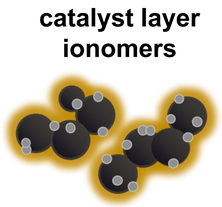
Development of Polymer Electrolytes for Electrochemical Devices

Sarah Eun Joo Park | MPA-11: Materials Synthesis and Integrated Devices, Los Alamos National Laboratory | 2020 DOE Hydrogen and Fuel Cell Technologies Postdoctoral Research Awardee

Polymer electrolytes used in electrochemical devices

Development of high-performing polymer electrolytes used for alkaline membrane fuel cells, high temperature proton exchange membrane fuel cells, and alkaline membrane water electrolyzers

- Ion exchange group-functionalized polymers are used as polymer electrolytes to conduct ions between electrodes while separating fuels and oxidants in the system.
- Polymer structure and properties may bring a huge impact on overall performance and durability of the system.
- Structural engineering of polymers is necessary for different electrochemical energy conversion and storage device requirements.



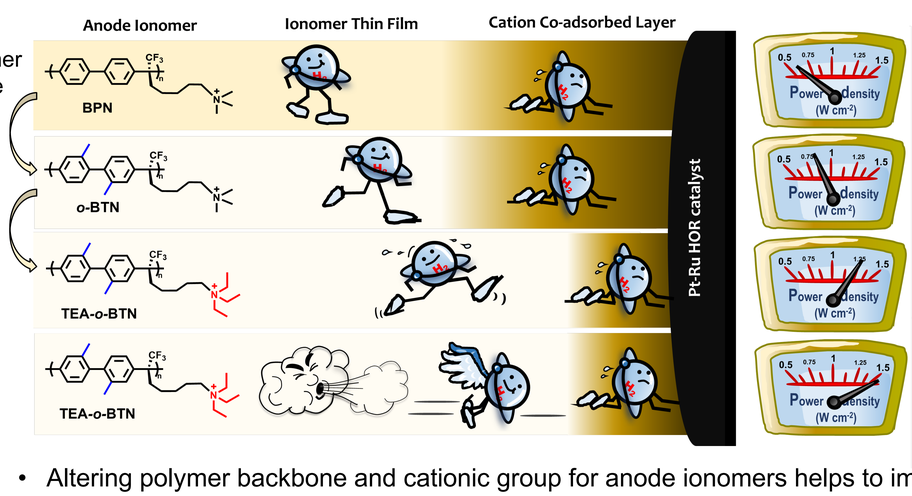
Anode ionomers for alkaline membrane fuel cells

Polymer electrolytes with higher H_2 diffusivity for ionomeric binding materials for the anode to improve the hydrogen oxidation reaction (HOR) kinetics

Challenges for anode ionomers:
1. Limited H_2 permeability, 2. Cation-hydroxide-water co-adsorption on HOR catalysts

Introducing symmetric dimethyl groups to polymer backbone to increase the fractional free volume to enhance H_2 permeability

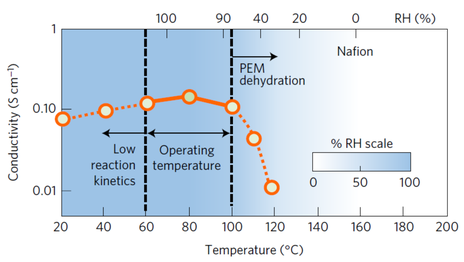
Replacing trimethylammonium with triethylammonium to minimize undesirable interaction with HOR catalysts



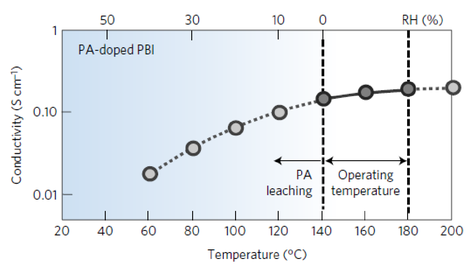
- Altering polymer backbone and cationic group for anode ionomers helps to improve H_2 permeability and fuel cell performance. The synthesis work of fluorinated anode ionomers to further increase gas diffusivity and electrode hydrophobicity is ongoing.

