Neutrons:
a journey through green energy

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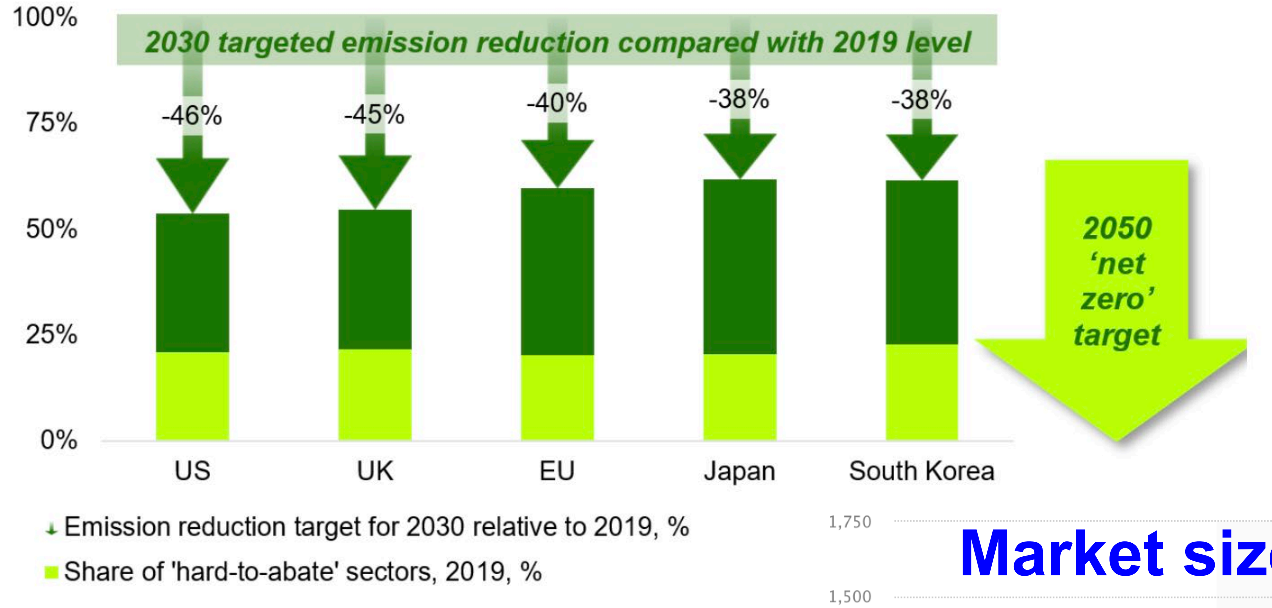
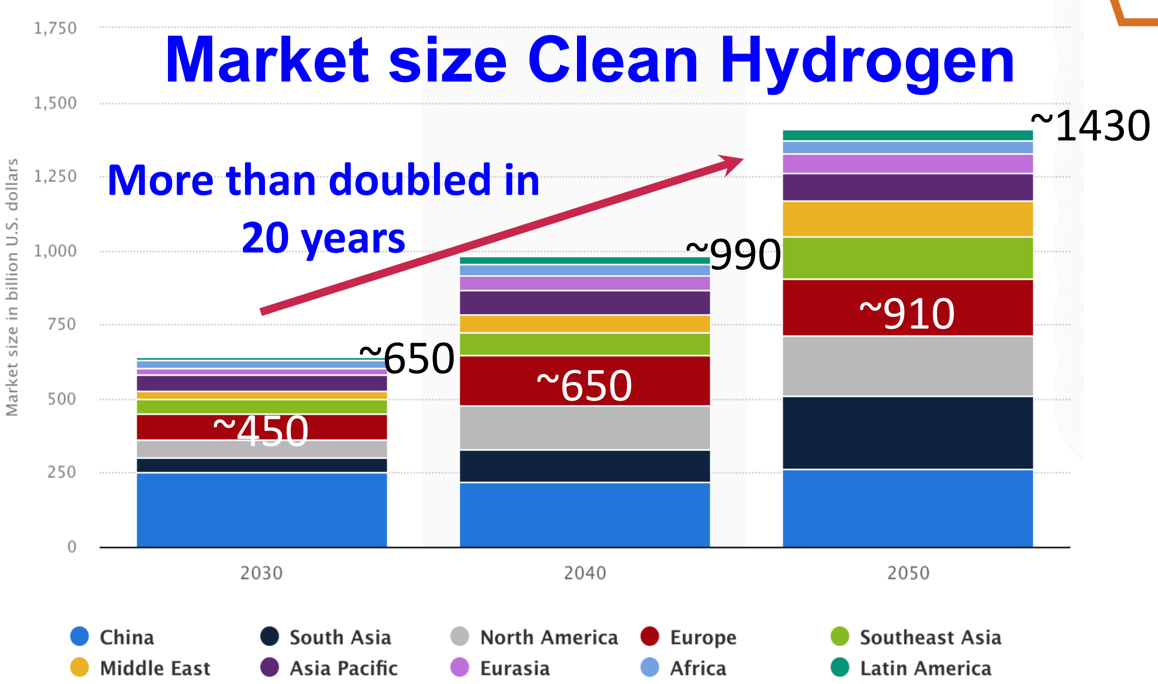
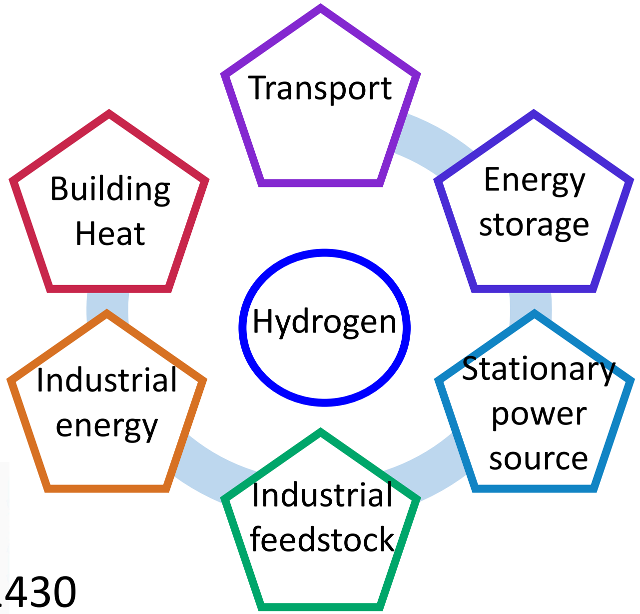
Net Zero



2030 targeted emission reduction compared with 2019 level
100%
75%
50%
25%
0%
-46%
-45%
-40%
-38%
-38%
US
UK
EU
Japan
South Korea
2050 'net zero' target
Emission reduction target for 2030 relative to 2019, %
Share of 'hard-to-abate' sectors, 2019, %



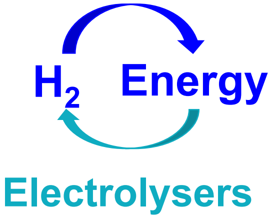
Market size Clean Hydrogen
More than doubled in 20 years
Market size in billion U.S. dollars
1,750
1,500
1,250
1,000
750
500
250
0
~650
~450
~990
~650
~1430
~910
2030
2040
2050
China
South Asia
North America
Europe
Southeast Asia
Middle East
Asia Pacific
Eurasia
Africa
Latin America



