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.
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.

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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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Projects:

Development of Porous Electrodes for Alkaline Electrolysers
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

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