Phosphonated polymers for high temperature fuel cells

Synthesis of phosphonated polymer electrolytes to prevent the loss of conductive acid during operation

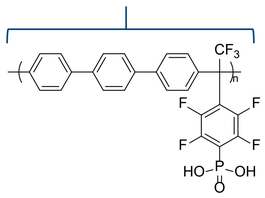


Perfluorinated sulfonic acid polymers (Nafion)
low proton conductivity at high temperature and low relative humidity (RH)



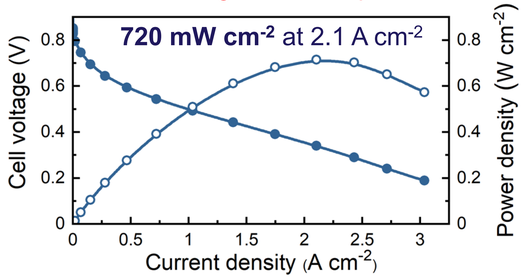
Phosphoric acid-doped polybenzimidazole (PA-doped PBI)
PA leaching and/or evaporation

Aryl ether-free polyaromatic backbone



Good solubility in polar aprotic solvents, thermally stable up to 350 °C

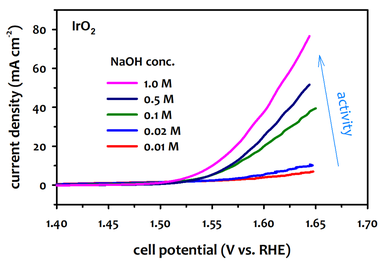
Highly acidic phosphonic acid
No phosphonic acid anhydride formation



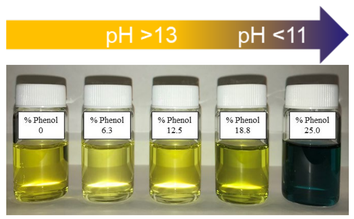
- The phosphonated polymer was developed to be used as an ionomeric binder for high temperature proton exchange membrane fuel cells at 200 °C.

Ionomers for alkaline membrane water electrolyzers

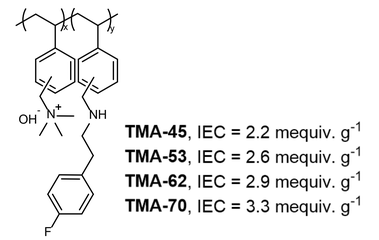
Synthesis of quaternized ammonium functionalized ionomers having high ion exchange capacity (IEC) for alkaline membrane water electrolysis



A high concentration of quaternary ammonium is required for high activity of hydrogen and oxygen evolution reactions.



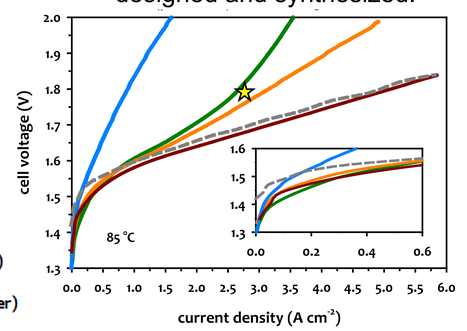
Polyaromatic backbone has a detrimental impact by forming acidic phenols at high anode potentials.



TMA-45, IEC = 2.2 mequiv. g^{-1}
TMA-53, IEC = 2.6 mequiv. g^{-1}
TMA-62, IEC = 2.9 mequiv. g^{-1}
TMA-70, IEC = 3.3 mequiv. g^{-1}

Polystyrene ionomers with high quaternary ammonium concentration were designed and synthesized.

- The highest IEC ionomer, TMA-70, demonstrated a record high performance, hydrogen-generating current density of 2.7 A/cm^2 at 1.8 V.
- The durability of the electrolyzer still remains as challenge because of the poor binding ability of the high IEC ionomer to the catalysts.



Acknowledgement US DOE, EERE, HFTO; ARPA-E; Los Alamos National Laboratory: Y.S. Kim, R. Mukundan, S. Maurya, D. Li, D. Leonard, A. Lee, H. Chung; Sandia National Laboratory: C. Fujimoto, M. Hibbs, E. Baca; Rensselaer Polytechnic Institute: C. Bae, S. Noh, J.Y. Jeon; Max-Planck-Institut für Festkörperforschung: K-D. Kreuer; Washington State University: W. Zhu, Q. Shi, Y. Zhou, H. Tian, Y. Lin; Pajarito Powder LLC: A. Serov, B. Zulevi

LA-UR-21-24420

Reference: *Nature energy* **2016**, *1*, 16120; **E.J. Park**†, S. Maurya† et al. *Journal of Material Chemistry A* **2019**, *7*, 25040; D. Li†, **E.J. Park**†, W. Zhu† et al. *Nature Energy* **2020**, *5*, 378.

Los Alamos NATIONAL LABORATORY