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Sulfonic acid-crosslinked nanocellulose as a novel polymer electrolyte membrane for hydrogen fuel cells

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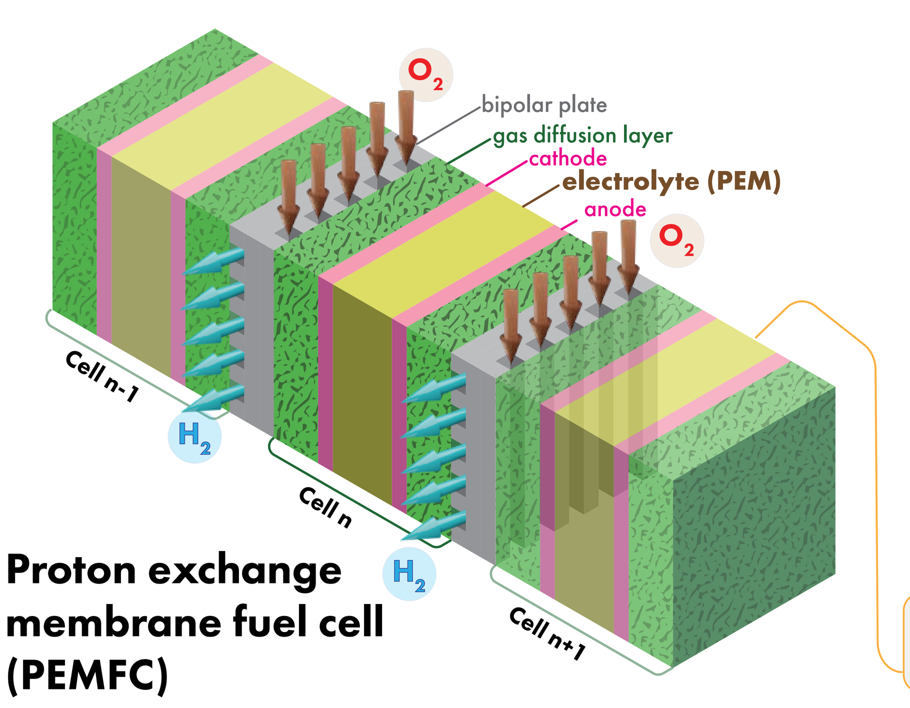
HYDROGEN FUEL CELL

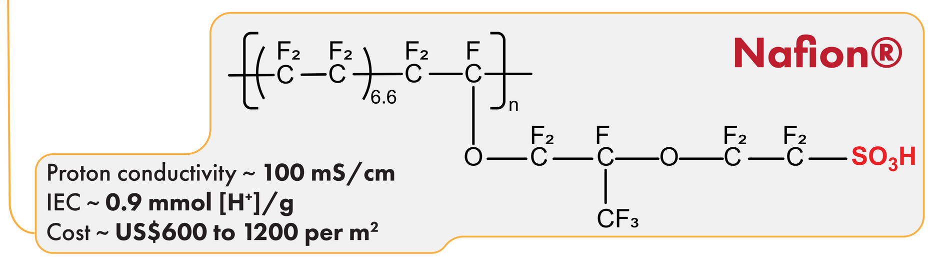


Proton exchange membrane fuel cell (PEMFC)

Fuel cell - core technologi`cal element of the sustainable "Hydrogen society"

Barriers of wide deploymet:
> Cost of hydrogen fuel
> Lack of infrastructure (e.g. fuelling stations)
> Cost of fuel cells (Pt in electrocatalyst, bipolar plates and proton exchange membrane)

Benchmark materials for PEM - perfluorinated sulfonic acid ionomers: **Nafion®, Aquivion®, 3M®**



Disadvantages: high-cost, degradation, non-recyclable

Purpose of this work:

