Influence of carbon monoxide on the cathode in high-temperature polymer electrolyte membrane fuel cells

This paper describes the results of adding small amounts of CO gas to the cathode side in a HT-PEM fuel cell with a polybenzimidazole (PBI) membrane running on either oxygen or air. Experimental conditions: Temperature ranges 120–160 °C, constant current either 200 mA/cm² or 800 mA/cm² and CO ranges 0.1–1.3%. In this case it was found that small amounts of CO under special conditions have a beneficial effect on the potential of the fuel cells, whereas larger amounts can bring the potential down to almost zero. An interesting phenomenon is that after the flow of CO is switched off a temporary improvement of the potential is seen before the situation goes back to normal. A good explanation for this is a competition between CO, O₂ and H₃PO₄ at the three phase boundaries, also that a steady state exist in which CO constantly is oxidized to CO₂⁻.
Long-term durability of HT-PEM fuel cells based on thermally crosslinked polybenzimidazole

Long-term durability of HT-PEM fuel cells based on thermally crosslinked polybenzimidazole

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Authors: Søndergaard, T. (Ekstern), Cleemann, L. N. (Intern), Becker, H. (Intern), Aili, D. (Intern), Steenberg, T. (Ekstern), Hjuler, H. A. (Ekstern), Seerup, L. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern)
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Scopus rating (2003): SJR 1.66 SNIP 1.583
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Probing phosphoric acid redistribution and anion migration in polybenzimidazole membranes

Micro platinum electrodes embedded in a laminated phosphoric acid doped polybenzimidazole membrane are employed to monitor the acid migration during hydrogen pump mode operation. Upon application of a constant current, an immediate ohmic resistance decrease of the membrane near the anode is observed, accompanied by a corresponding increase near the cathode side. This is a direct evidence of migration of the acid anions via the vehicle conducting mechanism, resulting in an accumulation of acid at the anode side and depletion at the cathode side. Both resistances reach a steady state value after a prolonged period of measurement, apparently balanced by the back diffusion of the acid molecules. The phenomenon is magnified at higher current densities and with increased thickness of the overall membrane, which is of significance in quantitative understanding of the proton conductivity mechanism e.g. for determination of the anionic transference number. The finding provides a technique to monitor the acid redistribution within the membrane as a basis for an engineering solution to address the long-term durability of fuel cells built around phosphoric acid doped polymer membranes.

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BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.811 SNIP 1.435 CiteScore 4.97
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
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Towards a stable ion-solvating polymer electrolyte for advanced alkaline water electrolysis

Advanced alkaline water electrolysis using ion-solvating polymer membranes as electrolytes represents a new direction in the field of electrochemical hydrogen production. Polybenzimidazole membranes equilibrated in aqueous KOH combine the mechanical robustness and gas-tightness of a polymer with the conductive properties of an aqueous alkaline salt solution, and are thus of particular interest in this field of research. This work presents a comprehensive study of ternary alkaline polymer electrolyte systems developed around a polybenzimidazole derivative that is structurally tailored towards improved stability in alkaline environments. The novel electrolytes are extensively characterized with respect to physicochemical and electrochemical properties and the chemical stability is assessed in 0-50 wt% aqueous KOH for more than 6 months at 88 degrees C. In water electrolysis tests using porous 3-dimensional electrodes completely free from noble metals, they show polarization characteristics comparable to those of commercially available separators and good performance stability over several days.
Acid–Base Chemistry and Proton Conductivity

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Organisations: Department of Energy Conversion and Storage, Proton conductors
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Main Research Area: Technical/natural sciences
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Advanced Materials for High-Temperature PEM Fuel Cells

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Authors: Hjuler, H. A. (Ekstern), Kerr, R. (Ekstern), Steenberg, T. (Ekstern), Terkelsen, C. (Ekstern), Jensen, J. O. (Intern), Cleemann, L. N. (Intern), Li, Q. (Intern)
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Advanced materials for polymer electrolyte membrane fuel cells

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Amino-Functional Polybenzimidazole Blends with Enhanced Phosphoric Acid Mediated Proton Conductivity as Fuel Cell Electrolytes

A new amino-functional polybenzimidazole copolymer is synthesized by homogeneous solution condensation polymerization from a novel monomer, N,N'-bis (2,4-diaminophenyl)-1,3-diaminopropane. The copolymer readily dissolves in organic solvents and shows good film forming characteristics. To balance the phosphoric acid uptake and to obtain mechanically robust membranes, the amino-functional polybenzimidazole derivative is blended with high molecular weight poly [2,2′-(m-phenylene)-5,5′-bistribenzimidazole] at different ratios. Due to the high acid uptake, the homogenous blend membranes show enhanced proton conductivity at temperatures well above 100 °C as also confirmed by the fuel cell polarization data.
A platinum-free oxygen reduction catalyst by a one-step pyrolysis process

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Approaches to a platinum free oxygen reduction catalyst for PEM fuel cells

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Can We Replace Platinum Metals in PEM Fuel Cells and Electrolyzers?

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Challenges in Membrane Electrode Assembly Technologies

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Comparative study of PBI Cross Linked Utilizing Agents of Varying Steric Configurations
The high thermal and chemical stability of poly[2',2''-(m-phenylene)-5,5’ bibenzimidazole] (PBI) accounts for its wide spread use in high temperature polymer electrolyte membrane fuel cells (HT- PEMFC). By doping the membrane with phosphoric acid (PA) ionic conductivity is obtained. Thus conductivity is dependent on the amount of PA present within the membrane. However mechanical properties are reduced are significantly reduced due to the plasticizing effect shown by PA [1]. This effect is due to PBI chain displacement. This effect can be lessened by use of cross linking [2-4]. This can be obtained using ionic or covalent cross linking. When considering such, little attention is devoted to explore the effect of the sterical configuration of the cross linking agent.
In this contribution three different cross linking agents are utilized to evaluate how these affects final membrane properties.

Corrosion behavior of construction materials for ionic liquid hydrogen compressor
The corrosion behavior of various commercially available stainless steels and nickel-based alloys as possible construction materials for components which are in direct contact with one of five different ionic liquids was evaluated. The ionic liquids, namely: 1-ethyl-3-methylimidazolium trifflate, 1-ethyl-3-methylimidazolium bis (trifluoromethylsulfonyl) imide, trihexyltetradecylphosphonium bis (trifluoromethylsulfonyl) imide, butyltrimethylammonium bis (trifluoromethylsulfonyl) imide, methyltrioctylammonium bis (trifluoromethylsulfonyl) imide have been identified, as performance fluids in an ionic liquid hydrogen compressor. An electrochemical cell was specially designed, and steady-state cyclic voltammetry was used to measure the corrosion resistance of the alloys in the ionic liquids at 23 °C, under atmospheric pressure.
The results showed a very high corrosion resistance and high stability for all the alloys tested. The two stainless steels, AISI 316L and AISI 347 showed higher corrosion resistance compared to AISI 321 in all the ionic liquids tested. It was observed that small addition of molybdenum, tantalum, and niobium to the alloys increased the corrosion stability in the ionic liquids studied. Hastelloy® C-276 showed the poorest corrosion resistance in all the ionic liquids tested. AISI 316L with high corrosion resistance and the lowest cost is recommended as the most attractive construction material for all the components, in an ionic liquid hydrogen compressor, which are in direct contact with ionic liquids used in this study.
Durability Issues and Status of PBI-Based Fuel Cells

This chapter briefly reviews durability and stability issues with key materials and components for HT-PEMFCs, including the polymer membrane, the doping acid, the electrocatalyst, the catalyst support and bipolar plates. Degradation mechanisms and their dependence on fuel cell operating conditions are summarized as well. To date, lifetimes of this type of fuel cells of up to 18,000 h with degradation rates of around 5 μV/h at temperatures of 150–160 °C have been demonstrated using hydrogen and air under constant moderate load. However, the degradation rate increases by a factor 10 when the cell is exposed to start-up–shutdown or load cycling.

Exceptional durability enhancement of PA/PBI based polymer electrolyte membrane fuel cells for high temperature operation at 200°C

The incorporation of phosphotungstic acid functionalized mesoporous silica in phosphoric acid doped polybenzimidazole (PA/PBI) substantially enhances the durability of PA/PBI based polymer electrolyte membrane fuel cells for high temperature operation at 200°C.
Fuel Cells and Electrolyzers. Recent Progress at DTU Energy and the Role in a Sustainable Society

Graphene layer encapsulated metal nanoparticles as a new type of non-precious metal catalysts for oxygen reduction
Cheap and efficient non-precious metal catalysts for oxygen reduction have been a focus of research in the field of low-temperature fuel cells. This review is devoted to a brief summary of the recent work on a new type of catalysts, i.e., the graphene layer encapsulated metal nanoparticles. The discussion is focused on the synthesis, structure, mechanism, performance, and further research.

Graphene layer encapsulated metal nanoparticles as a new type of non-precious metal catalysts for oxygen reduction
Graphitic Layer Encapsulated Iron Based Non-precious Catalysts for the Oxygen Reduction Reaction

Proton exchange membrane fuel cells (PEMFCs) are highly efficient energy conversion devices, which can be in combination with hydrogen fuel providing a clean energy technology to produce electricity. One crucial challenge for this technology is the large cathodic overpotential due to the sluggish oxygen reduction reaction (ORR) kinetics. Carbon supported platinum (Pt/C) is the state-of-the-art benchmarking catalyst for PEMFCs since it exhibits the highest activity. However, the high cost and low abundance of noble metals have limited large-scale commercialization of the technology. Current efforts are made to develop non-precious metal catalysts (NPMCs) as a replacement to the Pt/C electrocatalysts.

In this thesis, a new type of NPMCs is synthesized by means of a dry autoclave with volatile ferrocene and cyanamide as precursors. The catalysts are morphologically featured by porous microspheres consisting of uniform metallic nanoparticles encapsulated in graphitic layers. The thesis work is conducted aiming at three major objectives: further optimization of the pyrolysis to achieve improved performance of catalysts, investigation of the complex Fe-containing components, and exploration of the possible active sites.

By systematic investigation of pyrolytic parameters i.e. temperature and duration, the best performance is achieved at 700 oC and 75 minutes, exhibiting a high catalytic activity in acid media (0.1 M HClO4) with an onset potential of 0.85 V at 0.1
mA cm⁻² and a mass specific kinetic current of 7.84 A g⁻¹ at 0.7 V vs. RHE. A good stability with 25 mV potential losses after 10,000 cycles of potential scan between 0.6 and 1.0 V has also been demonstrated.

The featuring morphology of the catalysts, i.e. the porous microspheres consisting of the graphitic layer encapsulated metal-containing nanoparticles, is essentially maintained during the pyrolysis of varied durations and temperatures. The metal-containing nanoparticles showed changes in the iron phases and their contents, as characterized by ⁵⁷Fe Mössbauer spectroscopy. The iron containing components include reduced metals (α-Fe and γ-Fe), oxide (γ-Fe₂O₃), carbide (Fe₃C) as well as a minor paramagnetic component due to Fe₃⁺ (high spin) and/or possibly Fe²⁺ (low spin), likely coordinated with nitrogen (FeNx/C) as well identified for the Fe/N/C type catalysts in the literatures.

Quantitative determination of these metal containing components by low temperature ⁵⁷Mössbauer spectra shows that the content of the reduced metal component is steadily increasing with the pyrolytic time and temperature while the content of iron oxide is nearly constant. The most interesting finding is that the Fe₃C content shows a peak in both the temperature-varying and the duration-varying series of samples. The possible FeNx/C coordination phase, however, varies to a very limited extent for the studied samples.

The catalytic activities and mechanisms for ORR are evaluated by rotating disk electrode (RDE) and rotating ring-disk electrode (RRDE) voltammetry. In terms of the mass specific kinetic current density and half-wave potential, a strong correlation of the catalytic activity is established with the Fe₃C content within the entire composition range from 1.1 wt% to 4.5 wt% as well as with the FeNx/C content in a narrow range from 0.5 wt% to 0.85 wt%. Other iron containing components, i.e. α-Fe, γ-Fe and Fe₂O₃, showed no association with the ORR activity. It is concluded that, for the present catalysts, the recognized encapsulated iron carbide is most likely contributing to the ORR catalysis, in addition to the well identified N-coordinated Fe species.

More evidences are found from the catalyst synthesized from nitrogen free precursors. This catalyst, consisting of only carbon encapsulated iron-based nanoparticles, shows some, though low, ORR activity, which is enhanced by the post heat treatment in an ammonia atmosphere, indicating the contribution of the nitrogen functionalities.

Two anions in the electrolyte are used to probe the iron containing active sites towards the ORR, cyanide (CN⁻) in alkaline and thiocyanate (SCN⁻) in acidic medium, which seem supporting the above conclusions. These findings provide new insights to the encapsulation structure of Fe based nanocatalysts and therefore options for further development of NPMCs.
Hydrogen Sulfide Tolerance in High Temperature PEMFCs

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Introduction

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Non-Platinum Oxygen Reduction Catalysts. From Crystalline to Molecular Moieties

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Optimization of Catalyst Layer Properties for High Temperature Polymer Fuel Cells

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Platinum Iron Intermetallic Nanoparticles Supported on Carbon Formed In Situ by High-Pressure Pyrolysis for Efficient Oxygen Reduction

Carbon-supported PtFe alloy catalysts are synthesized by the one-step, high-temperature pyrolysis of Pt, Fe, and C precursors. As a result of the high temperature, the formed PtFe nanoparticles possess highly ordered, face-centered tetragonal, intermetallic structures with a mean size of $\approx$11.8 nm. At 0.9 V versus the reversible hydrogen electrode, the PtFe nanoparticles show a 6.8 times higher specific activity than the reference Pt/C catalyst towards the oxygen reduction reaction (ORR) as well as excellent stability, most likely because of the durable intermetallic structure and the preleaning treatment of the catalyst. During these preliminary syntheses, we found that a portion of the PtFe nanoparticles is buried in the in situ formed carbon phase, which limits Pt utilization in the catalyst and results in a mass-specific activity equivalent to the commercial Pt/C catalyst. Moreover, the possible presence of other active sites, for example, FeNx, CNx, and carbon-encapsulated metal nanoparticles, and their contribution to the ORR performance of the catalyst are also investigated.

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Polybenzimidazole Membranes by Post Acid Doping

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Polybenzimidazole membranes for zero gap alkaline electrolysis cells

Membranes of m-PBI doped in KOH (aq), 15-35 wt%, show high ionic conductivity in the temperature range 20-80 ºC. In electrolysis cells with nickel foam electrodes m-PBI membranes provide low internal resistance. With a 60 µm membrane at 80ºC in 20 wt% KOH, 1000 mA/cm² is achieved at 2.25.

Probing the active site structures of iron-based ORR catalysts

Systematic Study of Durability of High Temperature PEM Fuel Cells at Selected Temperatures, Flow Rates and Loads
Understanding ternary poly(potassium benzimidazolide)-based polymer electrolytes
Poly(2,20-(m-phenylene)-5,50-bisbenzimidazole) (m-PBI) can dissolve large amounts of aqueous electrolytes to give materials with extraordinary high ion conductivity and the practical applicability has been demonstrated repeatedly in fuel cells, water electrolyzers and as anion conducting component in fuel cell catalyst layers. This work focuses on the chemistry of m-PBI in aqueous potassium hydroxide. Equilibration in aqueous KOH with concentrations of 15e20 wt.% was found to result in ionization of the polymer, causing released intermolecular hydrogen bonding. This allowed for extensive volume swelling, high electrolyte uptake, dramatic plasticization and increase of the ion conductivity for the formed poly(potassium benzimidazolide)-based structure. Further increasing the concentration of the bulk solution to 50 wt.% resulted in dehydration and extensive crystallization of the polymer matrix as evidenced by X-ray diffraction, increased density and enhanced elastic modulus. © 2016 Elsevier Ltd. All rights reserved.
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Web of Science (2011): Indexed yes
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Scopus rating (2010): SJR 1.851 SNIP 1.8
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Scopus rating (2009): SJR 1.999 SNIP 1.72
Web of Science (2009): Indexed yes
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Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.889 SNIP 1.707
Web of Science (2007): Indexed yes
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Scopus rating (2005): SJR 1.626 SNIP 1.576
Web of Science (2005): Indexed yes
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Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.582 SNIP 1.617
Web of Science (2003): Indexed yes
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Zero-Gap Alkaline Water Electrolysis Using Ion-Solvating Polymer Electrolyte Membranes at Reduced KOH Concentrations
Membranes based on poly(2,2'-(m-phenylene)-5,5-bibenzimidazole) (m-PBI) can dissolve large amounts of aqueous KOH to give electrolyte systems with ion conductivity in a practically useful range. The conductivity of the membrane strongly depends on the concentration of the aqueous KOH phase, reaching about $10^{-1}$ S cm$^{-1}$ or higher in 15-25 wt% KOH. Herein, m-PBI membranes are systematically characterized with respect to performance and short-term stability as electrolyte in a zero-gap alkaline water electrolyzer at different KOH concentrations. Using plain uncatalyzed nickel foam electrodes, the cell based on m-PBI outperforms the cell based on the commercially available state-of-the-art diaphragm and reaches a current density of 1500 mA cm$^{-2}$ at 2.4 V in 20 wt% KOH at 80°C. The cell performance remained stable during two days of operation, though post analysis of the membrane using size exclusion chromatography and spectroscopy reveal evidence of oxidative degradation of the base polymer at KOH concentrations of 15 wt% and higher.

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State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Kraglund, M. R. (Intern), Aili, D. (Intern), Jankova Atanasova, K. (Intern), Christensen, E. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern)
Number of pages: 7
Method for producing and controlling the morphology of metal-oxide nanofiber and/or nanotube catalysts.

Disclosed herein is a process for the controlled production of metal-containing nanofibers and/or nanotubes, where the morphology of the nanofibers and/or nanotubes is followed in real time by TEM measurements.

Acid-base Chemistry and Proton Conductivity of High Temperature Polymer Electrolytes

Acid-base Chemistry and Proton Conductivity of High Temperature Polymer Electrolytes
Carbon Thin-layer Encapsulated Fe-N-C as Active Catalysts for Oxygen Reduction

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Zhong, L. (Intern), Pan, C. (Intern), Hu, Y. (Intern), Cleemann, L. N. (Intern), Jensen, J. O. (Intern), Li, Q. (Intern)
Number of pages: 1
Publication date: 2015
Main Research Area: Technical/natural sciences

Bibliographical note
Oral by Zhong)
Source: PublicationPreSubmission
Source-ID: 127806810
Publication: Research - peer-review » Conference abstract for conference – Annual report year: 2016

CsH2PO4/NdPO4 Composites as Proton Conducting Electrolytes for Intermediate Temperature Fuel Cells
Composite proton conducting materials based on cesium dihydrogen phosphate and neodymium phosphate hydrate were prepared and investigated in terms of X-ray diffraction, thermogravimetry, conductivity, stability and fuel cell performance. At 150°C the conductivity was $1.8 \times 10^{-6}$ S cm$^{-1}$ for the pristine cesium dihydrogen phosphate and $0.8 \times 10^{-4}$ S cm$^{-1}$ for neodymium phosphate hydrate, while that of the composite containing 29 mol% neodymium phosphate and 71 mol% cesium dihydrogen phosphate was $0.4 \times 10^{-2}$ S cm$^{-1}$. It was proposed that the interaction between the two components establishes a dynamic hydrogen bonding network enabling efficient proton conduction long before the development of the extensive phase disordering of the superprotonic transition. The presence of thermally stable hydrate water present in neodymium phosphate may also play a role in improving both conductivity and stability of the solid acid. The electromotive force, open circuit voltage and fuel cell performance were measured as demonstration of the material application.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Anfimova, T. (Intern), Jensen, A. H. (Intern), Christensen, E. (Intern), Jensen, J. O. (Intern), Bjerrum, N. J. (Intern), Li, Q. (Intern)
Pages: F436-F441
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Electrochemical Society. Journal
Volume: 162
Issue number: 4
ISSN (Print): 0013-4651
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.97 SJR 1.134 SNIP 0.867
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.037 SNIP 1 CiteScore 3.17
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.147 SNIP 1.206 CiteScore 3.36
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.151 SNIP 1.299 CiteScore 2.92
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.329 SNIP 1.296 CiteScore 2.61
Development of high temperature PEM fuel cells. Simplification and CO tolerance mapping

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Jensen, J. O. (Intern), Fernandez, S. M. (Intern), Vassiliev, A. (Intern), Cleemann, L. N. (Intern), Li, Q. (Intern)
Number of pages: 27
Publication date: 2015

Publication information
Media of output: PowerPoint
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions: Presentation

Bibliographical note
Fe$_3$C-based oxygen reduction catalysts: synthesis, hollow spherical structures and applications in fuel cells

We present a detailed study of a novel Fe$_3$C-based spherical catalyst with respect to synthetic parameters, nanostructure formation, ORR active sites and fuel cell demonstration. The catalyst is synthesized by high temperature autoclave pyrolysis using decomposing precursors. Below 500 °C, melamine-rich microspheres are first developed with uniformly dispersed amorphous Fe species. During the following pyrolysis at temperatures from 600 to 660 °C, a small amount of Fe$_3$C phase with possible Fe–Nx/C active sites are formed, however, with moderate catalytic activity, likely limited by the low conductivity of the catalyst. At high pyrolytic temperatures of 700–800 °C, simultaneous formation of Fe$_3$C nanoparticles and encasing graphitic layers occur within the morphological confinement of the microspheres. With negligible surface nitrogen or iron functionality, the thus-obtained catalysts exhibit superior ORR activity and stability. A new ORR active phase of Fe$_3$C nanoparticles encapsulated by thin graphitic layers is proposed. The activity and durability of the catalysts are demonstrated in both Nafion-based low temperature and acid doped polybenzimidazole-based high temperature proton exchange membrane fuel cells.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Imaging and Structural Analysis, Institut National de la Recherche Scientifique
Pages: 1752-1760
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Materials Chemistry A
Volume: 3
ISSN (Print): 2050-7488
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 8.46 SJR 3.037 SNIP 1.468
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.672 SNIP 1.663 CiteScore 8.36
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.343 SNIP 1.526 CiteScore 7.27
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
Original language: English
DOIs: 10.1039/c4ta03986f
Source: PublicationPreSubmission
Source-ID: 127806915
Publication: Research › Sound/Visual production (digital) – Annual report year: 2016

Hydrogen Energy by Means of Proton Conductors
If we dare to take serious what we know today about climate issues the challenges to our energy systems are immense. If we really chose - also in practice - to phase out the fossil fuels major changes to the way we handle energy are required. The renewable energy resources are by far sufficient, but matching supply and demand in time as well as in form calls for new engineering solutions. Hydrogen as energy carrier and energy storage medium has often been mentioned as an option for the future. A protons is an elementary particles, but at the same time the ion of hydrogen. When hydrogen (H$_2$) is extracted from water (H$_2$O) it can happen via formation of protons (hydrogen ions, H$^+$) which must be transported away by proton conducting materials to form molecular hydrogen (H$_2$). This process is called electrolysis and converts electrical...
energy into the chemical energy of a fuel. The reverse process of making electricity from a fuel takes place in a fuel cell. The talk will present different aspects of the concept of hydrogen energy and how materials science can bring this technology of the future closer to the present.

**General information**

**State:** Published  
**Organisations:** Department of Energy Conversion and Storage, Proton conductors  
**Authors:** Jensen, J. O. (Intern)  
**Publication date:** 2015  
**Event:** Abstract from Tiltrædelsesforelæsning, Lyngby, Denmark.  
**Main Research Area:** Technical/natural sciences

**Bibliographical note**

Inaugural Lecture (Professor)  
**Source:** PublicationPreSubmission  
**Source-ID:** 127806504  
**Publication:** Communication › Conference abstract for conference – Annual report year: 2016

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**Lowering the platinum loading of high temperature polymer electrolyte membrane fuel cells with acid doped polybenzimidazole membranes**

Membrane electrode assemblies (MEAs) with ultra-low Pt loading electrodes were prepared for high temperature polymer electrolyte membrane fuel cells (HT-PEMFCs) based on acid doped polybenzimidazole. With no electrode binders or ionomers, the triple phase boundary of the catalyst layer was established by the acid transfer from the acid doped membrane to the electrodes and can therefore be tailored by using catalysts with varied Pt to C ratios. With a loading of ca. 0.1 mgPt cm⁻² on each electrode, the best performance was obtained with electrodes prepared from 10 wt.% Pt/C due to the improved Pt dispersion, extended triple phase boundary upon the acid transfer and the alleviated acid flooding of the catalytic layer. The MEA delivered a peak power density of 482 mW cm⁻² for H₂/O₂ and 321 mW cm⁻² for H₂/air, corresponding to an overall Pt utilization of 2.5 and 1.7 kW gPt⁻¹, respectively. The durability test revealed no net voltage decay during more than 1700 h of uninterrupted operation at 200 mA cm⁻² and 160 °C.