Transport
Building Heat
Energy storage
Hydrogen
Industrial energy
Stationary power source
Industrial feedstock

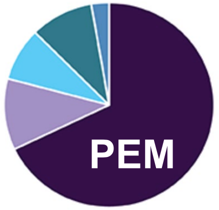
FUEL CELLS

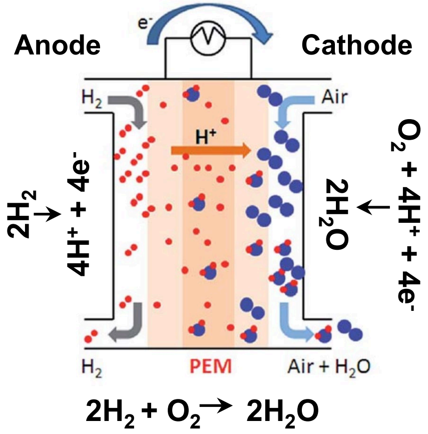
$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$

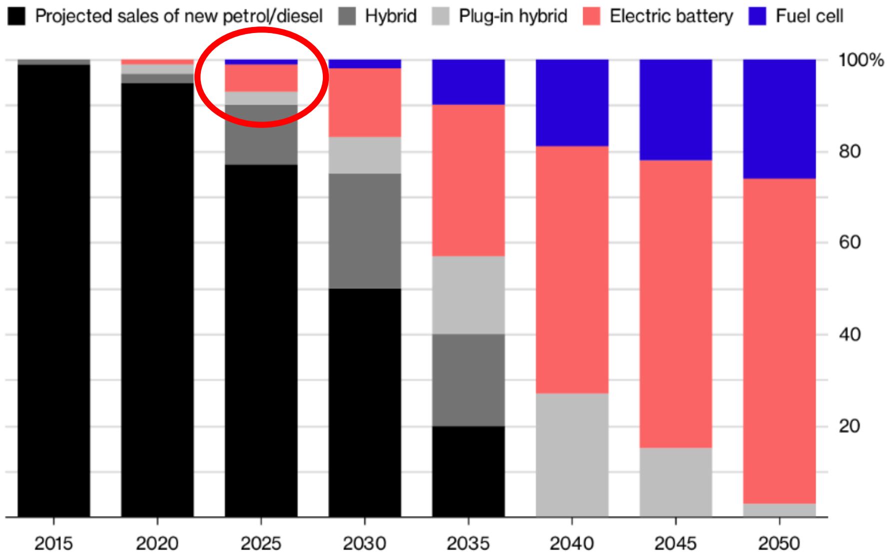


Environmentally friendly

i) water is the byproduct of the electrochemical reaction in a fuel cell (ideal candidate in the quest for fighting climate change);





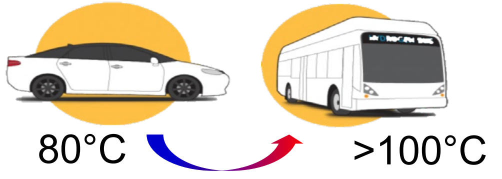


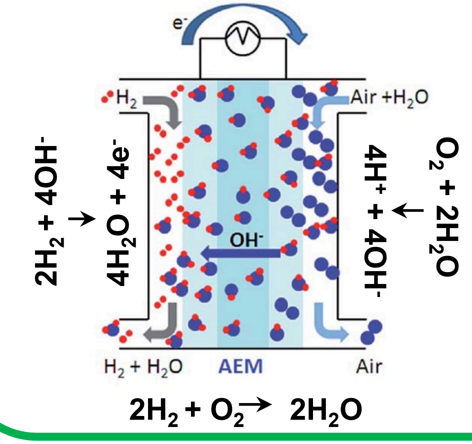
Cons

i) Pt-based catalysts (**expensive**).

ii) the cell performance is affected by the **water content**;

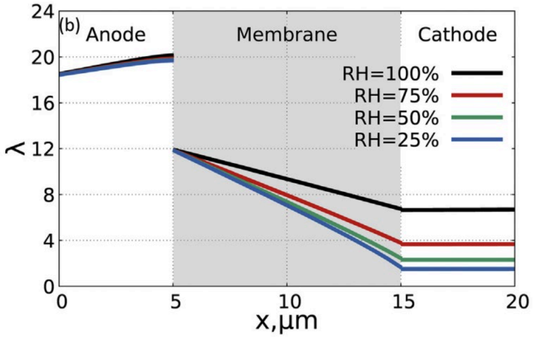
iii) at **low-T** (60-80°C) it is necessary to eliminate CO to avoid catalyst poisoning.





OH^- nucleophile (stability)

performance



DR Dekel, et al, J Power Sources 375, 191 (2018)

F Foglia*, et al, *J Non-Crystalline Solids: X* 13 100073 (2022)