Development of low-cost and efficient PEM based on nanocellulose

RESEARCH MATERIAL: NANOCELLULOSE

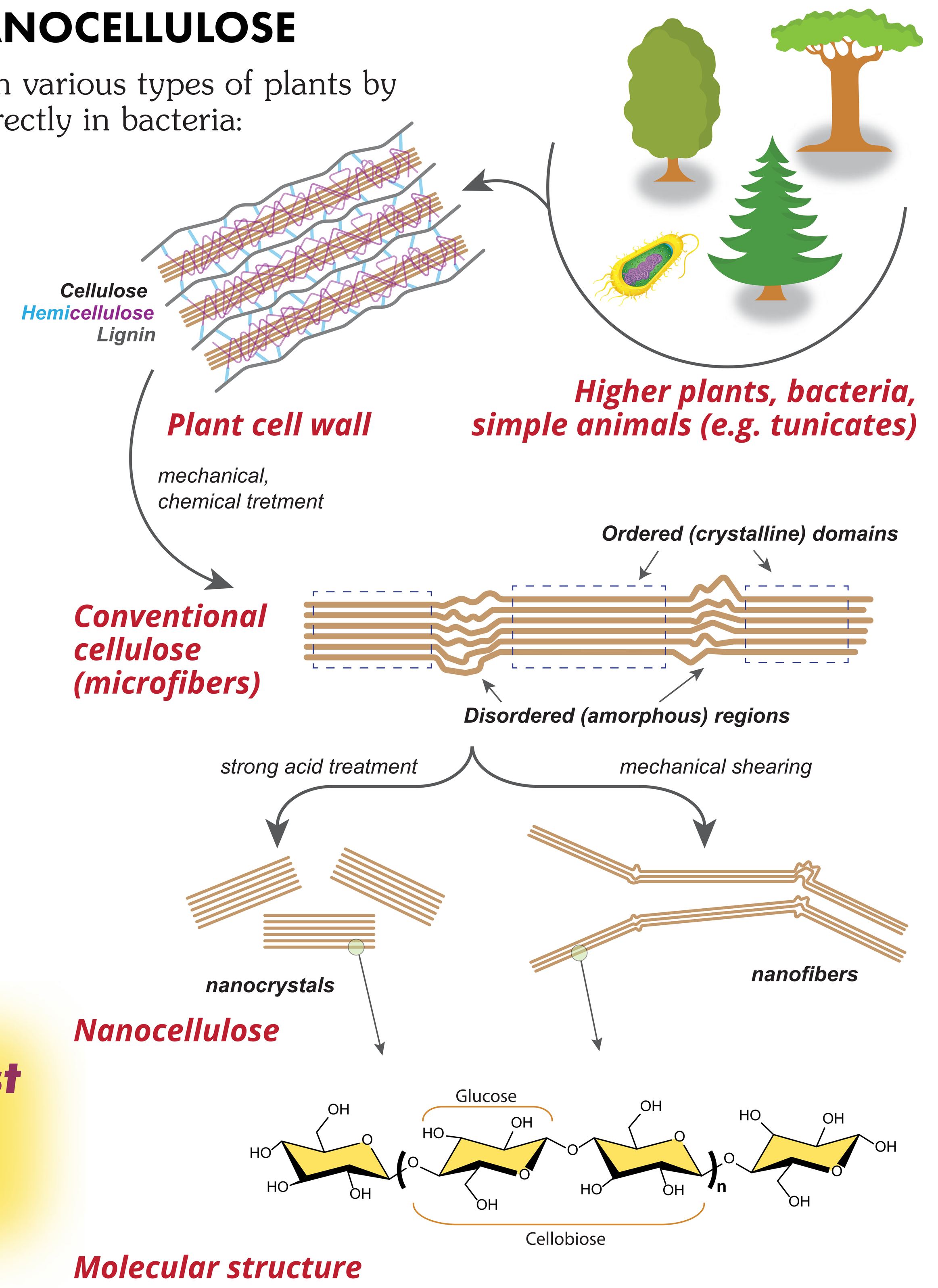
Nanocellulose can be obtained from various types of plants by mechanochemical processing or directly in bacteria:
- strong acid treatment
- mechanical shearing
- grown in microorganisms

Main types of NC:
- cellulose nanocrystals (CNC)
- cellulose nanofibers (CNF)

Characteristic properties:
- high mechanical strength
- low density & high surface area
- non toxicity & biodegradability
- flexibility

Membranes features
- uniform thickness in casted membranes (aqueous solution)
- natural drying (no extra energy)
- suitable for mass production
- flat and stable after hot-pressing