**General information**

**State:** Published  
**Organisations:** Department of Energy Conversion and Storage, Proton conductors  
**Authors:** Fernandez, S. M. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern)  
**Number of pages:** 6  
**Pages:** 51-56  
**Publication date:** 2015  
**Main Research Area:** Technical/natural sciences

**Publication information**

**Journal:** Journal of Power Sources  
**Volume:** 293  
**ISSN (Print):** 0378-7753  
**BFI (2017):** BFI-level 1  
**Web of Science (2017):** Indexed Yes  
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**Scopus rating (2016):** CiteScore 6.22 SJR 1.945 SNIP 1.483  
**Web of Science (2016):** Indexed yes  
**BFI (2015):** BFI-level 1  
**Scopus rating (2015):** SJR 1.945 SNIP 1.686 CiteScore 6.34  
**Web of Science (2015):** Indexed yes  
**BFI (2014):** BFI-level 1  
**Scopus rating (2014):** SJR 1.983 SNIP 2.071 CiteScore 6.3  
**Web of Science (2014):** Indexed yes  
**BFI (2013):** BFI-level 1  
**Scopus rating (2013):** SJR 1.985 SNIP 2.138 CiteScore 5.63  
**ISI indexed (2013):** ISI indexed yes  
**Web of Science (2013):** Indexed yes  
**BFI (2012):** BFI-level 1  
**Scopus rating (2012):** SJR 2.293 SNIP 2.016 CiteScore 5.04
Methyl phosphate formation as a major degradation mode of direct methanol fuel cells with phosphoric acid based electrolytes

Phosphoric acid and phosphoric acid doped polymer membranes are widely used as electrolytes in hydrogen based fuel cells operating at elevated temperatures. Such electrolytes have been explored for direct oxidation of methanol to further increase the versatility of the systems, however, with demonstrated lifetimes of only a few days to weeks. In this work the methyl phosphate formation from the acid and methanol is identified and proposed to be a major mechanism for the cell degradation. Proton conductivity and fuel cell durability tests validate the mechanism at high methanol contents.
Non-Noble Oxygen Reduction Catalysts

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Jensen, J. O. (Intern), Hu, Y. (Intern), Zhong, L. (Intern), Pan, C. (Intern), Cleemann, L. N. (Intern), Li, Q. (Intern)
Number of pages: 1
Publication date: 2015
Main Research Area: Technical/natural sciences

Bibliographical note
Invited Plenary Talk
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Porous poly(perfluorosulfonic acid) membranes for alkaline water electrolysis

Poly(perfluorosulfonic acid) (PFSA) is one of a few polymer types that combine excellent alkali resistance with extreme hydrophilicity. It is therefore of interest as a base material in separators for alkaline water electrolyzers. In the pristine form it, however, shows high cation selectivity. To increase its ion conductivity in aqueous KOH, a method for the preparation of porous PFSA membranes was developed. It was based on an approach where PFSA was co-cast with poly(vinylpyrrolidone) (PVP) at different ratios to give transparent and colorless blend membranes. The PVP was subsequently dissolved and washed out and the obtained porous materials allowed for swelling to reach water contents up to \( \lambda = 85 \left[ \text{H}_2\text{O} \right] \left[ -\text{SO}_3\text{K} \right] ^{-1} \). After equilibration in 22 wt% aqueous KOH, ion conductivity of 0.2 S cm\(^{-1}\) was recorded for this membrane type at room temperature, which is significantly higher than 0.01 S cm\(^{-1}\) for the unmodified membrane. The technological feasibility was demonstrated by testing the membranes in an alkaline water electrolysis cell with encouraging performance.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Imaging and Structural Analysis, Department of Chemistry, NanoChemistry, Organic Chemistry
Pages: 589–598
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Membrane Science
Volume: 493
ISSN (Print): 0376-7388
Ratings:
Poly(perfluorosulfonic acid), Membranes, Porous, Water electrolysis, Alkaline

DOIs:
10.1016/j.memsci.2015.06.057

Source: PublicationPreSubmission
Source-ID: 116571993
Publication: Research - peer-review › Journal article – Annual report year: 2015
Pt-Si Bifunctional Surfaces for CO and Methanol Electro-Oxidation

Bimetallic surfaces offer activity benefits derived from synergistic effects among active sites with uniquely different functions, which is particularly important for the development of highly effective heterogeneous catalysts for specific technological applications, such as energy conversion and storage. Here we report on Pt-Si bulk samples prepared by arc-melting, for the first time, with high activities toward the electro-oxidation of CO and methanol. Increasing the Si concentration on the surface was correlated with the shifts of onset oxidation potentials to lower values and higher activities for CO and methanol electro-oxidation. It is proposed that the reaction on the Pt-Si catalyst could follow a Langmuir-Hinshelwood type of mechanism, where substantially enhanced catalytic activity is attributed to the fine-tuning of the surface Pt-Si atomic structure.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Massachusetts Institute of Technology
Authors: Permyakova, A. A. (Ekstern), Han, B. (Ekstern), Jensen, J. O. (Intern), Bjerrum, N. (Intern), Shao-Horn, Y. (Ekstern)
Pages: 8023-8031
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Volume: 119
Issue number: 15
ISSN (Print): 1932-7447
Ratings:
  BFI (2017): BFI-level 1
  Web of Science (2017): Indexed Yes
  BFI (2016): BFI-level 1
  Scopus rating (2016): CiteScore 4.48 SJR 1.948 SNIP 1.181
  Web of Science (2016): Indexed yes
  BFI (2015): BFI-level 1
  Scopus rating (2015): SJR 1.917 SNIP 1.268 CiteScore 4.68
  Web of Science (2015): Indexed yes
  BFI (2014): BFI-level 1
  Scopus rating (2014): SJR 2.027 SNIP 1.448 CiteScore 5.08
  Web of Science (2014): Indexed yes
  BFI (2013): BFI-level 1
  Scopus rating (2013): SJR 2.134 SNIP 1.439 CiteScore 5.14
  ISI indexed (2013): ISI indexed yes
  Web of Science (2013): Indexed yes
  BFI (2012): BFI-level 1
  Scopus rating (2012): SJR 2.514 SNIP 1.46 CiteScore 4.98
  ISI indexed (2012): ISI indexed yes
  Web of Science (2012): Indexed yes
  BFI (2011): BFI-level 1
  Scopus rating (2011): SJR 2.32 SNIP 1.457 CiteScore 4.92
  ISI indexed (2011): ISI indexed yes
  Web of Science (2011): Indexed yes
  BFI (2010): BFI-level 1
  Scopus rating (2010): SJR 2.438 SNIP 1.356
  Web of Science (2010): Indexed yes
  BFI (2009): BFI-level 1
  Scopus rating (2009): SJR 2.128 SNIP 1.417
  Web of Science (2009): Indexed yes
  BFI (2008): BFI-level 1
  Scopus rating (2008): SJR 1.856 SNIP 1.033
Tetrazole substituted polymers for high temperature polymer electrolyte fuel cells

While tetrazole (TZ) has much lower basicity than imidazole and may not be fully protonated in the presence of phosphoric acid (PA), DFT calculations suggest that the basicity of TZ groups can be increased by the introduction of a 2,6-dioxophenyl-group in position 5 of TZ. This structure allows hydrogen bonds between TZ protons and ether oxygen atoms, and thereby establishes a resonance stabilised, co-planar structure for tetrazolium ions. Molecular electrostatic potential (MEP) calculations also indicate that tetrazolium ions possess two sites for proton hopping. This makes such materials interesting for use in a high temperature fuel cell (HT PEMFC). Based on these findings, two polymers incorporating the proposed TZ groups were synthesised, formed into membranes, doped with PA and tested for fuel cell relevant properties. At room temperature, TZ-PEEN and commercial meta-PBI showed an equilibrium uptake of 0.5 and 4.7 mol PA per mol heterocycle, respectively, indicating that PBI has higher affinity for PA than TZ-PEEN. The highest achieved PA uptake was ca. 110 wt%, resulting in a proton conductivity of 25 mS cm−1 at 160 °C with a low activation energy of about 35 kJ mol−1. In a first HT PEMFC test at 160 °C, a peak power density of 287 mW cm−2 was achieved.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Korea Institute of Science and Technology, Jagiellonian University, Korea University
Authors: Henkensmeier, D. (Ekstern), My Hanh Duong, N. (Ekstern), Brela, M. (Ekstern), Dyduch, K. (Ekstern), Michalak, A. (Ekstern), Jankova Atanasova, K. (Intern), Cho, H. (Ekstern), Hyun Jang, J. (Ekstern), Kim, H. (Ekstern), Cleemann, L. N. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern)
Pages: 14389-14400
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Materials Chemistry A
Volume: 3
Issue number: 27
ISSN (Print): 2050-7488
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 8.46 SJR 3.037 SNIP 1.468
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.672 SNIP 1.663 CiteScore 8.36
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.343 SNIP 1.526 CiteScore 7.27
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
ISI indexed (2013): ISI indexed no
The effect of hydrogen pressure on the tolerance for CO of high temperature PEM fuel cells

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Jensen, J. O. (Intern), Fernandez, S. M. (Intern), Vassiliev, A. (Intern), Cleemann, L. N. (Intern), Li, Q. (Intern)
Number of pages: 1
Publication date: 2015
Event: Abstract from Annual Meeting of the Danish Electrochemical Society 2015, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences

Bibliographical note
Oral presentation
Source: PublicationPreSubmission
Source-ID: 127806532
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Theoretical understanding about the interaction between iron carbide and graphitic layers towards oxygen reduction

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Hu, Y. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern), Pan, C. (Intern), Cleemann, L. N. (Intern), Zhong, L. (Intern)
Number of pages: 1
Publication date: 2015
Event: Abstract from Conference on Electrochemical Science and Technology 2015, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences

Bibliographical note
Oral by Yang Hu
Source: PublicationPreSubmission
Source-ID: 127806554
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

The stability of poly(2,2′-(m-phenylene)-5,5′-bibenzimidazole) membranes in aqueous potassium hydroxide

In the form of membranes, poly(2,2′-(m-phenylene)-5,5′-bibenzimidazole) (mPBI) is known to exhibit high ionic conductivity when doped with aqueous KOH, which makes it interesting as electrolyte in e.g. alkaline fuel cells and water electrolyzers. The conductivity peaks at KOH concentrations around 25wt%. This work is devoted to a comprehensive stability study of mPBI in aqueous KOH of different concentrations for up to 200 days under conditions relevant for electrochemical energy conversion technologies. The polymer membranes were kept at 88°C in aqueous KOH with concentrations ranging from 0 to 50wt%, and the chemical and physicochemical changes were monitored. The degradation was connected to the hydrolysis of the polymer backbone and the degradation rate increased with increasing KOH concentration. In the lower concentration range mPBI proved to be stable but exhibited low ionic conductivity (10−4Scm−1). The preparation of a porous mPBI matrix was demonstrated as an effective approach to increase the ionic conductivity in the lower KOH concentration range, with great potential for further improvement through optimization of the porous structure.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Aili, D. (Intern), Jankova Atanasova, K. (Intern), Li, Q. (Intern), Bjerrum, N. J. (Intern), Jensen, J. O. (Intern)
Number of pages: 8
Pages: 422-429
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Membrane Science
Polybenzimidazole, Membrane, Alkaline, Stability, Degradation

DOIs:
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Source: FindIt
Source-ID: 275522127
Transition metal carbides (WC, Mo$_2$C, TaC, NbC) as potential electrocatalysts for the hydrogen evolution reaction (HER) at medium temperatures

One limitation for large scale water electrolysis is the high price of the Pt cathode catalyst. Transition metal carbides, which are considered as some of the most promising non-Pt catalysts, are less active than Pt at room temperature. The present work demonstrates that the situation is different at medium temperatures (200-400 degrees C). By introducing a new setup which makes use of molten KH$_2$PO$_4$ as electrolyte, a model system for solid acid membrane electrolyser cells was obtained. Metal carbide coated wires prepared by a two-step oxidation carburization reaction of the metal wire surfaces were used as electrodes and allowed the measurement of the intrinsic catalytic properties of different transition metal carbides in direct comparison to Pt at 260 degrees C. Under these conditions, the activity in the hydrogen evolution reaction (HER) followed the order WC > Pt approximate to MO$_2$C > NbC > TaC. Copyright (C) 2014, Hydrogen Energy Publications, LLC. Published by Elsevier Ltd. All rights reserved.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Technische Universität München
Authors: Meyer, S. (Ekstern), Nikiforov, A. V. (Intern), Petrushina, I. M. (Intern), Köhler, K. (Ekstern), Christensen, E. (Intern), Jensen, J. O. (Intern), Bjerrum, N. J. (Intern)
Pages: 2905-2911
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Volume: 40
Issue number: 7
ISSN (Print): 0360-3199
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.74 SJR 1.142 SNIP 1.286
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.294 SNIP 1.319 CiteScore 3.46
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.212 SNIP 1.494 CiteScore 3.54
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.278 SNIP 1.467 CiteScore 3.38
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.515 SNIP 1.729 CiteScore 3.96
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.456 SNIP 1.837 CiteScore 4.42
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.589 SNIP 1.871
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.333 SNIP 1.885
Web of Science (2009): Indexed yes
A Stability Study of Alkali Doped PBI Membranes for Alkaline Electrolyzer Cells

Polybenzimidazole membranes in a linear, a crosslinked and a thermally cured form were subjected to aging in 6 M aqueous KOH at 85 ºC for periods of up to 176 days. The aged membranes were characterized with respect to weight loss, mechanical properties and ionic conductivity. The area specific conductivity was similar to a commercial Zirfon membrane and suitable for a water electrolyzer. Some chemical degradation was seen during the aging period, but the crosslinked and the cured materials were both integral after 176 days of aging. A simplified electrolyzer test cell was operated successfully.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Siemens (DK)
Authors: Jensen, J. O. (Intern), Aili, D. (Intern), Hansen, M. K. (Intern), Li, Q. (Intern), Bjerrum, N. J. (Intern), Christensen, E. (Intern)
Number of pages: 10
Pages: 1175-1184
Publication date: 2014
Conference: 226th Meeting of the Electrochemical Society (ECS) and 7th Meeting of the Mexico Section of the Electrochemical Society ECS and SMEQ Joint International Meeting, Cancun, Mexico, 05/10/2014 - 05/10/2014
Main Research Area: Technical/natural sciences

Publication information
Journal: ECS Transactions
Volume: 64
Issue number: 3
ISSN (Print): 1938-5862
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BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.4 SJR 0.231 SNIP 0.246
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.214 SNIP 0.257 CiteScore 0.36
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.214 SNIP 0.246 CiteScore 0.36
Bed geometries, fueling strategies and optimization of heat exchanger designs in metal hydride storage systems for automotive applications: A review

This review presents recent developments for effective heat management systems to be integrated in metal hydride storage tanks, and investigates the performance improvements and limitations of each particular solution. High pressures and high temperatures metal hydrides can lead to different design considerations, which are discussed in the paper. Studies analyzing design procedures based upon different geometrical solutions and/or operation strategies are considered, and their related advantages are explained. Restrictions to the validity of particular results are also evaluated. Major attention is here given to metal hydride storage tanks for light duty vehicles, since this application is the most promising one for such storage materials and has been widely studied in the literature. Enhancing cooling/heating during hydrogen uptake and discharge has found to be essential to improve storage systems capacities and minimize time requirements. Various fueling strategies are widely explained differing by the particular system approach taken into account. At the end, optimization criteria and outcomes for both geometry-oriented and operative strategies-oriented methods are analyzed and presented to the reader as a helpful tool for future design considerations.

General information
State: Published
Organisations: Department of Mechanical Engineering, Thermal Energy, Department of Energy Conversion and Storage, Proton conductors, Geesthacht Centre for Materials and Coastal Research, H2Logic A/S, Aarhus University
Pages: 17054-17074
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Volume: 39
Issue number: 30
ISSN (Print): 0360-3199
Ratings:
BFI (2017): BFI-level 2
Binderless electrodes for high-temperature polymer electrolyte membrane fuel cells

A new electrode concept was proved with no polymeric binder in the catalyst layer for acid-doped polybenzimidazole (PBI) membrane fuel cells. It shows that a stable interface between the membrane and the catalyst layer can be retained when a proton conducting acid phase is established. The absence of the polymer in the catalytic layer turned out to be beneficial for the PBI cell performance particularly under high load operation. The influence on performance of the Pt loading of the
cathode was studied in a range from 0.11 to 2.04 mgPt cm$^{-2}$ showing saturation of the maximum performance for Pt loadings higher than 0.5 mgPt cm$^{-2}$. For fuel cell operation on H$_2$ and air supplied under ambient pressure, a peak power density as high as 471 mW cm$^{-2}$ was measured. The tolerance to carbon monoxide (CO) was also studied with Pt loadings of the anode ranging from 0.24 to 1.82 mgPt cm$^{-2}$. Lifetime test for a MEA loaded with 0.96 mgPt cm$^{-2}$ on both electrodes revealed no voltage decay during 900 h of uninterrupted operation at 200 mA cm$^{-2}$ and 160 °C.

### General information

State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Danish Power Systems ApS
Authors: Fernandez, S. M. (Intern), Li, Q. (Intern), Steenberg, T. (Ekstern), Jensen, J. O. (Intern)
Number of pages: 8
Pages: 559-566
Publication date: 2014
Main Research Area: Technical/natural sciences

### Publication information

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Volume: 272
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- Scopus rating (2013): SJR 1.985 SNIP 2.138 CiteScore 5.63
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- Scopus rating (2011): SJR 2.247 SNIP 2.181 CiteScore 5.13
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- BFI (2010): BFI-level 1
- Scopus rating (2010): SJR 2.297 SNIP 1.981
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- Scopus rating (2009): SJR 2.117 SNIP 1.793
- Web of Science (2009): Indexed yes
- BFI (2008): BFI-level 2
- Scopus rating (2008): SJR 1.968 SNIP 1.726
- Web of Science (2008): Indexed yes
- Scopus rating (2007): SJR 1.597 SNIP 1.489
- Web of Science (2007): Indexed yes
- Scopus rating (2006): SJR 1.8 SNIP 2.224
- Web of Science (2006): Indexed yes
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Boron-nitrogen based hydrides and reactive composites for hydrogen storage

Hydrogen forms chemical compounds with most other elements and forms a variety of different chemical bonds. This fascinating chemistry of hydrogen has continuously provided new materials and composites with new prospects for rational design and the tailoring of properties. This review highlights a range of new boron and nitrogen based hydrides and illustrates how hydrogen release and uptake properties can be improved. © 2014 Elsevier Ltd.

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ISI indexed (2012): ISI indexed yes
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Complex hydrides for hydrogen storage - New perspectives
Since the 1970s, hydrogen has been considered as a possible energy carrier for the storage of renewable energy. The main focus has been on addressing the ultimate challenge: developing an environmentally friendly successor for gasoline. This very ambitious goal has not yet been fully reached, as discussed in this review, but a range of new lightweight hydrogen-containing materials has been discovered with fascinating properties. State-of-the-art and future perspectives for hydrogen-containing solids will be discussed, with a focus on metal borohydrides, which reveal significant structural flexibility and may have a range of new interesting properties combined with very high hydrogen densities. © 2014 Elsevier Ltd.
Direct Dimethyl Ether High Temperature Fuel Cells

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Direct Dimethyl Ether High Temperature PEM Fuel Cells

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Direct Synthesis of Fe3C-Functionalized Graphene by High Temperature Autoclave Pyrolysis for Oxygen Reduction
We present a novel approach to direct fabrication of few-layer graphene sheets with encapsulated Fe3C nanoparticles from pyrolysis of volatile non-graphitic precursors without any substrate. This one-step autoclave approach is facile and potentially scalable for production. Tested as an electrocatalyst, the graphene-based composite exhibited excellent catalytic activity towards the oxygen reduction reaction in alkaline solution with an onset potential of ca. 1.05 V (vs. the reversible hydrogen electrode) and a half-wave potential of 0.83 V, which is comparable to the commercial Pt/C catalyst.

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Highly active and stable Pt electrocatalysts promoted by antimony-doped SnO$_2$ supports for oxygen reduction reactions

Alternative composite supports for platinum catalysts were synthesized from antimony doped tin dioxide (ATO) nanoparticles. In the range of the antimony content from 0 to 11mol%, the highest electrical conductivity of 1.1Scm$^{-1}$ at 130°C was obtained for the 5mol% Sb ATO, from which composite supports composed of oxides and carbon and supported platinum catalysts were prepared. Using the pure oxide support, the Pt/ATO catalyst displayed superior specific activity and stability for the oxygen reduction reactions (ORRs). Low surface area of ATO caused poor dispersion of Pt particles compared to composite supports, which limited the mass activity of the supported catalysts. When the ATO composites were used as supports, the Pt/C-ATO catalysts showed significantly enhanced catalytic activity and durability for the ORR, attributable to the high ECSA and modified electronic structure of Pt by the ATO phase in the catalyst support. © 2013.

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Organisations: Department of Energy Conversion and Storage, Proton conductors, Chinese Academy of Sciences, University of Science and Technology of China
Authors: Yin, M. (Ekstern), Xu, J. (Ekstern), Li, Q. (Intern), Jensen, J. O. (Intern), Huang, Y. (Intern), Cleemann, L. N. (Intern), Bjerrum, N. J. (Intern), Xing, W. (Ekstern)
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High Molecular Weight Polybenzimidazole Membranes for High Temperature PEMFC

High temperature operation of proton exchange membrane fuel cells under ambient pressure has been achieved by using phosphoric acid doped polybenzimidazole (PBI) membranes. To optimize the membrane and fuel cells, high performance polymers were synthesized of molecular weights from 30 to 94 kDa with good solubility in organic solvents. Membranes fabricated from the polymers were systematically characterized in terms of oxidative stability, acid doping and swelling, conductivity, mechanical strength and fuel cell performance and durability. With increased molecular weights the polymer membranes showed enhanced chemical stability towards radical attacks under the Fenton test, reduced volume swelling upon the acid doping and improved mechanical strength at acid doping levels of as high as about 11 mol H3PO4 per molar repeat polymer unit. The PBI-78kDa/10.8PA membrane, for example, exhibited tensile strength of 30.3 MPa at room temperature or 7.3 MPa at 130 °C and a proton conductivity of 0.14 S cm–1 at 160 °C. Fuel cell tests with H2 and air at 160 °C showed high open circuit voltage, power density and a low degradation rate of 1.5 μV h–1 at a constant load of 300 mA cm–2.

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Organisations: Department of Energy Conversion and Storage, Proton conductors, Northeastern University, Danish Power Systems ApS
Authors: Yang, J. (Ekstern), Cleemann, L. N. (Intern), Steenberg, T. (Ekstern), Terkelsen, C. (Ekstern), Li, Q. (Intern), Jensen, J. O. (Intern), Hjuler, H. A. (Ekstern), Bjerrum, N. J. (Intern), He, R. H. (Ekstern)
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Scopus rating (2014): SJR 0.629 SNIP 0.816 CiteScore 2.05
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BFI (2010): BFI-level 1
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Web of Science (2010): Indexed yes
High Surface Area Tungsten Carbides: Synthesis, Characterization and Catalytic Activity towards the Hydrogen Evolution Reaction in Phosphoric Acid at Elevated Temperatures

Tungsten carbide powders were synthesized as a potential electrocatalyst for the hydrogen evolution reaction in phosphoric acid at elevated temperatures. With ammonium metatungstate as the precursor, two synthetic routes with and without carbon templates were investigated. Through the intermediate nitride route and with carbon black as template, the obtained tungsten carbide samples had higher BET area. In 100% H₃PO₄ at temperatures up to 185°C, the carbide powders showed superior activity towards the hydrogen evolution reaction. A deviation was found in the correlation between the BET area and catalytic activity; this was attributed to the presence of excess amorphous carbon in the carbide powder. TEM imaging and TGA-DTA results revealed a better correlation of the activity with the carbide particle size.

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Web of Science (2014): Indexed yes
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Web of Science (2013): Indexed yes
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Scopus rating (2011): SJR 0.687 SNIP 1.444 CiteScore 3.9
ISI indexed (2011): ISI indexed no
Modern way of life demands enormous amounts of energy, which so far has been mainly produced by combustion of various types of fossil fuel. Increased amounts of atmospheric CO2 and global warming leading to severe climate changes are the consequence. There is a need to make the energy production sustainable and break the dependency on fossil fuels. Hydrogen economy provides such a solution, where hydrogen produced by renewables, such as wind and solar power, becomes the energy carrier. The storage, handling and transportation of hydrogen are the main obstacles on the route to a sustainable future when it comes to powering small and medium sized applications, transportation sector in particular. This is mainly due to the gravimetric energy density being immensely inferior to the liquid fuels gasoline and diesel. Dimethyl ether has already been identified as an excellent renewable fuel and a diesel substitute, which possesses energy density not much less than those of conventional diesel and gasoline. With its predicted widespread, there is an interest in harvesting electricity from dimethyl ether directly, rather than using it solely for combustion. High temperature PEM fuel cells provide such an opportunity. Some knowledge about the electrooxidation of DME is available, together with its limited use in low temperature PEM fuel cells, where the low temperature poses an obstacle in the form of phase separation in the fuel supply, making the cells less effective and reducing the amount of power harvested from the cells. This is completely avoided at the elevated temperatures with the additional benefit of increased kinetics. In the presented work an experimental setup for testing direct dimethyl ether high temperature fuel cells is described, proposing a novel design of an evaporator for a burst-free supply of a fuel and steam mixture. Based on the knowledge gathered with the construction and operation of the single cell setup a more versatile and flexible setup was designed and commissioned for independent testing of up to 6 cells, enabling fuel cell experiments with up to 3 gasses and a single evaporated liquid stream supply to either of the electrodes. A large number of MEAs with different component compositions have been prepared and tested in different conditions using the constructed setups to obtain a basic understanding of the nature of direct DME HT-PEM FC, to map the processes occurring inside the cells and to determine the lifetime. Additionally, comparison was made with methanol as fuel, which is the main competitor to DME in direct oxidation of organic fuels in fuel cells. For the reference, measurements have also been done with conventional hydrogen/air operation. All the experiments have been conducted at atmospheric pressure. Experiments with varying amounts of PBI in the cathode catalyst layer has shown that there is a minimum content limit for the preparation of a well dispersed catalyst ink of 15 carbon to PBI weight ratio in the currently used ink formulation. On the other hand, for the MEA operation it has been shown that too much PBI has had an effect with large mass transport limitations as a consequence. The amount of catalyst in the electrode has also shown an effect on the performance, with the optimum being between 3 and 4 mg/cm² of a 60 wt% Pt50Ru50 catalyst on 40 wt% carbon support. Catalysts with varying Pt, Ru and Sn content on carbon support has been synthesised and used for MEA testing, with the outcome of other operation and MEA composition parameters, such as reliable fuel supply, MEA assembly and operation and the characteristics of the electrolyte membrane having a much more pronounced effect on the final performance than the catalyst composition. The increased operating temperature showed improved performances for all 3 investigated fuels, hydrogen, DME and methanol, with the additional energy supplied in terms of heat helping to overcome the kinetic barriers of the oxidation of the fuels. The resistance of the electrolyte was also found to be decreasing until 200 °C, passing which would result in a rapid membrane dryout and supposed polymerisation of the phosphoric acid, irreversibly lowering the conductivity of the membrane. By increasing the partial pressure of oxygen on the cathode side from 0.21 bar to 1 bar an overall increase in cell voltages was observed for all 3 fuels, with peak power densities increasing by 25 % and 35 % for DME and MeOH operation respectively, thereby also indirectly confirming the larger fuel crossover effect of the latter. Gas chromatography study of the anode exhaust gas at open circuit voltage revealed a small degree of internal fuel reforming with different products when operated on dimethyl ether or methanol. While methanol seemed to reform to syngas, the DME yielded methane rather than CO as one of the products. The observation of internal reforming was indirectly confirmed by electrochemical impedance spectroscopy, where the best fits were obtained when a Gerischer element describing preceding chemical reaction and diffusion was included in the equivalent circuit of a methanol/air operated cell. In general it has been shown that EIS is a powerful tool for studying MEAs and making reference electrodes unnecessary. Finally, durability studies have shown that the average lifetimes of the cells are between 300 – 600 hours, depending on the operating temperature and water content in the anode fuel supply. However, a potential to operate past 1500 hours has been demonstrated. Post-mortem analyses of the MEAs have shown that one of the reasons for the cell death was formation of pinholes in the membrane, rather than an overall thinning.
Hollow Spheres of Iron Carbide Nanoparticles Encased in Graphitic Layers as Oxygen Reduction Catalysts

Nonprecious metal catalysts for the oxygen reduction reaction are the ultimate materials and the foremost subject for low-temperature fuel cells. A novel type of catalysts prepared by high-pressure pyrolysis is reported. The catalyst is featured by hollow spherical morphologies consisting of uniform iron carbide (Fe3C) nanoparticles encased by graphitic layers, with little surface nitrogen or metallic functionalities. In acidic media the outer graphitic layers stabilize the carbide nanoparticles without depriving them of their catalytic activity towards the oxygen reduction reaction (ORR). As a result the catalyst is highly active and stable in both acid and alkaline electrolytes. The synthetic approach, the carbide-based catalyst, the structure of the catalysts, and the proposed mechanism open new avenues for the development of ORR catalysts.
Hollow Spheres of Iron Carbide Nanoparticles Encased in Graphitic Layers as Oxygen Reduction Catalysts

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Scopus rating (2014): SJR 5.805 SNIP 2.309 CiteScore 10.84
Web of Science (2014): Indexed yes
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Scopus rating (2013): SJR 5.681 SNIP 2.204 CiteScore 10.7
ISI indexed (2013): ISI indexed yes
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Scopus rating (2012): SJR 6.362 SNIP 2.338 CiteScore 10.55
ISI indexed (2012): ISI indexed yes
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BFI (2011): BFI-level 2
Scopus rating (2011): SJR 6.062 SNIP 2.387 CiteScore 10.75
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
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Scopus rating (2010): SJR 5.858 SNIP 2.31
Hydrogen evolution activity and electrochemical stability of selected transition metal carbides in concentrated phosphoric acid

Alternative catalysts based on carbides of Group 5 (niobium and tantalum) and 6 (chromium, molybdenum and tungsten) metals were prepared as films on the metallic substrates. The electrochemical activities of these carbide electrodes towards the hydrogen evolution reaction (HER) in concentrated phosphoric acid were investigated in a temperature range from 80 to 170°C. A significant dependence of the activities on temperature was observed for all five carbide samples. Through the entire temperature range Group 6 metal carbides showed higher activity than that of the Group 5 metal carbides, attributable to the different electronic structures. Tungsten carbide among the studied electrode samples exhibited the highest HER activity. Upon anodic potential scans in the presence of oxygen, chromium, tantalum and tungsten carbides displayed passivation due to the formation of stable surface layers whereas niobium and molybdenum carbides seemed to undergo corrosion.
meta-PBI/methylated PBI-OO blend membranes for acid doped HT PEMFC

Methylation of polybenzimidazole leads to positively charged polymer backbones, and moveable anions. Ion exchange of methylated PBI-OO in phosphoric acid (PA) shows that the resulting polymers dissolve. meta-PBI, however, absorbs about 400wt% PA while remaining a self supported membrane. We investigate the properties of blend membranes, employing meta-PBI for mechanical integrity and methylated PBI-OO for high PA uptake and resulting proton conductivity. While small additions of PBI-OO decrease the tensile strength of blend membranes (58MPa for 10% PBI-OO), further
addition leads to an increase, and 50% blend membranes show again a tensile strength of 74 MPa, just 3 MPa lower than pure meta-PBI membranes. Thermal stability of iodide exchanged blend membranes appears to be remarkably high, probably because cleaved iodomethane does not evaporate but methylates meta-PBI. PA concentration in doped membranes of 60–63% is reached by doping in 60% PA (blend; 6.3PA/repeat unit) and 70% PA (meta-PBI; 4.6PA/r.u.). This suggests that blends absorb PA more strongly. Both membranes show similar conductivity between rt and 140°C, indicating that PA concentration describes these membranes better than PA/r.u. In the fuel cell, blend membranes show similar or better performance than meta-PBI. In the TGA, blends doped in 20% PA showed a stable plateau between 115 and 180°C, while meta-PBI lost weight continuously.