Design

HIGH-PERFORMING MEMBRANES

explicate the

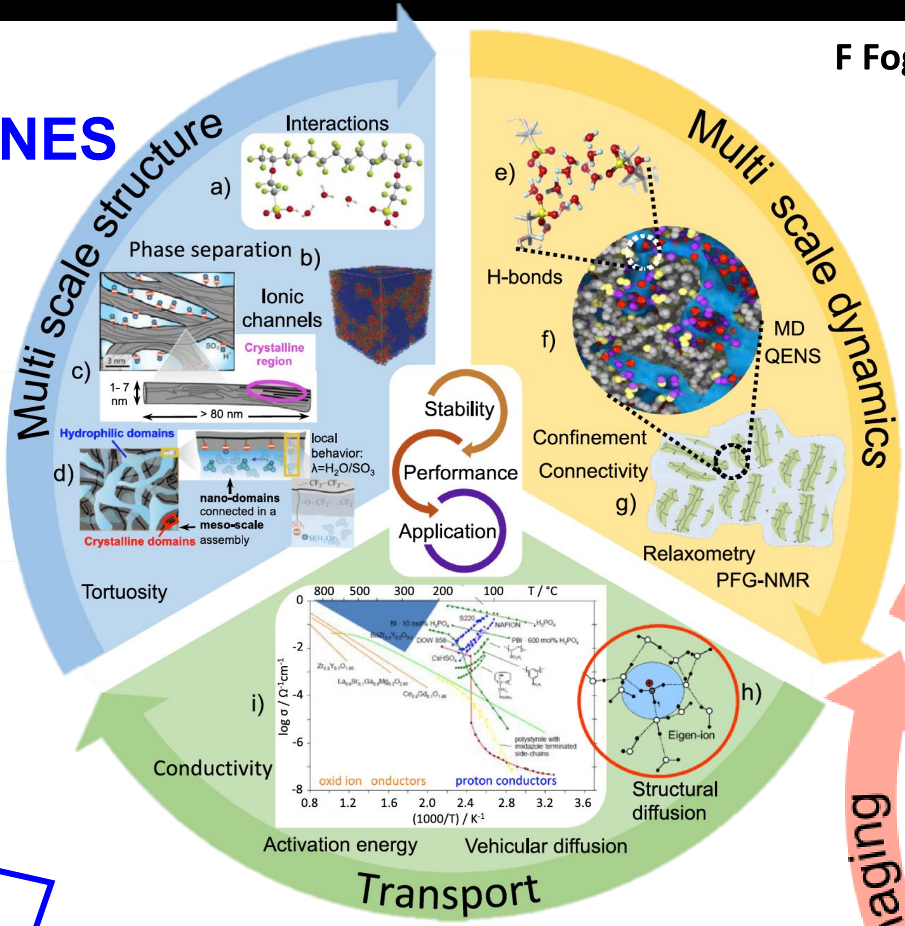
structure-to-function interplay

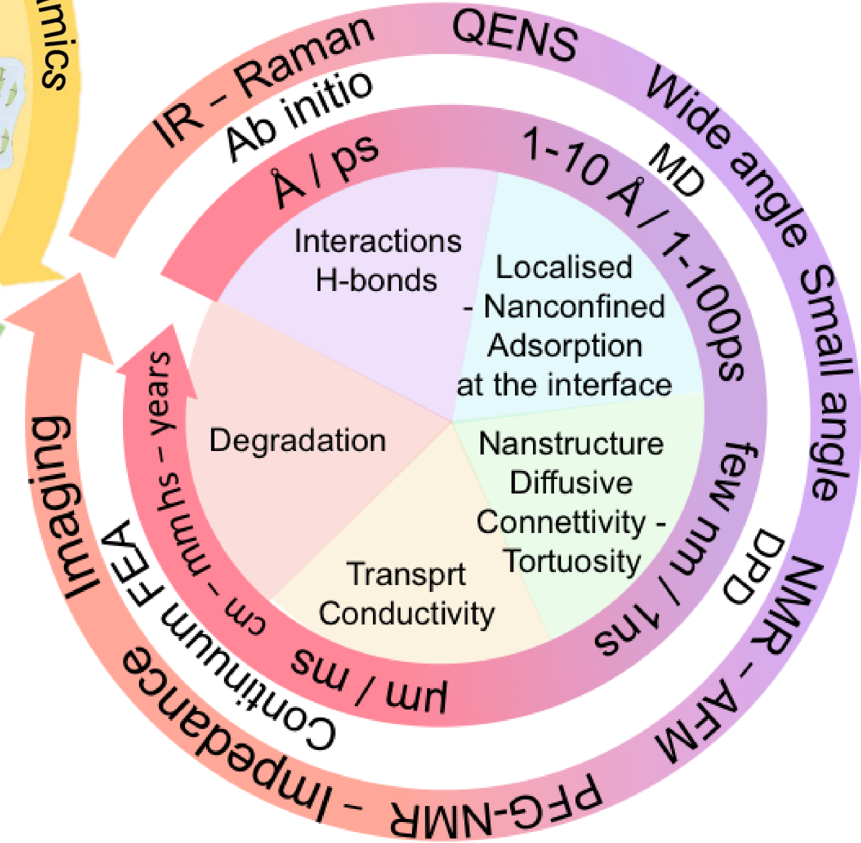
disentangle processes

(within polymer & solute)

holistic approach

Industrial requirement & demands





HIGH-PER

structure-

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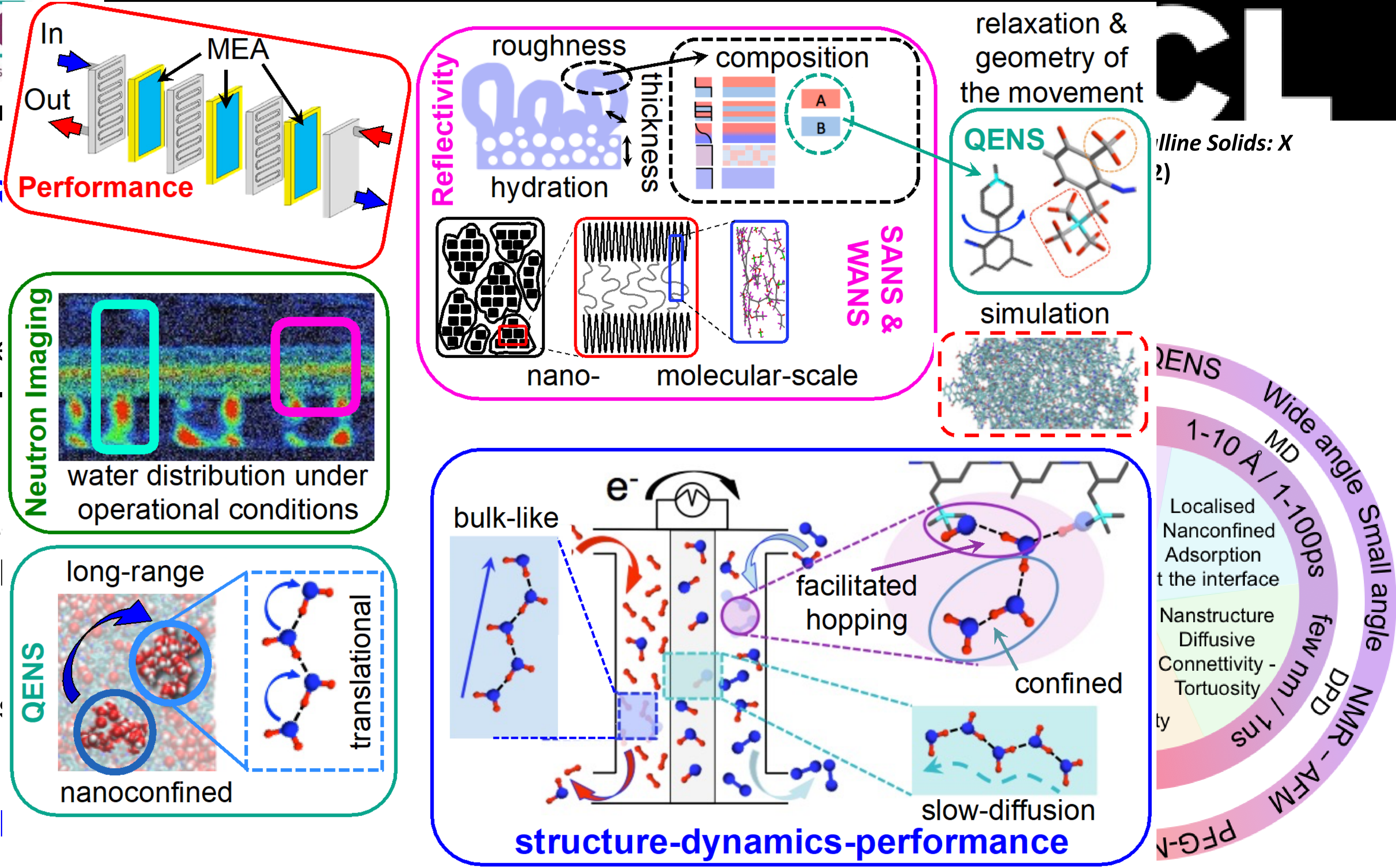
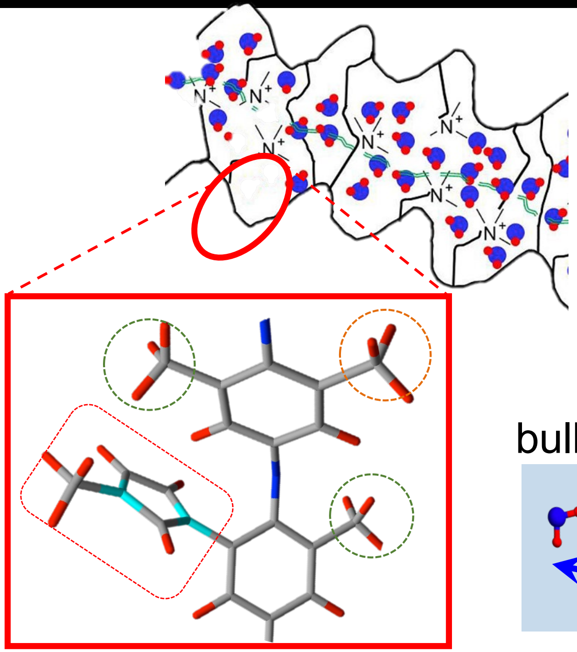
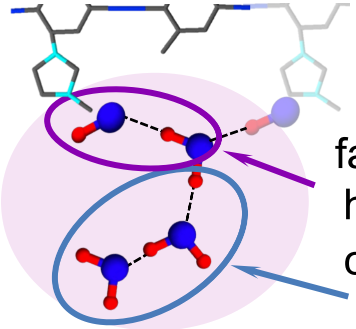
Industrial