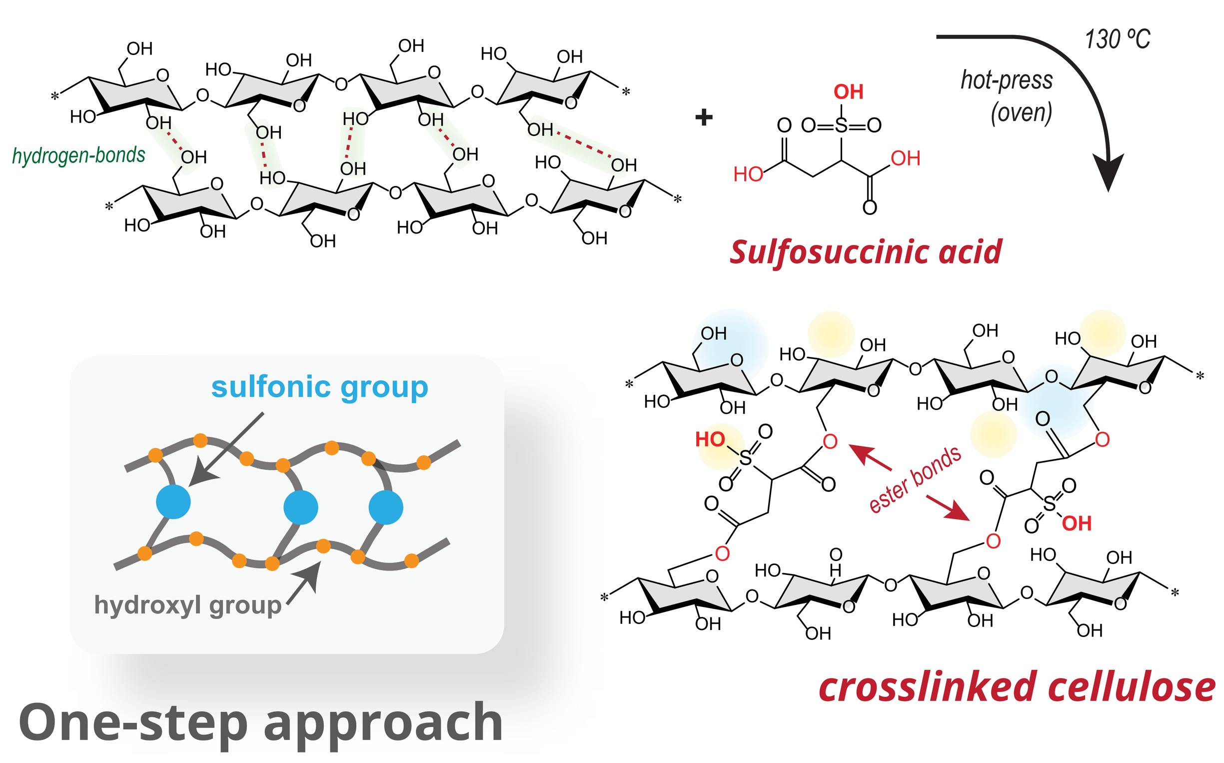
"Eco-friendly, low-cost material for fuel cell applications"



MODIFICATION APPROACH: SULFONIC ACID CROSSLINKING

Crosslinking: one-step reaction between mixed acid and nanocellulose results in a formation of multiple ester bonds disrupting the natural hydrogen-bonding network of cellulose.

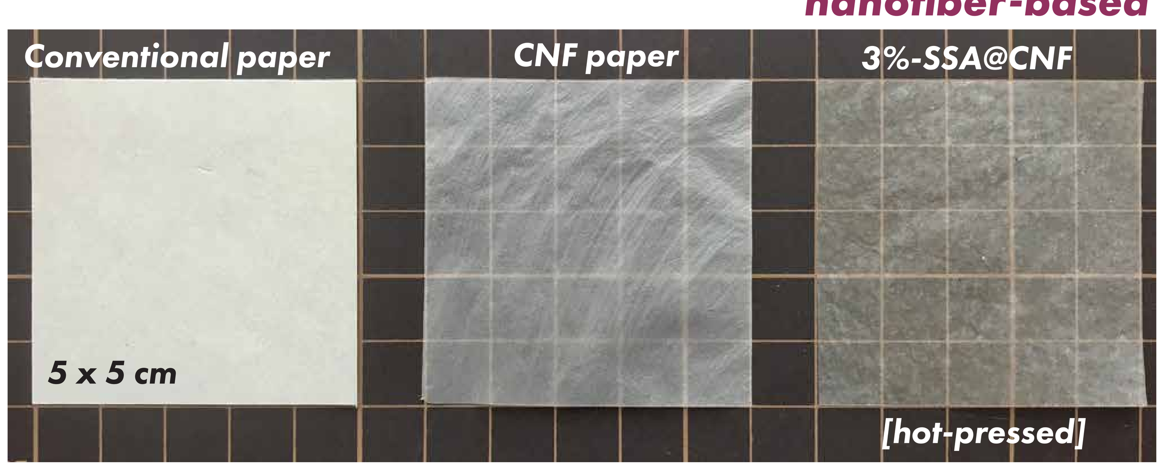
Hypothesis: surface of nanocellulose covered with sufficient amount of sulfonic acid group (strong proton conducting moiety) will make a good proton conductor.