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Web of Science (2015): Indexed yes
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Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
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Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
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ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.298 SNIP 1.569
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.165 SNIP 1.356
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.118 SNIP 1.293
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.15 SNIP 1.374
Web of Science (2007): Indexed yes
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Insights to durability and impedance of direct DME HT-PEM FCs

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Abstract

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Invited: A Stability Study of Alkali Doped PBI Membranes for Alkaline Electrolyzer Cells

Alkaline fuel cells and electrolyzers are attracting increasing interest. This is to a large extent due to the broad selection of catalyst materials not based on resource limited and expensive noble metals. The first fuel cells in practical use were Francis Thomas Bacon’s based on an alkaline electrolyte. The system has been quite successful with good oxygen kinetics, but the electrolyte suffers from carbonization when operated in normal CO2-containing air and this has limited the application to space technology and similar niches. The alkaline electrolyzer on the other hand has been the state of art commercial choice for decades and the carbonization problem is absent since oxygen is produced, not consumed.

However, the demand for high voltage efficiency has been limited and the alkaline electrolyzer has been optimized in the direction of robustness and long lifetime instead. Today it has become obvious that an energy system based on renewable energy will need conversion of a large amount of electrical energy to fuel for storage and for transport. We believe that from a materials perspective the alkaline electrolyzer has the strongest potential for meeting the manufacturing cost targets given, but voltage efficiency and rate capability must be improved significantly. One important component with room for improvement is the electrolyte which traditionally fills a gap of up to several mm between the electrodes. The resistance can be much reduced if a thin anion conducting membrane or a porous diaphragm is used instead in direct contact with both electrodes (zero gap). In proton exchange membrane (PEM) electrolyzers proton conducting membranes like in PEM fuel cells have been very successful, but for the equivalent anion exchange membranes a similar conductivity has not yet been demonstrated; in contrast it is typically about an order of magnitude lower, which is insufficient [1]. The aromatic fluorine free polymer polybenzimidazole (PBI) has been very successful as a high temperature fuel cell membrane when doped with phosphoric acid [2] and it has been shown by Xing and Savadogo [3] that it can also be doped with potassium hydroxide and serve as electrolyte for alkaline fuel cells. See figure 1. In this work the stability of PBI doped with aqueous KOH was studied after storage in 6 M KOH at 85 °C for up to 176 days, i.e. close to half a year [4]. The pristine polymer was supplied by Danish Power Systems ApS and solution cast from DMAC. Three different variants of the PBI were used. 1) The pristine linear PBI, 2) PBI crosslinked by dibromoparaxylene and 3) PBI thermally cured at 350°C. Tensile strength and elastic modulus decreased somewhat during storage, but all membranes remained integral throughout the entire storage period with the exception of the linear untreated sample which disintegrated when handled after the full 176 days. A gradual weight loss was seen for all membranes but the effect was much reduced for the crosslinked and the cured pieces. The thermally cured membrane lost less that 10 mass %.
Viscosity measurement on the linear PBI (the only one soluble) showed a decreasing molecular weight over time of storage. The materials were also examined by IR, NMR and TGA. Finally, electrolysis tests were made including comparison with a commercial diaphragm material (Zirfon). The conductivity of the alkali doped PBI samples was around 0.05 S cm⁻² at 85°C, while that of Zirfon was ca. 0.2 S cm⁻², but since Zirfon is much thicker to ensure a low bubble point pressure the practical area specific resistances were more or less equal and the cells showed very similar polarization characteristics. [1] G. Merle, M. Wessling and K. Nijmeijer. J. Membrane Sci. 377 (2011) 1–35 [2] Q. F. Li, J. O. Jensen, R. F. Savinell and N. J. Bjerrum. Prog. Polym. Sci. 34(2009) 449 [3] B. Xing, O. Savadogo, Electrochemistry Communications 2(2000) 697-702 [4] D. Aili, M. K. Hansen, R.F. Renzaho, Q. F. Li, E. Christensen, J. O. Jensen and N. J.Bjerrum. J. Membrane Sci. 447 (2013) 424–432 [Formula]

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Metal Phosphates as Proton Conducting Materials for Intermediate Temperature Fuel Cell and Electrolyser Applications
The present thesis presents the results achieved during my ph.d. project on a subject of intermediate temperature proton conducting metal phosphates as electrolyte materials for fuel cells and electrolysers. Fuel cells and electrolysers are electrochemical devices with high energy conversion efficiency and have been proposed as the future energy technology in association with renewable power sources. The currently available technologies are either operating at lower or higher temperatures. To achieve an intermediate temperature operation between 200 and 400 °C, a key material is the electrolyte with a proton conductivity of above 10⁻²S cm⁻¹. Chapter 1 of the thesis is an introduction to basics of fuel cell and electrolyser technologies as well as proton conducting materials. Extended discussion on the proton conducting materials, a particularly phosphates is made in Chapter 2. Three major types of phosphates were systematically reviewed including solid acids or alkali hydrogen phosphates, pyrophosphates, and rare earth metal phosphates. Demonstration of the fuel cell technology based on solid acid proton conductor CsH₂PO₄ has inspired the active research in the area.

Based on the literature survey, the thesis work is defined and outlined. Chapter 3 describes in details the theoretical background of techniques used in the present study. A significant part of the present study involves conductivity measurements with electrochemical impedance technique, which are discussed in Chapter 4. The research work starts with synthesis and investigation of three rare earth metal phosphate hydrates, which is first presented in Chapter 5. Structural and surface water as well as its stability has been investigated using thermogravimetric and differential thermal analyses combined with structural modeling calculations. Conductivity results of the phosphates are presented. The rare earth metal phosphates are further explored by preparing composites with cesium dihydrogen phosphate. The properties of the composites are characterized using SEM/EDX, XRD, TGA/DTA and conductivity measurements in slightly humidified atmosphere. The results are presented in Chapter 6. In Chapter 7 the structure and conductivity mechanism of indium doped tin pyrophosphates are reported. For this purpose three synthetic techniques are employed to prepare a variety of the pyrophosphates with or without post treatments with phosphoric acid. The conductivity and its stability are studied and correlated with the phosphate morphologies. The additional solid state NMR studies have been performed in collaboration with Southern Denmark University (SDU). Chapter 8 presents the result obtained for a novel proton conductor based on cerium ultraphosphate. The ultraphosphate is found to be in form of the orthorhombic phase, whose stability is confirmed by heat treatments combined with XRD measurements. Initial measurements of the conductivity and its stability for the cerium ultraphosphate are also presented. Chapter 9 summarizes conclusions of the thesis work. Further information concerning experimental measurements is given in Appendixes.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Anfimova, T. (Intern), Li, Q. (Intern), Bjerrum, N. J. (Intern), Jensen, J. O. (Intern)
Methods for HT-PEM FC electrodes preparation

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Ceramic Engineering & Science, Technical University of Denmark
Authors: Vassiliev, A. (Intern), Andersen, K. B. (Intern), Martin, S. (Ekstern), Cleemann, L. N. (Intern), Jensen, J. O. (Intern)
Number of pages: 1
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Abstract
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Novel non-platinum metal catalyst material
The present invention relates to a novel non-platinum metal catalyst material for use in low temperature fuel cells and electrolyzers and to fuel cells and electrolyzers comprising the novel non-platinum metal catalyst material. The present invention also relates to a novel method for synthesizing the novel non-platinum metal catalyst material.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Qingfeng, L. (Ekstern), Jensen, J. O. (Intern), Hu, Y. (Ekstern), Bjerrum, N. (Intern)
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Publication: Research › Patent – Annual report year: 2015

Oxygen evolution catalysts on supports with a 3-D ordered array structure and intrinsic proton conductivity for proton exchange membrane steam electrolysis
Proton exchange membrane steam electrolyzers suffer from insufficient catalyst activity and durability due to the slow reaction kinetics for oxygen evolution reaction (OER) and poor durability under harsh operating environments. Aiming at enhancement of oxygen electrode kinetics and durability, composite support materials for iridium oxide are synthesized via in situ phosphorization reaction on tin doped indium oxide and possess functionalities of high electronic and intrinsic proton conductivity. At 130 °C under a water vapor atmosphere an overall conductivity of 0.72 S cm⁻¹ is achieved with a contribution of around 10−2 S cm⁻¹ proton conductivity. The support structure of three-dimensionally ordered hexagonal...
arrays displays a high specific surface area of 180 m² g⁻¹. Benefiting from the mixed conductivities and porous structure in the composite support materials, the supported IrO₂ catalysts exhibit about five times enhancement of the OER activity in acidic electrolytes. The improved catalytic performance for the OER was further confirmed by PEM electrolyzer tests at 130 °C. A test of such a steam electrolyzer cell at 350 mA cm⁻² shows good durability within a period of up to 1150 hours.

**General information**

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Organisations: Energy and Materials, Department of Energy Conversion and Storage, Proton conductors, Imaging and Structural Analysis, University of Science and Technology of China
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- Scopus rating (2013): CiteScore 14.81
- ISI indexed (2013): ISI indexed yes
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- Scopus rating (2012): CiteScore 11.84
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 1
- Scopus rating (2011): CiteScore 9.96
- ISI indexed (2011): ISI indexed no
- Web of Science (2011): Indexed yes
- Scopus rating (2010): CiteScore 2.41
- Web of Science (2010): Indexed yes
- Scopus rating (2009): CiteScore 1.139
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Source-ID: n::oai:DTIC-ART:rsc/433040111::38220
Publication: Research - peer-review » Journal article – Annual report year: 2014

**Perovskites As Electrocatalysts for Alkaline Water Electrolysis**

Water electrolysis is a promising technology for the production of hydrogen as a sustainable energy storage source, combined with solar or wind power. In this work various electrocatalysts for the Oxygen Evolution Reaction (OER) electrode were synthesized and characterized by several techniques such as X-ray diffraction, electrical conductivity, scanning electron microscopy (SEM), energy dispersive microscopy (EDX) and rotating disk electrode. The perovskites tested in this work were both produced by a ball-milling technique and by an auto-combustion synthesis, which appeared
to be a fast and robust method for synthesis of perovskites with various chemical compositions. The electrochemical performance of the materials was tested through pellet pressing of the perovskite powders. This involved in some case a time consuming preparation process. Furthermore the technique should show the adequate reproducibility. In this work we show the development of the method, which was further used to compare the activity of various electrocatalysts (Figures 1, 2). The electrocatalytic activity of all prepared perovskites was tested in 1M KOH at 80 °C, using an ink consisting of potassium exchanged Nafion®. All tests were performed in the potential window 0-700 mV on a glassy carbon electrode. All the tested perovskites were characterized by their overpotential, measured current at 650 mV, obtained kinetic current and Tafel slopes. It was also shown that this technique do not depend on the initial powder electric conductivity which varied by several orders of magnitude, as shown on Figure 3. H. Nijjar, J. Lamonier, O. Mentr'e, J. Giraudon, H. Batie, Appl. Catal. B, 106, 149–159, 2011 2 J.O'M. Bockris and T. Otagawa J. Phys. Chem. 87:2960-2971, 1983.

**General information**

State: Published

Organisations: Department of Energy Conversion and Storage, Proton conductors, University of Castilla–La Mancha

Authors: Nikiforov, A. V. (Intern), De La Osa Puebla, A. R. (Ekstern), Jensen, J. O. (Intern), Petrushina, I. M. (Intern), Bjerrum, N. J. (Intern)

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**Phosphate-Doped Carbon Black as Pt Catalyst Support: Co-catalytic Functionality for Dimethyl Ether and Methanol Electro-oxidation**

Niobium-phosphate-doped (NbP-doped) carbon blacks were prepared as the composite catalyst support for Pt nanoparticles. Functionalities of the composite include intrinsic proton conductivity, surface acidity, and interfacial synergistic interactions with methanol and dimethyl ether (DME). The supported Pt catalysts show significant improvement in catalytic activity towards the direct oxidation of methanol and DME, attributable to the enhanced adsorption and dehydrogenation of methanol and DME, as well as the presence of activated OH species in the catalysts. The latter is demonstrated to facilitate the removal of CO intermediates formed during the oxidation reactions.

**General information**

State: Published

Organisations: Department of Energy Conversion and Storage, Proton conductors, Imaging and Structural Analysis, Chinese Academy of Sciences

Authors: Yin, M. (Intern), Huang, Y. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern), Cleemann, L. N. (Intern), Zhang, W. (Intern), Bjerrum, N. J. (Intern), Xing, W. (Ekstern)

Number of pages: 7

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Polybenzimidazole and sulfonated polyhedral oligosilsesquioxane composite membranes for high temperature polymer electrolyte membrane fuel cells

Composite membranes based on poly(2,2′-(m-phenylene)-5,5bibenzimidazole) (PBI) and sulfonated polyhedral oligosilsesquioxane (S-POSS) with S-POSS contents of 5 and 10wt.% were prepared by solution casting as base materials for high temperature polymer electrolyte membrane fuel cells. With membranes based on pure PBI as a reference point, the composite membranes were characterized with respect to spectroscopic and physicochemical properties. After doping with phosphoric acid, the composite membranes showed considerably improved ex situ proton conductivity under anhydrous as well as under fully humidified conditions in the 120-180°C temperature range. The conductivity improvements were also confirmed by in situ fuel cell tests at 160°C and further supported by the electrochemical impedance spectroscopy data based on the operating membrane electrode assemblies, demonstrating the technical feasibility of the novel electrolyte materials.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Danish Power Systems ApS, Michigan Molecular Institute
Authors: Aili, D. (Intern), Allward, T. (Ekstern), Alfaro, S. M. (Ekstern), Hartmann-Thompson, C. (Ekstern), Steenberg, T. (Ekstern), Hjuler, H. A. (Ekstern), Li, Q. (Intern), Jensen, J. O. (Intern), Stark, E. J. (Ekstern)
Pages: 182-190
Publication date: 2014
Main Research Area: Technical/natural sciences

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Scopus rating (2015): SJR 1.349 SNIP 1.344 CiteScore 4.86
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.391 SNIP 1.482 CiteScore 4.59
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.435 SNIP 1.607 CiteScore 4.44
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Polybenzimidazole, Composite membrane, Sulfonated polyhedral oligosilsesquioxane, S-POSS, Fuel cells

Polymers for Fuel Cells

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Aili, D. (Intern), Jensen, J. O. (Intern), Li, Q. (Intern)
Number of pages: 13
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Main Research Area: Technical/natural sciences
Polymer electrolyte membrane, Solid polymer electrolyte
DOIs: 10.1007/978-3-642-36199-9_270-1
Source: PublicationPreSubmission
The Electrochemical Behavior of Phosphoric-Acid-Doped Poly(perfluorosulfonic Acid) Membranes

Highly conductive phosphoric-acid-doped poly(perfluorosulfonic acid) membranes have long been known to malfunction in fuel cells. This is investigated and found to be due to failure of the anode, in which a limiting current is observed in the very low current-density range. It is proposed that the strongly acidic sulfonic acid groups protonate the phosphoric acid under anhydrous conditions, forming excess proton defects that are involved in proton conduction by means of the vehicle mechanism. The slow back-diffusion of phosphoric acid molecules as proton carriers thus limits the long-range conductivity of the membranes during fuel cell operation. The hypothesis is experimentally verified using a specially designed halfcell test.

Thermal Stability and Proton Conductivity of Rare Earth Orthophosphate Hydrates

Hydrated orthophosphate powders of three rare earth metals, lanthanum, neodymium and gadolinium, were prepared and studied as potential proton conducting materials for intermediate temperature electrochemical applications. The phosphates undergo a transformation from the rhabdophane structure to the monazite structure upon dehydration. The thermal stability of the hydrate is studied and found to contain water of two types, physically adsorbed and structurally bound hydrate water. The adsorbed water is correlated to the specific surface area and can be reversibly recovered when dehydrated as long as the rhabdophane structure is preserved. The bound hydrate water is accommodated in the rhabdophane structure and is stable at temperatures of up to 650 °C. The thermal stability of the hydrate water and the phosphate structure are of significance for the proton conductivity. The LaPO4·0.6H2O and NdPO4·0.5H2O exhibited the structure dependence of the proton conductivity while the GdPO4·0.5H2O showed a large effect of the phosphate morphology.
Activity and Durability Studies of Nanoparticulate, Thin Film and Bulk Electro catalysts and they Supporting Materials for PEM and DMFCs

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Massachusetts Institute of Technology
Authors: Permyakova, A. A. (Intern), Han, B. (Ekstern), Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. J. (Intern), Shao-Hom, Y. (Ekstern)
Number of pages: 1
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Main Research Area: Technical/natural sciences
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Publication: Research › Poster – Annual report year: 2014

Antimony doped tin oxide modified carbon nanotubes as catalyst supports for methanol oxidation and oxygen reduction reactions

General information
State: Published
Organisations: Energy and Materials, Department of Energy Conversion and Storage, Proton conductors, Imaging and Structural Analysis, University of Science and Technology of China
Pages: 9737-9745
Benzimidazole grafted polybenzimidazoles for proton exchange membrane fuel cells

High molecular weight polybenzimidazole (PBI) was synthesized and grafted with benzimidazole pendant groups. The high molecular weight of PBI resulted in good film-forming properties and superior tensile strength. With a phosphoric acid doping level (ADL) of 13.1, a tensile strength of 16 MPa was achieved at room temperature. Grafting of benzimidazole moieties onto the PBI macromolecular chain introduced additional basic sites which allowed the membrane to achieve higher phosphoric acid uptakes. A molar acid conductivity, defined as the specific conductivity of each mole of doping acid, was proposed to evaluate the effective conductivity contributed from the doping acids. With a grafting degree of 5.3% and an ADL of 13.1, the PBI membranes exhibited a total conductivity of 0.15 S cm⁻¹. A H₂-air fuel cell based on this membrane showed a peak power density of 378 mW cm⁻² at 180 °C without humidification. © 2013 The Royal Society of Chemistry.
Degradation of carbon supported platinum catalysts is a major failure mode for the long term durability of high temperature proton exchange membrane fuel cells based on phosphoric acid doped polybenzimidazole membranes. With Vulcan carbon black as a reference, thermally treated carbon black and multi-walled carbon nanotubes were used as supports for electrode catalysts and evaluated in accelerated durability tests under potential cycling at 150 °C. Measurements of open circuit voltage, area specific resistance and hydrogen permeation through the membrane were carried out, indicating little contribution of the membrane degradation to the performance losses during the potential cycling tests. As the major mechanism of the fuel cell performance degradation, the electrochemical active area of the cathodic catalysts showed a steady decrease in the cyclic voltammetric measurements, which was also confirmed by the post TEM and XRD analysis. A strong dependence of the fuel cell performance degradation on the catalyst supports was observed. Graphitization of the carbon blacks improved the stability and catalyst durability though at the expense of a significant decrease in the specific surface area. Multi-walled carbon nanotubes as catalyst supports showed further significant improvement in the catalyst and fuel cell durability.
Corrosion behavior of construction materials for Intermediate temperature steam electrolysers

Different corrosion resistant stainless steels, nickel-based alloys, pure nickel, Ta-coated stainless steel (AISI 316L), niobium, platinum and gold rods were evaluated as possible materials for use in the intermediate temperature (200-400 °C) acidic water electrolysers. The corrosion resistance was measured under simulated conditions (molten KH2PO4) corresponding to the proton-conducting solid acids or transition metal phosphates as electrolytes. It was shown that, unlike at temperatures below 200 °C, gold is unstable with respect to corrosion in molten KH2PO4. Platinum demonstrated high corrosion resistance and the anodic and cathodic limits were for the first time found for the electrolyte. Nickel, niobium, Inconel®625, Hastelloy®C-276 and Ta-coated stainless steel (AISI 316L) demonstrated high corrosion stability and can be recommended as construction materials for bipolar plates. © (2013) Trans Tech Publications, Switzerland.

General information

State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Nikiforov, A. (Intern), Petrushina, I. (Intern), Jensen, J. O. (Intern), Bjerrum, N. J. (Intern)
Pages: 596-605
Covalently Cross-Linked Sulfone Polybenzimidazole Membranes with Poly(Vinylbenzyl Chloride) for Fuel Cell Applications

Covalently cross-linked polymer membranes were fabricated from poly(aryl sulfone benzimidazole) (SO(2) PBI) and poly(vinylbenzyl chloride) (PVBCl) as electrolytes for high-temperature proton-exchange-membrane fuel cells. The cross-linking imparted organo insolubility and chemical stability against radical attack to the otherwise flexible SO(2) PBI membranes. Steady phosphoric acid doping of the cross-linked membranes was achieved at elevated temperatures with little swelling. The acid-doped membranes exhibited increased mechanical strength compared to both pristine SO(2) PBI and poly[2,2'-(m-phenylene)-5,5'-bibenzimidazole] (mPBI). The superior characteristics of the cross-linked SO(2) PBI membranes allowed higher acid doping levels and, therefore, higher proton conductivity. Fuel-cell tests with the cross-linked membranes demonstrated a high open circuit voltage and improved power performance and durability.
Crosslinked Hexafluoropropylidene Polybenzimidazole Membranes with Chloromethyl Polysulfone for Fuel Cell Applications

Hexafluoropropylidene polybenzimidazole (F6PBI) was synthesized with excellent chemical stability and improved solubility. When doped with phosphoric acid, however, the F6PBI membranes showed plastic deformation at elevated temperatures. Further efforts were made to covalently crosslink F6PBI membranes with chloromethyl polysulfone as a polymeric crosslinker. Comparing with linear F6PBI and mPBI membranes, the polymer crosslinked F6PBI membranes exhibited little organo solubility, excellent stability towards the radical oxidation, high resistance to swelling in concentrated phosphoric acid solutions, and improved mechanical strength, especially at elevated temperatures. The superior characteristics of crosslinked membranes allowed for higher acid doping levels and therefore increased proton conductivity as well as significantly improved fuel cell performance and durability, as compared with the linear F6PBI and mPBI membranes.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Northeastern University
Authors: Yang, J. (Ekstern), Li, Q. (Intern), Cleemann, L. N. (Intern), Jensen, J. O. (Intern), Pan, C. (Intern), Bjerrum, N. J. (Intern), He, R. (Ekstern)
Electrocatalysts and their Supporting Materials for Proton Exchange Membrane Fuel Cells: Activity and Durability Studies

This thesis describes investigations conducted exploring the activity, stability and durability of supported nano-particulate, bulk and thin film electrocatalysts used in proton exchange membrane fuel cells (PEMFCs). The effects of different factors and conditions on the reactions involved in oxygen reduction, carbon monoxide and methanol electro-oxidation reactions were explored. Employed catalysts were characterized electrochemically and physiochemically using techniques such as: cyclic voltammetry, rotating disk electrode technique, SEM, TEM, EDS, XPS, TGA/DTA, Raman, XRD, FTIR-IR among other methods. The thesis begins with an introduction in Chapter 1 providing an overview of fuel cells, their associated reaction mechanisms, catalysts and catalysts supports. Chapter 2 presents the theoretical background to the study including equipment and the techniques used to analyse the catalysts. Subsequently examples of electrochemical characterization for electrochemical surface area are given followed by a description of rotation disk electrode (RDE) principles and set-up. Next the determination of oxygen reduction activity and carbon monoxide electro-oxidation voltammetry are described in addition to long-term durability procedures. A significant part of the PhD study involved development of electrochemical instrumentation and techniques, such as: RDE and set-up, oxygen reduction, methanol and CO electrooxidation, long-term durability procedures, etc. The techniques employed by the author were self-taught or learnt by working with experienced collaborators during the first years of the PhD study. In the advanced stages of the project these techniques were employed by the DTU Proton Conductor group on a daily basis. In addition the author attained a high level of proficiency in operating the following instruments: TEM (FEI Tecnai T20 G2), EDS, AFM, XRD (PANalytical Multipurpose Diffractometer) and FTIR-IR. Chapter 3 describes the results of synthesis and testing of the Pt nanoparticulate catalyst supported by PBI wrapped Graphene for oxygen reduction reaction in PEMFCs. The physiochemical material’s characterisation, preparation procedures for bulk and surface compositions of Pt-Si alloys is also presented. Electrochemical characterisation showed a gradual improvement of activity
for carbon monoxide and methanol electro-oxidation when higher Si contents were employed in the Pt-Si alloy. Chapter 5 describes the preparation, material characterisation and initial electrochemical measurements of methanol electro-oxidation for ALD deposited Pt films on Si(100) and Pt-Si alloys on Si(100). ALD deposited Pt films on Si(100) were subsequently annealed at various temperatures to obtain Pt-Si alloy film on Si(100). Obtained alloys were subsequently characterised as potentially highly active methanol electro-oxidation catalysts, based on conclusions from Chapter 4. Chapter 6 consists of concluding remarks and describes prospective future research. Chapter 7 contains Appendixes.