EPSRC
Engineering and Physical Sciences Research Council

UCL

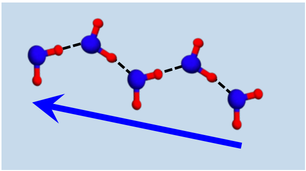


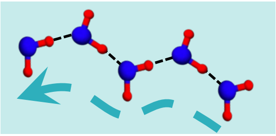


facilitated hopping

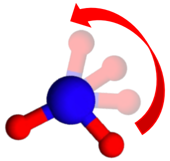
confined water

bulk-like diffusion





slow diffusion



rotation

a few (coupled) dynamics:

Polymer
- $-CH_3$ rotation
- backbone relaxation

Ion
- facilitated hopping

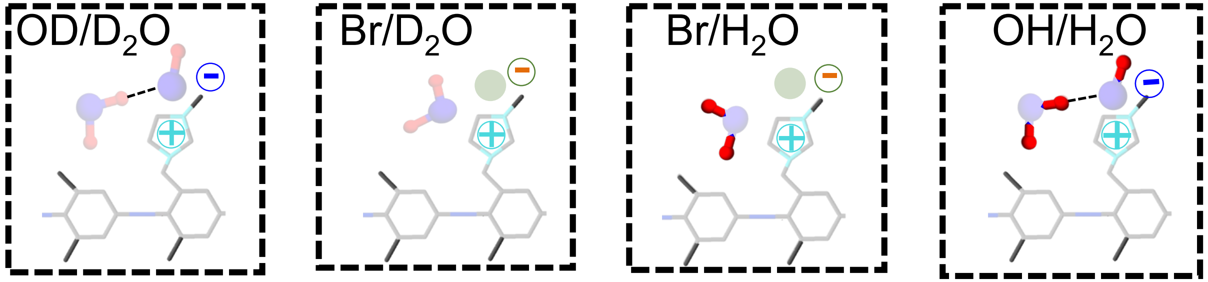
Water
- rotation
- c-o-m diffusion
- confinement

disentangling dynamics

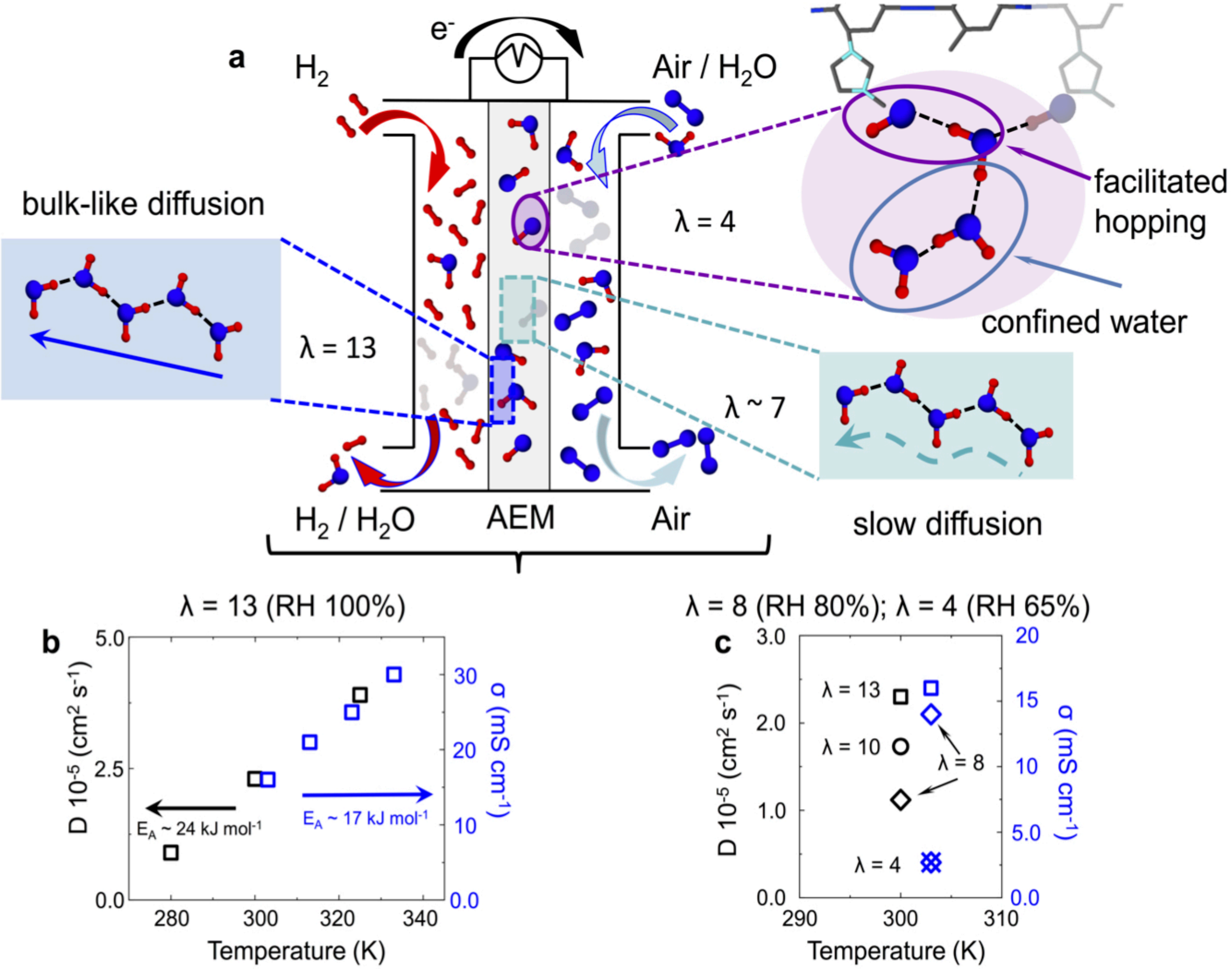
time

~0.5 ≤ τ ≤ 20 ps E_{res} = 70 μeV **IN6**	**~5 ≤ τ ≤ 100 ps** E_{res} = 17.5 μeV **IRIS**	**~0.07 ≤ τ ≤ 3 ns** E_{res} = 0.75 μeV **IN16B** E_{res} = 1.0 μeV **HFBS**