MACROSCOPIC & MICROSCOPIC MORPHOLOGY

Membranes of 3-30 microns in thickness are distinctively different from conventional cellulosic membranes (e.g. paper), free-standing and self supporting.

Maximum concentration of SSA in CNF ~ 10 wt%, up to 50 wt% can be blended with CNC



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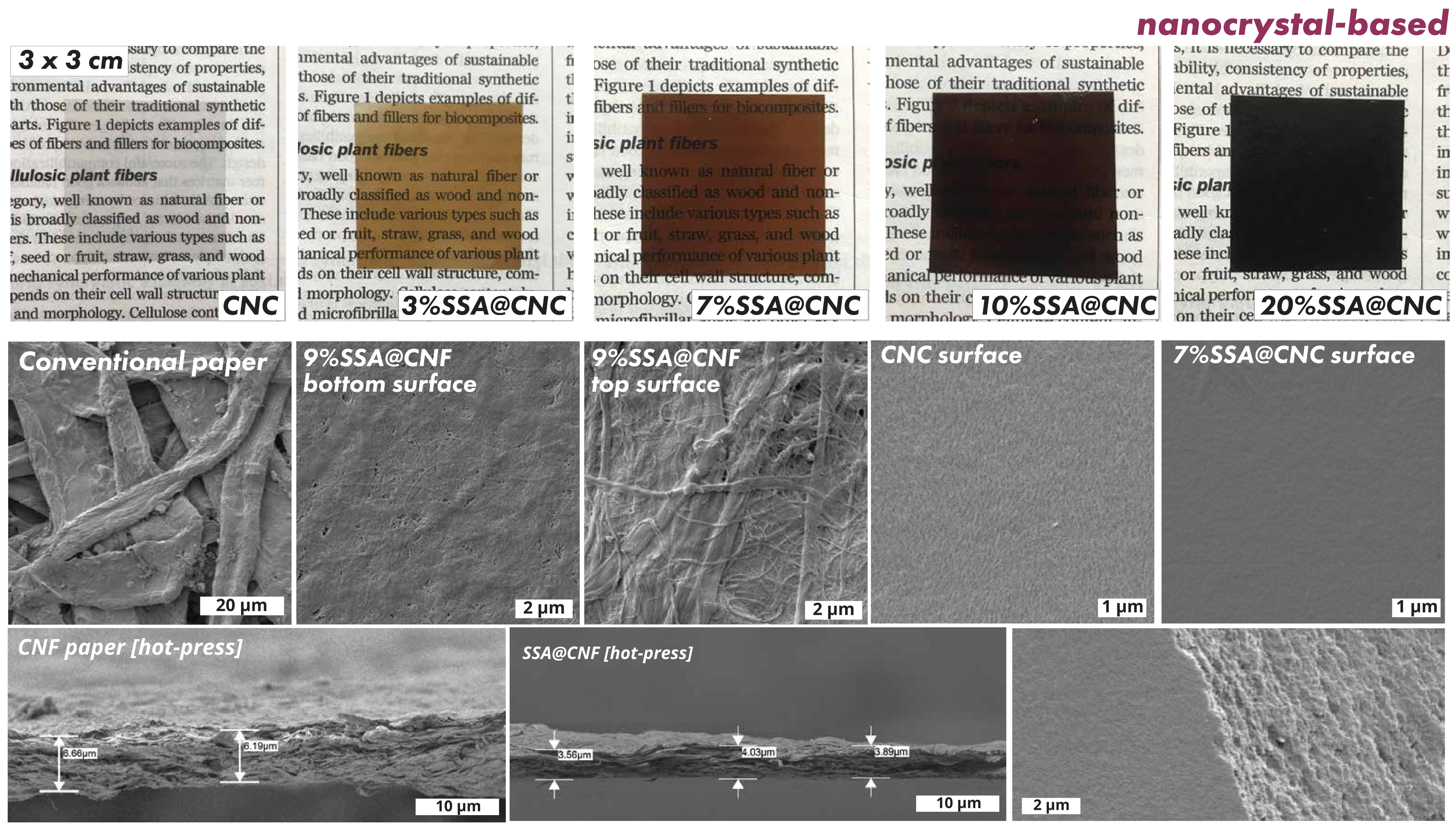
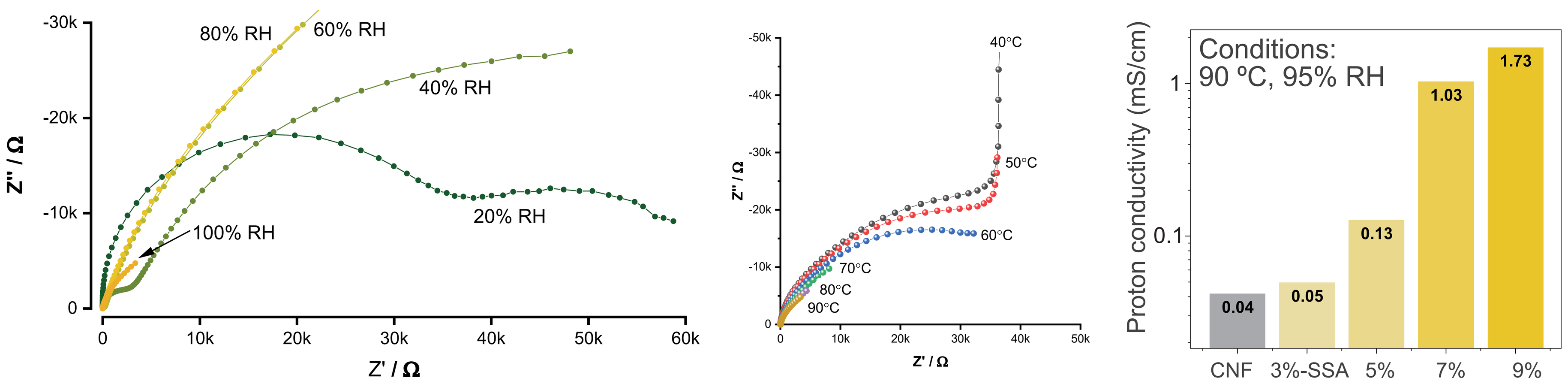


