emissions, improve passenger health and reduce maintenance and operating costs.

The company's mission is to offer ecological and safe transport solutions, and thus preserve a greener planet for future generations.



R&T ČR, s. r. o.

Karlštejnská 32

252 17 Chýnice

Czech Republic

Tel.: +420 602 213 747

E-mail: luxfer@luxfer.cz

www.luxfer.cz



Save the Date

www.hydrogendays.cz



HydrogenDays 2022

12th International Conference
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March 23rd–24th, 2022

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