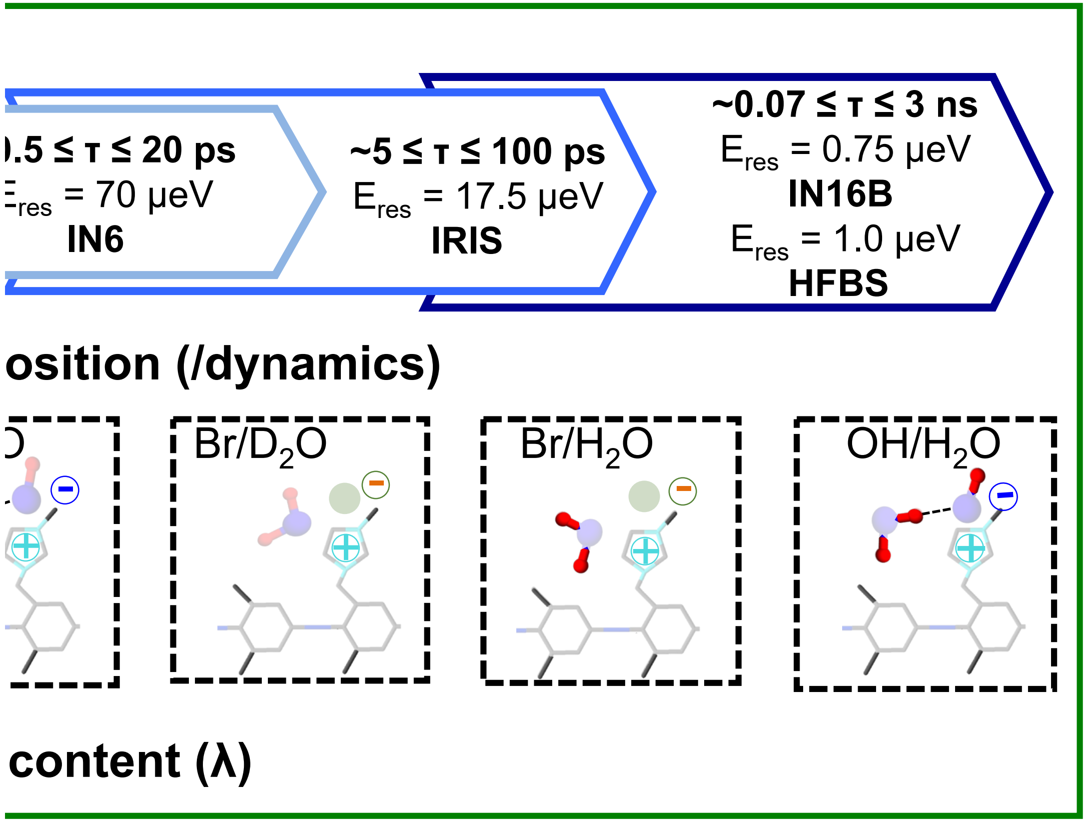
composition (/dynamics)



water content (λ)