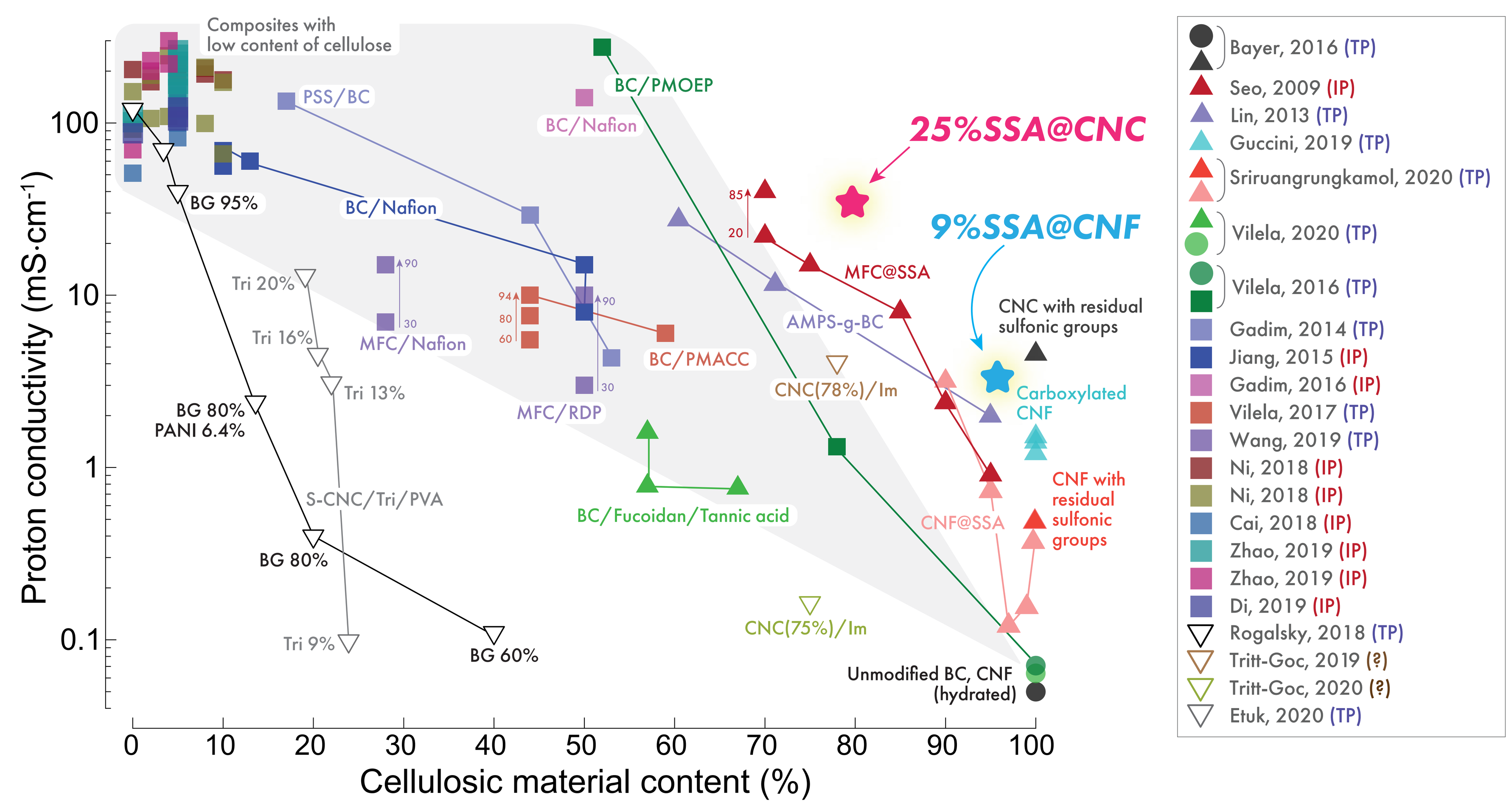
Lower thickness of nanocellulose PEMs is possible due to material properties + high gas barrier
- Thickness of the CNF and SSA@CNF membranes is below 10 μm
- State-of-art Nafion in Toyota Mirai: 2008 (~50 μm); 2017 (14 μm); goal for 2020 - 10 μm