**General information**

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Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Permyakova, A. A. (Intern), Bjerrum, N. J. (Intern), Jensen, J. O. (Intern), Li, Q. (Intern)
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Publisher: Department of Energy Conversion and Storage, Technical University of Denmark
Original language: English
Main Research Area: Technical/natural sciences

**Heterogeneous anion conducting membranes based on linear and crosslinked KOH doped polybenzimidazole for alkaline water electrolysis**

Polybenzimidazole is a highly hygroscopic polymer that can be doped with aqueous KOH to give a material with high ion conductivity in the 10−2–2S cm−1 range, which in combination with its low gas permeability makes it an interesting electrolyte material for alkaline water electrolysis. In this study membranes based on linear and crosslinked polybenzimidazole were evaluated for this purpose. Extensive characterization with respect to spectroscopic and physicochemical properties during aging in 6molL−1 KOH at 85°C for up to 176 days indicated structural stability of the high molecular weight specialty polymer, however, with limitations with respect to hydrolytic stability. The gradual decay of the average molecular weight resulted in a severe deterioration of the mechanical properties over time. Membranes based on crosslinked polybenzimidazole showed better stability than the membranes based on their linear counterpart. The technical feasibility of the membranes was evaluated by the preliminary water electrolysis tests showing performance comparable to that of commercially available cell separators with great potential of further improvement.

**General information**

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Organisations: Department of Energy Conversion and Storage, Proton conductors, Siemens Corporate Technology
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Volume: 447
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Scopus rating (2016): CiteScore 6.13 SJR 2.062 SNIP 1.72
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2 SNIP 1.771 CiteScore 5.89
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.433 SNIP 1.935 CiteScore 5.42
Web of Science (2014): Indexed yes
Indium doped niobium phosphates as intermediate temperature proton conductors

Indium doped niobium phosphates were prepared from precursors of trivalent indium oxide, pentavalent niobium oxide and phosphoric acid. The obtained materials were characterized by X-ray diffraction, impedance spectroscopy, FT-IR spectroscopy and scanning electron microscopy. It was found that the indium doping promoted formation of the cubic Nb2P4O15 phase instead of the monoclinic Nb5P7O30 phase in the pristine niobium phosphates and enhanced the preservation of OH functional groups in the phosphates. The preserved OH functionalities in the phosphates after the heat treatment at 650 °C contributed to the anhydrous proton conductivity. The Nb0.9In0.1 phosphate exhibited a proton conductivity of five times higher than that of the un-doped analog at 250 °C. The conductivity was stabilized at a level of above 0.02 S cm⁻¹ under dry atmosphere at 250 °C during the stability evaluation for 3 days.

General information

State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Chinese Academy of Sciences
Authors: Huang, Y. (Intern), Li, Q. (Intern), Anfimova, T. (Intern), Christensen, E. (Intern), Yin, M. (Intern), Jensen, J. O. (Intern), Bjerrum, N. J. (Intern), Xing, W. (Ekstern)
Oxidative degradation of acid doped polybenzimidazole membranes and fuel cell durability in the presence of ferrous ions

Phosphoric acid doped polybenzimidazole membranes have been explored as proton exchange membranes for high temperature polymer electrolyte membrane fuel cells. Long-term durability of the membrane is of critical concern and has been evaluated by accelerated degradation tests under Fenton conditions. In this study effects of phosphoric acid and ferrous ions were investigated by measurements of the weight loss, intrinsic viscosity and size exclusion chromatography (SEC) of the polymer membranes. Ferrous ions resulted in, as expected, catalytic formation of peroxide radicals and hence the accelerated polymer degradation in terms of weight loss and molecular weight decrease. The presence of phosphoric acid as an inevitable dopant of the membranes, on the other hand, significantly impeded the membrane degradation by means of metal ion complexing, decreased pH, and acid–base interactions with the amino groups of the polymer. Fuel cell durability tests with contaminations of ferrous ions did show considerable performance degradation, however, primarily due to the catalyst deterioration rather than the membrane degradation.
The 3rd CARISMA international conference on medium and high temperature proton exchange membrane fuel cells: 
Three approaches to better platinum catalysts at biannual conference

The 3rd CARISMA International Conference was held at the Axelborg venue in Copenhagen, Denmark, from September 3-5, 2012. The CARISMA conference series was specifically devoted to challenges in the development and testing of fuel cell materials and membrane electrode assemblies (MEAs) for proton exchange membrane fuel cells (PEMFCs) to be operated at intermediate and high temperatures. The conference series was initiated by the European CARISMA Coordination Action for Research on Intermediate and High Temperature Specialized Membrane Electrode Assemblies. The 2012 event in Copenhagen had around 150 participants from 20 countries in five continents. The majority of the audience was academic or from research organizations, along with industrial representatives from 20 companies.

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Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Jensen, J. O. (Intern), Cleemann, L. N. (Intern), Li, Q. (Intern)
Number of pages: 4
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Three-dimensional Nanofiber Cathode for Low Temperature and High Temperature Fuel Cells

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Three-dimensional Nanofiber Cathode for Low Temperature and High Temperature Fuel Cells

Materials testing, Proton exchange membrane fuel cells (PEMFC), Coordination action, Development and testing, Fuel cell materials, High temperature proton exchange membrane fuel cells, Membrane electrode assemblies, Platinum catalysts, Proton exchange membrane fuel cell (PEMFCs), Research organization

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Publication: Research - peer-review › Journal article – Annual report year: 2014
A Direct DME High Temperature PEM Fuel Cell

Dimethyl ether (DME) has been identified as an alternative to methanol for use in direct fuel cells. It combines the advantages of hydrogen in terms of pumpless fuel delivery and high energy density like methanol, but without the toxicity of the latter. The performance of a direct dimethyl ether fuel cell suffers greatly from the very low DME-water miscibility. To cope with the problem polybenzimidazole (PBI) based membrane electrode assemblies (MEAs) have been made and tested in a vapor fed system. PtRu on carbon has been used as anode catalyst and air at ambient pressure was used as oxidant. A power density of 79 mW/cm² has been achieved at 200 °C.
Advanced Construction Materials for High Temperature Steam PEM Electrolysers

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Nikiforov, A. (Intern), Christensen, E. (Intern), Petrushina, I. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: 61-86
Publication date: 2012

Host publication information
Title of host publication: Electrolysis
Publisher: InTech
Editor: Linkov, V.
Chapter: 4
Main Research Area: Technical/natural sciences
Electronic versions:
Advanced_Construction_Materials.pdf
DOIs:
10.5772/51928
Links:
http://www.intechopen.com/download/books/books_isbn/978-953-51-0793-4

Bibliographical note
This is an open access chapter distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Anion conducting polymer membranes for hydrogen production through alkaline water electrolysis

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Aili, D. (Intern), Li, Q. (Intern), Christensen, E. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: 78-78
Publication date: 2012

Host publication information
Title of host publication: Book of abstracts - 3rd CARISMA International Conference on Medium and High Temperature PEM Fuel Cells
Main Research Area: Technical/natural sciences
Conference: 3rd CARISMA International Conference on Medium and High Temperature Proton Exchange Membrane Fuel Cells, Copenhagen, Denmark, 03/09/2012 - 03/09/2012
Electronic versions:
Links:
http://carisma2012.com
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2012

Bifunctional Pt-Si Alloys for Small Organic Molecule Electro-oxidation

Designing highly active catalysts for electro-oxidation of small organic molecules can help to reduce the anodic overpotential for more efficient utilization of hydrocarbon fuels. The challenge in developing more active electrocatalysts for electro-oxidation reactions is to satisfy the stringent bifunctional requirement, which demands both adsorption and water oxidation sites. In this contribution, we explore the possibility of using Pt-Si alloys to fulfill this bifunctional requirement. Silicon, a highly oxophilic element, is alloyed into Pt as a site for water oxidation, while Pt serves as a CO
adsorption site. We will discuss the enhanced activity of Pt-Si alloys for small organic molecule oxidation, which can be attributed to the improved CO electro-oxidation kinetics on Pt-Si.

**General information**

State: Published

Organisations: Department of Energy Conversion and Storage, Proton conductors

Authors: Permyakova, A. A. (Intern), Suntivich, J. (Ekstern), Han, B. (Ekstern), Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern), Shao-Horn, Y. (Ekstern)

Publication date: 2012

Event: Abstract from 2012 MRS Fall Meeting & Exhibit, Boston, MA, United States.

Main Research Area: Technical/natural sciences

**Bibliographical note**

Symposium C: Electrocatalysis and Interfacial Electrochemistry for Energy Conversion and Storage

Source: PublicationPreSubmission

Source-ID: 97477005

Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2012

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**Conductive Properties of Neodymium Phosphate composites Investigated by Electrochemical Impedance Spectra**

**General information**

State: Published

Organisations: Department of Energy Conversion and Storage, Proton conductors

Authors: Anfimova, T. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)

Publication date: 2012

Event: Poster session presented at 16th Solid State Protonic Conductors (SSPC16), Grenoble, France.

Main Research Area: Technical/natural sciences

Links:

http://sspc16.weebly.com/

**Bibliographical note**

Poster presentation

Publication: Research › Poster – Annual report year: 2012

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**Conductivity of NdPO_4-CsH_2PO_4 composites investigated by electrochemical impedance spectroscopy**

**General information**

State: Published

Organisations: Department of Energy Conversion and Storage, Proton conductors

Authors: Anfimova, T. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)

Pages: 80-80

Publication date: 2012

**Host publication information**

Title of host publication: Book of abstracts - 3rd CARISMA International Conference on Medium and High Temperature PEM Fuel Cells

Main Research Area: Technical/natural sciences

Conference: 3rd CARISMA International Conference on Medium and High Temperature Proton Exchange Membrane Fuel Cells, Copenhagen, Denmark, 03/09/2012 - 03/09/2012

Electronic versions:


Links:

http://carisma2012.com

Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2012

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**Corrosion behavior of construction materials for intermediate temperature steam electrolyzers**

**General information**

State: Published

Organisations: Department of Energy Conversion and Storage, Proton conductors

Authors: Nikiforov, A. (Intern), Petrushina, I. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)

Pages: 121-121

Publication date: 2012
Corrosion Behavior of Construction Materials for Intermediate Temperature Steam Electrolysers

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Nikiforov, A. (Intern), Petrushina, I. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Number of pages: 1
Publication date: 2012

Direct dimethyl ether fueling of a high temperature polymer fuel cell
Direct dimethyl ether (DME) fuel cells suffer from poor DME–water miscibility and so far peak powers of only 20–40 mW cm\(^{-2}\) have been reported. Based on available literature on solubility of dimethyl ether (DME) in water at ambient pressure it was estimated that the maximum concentration of DME at 80 °C will be 300–600 times lower than the ratio 1 to 3 which is the stoichiometric ratio for full conversion to CO2. To overcome this dilution problem a high temperature polymer fuel cell was operated on DME–water vapor at ambient pressure and with air as oxidant. A peak power density of 67 mW cm\(^{-2}\) was measured at 200 °C. A series of performance curves at temperatures ranging from 150 to 250 °C showed a pronounced temperature effect on the performance. Comparison was made between performances as direct DME and direct methanol cells and the difference was not as large as normally seen with conventional liquid fed cells below 100 °C.

General information
State: Published
Organisations: Department of Chemistry, Energy and Materials
Pages: 173-176
Publication date: 2012
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Power Sources
Volume: 211
ISSN (Print): 0378-7753
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 6.22 SJR 1.945 SNIP 1.483
A high temperature polybenzimidazole (PBI) polymer fuel cell was fed with dimethyl ether (DME) and water vapour mixture on the anode at ambient pressure with air as oxidant. A peak power density of 79 mW/cm² was achieved at 200°C. A conventional polymer based direct DME fuel cell is liquid fed and suffers from low DME solubility in water. When the DME-water mixture is fed as vapour miscibility is no longer a problem. The increased temperature is more beneficial for the kinetics of the direct oxidation of DME than of methanol. The Open Circuit Voltage (OCV) with DME operation was 50 to 100 mV higher than that of methanol, indicating less fuel crossover.
Direct dimethyl ether high temperature polymer electrolyte membrane fuel cells with improved performance

Energy Dispersive X-ray Analysis used to quantify the Phosphoric Acid Doping Level in Polybenzimidazole based Fuel Cells

High Temperature Polymer Electrolyte Membrane Fuel Cells - Performance and degradation
High Temperature Polymer Fuel Cells: From laboratory towards commercialization

General information
State: Published
Organisations: Department of Chemistry, Department of Energy Conversion and Storage, Proton conductors
Authors: Hjuler, H. A. (Intern), Steenberg, T. (Intern), Terkelsen, C. (Ekstern), Jensen, J. O. (Intern), Cleemann, L. N. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern), Andreasen, S. (Ekstern), Kær, S. (Ekstern)
Publication date: 2012
Main Research Area: Technical/natural sciences
Publication: Research › Paper – Annual report year: 2012

Metal Phosphates as Intermediate Temperature Proton Conducting Electrolytes

A series of metal phosphates were synthesized and screened as potential proton conductor electrolytes for fuel cells and electrolyzers operational at intermediate temperatures. Among the selected, niobium and bismuth phosphates exhibited a proton conductivity of $10^{-2}$ and $10^{-7}$ S cm$^{-1}$, respectively, under the anhydrous atmosphere at 250 °C, showing close correlation with the presence of hydroxyl groups in the phosphate phases. At water partial pressure of above 0.6 atm, both phosphates possessed proton conductivity to a level of above $3 \times 10^{-2}$ S cm$^{-1}$. Reasonable stability of the proton conductivity was observed under either a constant low water partial pressure or under a humidity cycling test within a period of more than 80 hours.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Huang, Y. (Intern), Li, Q. (Ekstern), Pan, C. (Intern), Anfimova, T. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: 99-104
Publication date: 2012
Conference: 221st ECS Meeting, Seattle, WA, United States, 06/05/2012 - 06/05/2012
Main Research Area: Technical/natural sciences
Publication information
Journal: E C S Transactions
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Issue number: 1
ISSN (Print): 1938-5862
Ratings:
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.4 SJR 0.231 SNIP 0.246
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.214 SNIP 0.257 CiteScore 0.36
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.214 SNIP 0.246 CiteScore 0.36
BFI (2013): BFI-level 1
Nickel and its alloys as perspective materials for intermediate temperature steam electrolyzers operating on proton conducting solid acids as electrolyte

Several stainless steels, nickel-based alloys, Ta-coated stainless steel, niobium, nickel, platinum and gold were evaluated as possible materials for use in the intermediate temperature water electrolyzers. The corrosion resistance was measured in molten KH₂PO₄ as simulated conditions corresponding to proton-conducting solid acids or transition metal phosphates as electrolytes. It was shown that Au is subject to corrosion in molten KH₂PO₄ during polarisation. However, Ni and Ta-coated stainless steel (AISI 316L) demonstrated high corrosion stability and can be recommended as a construction material for bipolar plates and cell housing. It was shown, that nickel, high-nickel alloys and austenitic stainless steels containing small amounts of Ti have high corrosion resistance in this media. © The Electrochemical Society.
Niobium phosphates as an intermediate temperature proton conducting electrolyte for fuel cells

A new proton conductor based on niobium phosphates was synthesized using niobium pentoxide and phosphoric acid as precursors. The existence of hydroxyl groups in the phosphates was confirmed and found to be preserved after heat treatment at 500 °C or higher, contributing to an anhydrous proton conductivity of $1.6 \times 10^{-2}$ S cm$^{-1}$ at 250 °C. The conductivity increased with water content in the atmosphere and reached $5.8 \times 10^{-2}$ S cm$^{-1}$ under pure water vapour at the same temperature. The conductivity showed good stability in the low water partial pressure range of up to 0.05 atm. The metal phosphates are of high interest as potential proton conducting electrolytes for fuel cells operational in an intermediate temperature range.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Changchun Institute of Applied Chemistry
Authors: Huang, Y. (Intern), Li, Q. (Intern), Jensen, A. H. (Intern), Yin, M. (Ekstern), Jensen, J. O. (Intern), Christensen, E. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern), Xing, W. (Ekstern)
Pages: 22452-22458
Publication date: 2012
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Materials Chemistry
Volume: 22
Issue number: 42
ISSN (Print): 0959-9428
Ratings:
BFI (2015): BFI-level 2
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BFI (2013): BFI-level 2
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Niobium Phosphates as Intermediate Temperature Proton Conductor

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Huang, Y. (Intern), Li, Q. (Intern), Pan, C. (Intern), Jensen, J. O. (Intern), Christensen, E. (Intern), Cleemann, L. N. (Intern), Jensen, A. H. (Intern), Anfimova, T. (Intern), Bjerrum, N. (Intern)
Pages: 77-77
Publication date: 2012

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Title of host publication: Book of abstracts - 3rd CARISMA International Conference on Medium and High Temperature PEM Fuel Cells
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Conference: 3rd CARISMA International Conference on Medium and High Temperature Proton Exchange Membrane Fuel Cells, Copenhagen, Denmark, 03/09/2012 - 03/09/2012
Electronic versions:
Links:
http://carisma2012.com
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2012

PEM steam electrolysis at 130 °C using a phosphoric acid doped short side chain PFSA membrane
Steam electrolysis test with a phosphoric acid doped Aquivion™ membrane was successfully conducted and current densities up to 775 mA cm⁻² at 1.8 V was reached at 130 °C and ambient pressure. A new composite membrane system using a perfluorosulfonic acid membrane (Aquivion™) as matrix and phosphoric acid as proton conducting electrolyte was developed. Traditional perfluorosulfonic acid membranes do not possess sufficient dimensional stability and proton conductivity to be used at elevated temperatures and ambient pressures. The elevated temperature, high potentials and acidic conditions implied that a new and highly corrosion resistant construction material was needed. Tantalum coated stainless steel felt was tested and found suitable as the anode gas diffusion layer.

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General information
State: Published
Organisations: Energy and Materials, Department of Chemistry, Department of Energy Conversion and Storage, Proton conductors, Tantaline A/S
Water electrolysis, High temperature, Tantalum coating, Proton exchange membrane, PEMEC
PEM Water Electrolysis at Elevated Temperatures

Global warming and the accelerating depletion of fossil based fuels have catalysed a tremendous surge in the development of alternative and sustainable energy sources e.g. wind-, solar- and hydropower. Common for most of these alternative energy sources is that they at times provide more power than needed and hence it has become acute to be able to store the energy. Hydrogen has been identified as a suitable energy carrier and water electrolysis is one way to produce it in a sustainable and environmentally friendly way.

In this thesis an introduction to the subject (chapter 1) is given followed by a literature review of the field of water electrolysis (chapter 2), with a focus on proton exchange membrane (PEM) electrolysis. In chapter 3 a short description of the experimental techniques used for synthesis of catalyst and characterisation of the components in the electrolysis cell is given. This is followed in chapter 4 by a description of the electrolysis setups and electrolysis cells used during the work. Two different setups were used, one operating at atmospheric pressure and another that could operate at elevated pressure so that liquid water electrolysis could be performed at temperature above 100 °C.

It was found that the gas diffusion layer on the anode side played an important role for the electrolyser performance. Different thicknesses and types, i.e. a single layer- and double layer type, were tested. Chapter 5 presents a characterisation of the gas diffusion layers, using parameters such as porosity and resistance which were supported by images acquired using scanning electron microscopy (SEM).

In chapters 6 and 7 the results of the steam electrolysis and pressurised water electrolysis, respectively, are presented and discussed. The steam electrolysis was tested at 130 °C and atmospheric pressure, whereas the pressurised water electrolysis was performed at 120 °C and 3 bar. For the steam electrolysis three different electrolytes were used. Chapter 6 is divided into subchapters in which the results are presented and discussed before a comparison between them is given. First phosphoric acid doped membranes of polybenzimidazole - poly[2,2'(m-phenylene)-5,5'-bibenzimidazole] (PBI) were used as electrolyte. Reasonably good short-term results were achieved using this membrane reaching a current density of 775 mA·cm$^{-2}$ at a cell voltage of 1.84 V. The durability of phosphoric acid doped PBI however was quite poor only lasting few hours in the setup used. Afterwards a range of different phosphoric acid doped commercial Nafion® and ternary phosphoric acid doped composite Nafion® membranes were tested. The performance was not as good as for the PBI system; only 310 mA·cm$^{-2}$ at 1.7V for the best ternary composite membrane. The durability, on the other hand, was greatly improved and test was run for approximately 70 hours (constant voltage of 1.7 V) with a 0.17 mA·h$^{-1}$ decline in performance. Finally, a new class of perfluorosulfonic acid (PFSA) membranes were tested. This was Aquivion™, which is a short side chained PFSA membrane. Aquivion™ was also tested doped with phosphoric acid. It showed better mechanical properties, larger uptake of phosphoric acid and hence improved performance. The best result achieved was 775 mA·cm$^{-2}$ at 1.8 V. Aquivion™ also showed quite promising durability features running for approximately 760 hours (constant current density of 400 mA·cm$^{-2}$) with a 0.023-0.04 mV·h$^{-1}$ decline in performance over the last 660 hours. For the pressurised water electrolysis the best result obtained was for an Aquivion™ membrane with a current density of 2125 mA·cm$^{-2}$ at 1.85 V. An attempt was made to quantify the significance of various parameters such as membrane electrode assembly (MEA) technique (chapter 6), binder content in anode (chapter 6), anode catalyst loading (chapter 6), gas diffusion layer (chapter 5 and 6) and flow patterns (chapter 4, 6 and 7). The different machined flow patterns used are described in chapter 4, and the results with the different patterns are shown and discussed in chapters 6 and 7.