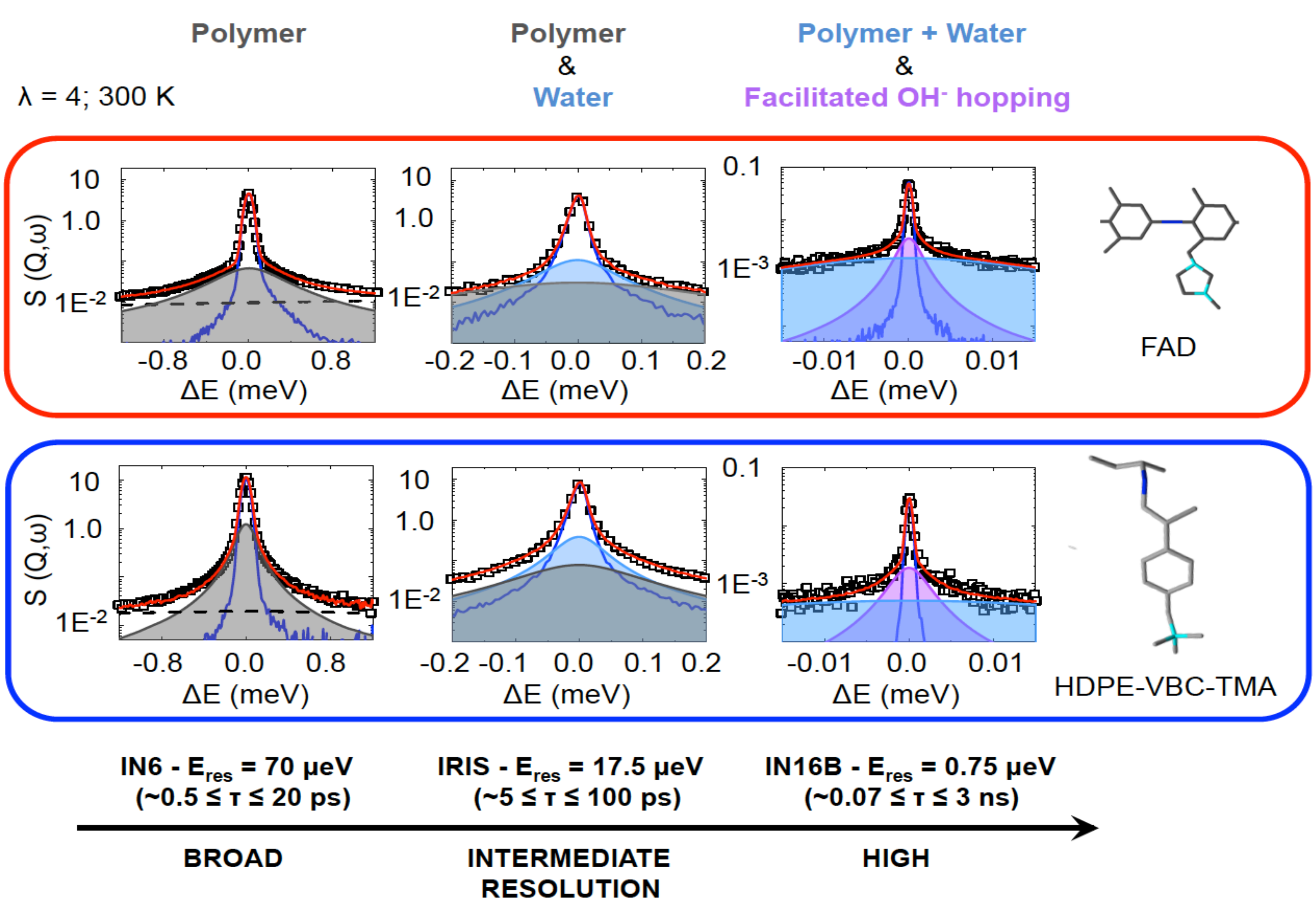
disentangling dynamics

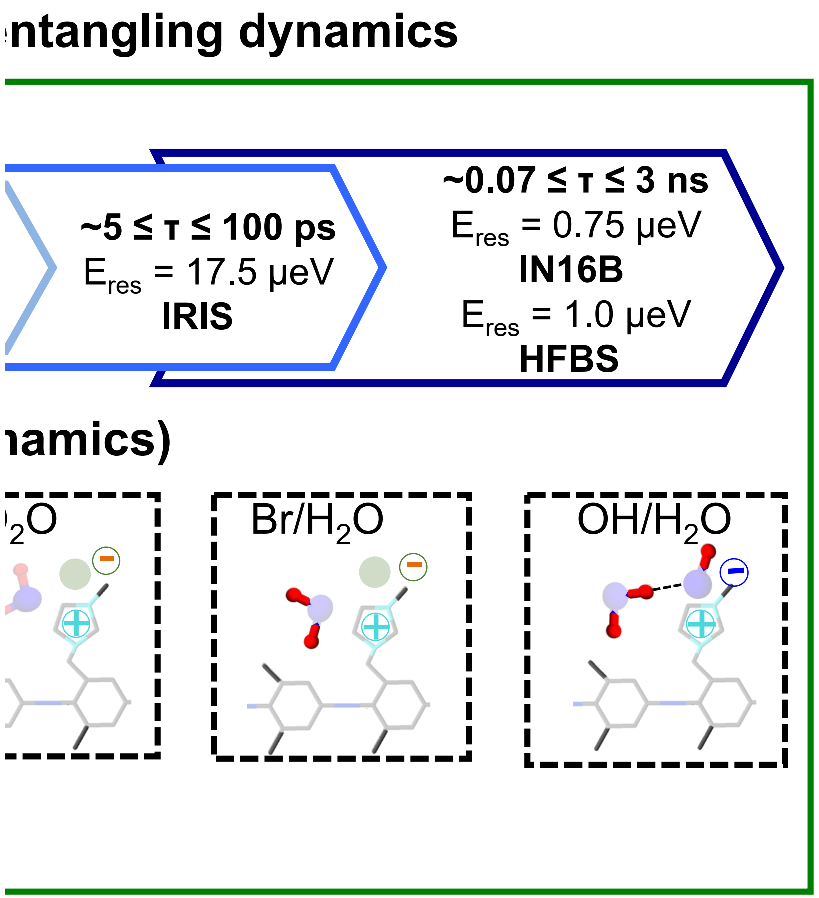


F. Foglia*et al. *Nature Materials* **21** 555 (2022)

understanding from atom to application

correlate dynamics parameters to performance





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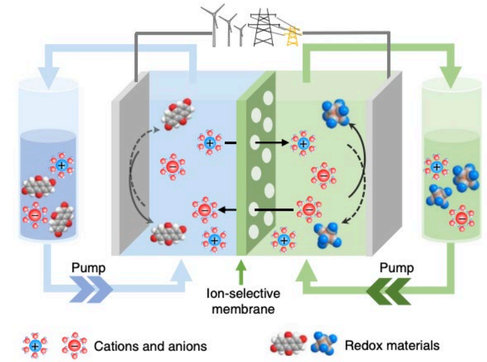
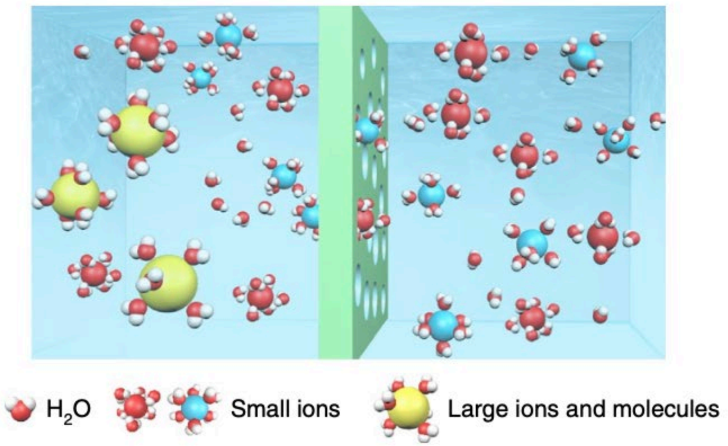
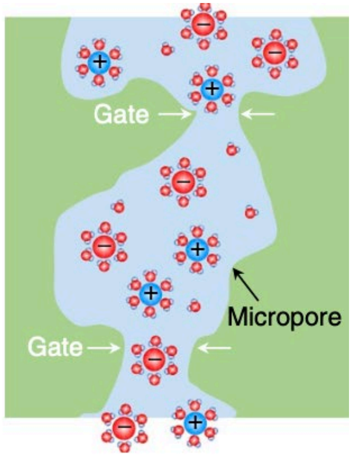


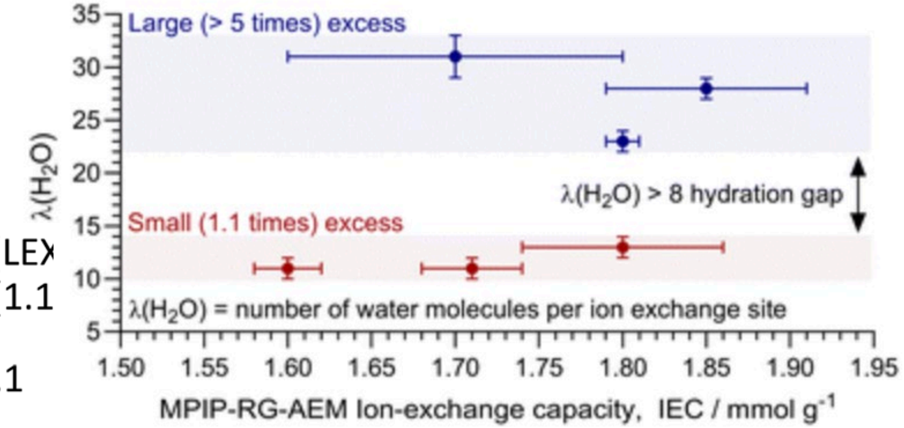




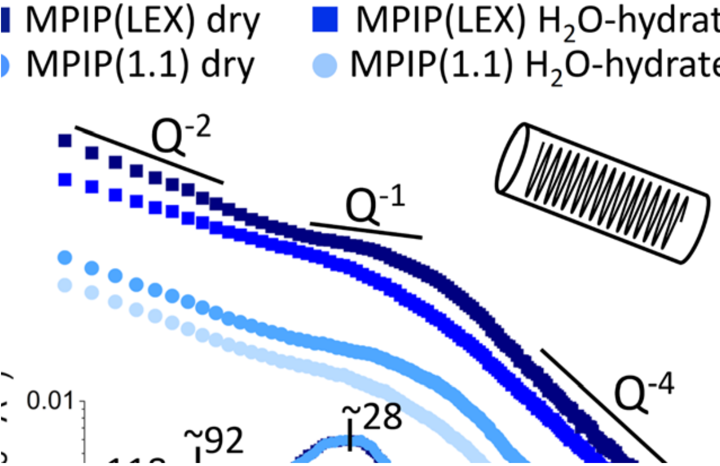
R. Tan et al. *Nature Materials* **19** 195 (2020)

