My research activity in ENAM group and project idea

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Electrochemistry and Nanotechnology for Advanced Materials

- Li-ion battery
- Li-S/O_2 battery
- Anode-less battery
- Operando analysis
- Na, K, Ca batteries
- Seawater battery
- All-solid-state battery
- Ionic liquids (ILs)
- Green materials
- Fuel cell
- Electrolyzer
- Conservation of cultural heritage

Prof. Sergio Brutti

Prof. Maria Assunta Navarra

Research groups in ENAM Lab

Prof. Sergio Brutti (PI) – Electrodes

Dr. Arcangelo Celeste

Prof. Marco Agostini

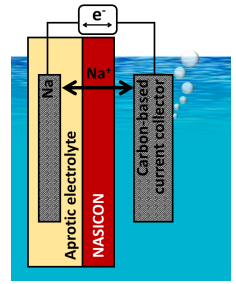


	Anode		Cathode		
	Carbon	A. less	TM	S	O_2
Li	**v**	v	**v**	v	v
Na	v	**v**	v		**v**
K	v				
Zn			**v**		**v**

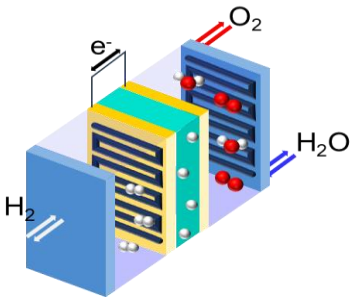
In collaboration with the group of
Prof. Jang-yeon Hwang in Hanyang Univ.

Prof. Maria Assunta Navarra (PI) – Fuel cells

PGM free electrocatalysts and AEM/PEM



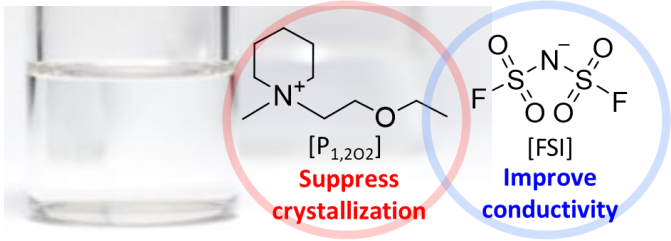
Seawater batteries

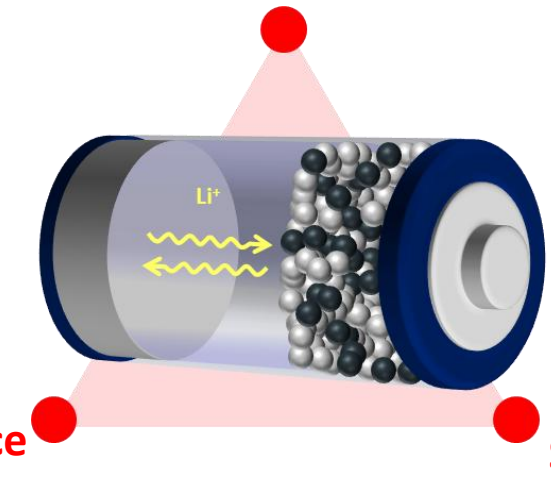


Fuel cell/electrolyzers

Dr. Akiko Tsurumaki – Electrolytes, Ionic liquids (ILs)

Functional ILs





- Good liquid properties in a wide T range
- High thermal and electrochemical stability
- High versatility in the design
- ⇒ Gel polymer electrolytes
  (quasi-)solid-state electrolytes

My research focus

Bachelor's, Master's, and Doctoral Degrees at Tokyo University of Agriculture and Technology (TUAT)

- **Supervisor: Prof. Hiroyuki Ohno**
- **Study of physical chemistry of ILs (structure vs properties) to design ILs for polymers**

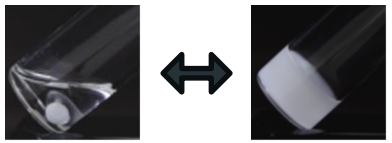
  Bachelor: Solubility of PEO in ILs explained by HSAB theory [DOI:10.1002/pat.1931]