Chapter 8 is devoted to a general discussion and the conclusions and outlook are given in chapter 9. It seems obvious that further effort should be put into characterisation and development of a more sophisticated anode electrode structure. Only when this parameter is optimised and performing at a high level, will it be possible to really quantify the importance of the other parameters under full single cell electrolysis tests.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Energy and Materials
Authors: Hansen, M. K. (Intern), Bjerrum, N. (Intern), Christensen, E. (Intern), Jensen, J. O. (Intern)
Number of pages: 233
Publication date: 2012

Publication information
Place of publication: Kgs.Lyngby
Publisher: Department of Energy Conversion and Storage, Technical University of Denmark
Original language: English
Note re. dissertation: This Ph.D. study has been financed by: 1/3 from Danish Hydrogen and Fuel Cell Academy 1/3 from Dean Scholarship – Technical University of Denmark 1/3 from DTU Chemistry
Main Research Area: Technical/natural sciences
Phosphoric acid doped imidazolium polysulfone membranes for high temperature proton exchange membrane fuel cells

A novel acid–base polymer membrane is prepared by doping of imidazolium polysulfone with phosphoric acid for high temperature proton exchange membrane fuel cells. Polysulfone is first chloromethylated, followed by functionalization of the chloromethylated polysulfone with alkyl imidazoles i.e. methyl (MePSU), ethyl (EtPSU) and butyl (BuPSU) imidazoliums, as revealed by 1H NMR spectra. The imidazolium polysulfone membranes are then doped with phosphoric acid and used as a proton exchange membrane electrolyte in fuel cells. An acid doping level of about 10–11mol H3PO4 per mole of the imidazolium group is achieved in 85wt% H3PO4 at room temperature. The membranes exhibit a proton conductivity of 0.015–0.022S cm−1 at 130–150°C under 15mol% water vapor in air, and a tensile strength of 5–6MPa at 130°C under ambient humidity. Fuel cell tests show an open circuit voltage as high as 0.96V and a peak power density of 175–204mW cm−2 at 150°C with unhumidified hydrogen and air under ambient pressure.
Poly(aryl sulfone benzimidazole) and its copolymers as high temperature membrane electrolyte for fuel cells

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Yang, J. (Ekstern), Li, Q. (Intern), Cleemann, L. N. (Intern), Jensen, J. O. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern), He, R. (Ekstern)
Publication date: 2012
Main Research Area: Technical/natural sciences

Bibliographical note
Oral presentation
Publication: Research - peer-review › Journal article – Annual report year: 2012

Poly(benzimidazole)–functionalized graphene as a stable and durable support for PEM fuel cell electrocatalysts

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Permyakova, A. A. (Intern), Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern)
Pages: 93-93
Publication date: 2012

Host publication information
Title of host publication: Book of abstracts - 3rd CARISMA International Conference on Medium and High Temperature PEM Fuel Cells
Main Research Area: Technical/natural sciences
Conference: 3rd CARISMA International Conference on Medium and High Temperature Proton Exchange Membrane Fuel Cells, Copenhagen, Denmark, 03/09/2012 - 03/09/2012
Poly(benzimidazole)-functionalized graphene supported Pt electrocatalyst and its application in high temperature PEM fuel cells

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Permyakova, A. A. (Intern), Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern)
Number of pages: 1
Publication date: 2012

Host publication information
Title of host publication: Abstract book - Pacific Rim Meeting on Electrochemical and Solid-State Science: 222nd Meeting of ECS — The Electrochemical Society and 2012 Fall Meeting of The Electrochemical Society of Japan
Article number: Abstract #1424
Main Research Area: Technical/natural sciences
Conference: Pacific Rim Meeting on Electrochemical and Solid-State Science, Honolulu, United States, 07/10/2012 - 07/10/2012
Electronic versions:
Permyakova_1424.pdf
Source: PublicationPreSubmission
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Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2012

Polybenzimidazoles -- Synthesis, characterizations and applications in the form of membranes

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Li, Q. (Intern), Aili, D. (Intern), Rudbeck, H. C. (Ekstern), Yang, J. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: 1-56
Publication date: 2012

Host publication information
Title of host publication: Advances in Materials Science Research
Volume: 14
Publisher: Nova Science Publishers, Incorporated
Editor: Wythers, M. C.
Series: Advances in Materials Science Research
Volume: 14
ISSN: 2159-1997
Main Research Area: Technical/natural sciences
Publication: Research - peer-review › Book chapter – Annual report year: 2012

Proton Conductive Niobium Phosphates as Electrolytes for Fuel Cells Operating with Renewable Biofuels

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Huang, Y. (Intern), Li, Q. (Intern), Anfimova, T. (Intern), Jensen, A. H. (Intern), Jensen, J. O. (Intern), Christensen, E. (Intern), Bjerrum, N. (Intern)
Publication date: 2012
Main Research Area: Technical/natural sciences
Publication: Research - peer-review › Paper – Annual report year: 2012
Proton Conductivity of Refractory Metal Phosphates at Intermediate Temperatures

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors
Authors: Li, Q. (Intern), Huang, Y. (Intern), Anfimova, T. (Intern), Jensen, J. O. (Intern), Christensen, E. (Intern), Bjerrum, N. (Intern)
Number of pages: 20
Publication date: 2012

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Proton_Conductivity.pdf
Links:
http://sspc16.weebly.com/

Bibliographical note
Oral presentation
Publication: Research - peer-review › Sound/Visual production (digital) – Annual report year: 2012

Recent Development of Acid Doped Polybenzimidazole Membranes in Denmark - Polymer Chemistry and Durability Issues

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Danish Power Systems ApS
Number of pages: 1
Pages: 36-36
Publication date: 2012

Host publication information
Title of host publication: Book of abstracts - 3rd CARISMA International Conference on Medium and High Temperature PEM Fuel Cells
Main Research Area: Technical/natural sciences
Conference: 3rd CARISMA International Conference on Medium and High Temperature Proton Exchange Membrane Fuel Cells, Copenhagen, Denmark, 03/09/2012 - 03/09/2012
Electronic versions:
Links:
http://carisma2012.com
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2012

Synthesis and properties of poly(aryl sulfone benzimidazole) and its copolymers for high temperature membrane electrolytes for fuel cells

Poly(aryl sulfone benzimidazole) (SO2PBI) and its copolymers with poly[2,2’-p-(phenylene)-5,5’-bibenzimidazole] (pPBI), termed as Co-SO2PBI, were synthesized with varied feeding ratios of 4,4’-sulfonyldibenzoic acid (SDBA) to terephthalic acid (TPA). Incorporation of the stiff para-phenylene and flexible aryl sulfone linkages in the macromolecular structures resulted in high molecular weight copolymers with good solubility. The chemical stability towards radical oxidation was improved for SO2PBI and its copolymer membranes due to the electron-withdrawing sulfone functional groups. Upon acid doping, the membrane swelling was reduced and the mechanical strength was improved, as compared with their meta structured analogues. At an acid doping level of 11 mol H3PO4 per average molar repeat unit, the Co-20%SO2PBI membrane exhibited a tensile strength of 16 MPa at room temperature and an H2-air fuel cell peak power density of 346 mW cm−2 at 180 °C at ambient pressure. Durability tests with the membrane under a constant current density of 300 mA cm−2 at 160 °C showed a degradation rate of 6.4 μV h−1 during a period of 2400 h, which was significantly lower than that for meta PBI membranes with a similar acid doping level.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Energy and Materials, Functional organic materials, Department of Chemistry, Newcastle University, Northeastern University
Phosphoric acid doped polybenzimidazole (PBI) has emerged as one of the most promising electrolyte materials for proton exchange membrane (PEM) fuel cells operating under anhydrous conditions at temperatures of up to 200 °C. The limited long-term durability of the membrane electrode assemblies (MEAs) is currently hampering the commercial viability of the technology. In the present study, thermoset PBI membranes were prepared by curing the membranes under inert atmosphere at temperatures of up to 350 °C prior to the acid doping. The systematic membrane characterizations with respect to solubility, phosphoric acid doping, radical-oxidative resistance and mechanical strength indicated that the PBI membranes were irreversibly cured by the thermal treatment. After curing, the PBI membranes demonstrated features that are fundamental characteristics of a thermoset resin including complete insolubility, high resistance to swelling and improved mechanical toughness. Additionally, the thermal treatment was found to increase the degree of crystallinity of the membranes. The improved physicochemical characteristics of the membranes after curing were further illustrated by a dramatically improved long-term durability of the corresponding fuel cell MEAs. During continuous operation for 1800 h at 160 °C and 600 mA cm−2, the average cell voltage decay rate of the MEA based on the cured membrane was 43 μV h−1. This should be compared with an average cell voltage decay rate of 308 μV h−1 which was recorded for the MEA based on its non-cured counterpart.
Tungsten carbide promoted Pd and Pd-Co electrocatalysts for formic acid electrooxidation

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Changchun Institute of Applied Chemistry
Authors: Yin, M. (Ekstern), Li, Q. (Intern), Jensen, J. O. (Intern), Huang, Y. (Intern), Cleemann, L. N. (Intern), Bjerrum, N. J. (Intern)
Pages: 95-95
Publication date: 2012
Original language: English
Electronic versions:
dlib.dtu.pdf
DOIs: 10.1039/c2jm14774b
Source: dtu
Source-ID: n:oai:DTIC-ART:rsc/320979018::15406
Publication: Research - peer-review › Journal article – Annual report year: 2012
Tungsten carbide promoted Pd and Pd–Co electrocatalysts for formic acid electrooxidation

Tungsten carbide (WC) promoted palladium (Pd) and palladium–cobalt (Pd–Co) nanocatalysts are prepared and characterized for formic acid electrooxidation. The WC as the dopant to carbon supports is found to enhance the CO tolerance and promote the activity of the Pd-based catalysts for formic acid oxidation. Alloying of Pd with Co further improves the electrocatalytic activity and stability of the WC supported catalysts, attributable to a synergistic effect of the carbide support and PdCo alloy nanoparticles.
Crosslinking of polybenzimidazolmembranes by divinylsulfone post-treatment for high-temperature proton exchange membrane fuel cell applications

Phosphoric acid-doped polybenzimidazole (PBI) has been suggested as a promising electrolyte for proton exchange membrane fuel cells operating at temperatures up to 200 °C. This paper describes the development of a crosslinking procedure for PBI membranes by post-treatment with divinylsulfone. The crosslinking chemistry was studied and optimized on a low-molecularweight model system and the results were used to optimize the crosslinking conditions of PBI membranes. The crosslinked membraneswere characterized with respect to chemical and physiochemical properties, showing improved mechanical strength and oxidative stability compared with their linear analogues. Fuel cell tests were further conducted in order to demonstrate the feasibility of the crosslinked membranes.
Effect of chloride impurities on the performance and durability of polybenzimidazole-based high temperature proton exchange membrane fuel cells

The effect of chloride as an air impurity and as a catalyst contaminant on the performance and durability of polybenzimidazole (PBI)-based high temperature proton exchange membrane fuel cell (HT-PEMFC) was studied. The ion chromatographic analysis reveals the existence of chloride contaminations in the Pt/C catalysts. Linear sweep voltammetry was employed to study the redox behavior of platinum in 85% phosphoric acid containing chloride ions, showing increase in oxidation and decrease in reduction current densities during the potential scans at room temperature. The potential scans at high temperatures in 85% phosphoric acid containing chloride ions showed both increase in oxidation and reduction current densities. The fuel cell performance, i.e. the current density at a constant voltage of 0.4 V and 0.5 V was found to be degraded as soon as HCl was introduced in the air humidifier. The performance loss was recovered when switching from the HCl solution back to pure water in the air humidifier. Under an accelerated aging performance test conducted through potential cycling between 0.9 V and 1.2 V, the PBI-based fuel cell initially containing 0.5 NaCl mg cm\(^{-2}\) on the cathode catalyst layer exhibited a drastic degradation in the performance as compared to the chloride free MEAs. The mechanisms of the chloride effect on the fuel cell performance and durability were further discussed.
High temperature proton exchange membranes based on polybenzimidazole and clay composites for fuel cells
dispersion of modified laponite clay was achieved in polybenzimidazole (PBI) solutions which, when cast and allowed to
dry, resulted in homogeneous and transparent composite membranes containing up to 20 wt% clay in the polymer. The
clay was organically modified using a series of ammonium and pyridinium salts with varying polarity and hydrogen-
bonding capacity. Clay modification by ion-exchange reactions involving replacement of interlayer inorganic cations was
confirmed using X-ray photoelectron and infrared spectroscopy techniques. The cast PBI membranes were characterized
by their water uptake, acid doping and swelling, tensile strength, conductivity and hydrogen permeability as well as by fuel
cell tests. For the composite membranes, high acid doping levels were achieved with sufficient mechanical strength and
improved dimensional stability or reduced membrane swelling. At an acid doping level of 12 mol H3PO4 per monomer
unit, proton conductivity as high as 0.12 S cm−1 was obtained at 150 °C and 12% relative humidity. The composite
membranes exhibited hydrogen permeability ranging from 0.6 to 1.2 × 10−10 mol cm−1 s−1 bar−1 from 100 to 200 °C,
which was five times lower than that of acid-doped pristine PBI membranes. In accordance with the hydrogen permeability
measurements, fuel cell tests exhibited high open circuit voltages (i.e., 1.02 V) at room temperature as well as high I−V
performance compared with normal PBI membranes.

General information
State: Published
Organisations: Solar Energy Programme, Risø National Laboratory for Sustainable Energy, Energy and Materials,
Department of Chemistry, Metal Structures in Four Dimensions, Materials Research Division
Authors: Plackett, D. (Intern), Siu, A. (Intern), Li, Q. (Intern), Pan, C. (Intern), Jensen, J. O. (Intern), Fæster Nielsen, S.
(Intern), Permyakova, A. A. (Intern), Bjerrum, N. (Intern)
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Scopus rating (2016): CiteScore 6.13 SJR 2.062 SNIP 1.72
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2 SNIP 1.771 CiteScore 5.89
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.433 SNIP 1.935 CiteScore 5.42
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.452 SNIP 2.001 CiteScore 5.38
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.201 SNIP 1.968 CiteScore 4.37
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.82 SNIP 1.726 CiteScore 4.29
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.802 SNIP 1.821
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
**Method of operating a direct dme fuel cell system**

The present invention relates to a method of operating a fuel cell system comprising one or more fuel cells with a proton exchange membrane, wherein the membrane is composed of a polymeric material comprising acid-doped polybenzimidazole (PBI). The method comprises adjusting the operating temperature of the fuel cell to between 120 and 250 degrees C, supplying an oxidant stream to the cathode, and supplying a humidified fuel stream to the anode, said fuel stream comprising dimethyl ether, wherein dimethyl ether is directly oxidised at the anode.

**General information**

State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Energy and Materials, Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern), Steenberg, T. (Intern)
Publication date: 2011

**Publication information**

Country: Denmark
IPC: H01M8/04
Patent number: WO2011035784
Date: 31/03/2011
Original language: English

**Bibliographical note**

DTU reference nummer: 92440-09
Main Research Area: Technical/natural sciences
Publication: Research – Patent – Annual report year: 2012
Polybenzimidazole membranes imbibed with acid are emerging as a suitable electrolyte material for high-temperature polymer electrolyte fuel cells. The oxidative stability of polybenzimidazole has been identified as an important issue for the long-term durability of such cells. In this paper the oxidative degradation of the polymer membrane was studied under the Fenton test conditions by the weight loss, intrinsic viscosity, size exclusion chromatography, scanning electron microscopy and Fourier transform infrared spectroscopy (FTIR) to evaluate the stability of the mentioned materials. It was found that stainless steels were the least resistant to corrosion under strong anodic polarization. On the contrary, Ni-based alloys showed higher corrosion resistance in the simulated PEM electrolyzer medium. In particular, Inconel®625 was the most promising among the tested corrosion-resistant alloys for the anodic compartment of high-temperature steam electrolyzer. The tantalum coated stainless steel showed outstanding resistance to corrosion in selected media, while passivation of titanium was weak, and the highest rate of corrosion among all tested materials was observed for titanium at 120 °C. Today, there is a high interest in the field towards investigation of new catalyst materials, which can make it possible to avoid noble metals. However, this work suggests a different approach of decreasing the loading of the active component at the oxygen electrode by using a catalyst support. In order to achieve this, investigation of a novel SiC-Si compound was performed and presented in Chapter 5. The active iridium oxide was deposited on the SiC-Si in-situ by the Adams fusion synthesis and characterized by different techniques. XRD and nitrogen adsorption experiments showed an influence of the support on surface properties of the IrO2 particles, affecting IrO2 particle size. The prepared catalysts were electrochemically characterized by cyclic voltammetry experiments at 25, 80, 120 and 150 °C. In accordance with the observed variation in particle size, a support loading of up to 80% improved the activity of the catalyst. Powder conductivity measurements were also performed, which showed the influence of the support on the packing of IrO2 particles. Investigation showed that even a support material with poor electrical conductivity contributes beneficially to the electrocatalyst active surface area, increasing its utilization. Results demonstrated potential perspectives of using low conductive ceramics as a catalyst support which means that further research in this field is of high interest. An essential part of the study was devoted to the development of a method of elevated temperature catalyst electrochemical characterization, which was implemented for the evaluation of the performance of the synthesized catalysts. Chapter 6 consists of concluding remarks and proposals for the future research. Chapter 7 contains two articles, which were published during the project period.

**Oxidative degradation of polybenzimidazole membranes as electrolytes for high temperature proton exchange membrane fuel cells**

Polybenzimidazole membranes imbibed with acid are emerging as a suitable electrolyte material for high-temperature polymer electrolyte fuel cells. The oxidative stability of polybenzimidazole has been identified as an important issue for the long-term durability of such cells. In this paper the oxidative degradation of the polymer membrane was studied under the Fenton test conditions by the weight loss, intrinsic viscosity, size exclusion chromatography, scanning electron microscopy and Fourier transform infrared spectroscopy. During the Fenton test, significant weight losses depending on the initial molecular weight of the polymer were observed. At the same time, viscosity and SEC measurements revealed a steady decrease in molecular weight. The degradation of acid doped PBI membranes under Fenton test conditions is proposed to start by the attack of hydroxyl radicals at the carbon atom linking imidazole ring and benzzenoid ring, which may eventually lead to the imidazole ring opening and formation of small molecules and terminal groups for further oxidation by an endpoint oxidation. Copyright © 2011 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.
Phosphoric acid doped membranes based on Nafion®, PBI and their blends – Membrane preparation, characterization and steam electrolysis testing

Proton exchange membrane steam electrolysis at temperatures above 100 °C has several advantages from thermodynamic, kinetic and engineering points of view. A key material for this technology is the high temperature proton exchange membrane. In this work a novel procedure for preparation of Nafion® and polybenzimidazole blend membranes was developed. Homogeneous binary membranes covering the whole composition range were prepared and characterized with respect to chemical and physiochemical properties such as water uptake, phosphoric acid doping, oxidative stability, mechanical strength and proton conductivity. An MEA based on phosphoric acid doped Nafion® was operated at 130 °C at ambient pressure with a current density of 300 mA cm⁻² at 1.75 V, with no membrane degradation observed during a test of 90 h. The PBI based MEAs showed better polarization curves (500 mA cm⁻² at 1.75 V) but poor durability.

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State: Published
Organisations: Energy and Materials, Department of Chemistry
Pages: 6985-6993
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Main Research Area: Technical/natural sciences

Phosphoric acid doped membranes based on Nafion®, PBI and their blends – Membrane preparation, characterization and steam electrolysis testing

Proton exchange membrane steam electrolysis at temperatures above 100 °C has several advantages from thermodynamic, kinetic and engineering points of view. A key material for this technology is the high temperature proton exchange membrane. In this work a novel procedure for preparation of Nafion® and polybenzimidazole blend membranes was developed. Homogeneous binary membranes covering the whole composition range were prepared and characterized with respect to chemical and physiochemical properties such as water uptake, phosphoric acid doping, oxidative stability, mechanical strength and proton conductivity. An MEA based on phosphoric acid doped Nafion® was operated at 130 °C at ambient pressure with a current density of 300 mA cm⁻² at 1.75 V, with no membrane degradation observed during a test of 90 h. The PBI based MEAs showed better polarization curves (500 mA cm⁻² at 1.75 V) but poor durability.

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Pages: 6985-6993
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Main Research Area: Technical/natural sciences

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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.212 SNIP 1.494 CiteScore 3.54
Web of Science (2014): Indexed yes
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Recent progress in material development and durability evaluation

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Organisations: Department of Energy Conversion and Storage, Proton conductors, Department of Chemistry
Publication date: 2011
Main Research Area: Technical/natural sciences
Links:
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Oral presentation
Publication: Research - peer-review › Paper – Annual report year: 2011
A direct DME fuel cell based on acid doped PBI

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Ingemann Olsen, M. (Ekstern), Li, Q. (Intern), Vassiliev, A. (Intern), Pan, C. (Intern), Steenberg, T. (Intern), Bjerrum, N. (Intern)
Publication date: 2010
Event: Abstract from Progress MEA 2010, La Grande Motte, France.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 273845
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010

A Medical Delivery Device
The present invention relates to a medical delivery device comprising at least two membrane electrode assembly units each of which comprises three layers: an upper and a lower electrode and a selective ionic conductive membrane provided there-between. At least one of the three layers are shared by the two MEA units which are individually controllable.

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry, Novo Nordisk A/S
Authors: Nielsen, O. C. (Ekstern), Jensen, J. O. (Intern), Nielsson, M. S. (Ekstern), Bjerrum, N. (Intern), Hennesø, E. (Intern)
Publication date: 2010

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Patent number: WO10000567
Date: 07/01/2010
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Publication: Research › Patent – Annual report year: 2010

Development and Characterizations of High Performance MEAs For High Temperature PBI Fuel Cells

General information
State: Published
Organisations: Department of Chemistry
Authors: Hjuler, H. A. (Intern), Steenberg, T. (Intern), Rudbeck, H. C. (Ekstern), Cleemann, L. N. (Intern), Li, Q. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Publication date: 2010
Event: Abstract from Progress MEA 2010, La Grande Motte, France.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 273835
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010

Durability Issues and Status of High Temperature Proton Exchange Membrane Fuel Cells Based on Acid Doped Polybenzimidazole Membranes

General information
State: Published
Organisations: Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Pan, C. (Intern), Liao, J. (Intern), Rudbeck, H. C. (Ekstern), Cleemann, L. N. (Intern), Bjerrum, N. (Intern)
Publication date: 2010

Publication information
High Temperature PEMFC and Its Integration with Fuel Processors - An Approach to Portable Fuel Cells

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State: Published
Organisations: Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Publication date: 2010

Introduktion til højtemperatur PEM brændselsceller

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Organisations: Energy and Materials, Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2010

Ongoing Efforts Addressing Degradation of High Temperature PEMFC

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2010

PEM fuel cells, Towards higher working temperature

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern)
Publication date: 2010
Polymer Degradation and Catalyst Sintering in High Temperature PEMFC Based on Acid Doped Polybenzimidazole Membranes

General information
State: Published
Organisations: Department of Chemistry, University of Stuttgart
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Rudbeck, H. C. (Ekstern), Liao, J. (Intern), Cleemann, L. N. (Intern), Chromik, A. (Ekstern), Kerres, J. (Ekstern), Bjerrum, N. (Intern)
Publication date: 2010
Event: Abstract from Progress MEA 2010, La Grande Motte, France.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 273843
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010

Possibilities of High Temperature PEMFC as Compared with Conventional PEMFC

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2010

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 272176
Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

Properties, degradation and high temperature fuel cell test of different types of PBI and PBI blend membranes

Polybenzimidazoles (PBIs) with synthetically modified structures and their blends with a partially fluorinated sulfonated aromatic polyether have been prepared and characterized for high temperature proton exchange membrane fuel cells. Significant improvement in the polymer chemical stability in terms of the oxidative weight loss, molecular weight decrease and onset temperatures for the thermal SO2 and CO splitting-off was achieved with the electron-deficient polybenzimidazoles containing -S(O)(2)- and -C(CF3)(2)- bridging groups. Ionical cross-linking in the form of acid-base blends was found to further improve the polymer stability and assist maintaining the membrane integrity. Upon acid doping the membrane swelling was reduced for the modified PBI and their blend membranes, which, in turn, results in enhancement of the mechanical strength, proton conductivity and high temperature fuel cell performance. (C) 2009 Elsevier B.V. All rights reserved.

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State: Published
Organisations: Energy and Materials, Department of Chemistry, University of Stuttgart
Authors: Li, Q. (Intern), Rudbeck, H. C. (Ekstern), Chromik, A. (Ekstern), Jensen, J. O. (Intern), Pan, C. (Intern), Steenberg, T. (Intern), Calverley, M. (Intern), Bjerrum, N. (Intern), Kerres, J. (Ekstern)
Pages: 260-270
Publication date: 2010
Main Research Area: Technical/natural sciences

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Properties, Degradation and High Temperature Fuel Cell Test of Different Types of PBI and PBI Blend Membranes

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Original language: English
Polybenzimidazole (PBI) synthesis, Partially fluorinated polyether, Phosphoric acid, Blend membrane, Oxidative stability, Fuel cell

DOI: 10.1016/j.memsci.2009.10.032
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Publication: Research - peer-review › Journal article – Annual report year: 2010
Recent advances with high temperature PEMFC in Denmark

General information
State: Published
Organisations: Department of Chemistry, Danish Power Systems ApS
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Rudbeck, H. C. (Ekstern), Steenberg, T. (Ekstern), Bjerrum, N. (Intern)
Publication date: 2010

Publication Information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 272191
Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

The energy efficiency of onboard hydrogen storage

Global warming resulting from the use of fossil fuels is threatening the environment and energy efficiency is one of the most important ways to reduce this threat. Industry, transport and buildings are all high energy-using sectors in the world and even in the most technologically optimistic perspectives energy use is projected to increase in the next 50 years. How and when energy is used determines society’s ability to create long-term sustainable energy systems. This is why this book, focusing on energy efficiency in these sectors and from different perspectives, is sharp and also important for keeping a well-founded discussion on the subject.

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern)
Number of pages: 180
Pages: 143-156
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Bibliographical note
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Publication: Research - peer-review › Book chapter – Annual report year: 2010

The Energy Efficiency of Onboard Hydrogen Storage

General information
State: Published
Organisations: Department of Chemistry
New nitrogen-containing materials for hydrogen storage and their characterization by high-pressure microbalance

Hydrogen storage for practical applications is under intense scrutiny worldwide since hopes are prevalent of being able to use hydrogen as energy vector in a continually difficult time in terms of having access to clean and affordable energy in the world. Hydrogen can be stored in compressed or liquid form, technologies that are well developed and usable, but not energy efficient. Certain metals and alloys are able to contain hydrogen within practical pressure and temperature ranges very efficient volume-wise, but they are too heavy for use in cars. Recently, attention has turned to the so-called complex hydrides, which contain hydrogen bound covalently often in very light materials involving elements such as lithium, sodium, nitrogen and aluminum. While these materials typically have high decomposition temperatures, the combination with other compounds helps to destabilize the material resulting in lowered effective dehydrogenation temperatures. From the discovery in 1996 by Borislav Bogdanović and his group that catalyzed sodium alanate, NaAlH4, can release hydrogen reversibly below 200 °C relatively fast, hydrogen storage in nitrogen-containing compounds beginning with lithium nitride, Li3N, was considered a next major step in the succession of research in complex hydrides. Many complex hydrides involving nitrogen are presently under examination. This thesis reviews some of the results so far and embarks on a study of hydrogen storage in some of the compounds. Following a brief introduction in Chapter 1, Chapter 2 of the text deals with general principles and an overview for hydrogen storage in solid materials. Chapter 3-5 deals with the development of an in-house high pressure microbalance in a glovebox built from scratch for the use of characterizing new hydrogen storage materials including giving an example of characterization on a well-known hydrogen storage material, CaNi5. Chapter 6 contains results on a new system based on Li, Al and N for hydrogen storage. It was shown that Li3AlN2 can be synthesized from Li3N and Al under nitrogen pressure. Furthermore, the compound was proven to be able to store hydrogen reversibly. Chapter 7 describes first time results for a new hydrogen system based on Li, Si, and N. It discusses the synthesis of Li5SiN3 and Li2SiN2. Li5SiN3 was treated in-depth and was seen to be able to store hydrogen reversibly at fairly moderate conditions. Furthermore, the effect of doping a system of lithiumamide and silicon, LiNH2+Si, with TiCl3 was examined, showing vastly improved desorption conditions with increased doping loads. Chapter 8 is about the newly publicized "hydrogen" pill, which in this work was attempted to be turned into a real hydrogen pill as opposed to an ammonia pill. The findings point to the possibility of combining the material in the ammonia pill with other compounds, which make it possible to store hydrogen reversibly.
Degradation of high temperature PEM fuel cells

General information
State: Published
Organisations: Department of Chemistry, Energy and Materials
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2009

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 257539
Publication: Research › Sound/Visual production (digital) – Annual report year: 2009

Durability Issues of High Temperature Proton Exchange Membrane Fuel Cells Based on Acid Doped Polybenzimidazole Membranes

To achieve high temperature operation of proton exchange membrane fuel cells (PEMFC), preferably under ambient pressure, phosphoric acid doped polybenzimidazole (PBI) membrane represents an effective approach, which in recent years has motivated extensive research activities with great progress. As a critical concern, issues of long term durability of PBI based fuel cells are addressed in this talk, including oxidative degradation of the polymer, mechanical failures of the membrane, acid leaching out, corrosion of carbon support and sintering of catalysts particles. Excellent polymer durability has observed under continuous operation with hydrogen and air at 150-160°C, with a fuel cell performance degradation rate of 5-10 µV/h. Improvement of the membrane performance such as mechanical strength, swelling and oxidative stability has achieved by exploring the polymer chemistry, i.e. covalently or ionically cross-linking and structure modification. With load, thermal or startup-shutdown cycling, the performance loss was found to be much bigger, about 300 µV per cycle or 40 µV per operating hour, due to the increased acid loss and catalyst support corrosion, particularly under open circuit voltage operation. Further efforts are outlined to the future work.