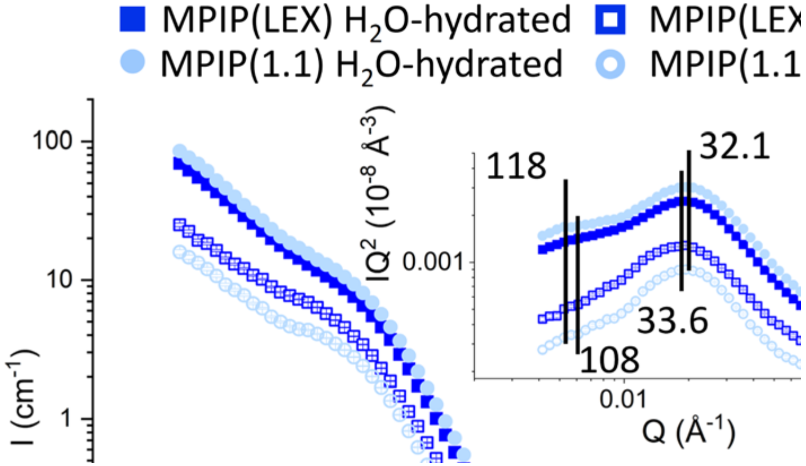
A. Wang et al. *Nature* **submitted**

Redox-flow batteries



Radiation-grafted anion-exchange membranes for CO_2 electroreduction cells





T. Willson et al. *J. Mater. Chem. A* **11** 20724 (2023)

Bypass water management issues, low fuel flexibility, and a relatively fast degradation.

Nafion

Low-T FC

T ≤ 80°C

Intermediate-T FC

100 ≤ T ≤ 120°C

High-T FC

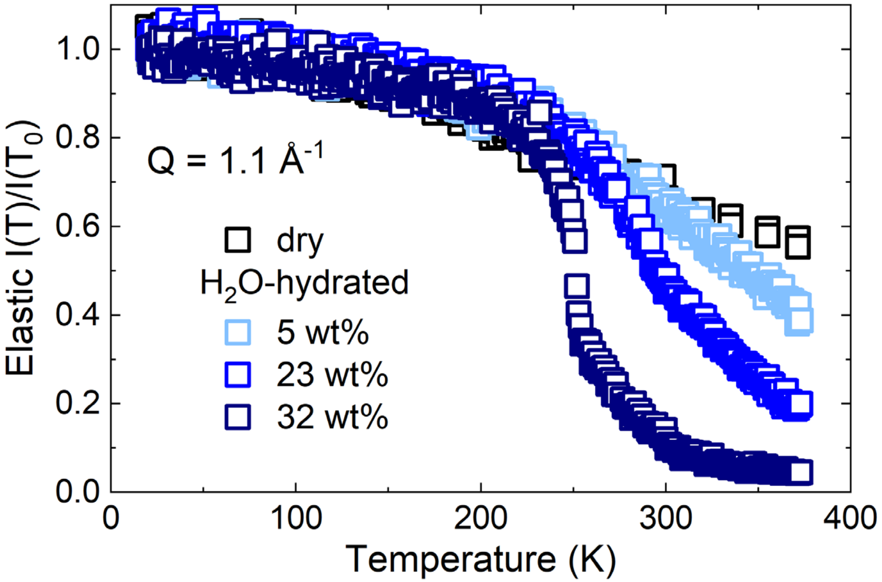
140 ≤ T ≤ 200°C

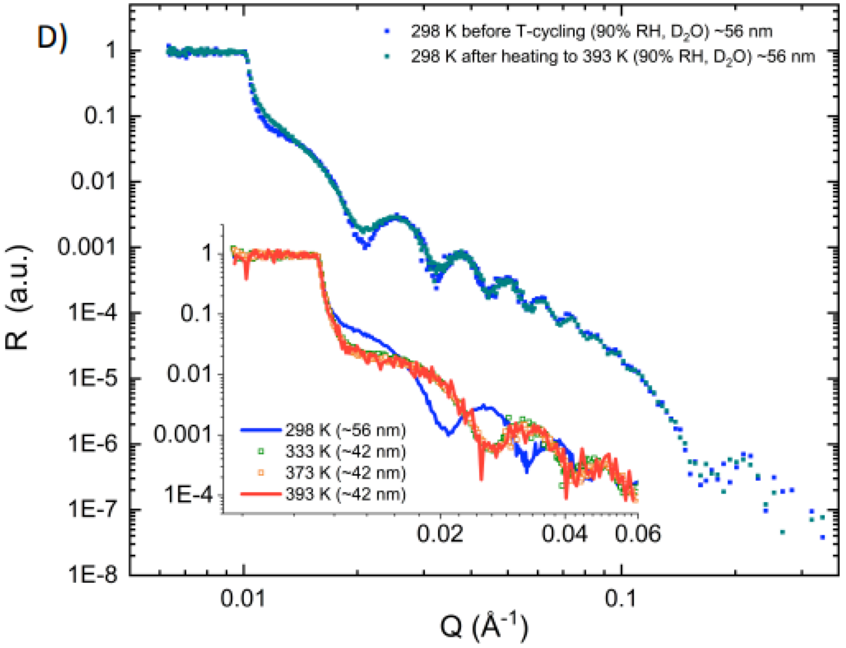
Develop a suitable PEM with comparable performance and lifetime to Nafion.

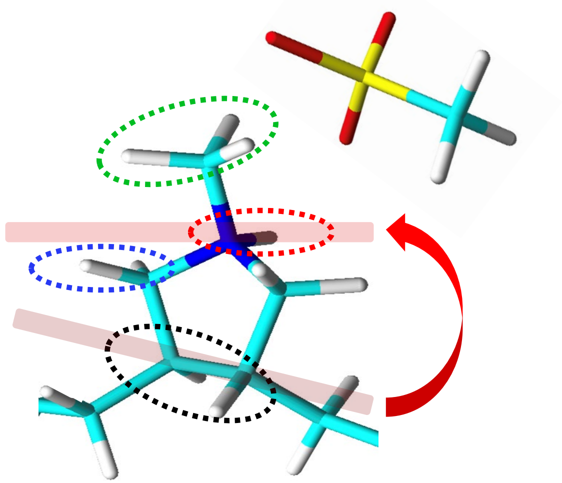
improve:

- mechanical strength
- water retention
- enhance proton conductivity

Polymat – Toyota:
Develop new chemistries



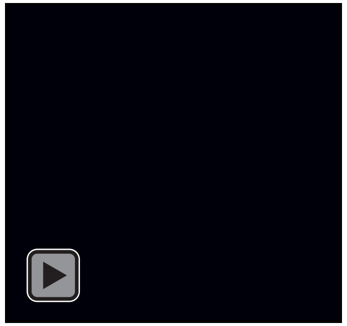




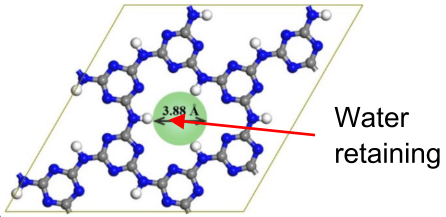
Polymat (& Toyota Motor Europe) has developed new chemistry for operation at intermediate-T conditions. We are testing the properties of this material **to improve performance**.