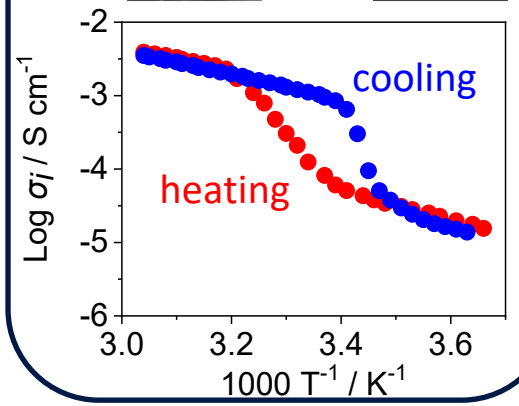
  Master: Solubility of PVdF in IL governed by the polarity of ILs (presented at the Gordon Research Conference)

  Doctor: Affinity with PTFE correlates with F-content of ILs [DOI:10.1039/C7CC08449H]

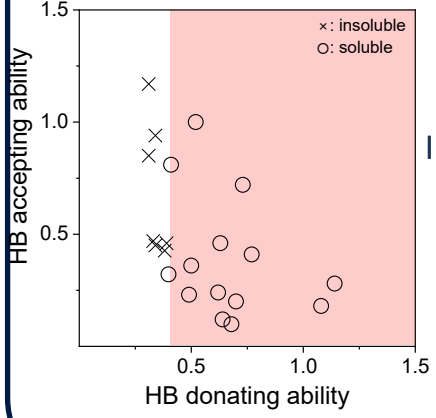
  Other: PMMA-ILs interaction affected by hydrophobicity of ILs [DOI:10.1016/j.electacta.2017.07.181]

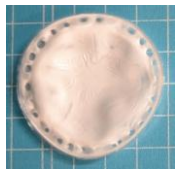
PEO



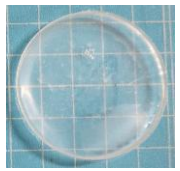


PVdF



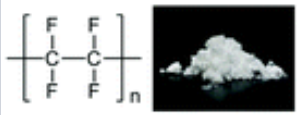


Insoluble pair

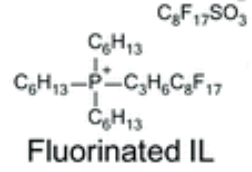


Soluble pair

PTFE



PTFE Powder



Fluorinated IL

Self-standing composites w/o IL bleed out

PMMA

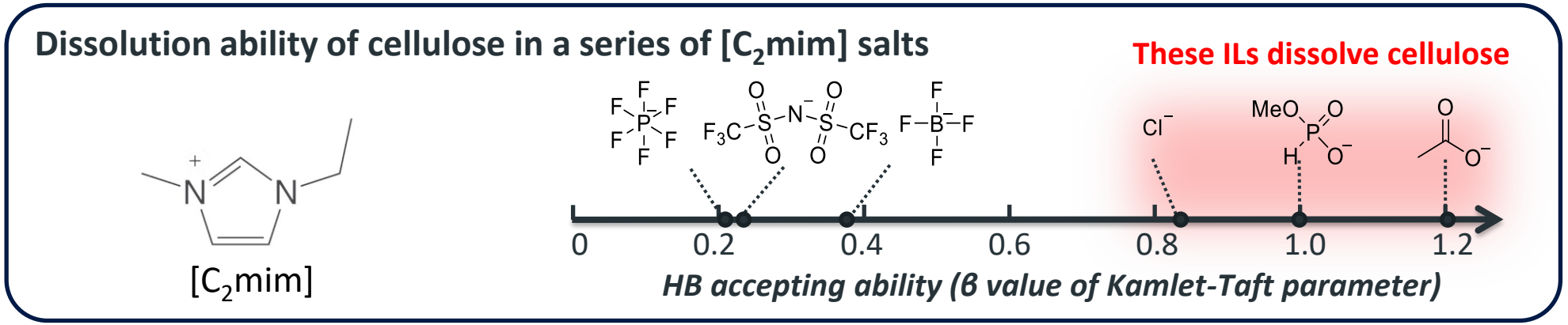
(a) PMMA		(b) PBMA				
X[Tf2N]		X[Tf2N]			[C4mim]Y	[P666,14]Y
X	T/°C	X	T/°C	Y	T/°C	T/°C
[C4mim]	60	[C4mim]	60	[Tf2N]	60	80
[C2OHmim]	–	[C2OHmim]	80	[FSI]	80	–
[C4py]	60	[C4py]	80	PF6	△	△
[Pyr14]	60	[Pyr14]	80	CF3SO3	△	×
[N4441]	60	[N4441]	80	BF4	×	×
[P4441]	100	[P4441]	80	SCN	×	100[1]
[P666,14]	100	[P666,14]	80	(CH3O)(H)PO2	×	120[1]