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2009

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Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 257734
Publication: Research › Sound/Visual production (digital) – Annual report year: 2009

Durable Catalysts for High Temperature Proton Exchange Membrane Fuel Cells

Durability of proton exchange membrane fuel cells (PEMFCs) is recognized as one of the most important issues to be addressed before the commercialization. The failure mechanisms are not well understood, however, degradation of carbon supported noble metal catalysts is identified as a major failure mode of PEMFCs. Under idle, load-cycling or start-up/shutdown modes of operation, which are prerequisite for automobile applications, the cathode will experience...
significantly higher potentials and therefore suffer from serious carbon corrosion, especially at the presence of platinum. The carbon corrosion, in turn, triggers the agglomeration of platinum particles resulting in reduction of the active surface area and catalytic activity. This is a major mechanism of the catalyst degradation and a key challenge to the PEMFC long-term durability. High temperature PEMFC, on the other hand, has attached significant attention in recent years because of its potential advantages such as high CO tolerance, easy cooling, better heat utilization and possible integration with fuel processing units. However, the high temperature obviously aggravates the carbon corrosion and catalyst degradation. Based on thermally treated carbon black and structurally designed carbon nanotubes (CNTs) as support, highly dispersed and adhered platinum nanoparticles were prepared in this work. Surface functionalization and activation of the support materials were found to be able to boost the catalyst activity and improve the selectivity for platinum loading. Fuel cell durability tests in term of performance degradation were performed with acid doped polybenzimidazole membrane fuel cells at temperatures of up to 160°C. The tests were focused on catalyst degradation by means of a potential cycling protocol. The electrochemical active area of the electrode, hydrogen permeability of the membrane and the area specific resistance of the cell were also measured during the tests. Compared with active carbon black supported catalysts, significant improvement in the catalyst durability was achieved.
High temperature PEM fuel cells in Denmark

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2009

High temperature proton exchange membranes based on polybenzimidazoles for fuel cells
To achieve high temperature operation of proton exchange membrane fuel cells (PEMFC), preferably under ambient pressure, acid–base polymer membranes represent an effective approach. The phosphoric acid-doped polybenzimidazole membrane seems so far the most successful system in the field. It has in recent years motivated extensive research activities with great progress. This treatise is devoted to updating the development, covering polymer synthesis, membrane casting, physicochemical characterizations and fuel cell technologies. To optimize the membrane properties, high molecular weight polymers with synthetically modified or N-substituted structures have been synthesized. Techniques for membrane casting from organic solutions and directly from acid solutions have been developed. Ionic and covalent cross-linking as well as inorganic–organic composites has been explored. Membrane characterizations have been made including spectroscopy, water uptake and acid doping, thermal and oxidative stability, conductivity, electrosmotic water drag, methanol crossover, solubility and permeability of gases, and oxygen reduction kinetics. Related fuel cell technologies such as electrode and MEA fabrication have been developed and high temperature PEMFC has been successfully demonstrated at temperatures of up to 200 °C under ambient pressure. No gas humidification is mandatory, which enables the elimination of the complicated humidification system, compared with Nafion cells. Other operating features of the PBI cell include easy control of air flowrate, cell temperature and cooling. The PBI cell operating at above 150 °C can tolerate up to 1% CO and 10ppm SO2 in the fuel stream, allowing for simplification of the fuel processing system and possible integration of the fuel cell stack with fuel processing units. Long-term durability with a degradation rate of 5Vh−1 has been achieved under continuous operation with hydrogen and air at 150–160 °C. With load or thermal cycling, a performance loss of 300V per cycle or 40Vh−1 per operating hour was observed. Further improvement should be done by, e.g. optimizing the thermal and chemical stability of the polymer, acid–base interaction and acid management, activity and stability of catalyst and more importantly the catalyst support, as well as the integral interface between electrode and membrane.

General information
State: Published
Organisations: Department of Energy Conversion and Storage, Proton conductors, Department of Chemistry, Energy and Materials, Case Western Reserve University
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Savinell, R. F. (Ekstern), Bjerrum, N. J. (Intern)
Pages: 449-477
Publication date: 2009
Main Research Area: Technical/natural sciences
Journal: Progress in Polymer Science
Volume: 34
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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 8.123 SNIP 9.135 CiteScore 28.32
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 8.861 SNIP 11.126 CiteScore 29.82
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 10.358 SNIP 12.167 CiteScore 32.16
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 9.993 SNIP 12.313 CiteScore 26.96
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 10.19 SNIP 10.878 CiteScore 26.75
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 11.314 SNIP 10.48
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 11.43 SNIP 8.344
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2005): SJR 7.082 SNIP 7.266
Scopus rating (2004): SJR 5.506 SNIP 6.625
Scopus rating (2003): SJR 5.352 SNIP 5.738
Scopus rating (2001): SJR 3.493 SNIP 3.43
Scopus rating (2000): SJR 2.589 SNIP 3.229
Scopus rating (1999): SJR 3.138 SNIP 3.637
Original language: English
Durability, Polybenzimidazole (PBI), Cross-linking, Fuel cell, Phosphoric acid, High temperature proton exchange membrane

Electronic versions:
2009 PBI review Progress in Polymer Science 34, 5, 449-477.pdf
DOIs:
10.1016/j.progpolymsci.2008.12.003
Source: orbit
Source-ID: 232784
Publication: Research - peer-review › Journal article – Annual report year: 2009

PEM Fuel cells

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2009
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 257541
Publication: Research › Conference abstract for conference – Annual report year: 2009

PEM fuel cells at elevated temperature

General information
State: Published
Organisations: Department of Chemistry, Energy and Materials
Thermal coupling of a high temperature PEM fuel cell with a complex hydride tank

Sodium alanate doped with cerium catalyst has been proven to have fast kinetics for hydrogen ab- and de-sorption as well as a high gravimetric storage density around 5 wt%. The kinetics of hydrogen sorption can be improved by preparing the alanate as nanocrystalline material. However, the second decomposition step, i.e. the decomposition of the hexahydride to sodium hydride and aluminium which refers to 1.8 wt% hydrogen is supposed to happen above 110 degrees C. The discharge of the material is thus limited by the level of heat supplied to the hydride storage tank. Therefore, we evaluated the possibilities of a thermal coupling of a high temperature PEM fuel cell operating at 160-200 degrees C. The starting temperatures and temperature hold-times before starting fuel cell operation, the heat transfer characteristics of the hydride storage tanks, system temperature, fuel cell electrical power (including efficiency) as well as alanate kinetics were varied by system modelling with gPROMS (R). The kinetics of the hydride decomposition was found to have a major influence on the performance of the system. A cumulative output of 0.8 kWh was reached in a test run.
Water electrolysis at elevated temperatures

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Publication date: 2009
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 249181
Publication: Research - peer-review › Journal article – Annual report year: 2009

A high temperature PEMFC integrated with a diesel reforming system

General information
State: Published
Organisations: Department of Chemistry, Energy and Materials
Pages: 275-283
Publication date: 2008

Host publication information
Title of host publication: Energy Materials : Advances in Characterization, Modelling and Application
Volume: 29
Partially fluorinated aarylene polyethers and their ternary blends with PBI and H3PO4.: Part II. Characterisation and fuel cell tests of the ternary membranes

Ternary blend membranes based on sulphonated partially fluorinated aarylene polyether, polybenzimidazole (PBI) and phosphoric acid were prepared and characterised as electrolyte for high temperature proton exchange membrane fuel cells. Partially fluorinated aarylene polyether was first prepared from polycondensation of decafluorobiphenyl with 2,2-bis(4-hydroxyphenyl)hexafluoropropane, followed by sulphonation with H2SO4/60% SO3, based on which binary blends with PBI were prepared and further doped with concentrated phosphoric acid at temperatures of up to 130 degrees C. Acid doping levels as high as 10-13 mol phosphoric acid per PBI repeat unit can be reached, showing small swelling and excellent mechanical strength. At an acid doping level of 11, a conductivity of 0.12 S cm(-1) was obtained at 175 degrees C and 10% relative humidity. Such a membrane exhibits a tensile strength of 6 MPa, elongation of 220% and modulus of 50 MPa at 150 degrees C. Based on these ternary membranes large MEAs with an active area of 256 cm(2) have been prepared for a 2 kW(el) stack showing good performance and reproducibility.
Partially fluorinated arylen polyethers and their ternary blend membranes with PBI and H3PO4.: Part I. Synthesis and characterisation of polymers and binary blend membranes

A partially fluorinated polyether ionomer from polycondensation of decafluorobiphenyl with 2,2-bis(4-hydroxyphenyl)-hexafluoropropane, followed by sulphonation with H2SO4 (60% SO3), has been prepared and optimised in terms of molecular weight and sulphonation degree. The partially fluorinated ionomer has been blended with poly(2,2'-mphenylene-5,5'-bibenzimidazole) (PBI), yielding base-acid blends with PBI in excess. The base-acid blend membranes have been characterised in terms of solubility in DMAc, water uptake and oxidative stability by immersion in aqueous 5 wt.-% H2O2 solutions and Fenton's Reagent, respectively. Ionomers with molecular masses of up to 140,000 Da (non-sulphonated) and 178,000 Da (sulphonated) with excellent thermal stabilities and high sulphonation degrees of up to 2.06 SO3H groups per repeat unit have been produced. Their base-excess blend membranes, where the ionomer blend component served as acidic ionomeric cross-linker, showed excellent oxidative stabilities which were better than that of pure PBI and comparable to the oxidative stability of Naftlon (R) in Fenton's Reagent.
partially fluorinated polyether, GPC, PBI, Fentons test, oxidative stability, sulfinaion, base-acid blend membrane
Recent progress in high temperature PEM fuel cells

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern)
Publication date: 2008
Main Research Area: Technical/natural sciences

Development of a high-pressure microbalance for hydrogen storage materials
Pressure-composition isotherms (PCI's) help to determine thermodynamic properties related to hydrogen uptake of materials. PCI's are normally obtained volumetrically with a Sieverts type apparatus or gravimetrically with a microbalance. A potential problem with the gravimetric technique is that the sample is momentarily exposed to air when transferring it to the system often causing unwanted changes such as oxidation and reaction with moisture in the air. In this study, a high-pressure microbalance was built from scratch inside a glove box with inert atmosphere. The system consists of an electromagnetic microbalance, pressure resistant casing for up to 100 bar hydrogen, a flow system for hydrogen and inert gas, heating elements for temperature control, and software for controlling the system. Thermal convection effects are observed and dampened by heating on both the sample and a counterweight. The precision of the mass measurements for a 1 g sample was +/- 5 μg, and this range proved to be the same independent of pressure and temperature.

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Vestbø, A. P. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: 703-706
Publication date: 31 Oct 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Alloys and Compounds
Volume: 446
Issue number: Special Issue
ISSN (Print): 0925-8388
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.05 SJR 0.961 SNIP 1.321
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.987 SNIP 1.43 CiteScore 3.03
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.135 SNIP 1.66 CiteScore 3.13
Web of Science (2014): Indexed yes
Cross-linked polybenzimidazole membranes for fuel cells

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Li, Q. (Intern), Pan, C. (Intern), Jensen, J. O. (Intern), Precht Noyé, P. (Intern), Bjerrum, N. (Intern)
Pages: 350-352
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Chemistry of Materials
Volume: 19
Issue number: 3
ISSN (Print): 0897-4756
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 8.89 SJR 4.114 SNIP 1.905
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 4.038 SNIP 2.102 CiteScore 9.38
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.603 SNIP 2.253 CiteScore 8.89
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 3.658 SNIP 2.277 CiteScore 8.94
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 4.169 SNIP 2.264 CiteScore 8.1
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 3.484 SNIP 2.145 CiteScore 7.38
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 3.267 SNIP 1.849
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.894 SNIP 1.763
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.882 SNIP 1.844
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.111 SNIP 1.863
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 3.168 SNIP 1.943
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.746 SNIP 1.937
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.5 SNIP 1.976
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.56 SNIP 1.938
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 2.499 SNIP 1.894
Scopus rating (2001): SJR 2.321 SNIP 1.911
Scopus rating (2000): SJR 2.201 SNIP 1.686
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 2.23 SNIP 1.796
Original language: English
DOIs: 10.1021/cm0627793
Source: orbit
Source-ID: 207151
Publication: Research - peer-review › Journal article – Annual report year: 2007
Doping phosphoric acid in polybenzimidazole membranes for high temperature proton exchange membrane fuel cells

Polybenzimidazole (PBI) membranes were doped in phosphoric acid solutions of different concentrations at room temperature. The doping chemistry was studied using the Scatchard method. The energy distribution of the acid complexation in polymer membranes is heterogeneous, that is, there are two different types of sites in PBI for the acid doping. The protonation constants of PBI by phosphoric acid are found to be 12.7 L mol⁻¹ (K₁) for acid complexing sites with higher affinity, and 0.19 L mol⁻¹ (K₂) for the sites with lower affinity. The dissociation constants for the complexing acid onto these two types of PBI sites are found to be 5.4 X 10⁻⁴ and 3.6 X 10⁻², respectively, that is, about 10 times smaller than that of aqueous phosphoric acid in the first case but 5 times higher in the second. The proton conducting mechanism is also discussed.

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: He, R. (Ekstern), Li, Q. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: 2989-2997
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Polymer Science
Volume: 45
Issue number: 14
ISSN (Print): 0887-624X
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 1.053 SNIP 0.781 CiteScore 2.83
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.002 SNIP 0.849 CiteScore 2.93
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.094 SNIP 0.942 CiteScore 3.05
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.154 SNIP 0.983 CiteScore 3.41
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.486 SNIP 0.988 CiteScore 3.33
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.641 SNIP 0.997 CiteScore 3.64
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.74 SNIP 1.03
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.22 SNIP 1.111
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.897 SNIP 1.121
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.048 SNIP 1.148
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.921 SNIP 1.235
Further Improvement and System Integration of High Temperature Polymer Electrolyte Membrane Fuel Cells: 36 Month Periodic Activity Report

The strategic developments of the FURIM are in three steps: (1) further improvement of the high temperature polymer membranes and related materials; (2) development of technological units including fuel cell stack, hydrocarbon reformer and afterburner, that are compatible with the HT-PEMFC; and (3) integration of the HT-PEMFC stack with these compatible subunits. The main goal of the project is a 2kWel HT-PEMFC stack operating in a temperature range of 150-200°C, with a single cell performance target of 0.7 A/cm² at a cell voltage around 0.6 V. The target durability is more than 5,000 hours. A hydrocarbon reformer and a catalytic burner are to be developed and integrated with the stack. The key issue of the project is development and improvement of the temperature-resistant polymer membranes with respect to durability, conductivity, mechanical and other properties. For this purpose, basic polymers will be first synthesized and optimized. Different routes to functionalize the polymers will be explored to increase proton conductivity.

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern)
Number of pages: 137
Publication date: 2007

Further Improvement and System Integration of High Temperature Polymer Electrolyte Membrane Fuel Cells: 24 Month Periodic Activity Report

The new development in the field of polymer electrolyte membrane fuel cell (PEMFC) is high temperature PEMFC for operation above 100°C, which has been successfully demonstrated through the previous EC Joule III and the 5th framework programme. New challenges are encountered, bottlenecks for the new technology have been identified, and new concepts and solutions have been provisionally identified. FURIM is directed at tackling these key issues by concentrating on the further materials development, compatible technologies, and system integration of the high temperature PEMFC. The strategic developments of the FURIM are in three steps: (1) further improvement of the high temperature polymer membranes and related materials; (2) development of technological units including fuel cell stack, hydrocarbon reformer and afterburner, that are compatible with the HT-PEMFC; and (3) integration of the HT-PEMFC stack with these compatible subunits. The main goal of the project is a 2kWel HT-PEMFC stack operating in a temperature range of 150-200°C, with a single cell performance target of 0.7 A/cm² at a cell voltage around 0.6 V. The target durability is more than 5,000 hours. A hydrocarbon reformer and a catalytic burner are to be developed and integrated with the stack. The key issue of the project is development and improvement of the temperature-resistant polymer membranes with respect to durability, conductivity, mechanical and other properties. For this purpose, basic polymers will be first synthesized and optimized. Different routes to functionalize the polymers will be explored to increase proton conductivity.

By the development of advanced materials, demonstration of the high temperature PEMFC stack and integration of such a system, FURIM is expected to sufficiently promote the commercialisation of the fuel cell technology for both vehicle
High temperature PEMFC and the possible utilization of the excess heat for fuel processing

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry, Fluid Mechanics, Department of Mechanical Engineering
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Vestbø, A. P. (Intern), Mortensen, K. (Ekstern), Petersen, H. N. (Intern), Sørensen, C. L. (Ekstern), Clausen, T. N. (Ekstern), Schramm, J. (Intern), Bjerrum, N. (Intern)
Pages: 1567-1571
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Volume: 32
Issue number: 10-11
ISSN (Print): 0360-3199
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.74 SJR 1.142 SNIP 1.286
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.294 SNIP 1.319 CiteScore 3.46
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.212 SNIP 1.494 CiteScore 3.54
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.278 SNIP 1.467 CiteScore 3.38
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.515 SNIP 1.729 CiteScore 3.96
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.456 SNIP 1.837 CiteScore 4.42
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.589 SNIP 1.871
Membranes for High Temperature PEFC Based on Polybenimidazoles

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern)
Publication date: 2007

Host publication information
Title of host publication: Membrane Handbook : Membranes for Energy Conversion
Volume: Vol 2
Publisher: Wiley-VCH
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 195505
Publication: Research › Book chapter – Annual report year: 2007

Membranes for High Temperature PEMFC Based on Acid-Doped Polybenzimidazoles

General information
State: Published
Organisations: Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern)
Pages: 61-96
Publication date: 2007

Host publication information
Title of host publication: Membranes for Energy Conversion
Volume: 2
Publisher: Wiley-VCH
Editors: Peinemann, K., Nunes, S. P.
ISBN (Print): 978-3-527-31481-2
Chapter: 3
Main Research Area: Technical/natural sciences
Recent Development of PBI Membranes for PEMFC

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry, Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Precht Noyé, P. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Pages: 1-10
Publication date: 2007

Host publication information
Title of host publication: Proceedings of World Hydrogen Technologies Convention
Main Research Area: Technical/natural sciences

Bibliographical note
Plenary talk
Source: orbit
Source-ID: 207346
Publication: Research › Article in proceedings – Annual report year: 2007

The Energy Efficiency of Onboard Hydrogen Storage
A number of the most common ways of storing hydrogen are reviewed in terms of energy efficiency. Distinction is made between energy losses during regeneration and during hydrogen liberation. In the latter case, the energy might have to be provided by part of the released hydrogen, and the true storage density is then equivalently smaller. Systems covered include compressed and liquid hydrogen, reversible and irreversible metal hydrides, and methanol and ammonia.

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Jensen, J. O. (Intern), Vestbø, A. P. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern)
Pages: 723-728
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Alloys and Compounds
Volume: 446–447
ISSN (Print): 0925-8388
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
Brief Introduction to Fuel Cells, Hydrogen Production and Storage
Brint og brændselsceller

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. J. (Intern)
Pages: 106-119
Publication date: 2006

Host publication information
Title of host publication: Kemiske Horisonter
Place of publication: DTU
Publisher: Kemisk Institut, DTU
ISBN (Print): 87-91233-07-0
Main Research Area: Technical/natural sciences
Electronic versions: Kemiske_Horisonter.pdf
Publication: Communication › Book chapter – Annual report year: 2006

Development of a high-pressure microbalance for hydrogen storage materials

General information
State: Published
Organisations: Department of Chemistry
Authors: Vestbø, A. P. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Publication date: 2006
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 194259
Publication: Research - peer-review › Poster – Annual report year: 2006

FURIM

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern)
Publication date: 2006
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 195583
Publication: Research › Poster – Annual report year: 2006

Gas Diffusion Electrodes for PBI Cells
Physicochemical properties of phosphoric acid doped polybenzimidazole membranes for fuel cells

Polybenzimidazole (PBI) membranes have been prepared with different molecular weights. The water and acid swelling, mechanical strength, gas permeability and proton conductivity were studied for the pristine and acid doped PBI membranes. When doped with 5 mol of phosphoric acid per mole repeat unit of the polymer, a level necessary to obtain high enough proton conductivity for fuel cell uses, the polymer membrane exhibits a volume swelling by 118%, resulting in separation of the polymer backbones. The separation in turn reduces the mechanical strength of the membrane especially at high temperatures. Another consequence is the increased H2 and O2 permeability through the membrane. In the temperature range from 120 to 180 °C, the hydrogen permeability was found to be 1.6–4.3×10−17 and 1.2–4.0×10−15 mol cm cm−2 s−1 Pa−1 for pristine and acid doped PBI membranes, respectively, while for oxygen it was 5.0–10×10−19 and 3.0–9.4×10−16 mol cm cm−2 s−1 Pa−1, respectively. High molecular weights of the polymers improve the mechanical strength but have little influence on the proton conductivity of the membranes.

General information
State: Published
Organisations: Department of Chemistry
Authors: He, R. (Ekstern), Li, Q. (Intern), Bach, A. (Ekstern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: 38-45
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Membrane Science
Volume: 277
ISSN (Print): 0376-7388
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 6.13 SJR 2.062 SNIP 1.72
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2 SNIP 1.771 CiteScore 5.89
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.433 SNIP 1.935 CiteScore 5.42
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.452 SNIP 2.001 CiteScore 5.38
ISI indexed (2013): ISI indexed yes
Recent Progress in Preparation and Characterization of PBI Membranes for PEMFC

General information

State: Published
Organisations: Department of Chemistry, Department of Chemistry
Authors: Li, Q. (Intern), Precht Noyé, P. (Intern), Jensen, J. O. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Pages: Abstract 412
Publication date: 2006

Host publication information

Title of host publication: Meeting Abstracts - Electrochemical Society
Publisher: Electrochemical Society, Incorporated
Main Research Area: Technical/natural sciences
Electronic versions: Noy.pdf

Bibliographical note

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The Energy Efficiency of On-board Hydrogen Storage

General information
State: Published
Organisations: Department of Chemistry, Department of Chemistry
Authors: Jensen, J. O. (Intern), Vestbø, A. P. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern)
Publication date: 2006
Main Research Area: Technical/natural sciences

100-200°C Polymer Fuel Cells for use with NaAlH4

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Pages: 653-656
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Alloys and Compounds
Volume: 404-406
ISSN (Print): 0925-8388
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.05 SJR 0.961 SNIP 1.321
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.987 SNIP 1.43 CiteScore 3.03
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.135 SNIP 1.66 CiteScore 3.13
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.064 SNIP 1.597 CiteScore 2.73
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.249 SNIP 1.584 CiteScore 2.43
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.166 SNIP 1.479 CiteScore 2.41
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.07 SNIP 1.221
200°C PEM Fuel Cells

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Bjerrum, N. (Intern)
Publication date: 2005
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188070
Publication: Research › peer-review › Journal article – Annual report year: 2005

Danish Hydrogen Association

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Petersen, J. H. (Ekstern), Markussen, P. (Ekstern), Lundsgaard, J. S. (Ekstern), Mortensen, P. V. (Ekstern), Sloth, M. (Ekstern), Bjerregård, H. (Ekstern), Yde, L. (Ekstern), Rathmann, S. (Ekstern)
Publication date: 2005
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188088
Publication: Research › Poster – Annual report year: 2005

Fuel cells: a promise of electrochemistry and challenges for electrochemists

General information
State: Published
Organisations: Department of Chemistry
Fuel cells: a promise of electrochemistry and challenges for electrochemists

General information
State: Published
Organisations: Department of Chemistry, Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Precht Noyé, P. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2005
Event: Abstract from the 13th National Conference of Electrochemistry, Guangzhou, China.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 195611
Publication: Research › Conference abstract for conference – Annual report year: 2005

FURIM: Further improvement of high temperature PEM fuel cells

General information
State: Published
Organisations: Department of Chemistry, Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Precht Noyé, P. (Intern), Bjerrum, N. (Intern)
Publication date: 2005

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 195571
Publication: Research › Sound/Visual production (digital) – Annual report year: 2005

Further Improvement and System Integration of High Temperature Polymer Electrolyte Membrane Fuel Cells: 12 Month Periodic Activity Report

Polymer electrolyte membrane fuel cell (PEMFC) technology based on Nafion membranes can operate at temperatures around 80°C. The new development in the field is high temperature PEMFC for operation above 100°C, which has been successfully demonstrated through the previous EC Joule III and the 5th framework programme. New challenges are encountered, bottlenecks for the new technology have been identified, and new concepts and solutions have been
provisionally identified. FURIM is directed at tackling these key issues by concentrating on the further materials development, compatible technologies, and system integration of the high temperature PEMFC. The strategic developments of the FURIM are in three steps: (1) further improvement of the high temperature polymer membranes and related materials; (2) development of technological units including fuel cell stack, hydrocarbon reformer, afterburner and power management system, that are compatible with the HT-PEMFC; and (3) integration of the HT-PEMFC stack with these compatible subunits. The main goal of the project is a 2kWe HT-PEMFC stack operating in a temperature range of 120-220°C, with a single cell performance target of 0.7 A/cm² at a cell voltage around 0.6 V. The target durability is more than 5,000 hours. A hydrocarbon reformer and a catalytic burner are to be developed and integrated with the stack. The key issue of the project is development and improvement of the temperature-resistant polymer membranes with respect to durability, conductivity, mechanical and other properties. For this purpose, basic polymers will be first synthesized and optimized. Different routes to functionalize the polymers will be explored to increase proton conductivity. By the development of advanced materials, demonstration of the high temperature PEMFC stack and integration of such a system, FURIM is expected to sufficiently promote the commercialisation of the fuel cell technology for both vehicle propulsion and stationary applications.
HT-PEMFC as a bridge to new metal hydride systems

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Vestbø, A. P. (Intern), Bjerrum, N. (Intern)
Publication date: 2005
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188116
Publication: Research › Paper – Annual report year: 2005

Integration of high temperature PEM fuel cells with a methanol reformer

On-board generation of hydrogen by methanol reforming is an efficient and practical option to fuel PEMFC especially for vehicle propulsion purpose. The methanol reforming can take place at temperatures around 200°C with a nearly 100% conversion at a hydrogen yield of about 400 L–(h–kg catalyst)-1. The CO content in the reformate gas at this temperature is less than 0.2 vol%. The recently developed high temperature PEMFC based on acid doped PBI membranes can operate in the same temperature range and tolerate a few percent of CO in the feeding gas. The high CO tolerance makes it possible to use the reformate gas directly from the reformer without further CO removal. Integration of high temperature PEMFC with a reformer is expected to improve the system efficiency and simplify the system construction and operation. The present work has demonstrated this possibility. (c) 2005 Elsevier B.V. All rights reserved.