PROTON CONDUCTIVITY OF CROSSLINKED MEMBRANES



Strong dependence of σ on relative humidity, weaker dependence on temperature (9%-SSA@CNF). Crosslinking of the CNF with SSA resulted in ***ca. 40 times increased proton conductivity*** compared to unmodified CNF sample.

(PRELIMINARY RESULTS): COMPARISON WITH LITERATURE



O.Selyanchyn, R.Selyanchyn & S.M.Lyth* Front.Energy.Res. 2020, doi.org/10.3389/fenrg.2020.596164

- Results of this work compared to literature shows that utilization of asid crosslinked nocellulose allows substantial increase in the proton conductivity and fabrication of thinner membranes.

- Considering high gas barrier of nanocellulose membranes PEMs with competitive properies (specific resistance, chemical & mechanical stability) can be fabricated, that are environmentally friendly and have substantially lower cost compared to benchmarks (e.g. Nafion).

CONCLUSIONS & FUTURE WORK

1. Nanocellulose is a promising biopolymer platform for the development of novel PEM for fuel cell applications.
2. Structural integrity of the organic acid crosslinked cellulose nanofiber and nanocrystal membranes was proven in the region of sub-10 micron thicknesses.
3. Morphological features (SEM), chemical structure (FTIR) and swelling behaviour in water suggest a promising material with competitive proton conductivity.

Future experiments: mechanical properties, proton conductivity at high temperatures, chemical stability in hot water, O_2 and H_2 permeability, fuel cell performance.

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