Developed ILs for use with polymers in gel polymer electrolytes and antistatic applications

My research focus (from synthetic polymer to bio-polymer)

A project assistant professor at Tokyo University of Agriculture and Technology (TUAT)

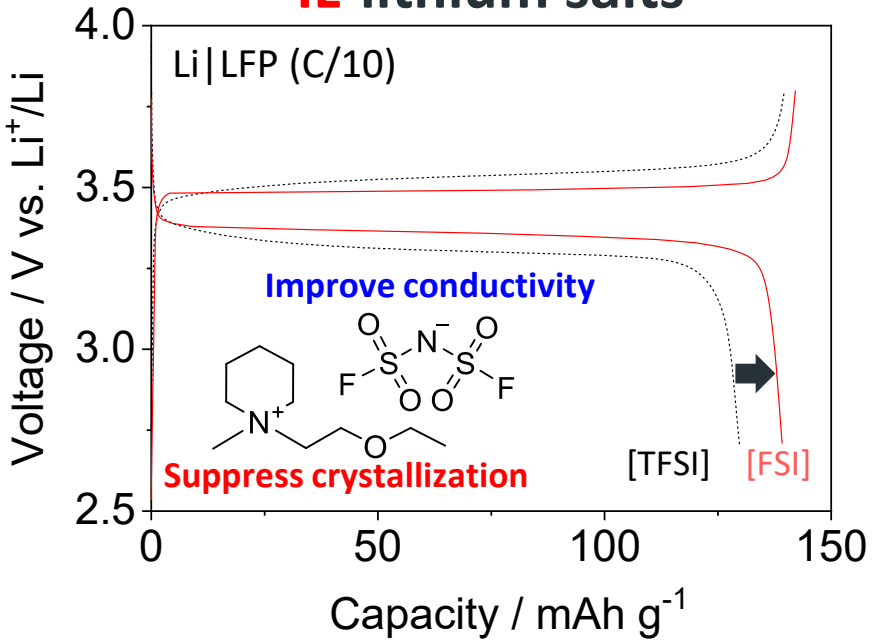
- **ILs designed for biomass:** Hydrogen bond (HB) accepting ability of ILs was believed to rule the dissolution of biomass in ILs. This is true for dissolution of cellulose [DOI: 10.1039/B713289A, from my colleague].



- Solubility differs depending on the biomass composition [DOI: 10.1039/C5GC00646E, from my colleague]
- Klason lignin is one of the most poorly soluble biomass components. By employing OH^- anions, the HB accepting ability of ILs is significantly enhanced, resulting in improved dissolution of Klason lignin. [DOI: 10.1016/j.ijbiomac.2019.03.152)
- For alkaline lignin, having a high HB donating ability is also important in addition to HB accepting ability [DOI: 10.1039/C7GC00626H]