General information
State: Published
Organisations: Department of Chemistry, Northeastern University
Authors: Pan, C. (Intern), He, R. (Ekstern), Li, Q. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern), Hjulmand, H. A. (Ekstern), Jensen, A. B. (Ekstern)
Pages: 392-398
Publication date: 2005
Conference: Meeting on Fuel Cells Science and Technology, Munich, Germany, 06/10/2004 - 06/10/2004
Main Research Area: Technical/natural sciences
Publication information
Journal: Journal of Power Sources
Volume: 145
Issue number: 2
ISSN (Print): 0378-7753
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 6.22 SJR 1.945 SNIP 1.483
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.945 SNIP 1.686 CiteScore 6.34
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.983 SNIP 2.071 CiteScore 6.3
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Proton Conductivity and Operational Features Of PBI-Based Membranes

As an approach to high temperature operation of PEMFCs, acid-doped PBI membranes are under active development. The membrane exhibits high proton conductivity under low water contents at temperatures up to 200°C. Mechanisms of proton conduction for the membranes have been proposed. Based on the membranes fuel cell tests have been demonstrated. Operating features of the PBI cell include no humidification, high CO tolerance, better heat utilization and possible integration with fuel processing units. Issues for further development are also discussed.

General information
State: Published
Organisations: Department of Chemistry
Authors: Qingfeng, L. (Intern), Jensen, J. O. (Intern), Precht Noyé, P. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Pages: 267-272
Publication date: 2005

Host publication information
Title of host publication: Solid State Electrochemistry : Proceedings of the 26th Risoe International Symposium on Materials Science
Proton Exchange Membranes for Fuel Cells: - Challenges and Recent Developments

General information
State: Published
Organisations: Department of Chemistry
Authors: Qingfeng, L. (Intern), Jensen, J. O. (Intern), Precht Noyé, P. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Pages: 666-667
Publication date: 2005

Host publication information
Title of host publication: Journal of Fudan University (Natural Science)
Volume: 44 (5)
Place of publication: Shanghai
Main Research Area: Technical/natural sciences
Conference: 15th International Symposium on Fine Chemistry and Functional Polymers, Shanghai, China, 17/10/2005 - 17/10/2005
Source: orbit
Source-ID: 184841
Publication: Research › Article in proceedings – Annual report year: 2005

Proton Exchange Membranes For Fuel Cells - Challenges And Recent Developments

General information
State: Published
Organisations: Department of Chemistry, Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Precht Noyé, P. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Pages: 17-20
Publication date: 2005

Host publication information
Title of host publication: Proceedings of 15th International Symposium on Fine Chemistry and Functional Polymers
Main Research Area: Technical/natural sciences
Conference: 15th International Symposium on Fine Chemistry and Functional Polymers, Shanghai, China, 17/10/2005 - 17/10/2005
Source: orbit
Source-ID: 195610
Publication: Research › Article in proceedings – Annual report year: 2005

Recent Progress in High Temperature PEMFC and the Possible Utilization of the Excess Heat for Fuel Processing

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2005
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188098
Publication: Research › Conference abstract for conference – Annual report year: 2005

The FURIM Project

General information
State: Published
Organisations: Department of Chemistry
X-ray diffraction of subfractions of petroleum asphaltenes

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Department of Chemistry
Authors: Andersen, S. I. (Intern), Jensen, J. O. (Intern), Speight, J. G. (Ekstern)
Pages: 2371 - 2377
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Energy & Fuels
Volume: 19
Issue number: 6
ISSN (Print): 0887-0624
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.25
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
100-200°C Polymer Fuel Cells for use with NaAlH4

General information
State: Published
Organisations: Department of Chemistry, Technical University of Denmark
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), He, R. (Ekstern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2004
Event: Abstract from 9th International Symposium on Metal-Hydrogen Systems, Cracow, Poland.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188066
Publication: Research - peer-review › Journal article – Annual report year: 2005

An in-situ neutron diffraction study of the ageing of CaNi5Dx at 80°C and 9 bar.
The intrinsic ageing of the CaNi5Dx system has been studied at 80·°C and 9 bar over a period of 13 days. The system displays a distinct two-phase mixture of the intermediate and phases, whose phase proportions approach 40 and 50 wt.%, respectively at the end of the ageing period. The change in proportion of each intermediate phase and free fcc Ni suggests two periods of Ni depletion. The amount of free Ni in the system is doubled through the ageing period. The orthorhombic symmetry of the and phase is preserved, albeit with a strong depletion of three of the four Ni positions from the phase during the second half of the ageing period. That one half of the hexagonally equivalent 2c Ni position does not release Ni indicates that low symmetry geometrical ordering in orthorhombic symmetry is responsible for the rapid loss of recoverable hydrogen capacity in this system.

General information
State: Published
Organisations: Department of Chemistry
Authors: Pitt, M. (Ekstern), Brinks, H. (Ekstern), Jensen, J. O. (Intern), Hauback., B. (Ekstern)
Pages: 190–196
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Alloys and Compounds
Volume: 372
ISSN (Print): 0925-8388
Ratings:
BFI (2017): BFI-level 1
A PEMFC operating at up to 200°C as a possible link to the complex metal hydrides like NaAlH₄
Ca-Ni alloys and the search for lighter interstitial hydrides. New metal hydrides for hydrogen storage

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Publication date: 2004

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 195564
Publication: Research › Sound/Visual production (digital) – Annual report year: 2004

Materials Issues and System Prospects of High Temperature PEMFC

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), He, R. (Ekstern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2004
Event: Paper presented at The International Hydrogen Energy Forum, Beijing, P.R. China,
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 195614
Publication: Research › Paper – Annual report year: 2004

PBI-based polymer membranes for high temperature fuel cells – preparation, characterizations and fuel cell demonstrations

General information
State: Published
Organisations: Department of Chemistry
Authors: Qingfeng, L. (Intern), He, R. (Ekstern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: 147-159
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Fuel Cells
Volume: 4
ISSN (Print): 1615-6846
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.79 SJR 0.498 SNIP 0.62
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.699 SNIP 0.787 CiteScore 2.02
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Polymer Membranes for Fuel Cells

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Li, Q. (Intern), He, R. (Ekstern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Publication date: 2004
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 156077
Publication: Research - peer-review » Journal article – Annual report year: 2004

Acid-doped Polybenzimidazole Membranes as Electrolyte for Fuel Cells Operating Above 100°C
The technical achievement and challenges for the PEMFC technology based on perfluorosulfonic acid (PFSA) polymer membranes (e.g. Nafion®) are briefly discussed. The newest development in the field is alternative polymer electrolytes for operation above 100°C. As one of the successful approaches to high operational temperatures, the development and evaluation of acid doped PBI membranes are reviewed, covering polymer synthesis, membrane casting, acid doping, physiochemical characterization and fuel cell tests. A high temperature PEMFC system operational at up to 200°C is demonstrated with no gas humidification and high CO-tolerance up to 10 vol%. This high CO tolerance allows for a direct use of reformed hydrogen without further CO removal, which opens the possibility for an integrated reformer-fuel cell system. The content of this review is to a large extent based on research performed by the authors’ group.
Approaches and Recent Development of Polymer Electrolyte Membranes For Fuel Cells Operational Above 100°C: A Review

The state-of-the-art of polymer electrolyte membrane fuel cell (PEMFC) technology is based on perfluorosulfonic acid (PFSA) polymer membranes operating at a typical temperature of 80 °C. Some of the key issues and shortcomings of the PFSA-based PEMFC technology are briefly discussed. These include water management, CO poisoning, hydrogen, reformate and methanol as fuels, cooling, and heat recovery. As a means to solve these shortcomings, high-temperature polymer electrolyte membranes for operation above 100 °C are under active development. This treatise is devoted to a review of the area encompassing modified PFSA membranes, alternative sulfonated polymer and their composite membranes, and acid-base complex membranes. PFSA membranes have been modified by swelling with nonvolatile solvents and preparing composites with hydrophilic oxides and solid proton conductors. DMFC and H2/O2(air) cells based on modified PFSA membranes have been successfully operated at temperatures up to 120 °C under ambient pressure and up to 150 °C under 3-5 atm. Alternative polymers are selected from silicon- and fluorine-containing inorganic polymers or aromatic hydrocarbon polymers and functionalized by sulfonation. The sulfonated hydrocarbons and their inorganic composites are potentially promising for high-temperature operation. High conductivities have been obtained at temperatures up to 180 °C. Acid-base complex membranes constitute another class of electrolyte membranes. A high-temperature PEMFC based on H3PO4-doped PBI has been demonstrated for operation at temperatures up to 200 °C under ambient pressure. The advanced features include high CO tolerance, simple thermal and water management, and possible integration with the fuel processing unit.
CO tolerance by the PEMFC operational at temperatures up to 200°C

The CO poisoning effect on carbon-supported platinum catalysts in polymer electrolyte membrane fuel cells has been investigated in a temperature range from 125 to 200°C with the phosphoric acid-doped polybenzimidazole membranes as
electrolyte. The effect is very temperature-dependent and can be sufficiently suppressed at elevated temperature. By defining a poisoning factor as less than 2% of power loss due to the poisoning effect, it is evaluated that 3% CO in hydrogen can be tolerated at current densities up to 0.7 A/cm² at 200°C, while at 125°C 0.1% CO in hydrogen can be tolerated at current densities lower than 0.25 A/cm². For comparison, the tolerance is only 0.0025% CO (25 ppm) at 80°C at current densities up to 0.15 A/cm². The effect of CO₂ in hydrogen was also studied. At 175°C, 25% CO₂ in the fuel stream showed only the dilution effect.

**General information**
State: Published
Organisations: Department of Chemistry
Authors: Li, Q. (Intern), He, R. (Ekstern), Gao, J. (Ekstern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Number of pages: 848
Pages: 253-262
Publication date: 2003

**Host publication information**
Title of host publication: Proceedings of the 2nd European PEFC Forum
Volume: Volume 1
Place of publication: Switzerland
Publisher: European Fuel Cell Forum
Edition: 1
ISBN (Print): 3-905592-13-4
Main Research Area: Technical/natural sciences
Conference: The 2nd European PEFC Forum, Lucerne, Switzerland, 01/01/2003
Source: orbit
Source-ID: 50549
Publication: Research › Article in proceedings – Annual report year: 2003

**Fuel Cell Activities at DTU**

**General information**
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern)
Publication date: 2003

**Host publication information**
Title of host publication: Fuel Cell Activities at DTU
Place of publication: Reykjavik, Iceland
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188082
Publication: Research › Article in proceedings – Annual report year: 2003

**High Temperature Polymer Fuel Cells.**

**General information**
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern)
Publication date: 2003

**Publication information**
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 195562
Publication: Research › Sound/Visual production (digital) – Annual report year: 2003

**HIGH TEMPERATURE POLYMER FUEL CELLS: HEAT UTILIZATION AND CO TOLERANCE**

This paper will report recent results from our group on polymer fuel cells (PEMFC) based on the temperature resistant polymer polybenzimidazole (PBI), which allow working temperatures up to 200°C. The membrane has a water drag number near zero and need no water management at all. The high working temperature allows for utilization of the excess heat for fuel processing. Moreover, it provides an excellent CO tolerance of several percent, and the system needs no purification of hydrogen from a reformer. Continuous service for over 6 months at 150°C has been demonstrated.
High temperature polymer fuel cells and their Interplay with fuel processing systems.
This paper reports recent results from our group on polymer electrolyte membrane fuel cells (PEMFC) based on the temperature resistant polymer polybenzimidazole (PBI), which allow working temperatures up to 200°C. The membrane has a water drag number near zero and need no water management at all. The high working temperature allows for utilization of the excess heat for fuel processing. Moreover, it provides an excellent CO tolerance of several percent, and the system needs no purification of hydrogen from a reformer. Continuous service for over 6 months at 150°C has been demonstrated.

Integration of high temperature PEMFC with a methanol reformer

Lifetime Test of High Temperature PEM Fuel Cells
Light Metal Hydrides: Application of Bulk Materials

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Li, Q. (Intern), He, R. (Ekstern), Pan, C. (Intern), Bjerrum, N. (Intern)
Publication date: 2003

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Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 195557
Publication: Research › Sound/Visual production (digital) – Annual report year: 2003

New Polymer Electrolyte Membranes For Fuel Cells

General information
State: Published
Organisations: Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), He, R. (Ekstern), Gao, J. (Ekstern), Bjerrum, N. (Intern)
Number of pages: 933
Pages: 685-696
Publication date: 2003

Host publication information
Title of host publication: Proceedings of HYPOTHESIS V (Hydrogen Power Theoretical and Engineering Solutions International Symposium)
Volume: 5
ISBN (Print): 88-86281-90-0
Main Research Area: Technical/natural sciences
Conference: HYPOTHESIS V (Hydrogen Power Theoretical and Engineering Solutions International Symposium, 01/01/2003
Source: orbit
Source-ID: 195606
Publication: Research › Article in proceedings – Annual report year: 2003

NEW POLYMER ELECTROLYTE MEMBRANES FOR FUEL CELLS OPERATING ABOVE 100°C: - APPROACHES AND RECENT PROGRESS
The state-of-the-art of PEMFC technology is based on perfluorosulfonic acid (PFSA) polymer membranes operating at a typical temperature of 80°C. The newest development in the field is alternative polymer electrolytes for operation above 100°C. This paper is devoted to a review on the development, which is classified into three groups: modified PFSA membranes, alternative sulfonated polymer and their inorganic composite membranes and acid-base complex membranes. High temperature PEMFC has been demonstrated with advanced features such as fast electrode kinetics, high CO tolerance, simple thermal and water management and possible integration with the fuel processing unit.

General information
State: Published
Organisations: Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), He, R. (Ekstern), Bjerrum, N. (Intern)
Publication date: 2003

Host publication information
Title of host publication: Proceedings of the 1st European Hydrogen Energy Conference
Main Research Area: Technical/natural sciences
Conference: 1st European Hydrogen Energy Conference, Grenoble, France, 01/01/2003
Source: orbit
Source-ID: 50590
Publication: Research › Article in proceedings – Annual report year: 2003

The CO poisoning effect in PEMFCs operational at temperatures up to 200 degrees C
The CO poisoning effect on carbon-supported platinum catalysts (at a loading of 0.5 mg Pt/cm² per electrode) in polymer electrolyte membrane fuel cells (PEMFCs) has been investigated in a temperature range from 125 to 200 degrees C with
the phosphoric acid-doped polybenzimidazole membranes as electrolyte. The effect is very temperature-dependent and can be sufficiently suppressed at elevated temperature. By defining the CO tolerance as a voltage loss less than 10 mV, it is evaluated that 3% CO in hydrogen can be tolerated at current densities up to 0.8 A/cm(2) at 200 degreesC, while at 125 degreesC 0.1% CO in hydrogen can be tolerated at current densities lower than 0.3 A/cm(2). For comparison, the tolerance is only 0.0025% CO (25 ppm) at 80 degreesC at current densities up to 0.2 A/cm(2). The relative anode activity for hydrogen oxidation was calculated as a function of the CO concentration and temperature. The effect of CO2 in hydrogen was also studied. At 175 degreesC, 25% CO2 in the fuel stream showed only the dilution effect. (C) 2003 The Electrochemical Society.

General information
State: Published
Organisations: Department of Chemistry, Department of Chemistry
Authors: Li, Q. (Intern), He, R. (Ekstern), Gao, J. (Ekstern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Pages: A1599-A1605
Publication date: 2003
Main Research Area: Technical/natural sciences

Publication information
Journal: Electrochemical Society. Journal
Volume: 150
Issue number: 12
ISSN (Print): 0013-4651
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.97 SJR 1.134 SNIP 0.867
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.037 SNIP 1 CiteScore 3.17
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.147 SNIP 1.206 CiteScore 3.36
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.151 SNIP 1.299 CiteScore 2.92
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.329 SNIP 1.296 CiteScore 2.61
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.33 SNIP 1.345 CiteScore 2.74
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.417 SNIP 1.312
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.45 SNIP 1.267
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.608 SNIP 1.416
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.58 SNIP 1.325
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.611 SNIP 1.54
Stability of CaNi5Hx stored at temperatures between 20 and 150 degrees C

The stability of CaNi5Hx stored at different temperatures was studied as a function of time. In general AB(5) metal hydrides are known to be metastable with a tendency to disproportionate at elevated temperatures. In the present study samples of CaNi5 were stored in the hydrided state (as CaNi5Hsimilar to4.7) at temperatures between 20 and 150degreesC. After different periods of time, up to 120 days, the hydrogen absorption capacity was measured electrochemically. Significant capacity decays were observed at temperatures of 40degreesC and higher. The capacity decay with storage time tended to stop at a level of 147 mAh/g corresponding to 1.83 hydrogen atoms per calcium atom. X-ray diffraction revealed that the CaCu5 structure was preserved after the degradation. A mathematical model for the decay is proposed.
The electrochemical impedance of metal hydride electrodes

The electrochemical impedance responses for different laboratory type metal hydride electrodes were successfully modeled and fitted to experimental data for AB5 type hydrogen storage alloys as well as one MgNi type electrode. The models fitted the experimental data remarkably well. Several AC equivalent circuits have been proposed in the literature. The experimental data, however, could not always be satisfactorily approximated. The approximation model presented here exhibits smooth fit to the experimental results for all frequencies in the whole range from 10 kHz to 0.1 mHz. Equivalent circuits, explaining the experimental impedances in a wide frequency range for electrodes of hydride forming materials mixed with copper powder, were obtained. Both charge transfer and spherical diffusion of hydrogen in the particles are important sub processes that govern the total rate of the electrochemical hydrogen absorption/desorption reaction. To approximate the experimental data, equations describing the current distribution in porous electrodes were needed. Indications of one or more parallel reduction/oxidation processes competing with the electrochemical hydrogen absorption/desorption reaction were observed. The impedance analysis was found to be an efficient method for characterizing metal hydride electrodes in situ.
High Temperature Polymer Fuel Cells

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Qingfeng, L. (Intern), Hennesø, E. (Intern), Hjuler, H. (Ekstern), Bjerrum, N. (Intern)
Publication date: 2001
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 50520
Publication: Research › Poster – Annual report year: 2001

Hydrogen Power

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Qingfeng, L. (Intern)
Publication date: 2001
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 50522
Publication: Research › Paper – Annual report year: 2001

The carbon monoxide poisoning effect on the performance of polymer electrolyte membrane fuel cells operational at temperatures up to 200°C

General information
State: Published
Organisations: Department of Chemistry
Authors: Qingfeng, L. (Intern), Zhou, D. (Ekstern), He, R. (Intern), Jensen, J. O. (Intern), Hjuler, H. A. (Ekstern), Bjerrum, N. (Intern)
Pages: 407-411
Publication date: 2001

Host publication information
Volume: 2
Place of publication: Stralsund, Germany
Publisher: Fachhochschule Stralsund
ISBN (Print): 3-9807963-0-2
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 156078
Publication: Research › Article in proceedings – Annual report year: 2001
Development of air metal hydride battery

General information
State: Published
Organisations: Department of Chemistry
Authors: Bjerrum, N. (Intern), Jensen, J. O. (Intern), al, E. (Ekstern)
Publication date: 2000
Event: Poster session presented at Hydrogen - Electrochemistry and Energetics: How far are we from the Hydrogen Society ?, Trondheim, Norway, .
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188079
Publication: Research › Poster – Annual report year: 2000

Mechanical Alloying for the Preparation of Alloys not Easily Cast (CaNi5, MgNi and MoCo3)

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Nørbygaard, T. N. (Ekstern), Berg, R. W. (Intern)
Pages: 247-252
Publication date: 2000

Host publication information
Title of host publication: Progress in Molten Salts Chemistry, Vol. 1
Publisher: Elsevier
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 176745
Publication: Research - peer-review › Article in proceedings – Annual report year: 2000

Metalhydridbatterier og lavtemperaturbrændselscelle

General information
State: Published
Organisations: Energy and Materials, Department of Chemistry
Authors: Li, Q. (Intern), Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Number of pages: 144
Pages: 34-43
Publication date: 2000

Host publication information
Title of host publication: Dansk electrokemi i 200 år
Publisher: Dansk Selskab for Historisk Kemi
Editor: Bostrup, O.
ISBN (Print): 87-89535-20-0
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 207355
Publication: Research › Book chapter – Annual report year: 2000

Metal hydride storage tank for demonstration in hydrogen vehicle

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Hennesø, E. (Intern), Bjerrum, N. (Intern)
Pages: 133-139
Publication date: 2000

Host publication information
Title of host publication: Proceedings of the Nordic Workshop on Materials for Energy Conversion: Bardøla Høyfjellshotel
Stability of CaNi5HX stored at temperatures between 20 and 150°C

General information
State: Published
Organisations: Department of Chemistry, Technical University of Denmark
Authors: Jensen, J. O. (Intern), Møller, T. S. (Ekstern), Bjerrum, N. (Intern)
Publication date: 2000
Event: Abstract from 7th International Symposium on Metal-Hydrogen Systems, Noosa, Australia.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188080
Publication: Research › Conference abstract for conference – Annual report year: 2000

Development of Air Metal Hydride Battery (Amhbat): Fourth Periodic Report 1/12-98 til 30/11-99

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (ed.) (Intern), Bjerrum, N. (ed.) (Intern)
Number of pages: 81
Publication date: 1999

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 174810
Publication: Research › peer-review › Report – Annual report year: 1999

Development of Air Metal Hydride Battery (Amhbat): Mid-term Review

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (ed.) (Intern), Bjerrum, N. (ed.) (Intern)
Number of pages: 33
Publication date: 1999

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 174812
Publication: Research › peer-review › Report – Annual report year: 1999

Metal hydrides for electrodes: Towards higher capacity

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Publication date: 1999

Host publication information
Title of host publication: Nordic workshop on hydrogen in electrochemical energy conversion
Place of publication: Ås
Structural studies of disordered Mg2NiH4 formed by mechanical grinding

The low temperature phase of Mg2NiH4 was mechanically ground in argon atmosphere. The ordered monoclinic structure was destroyed to form the disordered cubic structure, previously only found above 510 K. With a Guinier-Hagg X-ray camera the cell parameter was determined to be a=6.492(3) Ångstrom. By performing a Rietveld refinement on neutron diffraction data it was confirmed that the disordered structure is similar to the high temperature form of Mg2NiH4 (space group Fm3m). (C) 1999 Elsevier Science S.A. All rights reserved.

General information
State: Published
Organisations: Department of Chemistry, Stockholm University
Authors: Rönnebro, E. (Ekstern), Jensen, J. O. (Intern), Noréus, D. (Ekstern), Bjerrum, N. (Intern)
Pages: 146-149
Publication date: 1999
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Alloys and Compounds
Volume: 293-295
ISSN (Print): 0925-8388
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.05 SJR 0.961 SNIP 1.321
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.987 SNIP 1.43 CiteScore 3.03
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.135 SNIP 1.66 CiteScore 3.13
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.064 SNIP 1.597 CiteScore 2.73
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.249 SNIP 1.584 CiteScore 2.43
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.166 SNIP 1.479 CiteScore 2.41
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.07 SNIP 1.221
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.957 SNIP 1.367
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Systematic B-metal substitution in CaNi5

The aim of this work has been to study the effect of B metal substitutions in CaNi5 (AB(5)) which is known to suffer from poor cycling stability as a hydride electrode material. Systematic monosubstitutions of nickel with the most common other B metals (i.e. Al, Cr, Mn, Fe, Co, Cu, Zn and Sn) and Mg were performed. The overall composition was in all cases CaNi5-xMx (x=0.5 or 1) where M is the substituting element. The alloys were prepared by mechanical alloying. The hydrogen storage capacity was measured electrochemically ranging from 39 to 390 mAh/g, but none of the substitutions increased the cycling stability to any significant extend compared to pure CaNi5. X-ray diffraction patterns of the alloys revealed that only in a few cases the hexagonal CaCu5 structure of a true AB(5) alloy was preserved. In most cases diffraction patterns matching Ca2Ni7, CaNi3 or CaNi2 were seen. It can be concluded that CaNi5 is much less tolerant towards B-metal substitution than LaNi5. This fact makes it less possible that the problem with cycling stability of Ca-based hydride electrodes can be solved by substitutions. (C) 1999 Elsevier Science S.A. All rights reserved.
Development of Air Metal Hydride Battery (Amhbat): Second Periodic Report 1/12-97 til 30/11-98

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (ed.) (Intern), Bjerrum, N. (ed.) (Intern)
Number of pages: 95
Publication date: 1998

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 170606
Publication: Research - peer-review › Report – Annual report year: 1998

Structural studies of disordered Mg2NiH4 formed by mechanical grinding

General information
State: Published
Organisations: Department of Chemistry, Stockholm University
Authors: Rönnebro, E. (Ekstern), Jensen, J. O. (Intern), Noréus, D. (Ekstern), Bjerrum, N. (Intern)
Publication date: 1998
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188078
Publication: Research › Conference abstract for conference – Annual report year: 1998

Systematic B-metal substitution in CaNi5

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern), Bjerrum, N. (Intern)
Publication date: 1998
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 188077
Publication: Research › Poster – Annual report year: 1998

Anodematerialer til metalhydridbatterier

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern)
Number of pages: 149
Publication date: 1997

Publication information
Original language: Danish
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 174824
Publication: Research - peer-review › Report – Annual report year: 1997
Anodematerials for Metal Hydride Batteries

