Water transport in Nafion membranes under various conditions studied by NMR
Jean-Christophe Perrin, Assma El Kaddouri, Mathieu Klein, Sébastien Leclerc, Jérôme Dillet, Laouès Guendouz, Olivier Lottin

To cite this version:
Jean-Christophe Perrin, Assma El Kaddouri, Mathieu Klein, Sébastien Leclerc, Jérôme Dillet, et al.. Water transport in Nafion membranes under various conditions studied by NMR. MRPM 13, Sep 2016, Bologna, Italy. hal-01704321

HAL Id: hal-01704321
https://hal.univ-lorraine.fr/hal-01704321
Submitted on 8 Feb 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
In a fuel cell, the membrane is exposed to water vapor. The values are ±0.5. We used Spin Echo effects of the interfacial resistance on the water released. One of our goals was to quantify the PEMFC but the quantity can vary depending on the fuel cell. Water is produced during the operation of the membrane.

STRETCHING

Self diffusion experiments were performed on Nafion N1110 membranes stretched inside the NMR spectrometer using a specifically designed system. A one-loop surface coil was used for emission and detection in order to increase sensitivity. Self diffusion coefficients (Ds) were measured in the three spatial directions. Due to the manufacturing process, there is a small diffusion anisotropy in the y direction. This anisotropy augment with the stretching: diffusion coefficient increases in the stretch direction (DD) and decreases in the other directions (TP, T).

These results were compared with other studies in the literature which were performed on membranes stretched ex-situ at high temperature and then hydrated at similar water content. The anisotropy is higher with our methodology, showing that the membrane stretches due to the applied stress.

Compression

In a fuel cell, the membrane is exposed to high compression loads. This is caused by the clamping of the membrane-electrode assembly but also by the swelling of the membrane due to the production of water during operation. We designed a pressure cell compatible with NMR in order to investigate this effect and its consequences on water transport. This system allows us to apply a pressure on the membrane up to 120 bars.

Water content was measured under pressure using chemical shift and signal integral. In highly hydrated membranes, the water content decrease for low pressure (~3 Mpa). This shows that internal pressures (elastic and osmotic) are lower than the applied stress. On the contrary, in the [0-85% RH] range, internal pressures are much higher and water content does not decrease with applied stress.

The diffusion measurements show that the water mobility is also affected in the stressed membrane: stress-induced structural modifications or reorganizations are seen in the angular evolution of the water self-diffusion coefficient measured in a Nafion membrane hydrated at 61% RH. This shows that internal pressures (elastic and osmotic) are lower than the applied stress. In highly hydrated membranes, the water content decrease for low pressure (<3 Mpa). This shows that internal pressures (elastic and osmotic) are lower than the applied stress. On the contrary, in the [0-85% RH] range, internal pressures are much higher and water content does not decrease with applied stress.

Hydration and Drying

Water profiles in a drying N1110 membrane. Before the experiment, the air relative humidity is 80%. In the start of the experiment, it is switched to dry air (RH=0%). One imaging profile is acquired every 45s. Signal intensity decrease due to T2 is corrected. The relaxation time varying with the water content.

During drying experiments, the water profiles across the membrane stay roughly flat. It means diffusion is fast and the desorption is limited by the transfer at the membrane interface. We also performed hydration experiments for different gas flow rates.

Hydration chamber designed for imaging the membrane. Air humidity can be varied separately for each face. The system is inserted in a 20 mm diameter gradient coil (1000 MHz).

Water profiles across a N1110 membrane during humidification between gas flow rate 1 L/min and 1 L/min. The air relative humidity is 80% in both cases.

Bi = R_diffusion / R_boundary (Biot number)

Bi << 1 Diffusion is not limiting during sorption and desorption

Bi ≥ 1 Effects of diffusion are visible on the profiles

By decreasing the flow rates, R_boundary also decrease and diffusion effects become more visible.