The Influence of Pre-Irradiation and Simultaneous Grafting Methods on the Physicochemical Properties of Polyethylene-Based Anion-Exchange Membranes and Ionomers

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Abstract

Controlling the synthesis parameters during radiation-induced grafting (RIG) is a key feature to design anion-exchange membranes (AEMs) with enhanced properties that lead to high performances and stability. The present study provides a systematic investigation of the effect of RIG methods on physicochemical properties of LDPE-based AEMs with similar degree of grafting (DoG) and ion exchange capacity (IEC). The LDPE films were grafted with 4-vinylbenzyl chloride using two methods: i) pre-irradiation (PIM), using electron-beam (EB), and ii) simultaneous (SM), using gamma-ray (γ), both in air atmosphere and with different absorbed doses. The AEMs grafted by SM were irradiated with 20, 25, and 30 kGy, while the ones grafted by PIM were irradiated with doses of 30, 70, and 100 kGy. Samples grafted by the two different methods have the same molecular structure, but distinct physicochemical properties due to markedly differences in the degree of crosslinking. The studies have shown that grafting step directly influences the internal structure and morphology of AEMs. Multi-technique characterization demonstrated that RIG method determines the mechanical properties, water

transport, and the distribution of ionic groups in AEMs. These characteristics have direct impact on fuel cell performance, anion-conductivity, and AEM stability.

Figure 1 shows the polarization curves of anion-exchange membrane fuel cells (AEMFCs) operating at 80 °C with AEMs grafted by PIM and SM. Comparing AEMFCs performances containing AEMs with similar IECs from the two different grafting methods, it is possible to notice that AEMs synthesized by PIM, in general, promote better fuel cell performances than the corresponding ones prepared by SM. The main differences in the polarization curves are evidenced in the ohmic and the mass transport limiting regions. This result suggests that water management is enhanced in AEMs synthesized by PIM compared to the SM-AEMs. A membrane that allows rapid back diffusion of liquid water from the anode to the cathode, should reduce the current losses due to mass transport limitations.

The gel content results confirmed the presence of more crosslinking in membranes synthesized by PIM than in the ones synthesized by the SM. As a consequence of that, enhanced mechanical properties were found for PIM-AEMs, indicating polymer backbone reinforcement due to high degree of crosslinking. Small-angle X-ray scattering measurements have confirmed that the microstructure of PIM and SM AEMs are different and this feature is directly related to ion conduction and water transportation.

Figure 1. AEMFCs performances at 80 °C with LDPE-based AEMs grafted by the pre-irradiation method and by the simultaneous method. H_2 anode gas flow=0.8 L min^{-1}, O_2 cathode gas flow=0.5 L min^{-1}, both supplied unpressurized with optimal dewpoint temperatures ranging from 77 to 80 °C. AEMs are referred according to the grafting method and absorbed dose. 30 and 70-EB-PIM refer to the samples irradiated with 30 and 70 kGy, respectively, in the EB accelerator and grafted by the pre-irradiation method. 20 and 25-γ-SM refer to AEMs irradiated with 20 and 25 kGy, respectively, by γ-rays and grafted by the simultaneous method.

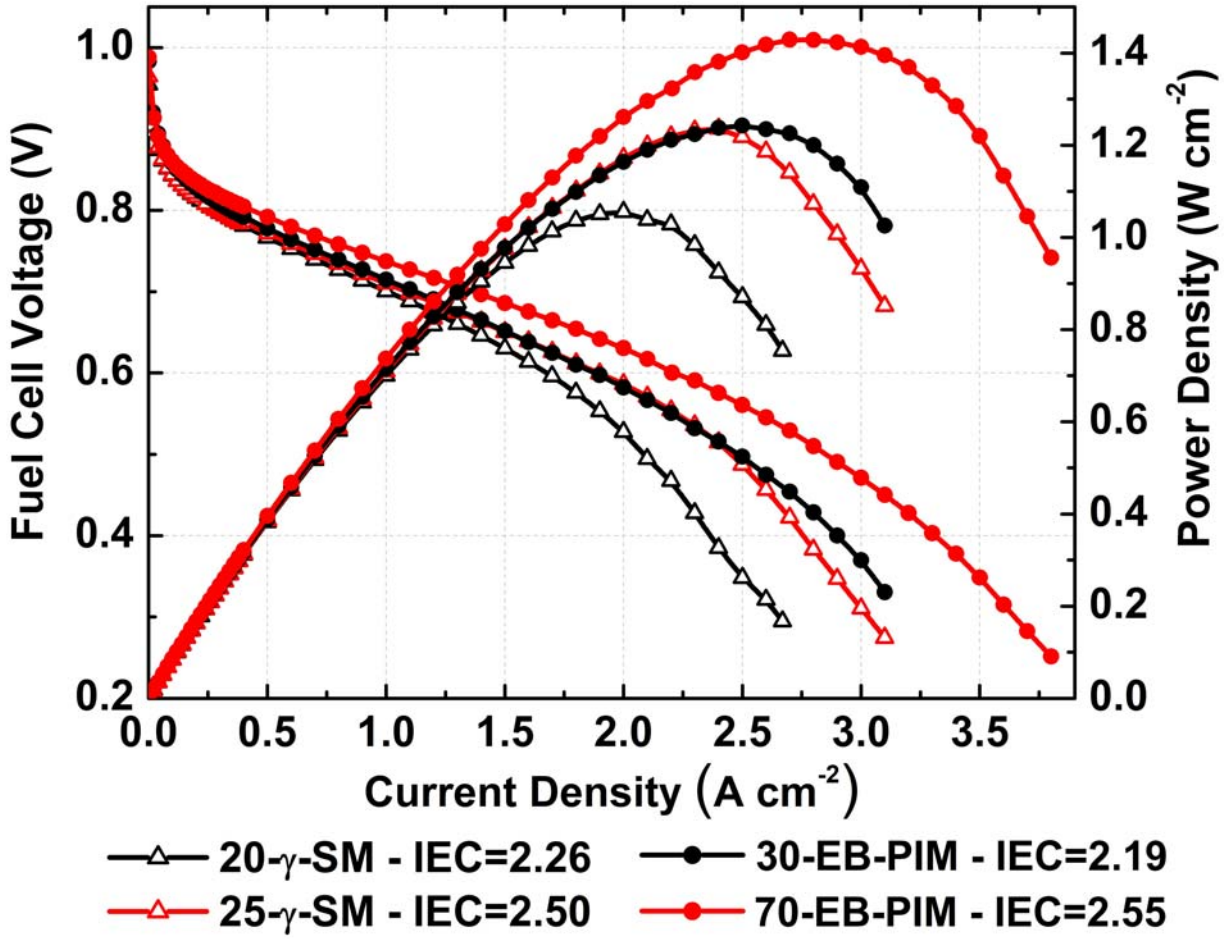

Figure 1

Exchange Membranes

The Latest Developments in Radiation-Grafted Anion-Exchange Polymer Electrolytes for Low Temperature Electrochemical Systems

Synthesis and Alkaline Stability of Solubilized Anion Exchange Membrane Binders Based on Poly(phenylene oxide) Functionalized with Quaternary Ammonium Groups via a Hexyl Spacer

Imidazolium-Based Anion Exchange Membranes for Alkaline Anion Fuel Cells: Interplay between Morphology and Anion Transport Behavior

Alkaline Durable Anion-Conducting Electrolyte Membranes Prepared by Radiation Induced Grafting of 2-Methyl-4-vinylimidazole for Non-Platinum Direct Hydrazine Hydrate Fuel Cells