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Smart membranes for energy conversion: a neutron approach

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Ion conducting polymer membranes are designed for applications ranging from separation and dialysis, to energy conversion and storage technologies. A key application is in fuel cells, where the semi-permeable polymer membrane plays several roles. In a fuel cell, the polymer membrane permits the selective transport of H+ or OH- to enable completion of the electrode half-reactions, plays a major role in the management of water that is necessary for the conduction process and is a product in the reactions, and provides a physical barrier against leakage across the cell. All of these functions must be optimised to enable high conduction efficiency under operational conditions, including high temperatures and aggressive chemical environments, while ensuring a long lifetime of the fuel cell. Polymer electrolyte membranes used in current devices only partially meet these stringent requirements, with ongoing research to assess and develop improved membranes for a more efficient operation and to help realise the transition to a hydrogen-fuelled energy economy. A key fundamental issue to achieving these goals is the need to understand and control the nature of the strongly coupled dynamical processes involving the polymer, water and ions, and their relationship to the conductivity, as a function of temperature and other environmental conditions. This can be achieved by using neutron scattering techniques that give access to information across a wide range of timescales. Here we apply QENS, applied over a wide range of timescales to disentangle the water, polymer relaxation and ion dynamics, using the concept of serial decoupling of relaxation and diffusional processes to analyse the data. The insights provided by these data [1-3] offer a guide for the design of new devices, where tuning the membrane nanostructure would result in activation of the anionic hopping mechanism, providing improved performance over a wide range of operational conditions.

References

[1] F. Foglia et al., Nature Materials (2022) 21 (5), 555.
[2] F. Foglia et al., Journal of non-crystalline solids X (2022) 13, 100073.
[3] F. Foglia et al., Journal of Physics: Condensed Matter 33, 264005.

Primary author: FOGLIA, Fabrizia (UCL)

Presenter: FOGLIA, Fabrizia (UCL)

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