A. Gallastegui et al. *Polymer* **280**, 126064 (2023)

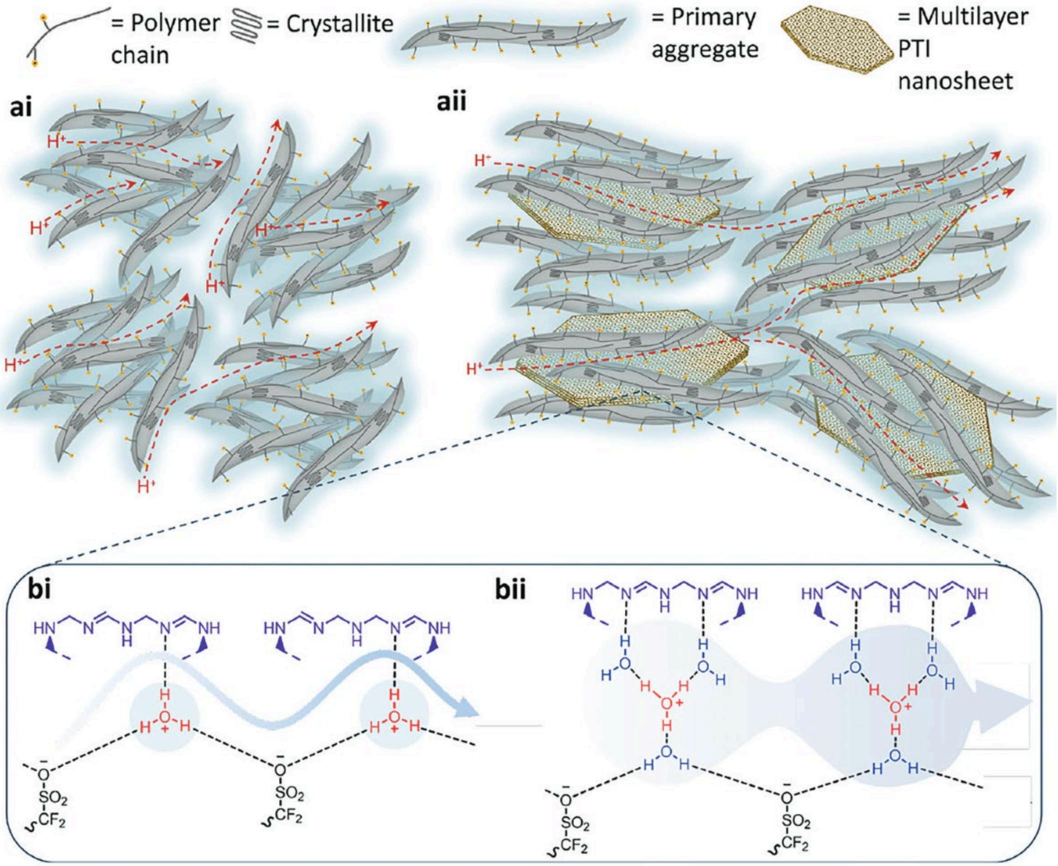
CEA – EIL: Nanocomposite membranes (Nafion + fillers)

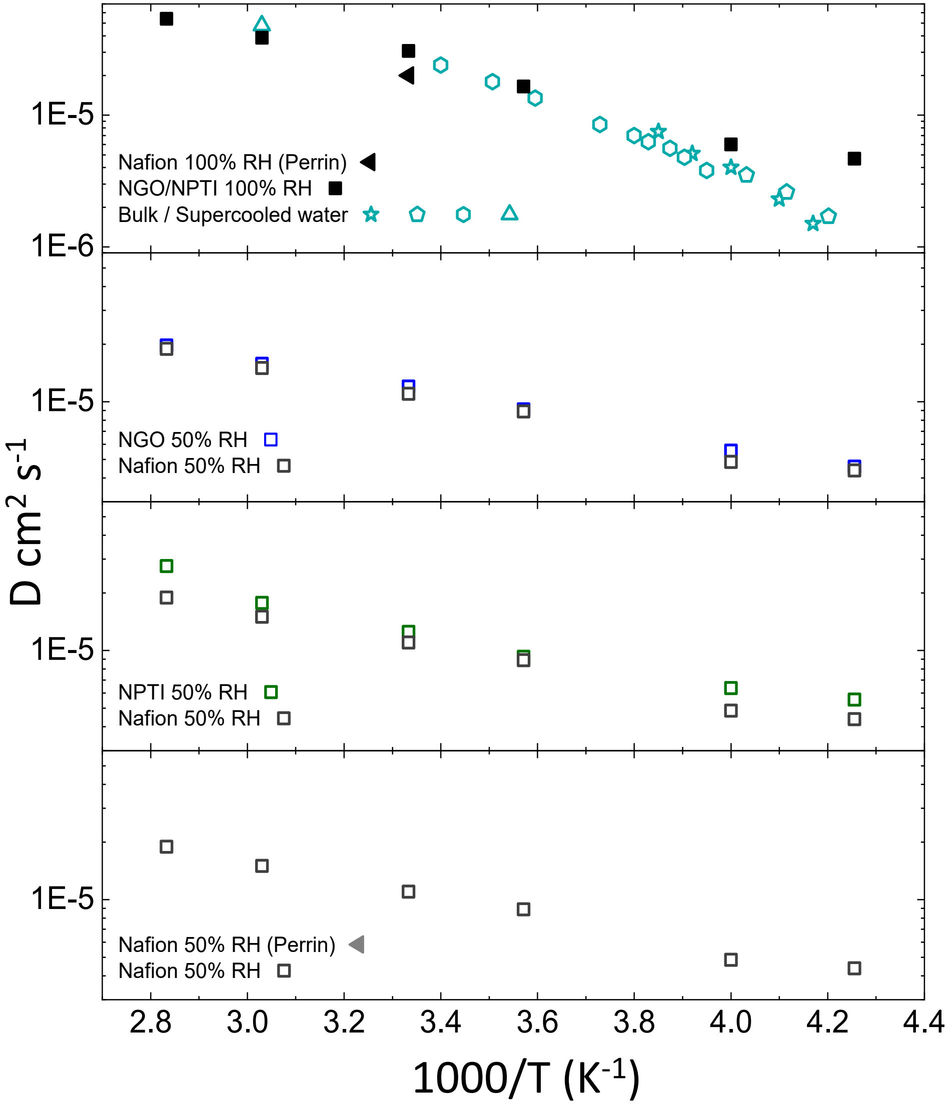


Polytriazine imide (PTI)



K Smith et al, Advanced Functional Materials 2304061 (2023)





The addition of C-material within Nafion enhancing the diffusivity improve performance at low-RH.

Acknowledgment

EPSRC Engineering and Physical Sciences Research Council

UCL

TOYOTA

TOYOTA MOTOR EUROPE

Imperial College London

cea

Oak Ridge National Laboratory

NIST Center for Neutron Research

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