This report describes the work on development of hydride forming alloys for use as electrode materials in metal hydride batteries. The work has primarily been concentrated on calcium based alloys derived from the compound CaNi5. This compound has a higher capacity compared with alloys used in today's hydride batteries, but a much poorer stability towards repeated charge/discharge cycling. The aim was to see if the cycleability of CaNi5 could be enhanced enough by modifications to make the compound a suitable electrode material. An alloying method based on mechanical alloying in a planetary ball mill was developed. The parameters milling time, milling intensity, number of balls and form of the alloying metals were investigated. Based on this a final alloying technique for the subsequent preparation of electrode materials was established. The technique comprises milling for 4 hours twice possibly followed by annealing at 700°C for 12 hours. The alloys appeared to be nanocrystalline with an average crystallite size around 10 nm before annealing. Special steel containers was developed for the annealing of the metal powders in inert atmosphere. The use of various annealing temperatures was investigated. The hydrogen absorbing alloy CaNi5 has been prepared by mechanical alloying and the structure was confirmed by X-ray diffraction. Gas absorption as well as electrochemical experiments showed hydride forming properties as fully developed as for a corresponding commercial alloy. For the electrochemical investigations simple methods were developed as for the manufacture of hydride electrodes as well as Hg/HgO reference electrodes. It is shown that CaNi5 is not corroded during currentless storage in 6M KOH in the uncharged state. The degradation process is closely related to charge and discharge. Upon cycling the capacity of the calcium containing electrodes decreased rapidly following an exponential-like curve. The decay curve levelled out around 30 mAh/g, the capacity only falling very slowly hereafter. This residual capacity was independent of the discharge current density in the range from 50 to 200 mAh/g. A suggested explanation of the residual capacity is the oxidation of Ni(0) to Ni(II) at the surface of the nickel remaining after leaching of calcium. A number of alloys with an overall formula of CaNi5-xMx (x = 0, 0.5 or 1 and M = Al, Co, Cr, Cu, Fe, Mg, Mn, Sn or Zn) were prepared and electrodes of these were cycled at constant current (100 mAh/g). Alloys with M = Cu, Mg or Zn had capacities between 321 and 390 mAh/g (CaNi5: 388 mAh/g). The rest of the alloys had even lower capacities. No alloys showed any significantly higher stability towards cycling. The AB5 phase (CaCu5 structure) was maintained for M = Cu, Zn and to some extend for M = Sn. In the other cases A2B7 and AB3 compounds with Gd2Co7- and PuNi3-structures were formed. It is shown that magnesium occupies positions normally occupied by calcium in calcium nickel alloys. Ca0.67Mg0.33Ni3 was prepared with PuNi3 structure. The compound can be regarded as CaNi3 with partial substitution of magnesium for calcium. The alloy had a capacity of 390 mAh/g and a little higher stability towards cycling than CaNi5. The alloys were also cycled "as milled" (without annealing). The capacities were then in general lower, but the stability somewhat higher. The higher stability is explained by a smaller volume expansion during charge. It is shown that sodium can substitute for calcium forming the compound Ca0.8Na0.2Ni5. The compound had CaCu5 structure and a capacity of 365 mAh/g but a poor electrochemical cycle life. The alloys Ca0.8Na0.2Ni4Mg0.5Cu0.5 and CaNi3.6Co0.7Mn0.4A10.3 were prepared and tested and found to have capacities of 325 mAh/g and 147 mAh/g, respectively. The cycle lives were also poor for these alloys. It is concluded that despite substitutions calcium alloys are not suited as electrode materials in an alkaline aqueous electrolyte. The Mischmetal alloy MmNi3.6Co0.7Mn0.4A10.3 was prepared with CaCu5 structure. The capacity and cycleability were a little poorer than a corresponding commercial alloy but activation was much faster. An amorphous magnesium nickel alloy with a capacity of 532 mAh/g at 18 mA/g was prepared. This capacity is at least at the level of the best results found in literature.
Metalhydrid til batteriformål: Kortlægning af udviklingmulighederne indenfor metalhydridforskningen på Kemisk Laboratorium A, Danmarks Tekniske Højskole

General information
State: Published
Organisations: Department of Chemistry
Authors: Jensen, J. O. (Intern)
Number of pages: 19
Publication date: 1993

Publication Information
Original language: Danish
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 174820
Publication: Research - peer-review › Report – Annual report year: 1993

Projects:

Development of Porous Electrodes for Alkaline Electrolyzers
Department of Energy Conversion and Storage
Period: 01/09/2017 → 31/08/2020
Number of participants: 4
Phd Student: Reumert, Alexander Kappel (Intern)
Supervisor: Cleemann, Lars Nilausen (Intern)
Kraglund, Mikkel Rykær (Intern)
Main Supervisor: Jensen, Jens Oluf (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Active Magnetic regenerator refrigeration with rotary multi-bed technology
Department of Energy Conversion and Storage
Period: 01/04/2016 → 20/09/2016
Number of participants: 7
Phd Student: Eriksen, Dan (Intern)
Supervisor: Bahl, Christian (Intern)
Bjørk, Rasmus (Intern)
Main Supervisor: Engelbrecht, Kurt (Intern)
Examiner: Jensen, Jens Oluf (Intern)
Kitanovski, Andrej (Ekstern)
Palm, Björn (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)

**Relations**
Publications:
Active magnetic regenerator refrigeration with rotary multi-bed technology
Project: PhD

**Development of a new synthesis for highly active fuel cell electrocatalysis**
Department of Energy Conversion and Storage
Period: 15/12/2015 → 14/12/2018
Number of participants: 4
Phd Student:
Brandes, Benedikt Axel (Intern)
Supervisor:
Cleemann, Lars Nilausen (Intern)
Li, Qingfeng (Intern)
Main Supervisor:
Jensen, Jens Oluf (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

**Development of non-precious metal polymer fuel cell catalysts**
Department of Energy Conversion and Storage
Period: 15/09/2015 → 14/09/2018
Number of participants: 4
Phd Student:
Shypunov, Illia (Intern)
Supervisor:
Cleemann, Lars Nilausen (Intern)
Li, Qingfeng (Intern)
Main Supervisor:
Jensen, Jens Oluf (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

**Acid-base chemistry and HT-polymer electrolyte membranes**
Department of Energy Conversion and Storage
Period: 15/12/2014 → 14/12/2017
Number of participants: 3
Phd Student:
Becker, Hans (Intern)
Supervisor:
Jensen, Jens Oluf (Intern)
Main Supervisor:
Li, Qingfeng (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Development of High temperature PEM fuel cells
Department of Energy Conversion and Storage
Period: 15/11/2014 → 14/11/2017
Number of participants: 2
Phd Student:
Kannan, Arvind (Intern)
Main Supervisor:
Jensen, Jens Oluf (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

Robust HT-MEAs for Dynamic Operation under Smart Grid Conditions
Department of Electrical Engineering
Center for Electric Power and Energy
Energy resources, services and control
Department of Energy Conversion and Storage
Proton conductors
Period: 01/08/2014 → 01/08/2017
Number of participants: 3
Acronym: SmartMEA
Project participant:
Pensini, Alessandro (Intern)
Træholt, Chresten (Intern)
Project Manager, organisational:
Jensen, Jens Oluf (Intern)

Alkaline Electrolyser Cell
Department of Energy Conversion and Storage
Period: 01/08/2014 → 31/07/2017
Number of participants: 8
Phd Student:
Kraglund, Mikkel Rykær (Intern)
Supervisor:
Aili, David (Intern)
Jensen, Jens Oluf (Intern)
Nikiforov, Aleksey Valerievich (Intern)
Main Supervisor:
Christensen, Erik (Intern)
Examiner:
Chatzichristodoulou, Christodoulos (Intern)
Sunde, Svein (Ekstern)
Therkildsen, Kasper Tipsmark (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD
Development of Proton Conductive membranes

Department of Energy Conversion and Storage
Period: 01/05/2014 → 09/07/2017
Number of participants: 7
Phd Student:
Kirkebæk, Andreas (Intern)
Supervisor:
Aili, David (Intern)
Jensen, Jens Oluf (Intern)
Main Supervisor:
Li, Qingfeng (Intern)
Examiner:
Søndergaard, Roar R. (Intern)
Hjuler, Hans Aage (Intern)
Kerres, Jochen (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Noble Metals Free Intermediate -Temperature Supported Liquid Phase Electrolyzer
The strategic development of the NobleFree project is noble metal free intermediate-temperature (200-400 C) fuel cells and water electrolyser with the same characteristics as of the Nafion®, PBI and Aquivion™ systems. This goal will be achieved by use of alkaline metals dihydrogen phosphates as proton-conducting supported liquid phase electrolytes (SLPE). These electrolytes will be liquid immobilized on ceramic nano fibers, whiskers and powders. It has been discovered recently, that nickel, high-nickel alloys and austenitic stainless steels containing small amounts of Ti have high corrosion resistance in the molten alkali metals dihydrogen phosphates in the above mentioned temperature range. The NobleFree will start with the parallel development of electrolytes and nickel-based catalysts. The final stage of the project will be design and test of noble metal free intermediate temperature water electrolyser. Possibilities of use SLPE system as a fuel cell will be also studied.

Department of Energy Conversion and Storage
Proton conductors
Energy and Materials
Period: 01/01/2014 → ...
Number of participants: 5
Acronym: Noble Free
Project participant:
Nikiforov, Aleksey Valerievich (Intern)
Bjerrum, Niels J. (Intern)
Petrushina, Irina (Intern)
Christensen, Erik (Intern)
Jensen, Jens Oluf (Intern)

Elektrokatalyse og Katalysatorer til Oxygenreduktion i Polymer Brændselceller
Department of Energy Conversion and Storage
Period: 01/01/2014 → 17/05/2017
Number of participants: 7
Phd Student:
Zhong, Lijie (Intern)
Supervisor:
Cleemann, Lars Nilausen (Intern)
Jensen, Jens Oluf (Intern)
Main Supervisor:
Li, Qingfeng (Intern)
Examiner:
Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering

Relations
Publications:
Graphitic Layer Encapsulated Iron Based Non-precious Catalysts for the Oxygen Reduction Reaction
Project: PhD

HT PEMFC Durability and Lifetime
Department of Energy Conversion and Storage
Period: 01/04/2013 → 30/06/2016
Number of participants: 7
Phd Student:
Søndergaard, Tonny (Intern)
Supervisor:
Cleemann, Lars Nilausen (Intern)
Li, Qingfeng (Intern)
Main Supervisor:
Jensen, Jens Oluf (Intern)
Examiner:
Petrushina, Irina (Intern)
Bajo, Justo Lobato (Ekstern)
Grahl-Madsen, Laila (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

Pressurized HT PEM Cells for H2/O2 operation
Department of Energy Conversion and Storage
Period: 01/08/2012 → 30/09/2015
Number of participants: 7
Phd Student:
Søndergaard, Stine (Intern)
Supervisor:
Cleemann, Lars Nilausen (Intern)
Jensen, Jens Oluf (Intern)
Main Supervisor:
Bjerrum, Niels J. (Intern)
Examiner:
Petrushina, Irina (Intern)
Schmidt, Thomas Justus (Ekstern)
Steenberg, Thomas (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering
Project: PhD

High-efficiency, low-cost electrode surfaces for next generation alkaline electrolysis
Department of Energy Conversion and Storage
Proton conductors

Energy and Materials

Department of Chemistry

Department of Chemistry
Period: 14/12/2011 → 12/12/2014
Number of participants: 3
Alkaline Electrolysis, Water splitting, Electrodes, Sustainable Energy
Project ID: J.nr. 068-2011-1
Project participant:
Nikiforov, Aleksey Valerievich (Intern)
Jensen, Jens Oluf (Intern)
Bjerrum, Niels J. (Intern)

Project

Optimizing the anaerobic digestion of manure

Department of Chemical and Biochemical Engineering
Period: 01/12/2011 → 01/07/2015
Number of participants: 6
Phd Student:
Sun, Guotao (Intern)
Supervisor:
Thygesen, Anders (Intern)
Main Supervisor:
Meyer, Anne S. (Intern)
Examiner:
Jørgensen, Henning (Intern)
Jensen, Jens Oluf (Intern)
Kroff, Pablo (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Stipendie fra udlandet
Project: PhD

Højtemperatur PEM Brandselsceller og organiske brændsler

Department of Energy Conversion and Storage
Period: 01/08/2010 → 30/09/2014
Number of participants: 7
Phd Student:
Vassiliev, Anton (Intern)
Supervisor:
Jensen, Jens Oluf (Intern)
Li, Qingfeng (Intern)
Main Supervisor:
Bjerrum, Niels J. (Intern)
Examiner:
Christensen, Erik (Intern)
Arico, Antonino Salvatore (Ekstern)
Kær, Søren Knudsen (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD
**Intermediate Temperature Proton Conducting Systems (PROCON)**

Energy and Materials  
Department of Chemistry  
Period: 01/06/2010 → 31/05/2013  
Number of participants: 6  
Acronym: PROCON  
Project participant:  
Li, Qingfeng (Intern)  
Petrushina, Irina (Intern)  
Jensen, Jens Oluf (Intern)  
Christensen, Erik (Intern)  
Cleemann, Lars Nilausen (Intern)  
Project Manager, organisational:  
Bjerrum, Niels J. (Intern)  

**Financing sources**  
Source: Forsk. Andre statslige danske - Grundforskn.fonden  
Name of research programme: Forsk. Andre statslige danske - Grundforskn.fonden  
Amount: 15,000,000.00 Danish Kroner  

**Development of improved electrodes in high temperature PEM fuel cells**  
Department of Energy Conversion and Storage  
Period: 15/03/2010 → 11/12/2013  
Number of participants: 7  
Phd Student:  
Permyakova, Anastasia Aleksandrovna (Intern)  
Supervisor:  
Jensen, Jens Oluf (Intern)  
Li, Qingfeng (Intern)  
Main Supervisor:  
Bjerrum, Niels J. (Intern)  
Examiner:  
Christensen, Erik (Intern)  
Arenz, Matthias (Ekstern)  
Bajo, Justo Lobato (Ekstern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: DTU, Samfinansiering  
Project: PhD  

**Fuel Cell Hydrogen Manifold for Lift Trucks**  
Department of Mechanical Engineering  
Period: 01/01/2010 → 04/04/2013  
Number of participants: 6  
Phd Student:  
Hosseinzadeh, Elham (Intern)  
Supervisor:  
Elmegaard, Brian (Intern)  
Main Supervisor:  
Rokni, Masoud (Intern)  
Examiner:  
Jensen, Jens Oluf (Intern)  
Nielsen, Mads Pagh (Ekstern)  
Yuan, Jinliang (Ekstern)
New Electrolytes for CO2 Electrolysis Cells

Department of Energy Conversion and Storage  
Period: 01/09/2009 → 19/03/2013  
Number of participants: 7  
PhD Student:  
Mollerup, Pia Lolk (Intern)  
Supervisor:  
Bonanos, Nikolaos (Intern)  
Tullmar, Peter Blennov (Ekstern)  
Main Supervisor:  
Holtappels, Peter (Intern)  
Examiner:  
Jensen, Jens Oluf (Intern)  
Friedrich, Kaspar Andreas (Ekstern)  
Kiros, Yohannes (Ekstern)

Danish high temperature PEMFC components, MEA and stack

Energy and Materials  
Energinet.dk  
Danish Power Systems ApS  
IRD Fuel Cells A/S  
Dantherm Power A/S  
Period: 01/04/2009 → 31/03/2013  
Number of participants: 9  
Acronym: HotMEA  
Project ID: 40469  
Project participant:  
Li, Qingfeng (Intern)  
Jensen, Jens Oluf (Intern)  
Permyakova, Anastasia Aleksandrovna (Intern)  
Behnke, Kim (Ekstern)  
Steenberg, Thomas (Ekstern)  
Lundsgaard, Jørgen (Ekstern)  
Themsen, Jesper (Ekstern)  
Albæk, Per (Ekstern)  
Project Manager, organisational:  
Bjerrum, Niels J. (Intern)

Financing sources
Source: Forskningsprojekter - Miljø- og Energiministeriet  
Name of research programme: Forskningsprojekter - Miljø- og Energiministeriet  
Project
**Fremstilling og synteseanvendelse af elektrolytisk fremstillet hydrogen**

Department of Energy Conversion and Storage  
Period: 01/03/2009 → 23/05/2012  
Number of participants: 7  
Phd Student:  
Hansen, Martin Kalmar (Intern)  
Supervisor:  
Christensen, Erik (Intern)  
Jensen, Jens Oluf (Intern)  
Main Supervisor:  
Bjerrum, Niels J. (Intern)  
Examiner:  
Petrushina, Irina (Intern)  
Bouzek, Karel (Ekstern)  
Steenberg, Thomas (Intern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Institut stipendie (DTU) Samf.  
Project: PhD

**Production of Hydrogen by Electrolysis**

Department of Chemistry  
Period: 01/06/2007 → 15/10/2008  
Number of participants: 4  
Phd Student:  
Wonsyld, Karen (Intern)  
Supervisor:  
Jensen, Jens Oluf (Intern)  
Petrushina, Irina (Intern)  
Main Supervisor:  
Bjerrum, Niels J. (Intern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: 1/3 DTU-stip, 2/3 FUR/andet  
Project: PhD

**Dry, intrinsic proton conducting membranes for fuel cells**

Department of Chemistry  
University of Copenhagen  
Danish Polymer Center  
Danish Power Systems ApS  
Period: 01/01/2006 → 31/12/2008  
Number of participants: 6  
Project participant:  
Li, Qingfeng (Intern)  
Jensen, Jens Oluf (Intern)  
Begstrup, Michael (Ekstern)  
Planckett, David Victor (Ekstern)  
Steenberg, Thomas (Ekstern)  
Project Manager, organisational:  
Bjerrum, Niels J. (Intern)  

**Financing sources**  
Source: Forskningsrådene - STVF  
Name of research programme: Forskningsrådene - STVF
Udvikling af lette materaler til brintlagring

Department of Chemistry
Period: 01/11/2005 → 01/04/2009
Number of participants: 7
Phd Student:
Vestbø, Andreas Peter (Intern)
Supervisor:
Barner, Jens H. Von (Intern)
Jensen, Jens Oluf (Intern)
Main Supervisor:
Bjerrum, Niels J. (Intern)
Examiner:
Jacobsen, Torben (Ekstern)
Jensen, Torben René (Ekstern)
Noréus, Dag (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

New Metal Hydrides for Energy Storage

Department of Chemistry
Department of Physics
Institute for Energy Technology
Stockholm University
University of Oslo
Lithuanian Energy Institute
Helsinki University of Technology
Period: 01/01/2003 → 31/12/2006
Number of participants: 8
Project ID: 62-02
Project participant:
Jensen, Jens Oluf (Intern)
Noréus, Dag (Ekstern)
Fjellvåg, Helmer (Ekstern)
Noréus, Dag (Ekstern)
Milcius, Darius (Ekstern)
Lampinen, Markku J. (Ekstern)
Project Manager, organisational:
Bjerrum, Niels J. (Intern)
Hauback, Bjørn C. (Ekstern)

Financing sources
Source: Forsk. Andre offentlige og private - Nordiske
Name of research programme: Forsk. Andre offentlige og private - Nordiske
Amount: 500,000.00 Danish Kroner
Project

Fremstilling og Karakterisering af nye Metalhydridere til Lagring af Brint

Department of Chemical and Biochemical Engineering
Period: 01/10/2002 → 07/03/2006
Number of participants: 8
Phd Student:
Andreasen, Anders (Ekstern)
Supervisor:
Besenbacher, Flemming (Intern)
Dahl, Søren (Intern)
Pedersen, Allan Schrøder (Intern)
Main Supervisor:
Chorkendorff, Ib (Intern)
Examiner:
Jensen, Jens Oluf (Intern)
Fichtner, Maximilian (Ekstern)
Züttel, Andreas (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Risø (Løn)
Project: PhD

High Temperature Polymer Methanol Fuel Cell,
Department of Chemistry
Statoil ASA
Norwegian University of Science and Technology
Volvo Teknisk Utveckling AB
Period: 01/01/2001 → 31/12/2002
Number of participants: 6
Project ID: P00030
Project participant:
Kløv, Kåre (Ekstern)
Jensen, Jens Oluf (Intern)
Li, Qingfeng (Intern)
Tunold, Reidar (Ekstern)
Ekdunge, Per (Ekstern)
Project Manager, organisational:
Bjerrum, Niels J. (Intern)

Financing sources
Source: Forsk. Andre offentlige og private - Nordiske
Name of research programme: Forsk. Andre offentlige og private - Nordiske
Amount: 512,500.00 Danish Kroner
Project

Metal hydride storage tank for hydrogen vehicle
The aim of the project is to develop and produce a metal hydride based hydrogen storage tank for demonstration purposes. The tank will be used (1) in a hydrogen car with combustion engine reconstructed by "Nordvestlyske Folkcenter for Vedvarende Energi" and (2) in a car with fuel cells from IRD A/S in cooperation with Fiat.

Department of Chemistry
Risø National Laboratory for Sustainable Energy
IRD A/S
Period: 01/01/1999 → 30/06/2000
Number of participants: 3
Project participant:
Jensen, Jens Oluf (Intern)
Hennesø, Erik (Intern)
Project Manager, organisational:
Development of air metal hydride battery (AMHBAT)

Development of air metal hydride battery (AMHBAT). The aim of the project is to develop a rechargeable air hydride battery to be used in electric vehicles (EV). The operating principle of an air metal hydride battery is rather simple: Water is split into hydrogen and oxygen as the battery is charged. Oxygen is released to the atmosphere and hydrogen is stored in the negative electrode which is made of a hydrogen storage alloy similar to those used in nickel metal hydride batteries. On discharge the process is reversed, and stored hydrogen recombines with atmospheric oxygen to form water. The air hydride battery has been studied since 1988 at Helsinki University of Technology (HUT) and the state of the art is a prototype batteries (24 V, 360 W) made by HUT and the Finnish company Hydrocell. The project involves 5 European universities and 6 industries. It is Supported by the European Community (JOULE, fourth framework programme).

Electrochemical and Spectroscopic Investigation of Electrochemical Cells and Catalysts

The project is concerned with a study of the different non-aqueous chemical processes using electrochemical (cyclic voltammetry, square-wave voltammetry, chronoamperometry etc.) and spectroscopic (Raman, IR, ESR, NMR etc.) techniques. All the studied processes involve electrochemical steps or electrochemical techniques were used for their study. The project involves investigation of following electrochemical reaction or systems: 1. Electroplating with refractory metals (niobium, tantalum) from molten salts. 2. Phosphoric acid, molten carbonate and solid oxide fuel cells. 3. Development of the active materials for nickel-metal hydride batteries. 4. Study of the mechanism of the catalytic SO2 oxidation using electrochemical techniques.
Lubricants for Cold Forging of Stainless Steel

One of the major problems related to cold forging of stainless steel is to secure sufficient lubrication during the process. The severe conditions during the process (i.e. high normal pressures and large surface expansion) usually requires a two component lubricant system consisting of a porous carrier coating lubricated with a suitable lubricant. This project deals with the development of two new lubricant systems for cold forging of stainless steel. The lubricant systems are based on zinc phosphate and iron(III) chloride respectively. The zinc phosphate coating serves as a porous “carrier coating” for the actual lubricant (i.e. sodium stearate or MoS2). Iron(III) chloride can be used alone or in combination with MoS2 or graphite. The work has been focusing on application methods, characterisation and tribological tests. An electrochemical method for depositing zinc/calcium phosphate coatings on stainless steel from an aqueous nitric acid solution has been developed. The method involves hydrogen evolution at the surface of the specimen and the deposition occurs due to decreasing solubility of the metal phosphates at increasing pH. The lubrication mechanism of iron(III) chloride is believed to involve the reaction between iron(III) chloride and the stainless steel surface to form iron(II) chloride. Results from backward can extrusion tests confirm that this reaction contributes significantly to the lubrication properties. Backward can extrusion tests of zinc/calcium phosphate (lubricated with sodium stearate) and iron(III) chloride show that a height/diameter ratio of more than two can be obtained. A height/diameter ratio of 1.2 can be obtained with the current State of The Art lubricant system (Iron oxalate combined with MoS2).

Anode Materials for Metal Hydride Batteries

The aim is to develop new hydrogen storage alloys. The alloys are to be used as active material in the negative electrode of nickel metal hydride batteries (NiMH). State-of-the-art for NiMH is intermetallic compounds based on rare earth elements. These are developed from LaNi5. CaNi5 has the same structure and comparable hydrogen storage properties. If suitable electrode materials can be developed based on CaNi5, there is a potential for cheaper materials with a higher capacity. Intermetallics based on CaNi5 with partial substitutions are prepared and tested during the project. The hydrogen storage alloys are prepared from the elements by mechanical alloying in a planetary ball mill. After milling for several hours nanocrystalline intermetallics or amorphous alloys are formed. The alloys are characterized by X-ray powder diffraction before and after annealing in inert atmosphere. The hydrogen storage capacity is measured by gas absorption and the electrochemical properties are tested in half cells.
Activities:

International Carisma Conference
Period: 1 Dec 2014 → 3 Dec 2014
Jens Oluf Jensen (Speaker)
Department of Energy Conversion and Storage
Proton conductors

Description

Related event
International Carisma Conference
01/12/2014 → 03/12/2014
Cape Town, South Africa
Activity: Talks and presentations › Conference presentations

Conference on Energy and Environment for the Future
Jens Oluf Jensen (Speaker)
Department of Energy Conversion and Storage
Proton conductors

Description

Related event
Conference on Energy and Environment for the Future: Sustainable energy for a fossil free society and environmentally friendly technologies
Copenhagen, Denmark
Activity: Talks and presentations › Conference presentations

A Stability Study of Alkali Doped PBI Membranes for Alkaline Electrolyzer Cells
Jens Oluf Jensen (Invited speaker)
Department of Energy Conversion and Storage
Proton conductors

Related event
226th Meeting of the Electrochemical Society (ECS) and 7th Meeting of the Mexico Section of the Electrochemical Society ECS and SMEQ Joint International Meeting : Joint international meeting
05/10/2014 → 09/10/2014
Cancun, Mexico
Activity: Talks and presentations › Conference presentations

Solid State Protonic Conductors - 17
Period: 14 Sep 2014 → 19 Sep 2014
Jens Oluf Jensen (Invited speaker)
Department of Energy Conversion and Storage
Proton conductors

**Description**

One great advantage of the most common fuel cells, the polymer-based fuel cells, is the low operating temperature which allows for easy and fast start-up and a variety of materials for construction and sealing. However, over the years the interest for increasing the working temperature has been growing. The motivation is diverse. A slight increase above 100-120°C is desired by the automotive industry to ease thermal control. This has been attempted via optimization of the perfluorosulphonic acid-based membranes. A further increase to 140-200°C is desired to increase the tolerance to CO and thus to ease the integration with a reformer for carbonaceous fuels. This has been achieved by the phosphoric acid doped polymer membranes like polybenzimidazole with the added benefit that water management is unnecessary. The next step in temperature could be to go above 230-250°C in order to utilize the waste heat for methanol steam reforming. This is most realistic with solid inorganic proton conductors or molten salts and phosphate systems like CsH2PO4 have proven promising. At even higher temperature reforming of dimethyl ether and after that ethanol should be possible. Another advantage of increased temperature might be that a candidate for replacing platinum as catalyst is more easily found. From the other end of the fuel cell temperature window solid oxide fuel cells are developing in the direction of lower operating temperatures from initially 1000°C to 600-700°C or even lower. The limiting factor is oxide ion conductivity, but which temperature would ultimately be the optimum if one could choose freely? The presentation will elaborate on the benefits of the different working temperatures based on simple system requirements with and without fuel reformers. Overall criteria are energy efficiency and system simplicity.


**Related event**

**Solid State Protonic Conductors - 17**
14/09/2014 → 19/12/2014
Seoul, Korea, Republic of
Activity: Talks and presentations › Conference presentations

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**Related event**

**20th World Hydrogen Energy Conference 2014**
Period: 15 Jun 2014 → 20 Jun 2014
Jens Oluf Jensen (Speaker)
Department of Energy Conversion and Storage
Proton conductors

**Description**


**Related event**

**20th World Hydrogen Energy Conference 2014**
15/06/2014 → 20/06/2014
Gwangju Metropolitan City, Korea, Republic of
Activity: Talks and presentations › Conference presentations