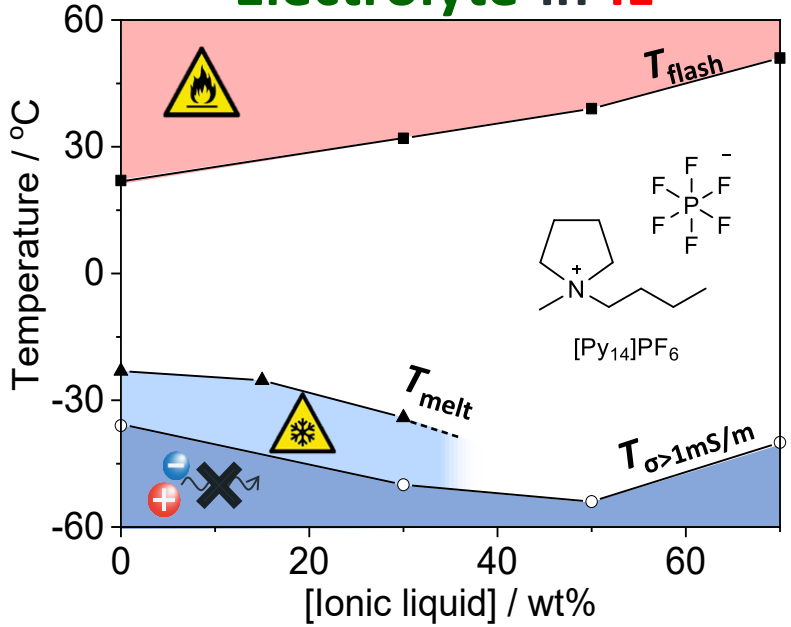
At the ENAM group: ILs designed for different electrolyte systems

IL-lithium salts



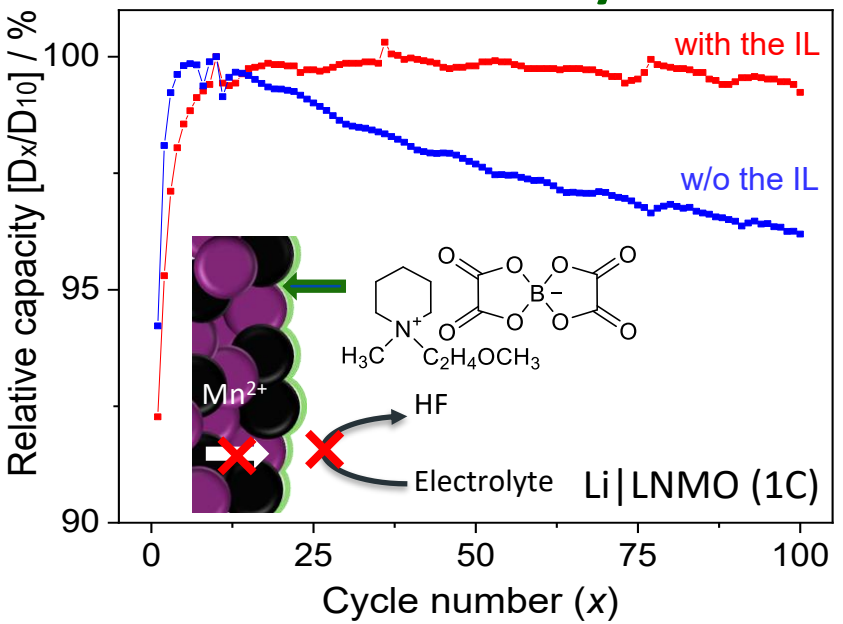
- ✓ ILs with no melting point, realized by ether functionalization
- ✓ Being a good liquid is predominant request, enabled by FSI anion
- ✓ DOI:10.1016/j.electacta.2018.09.205

Electrolyte-in-IL



- ✓ ILs was used as a flame retardant
- ✓ [IL] > 50wt%, the mixture has a T_{flash} > 35 °C w/o combustion tendency, which is considered **not flammable** according to GHS classification
- ✓ DOI:10.1016/j.electacta.2019.05.086

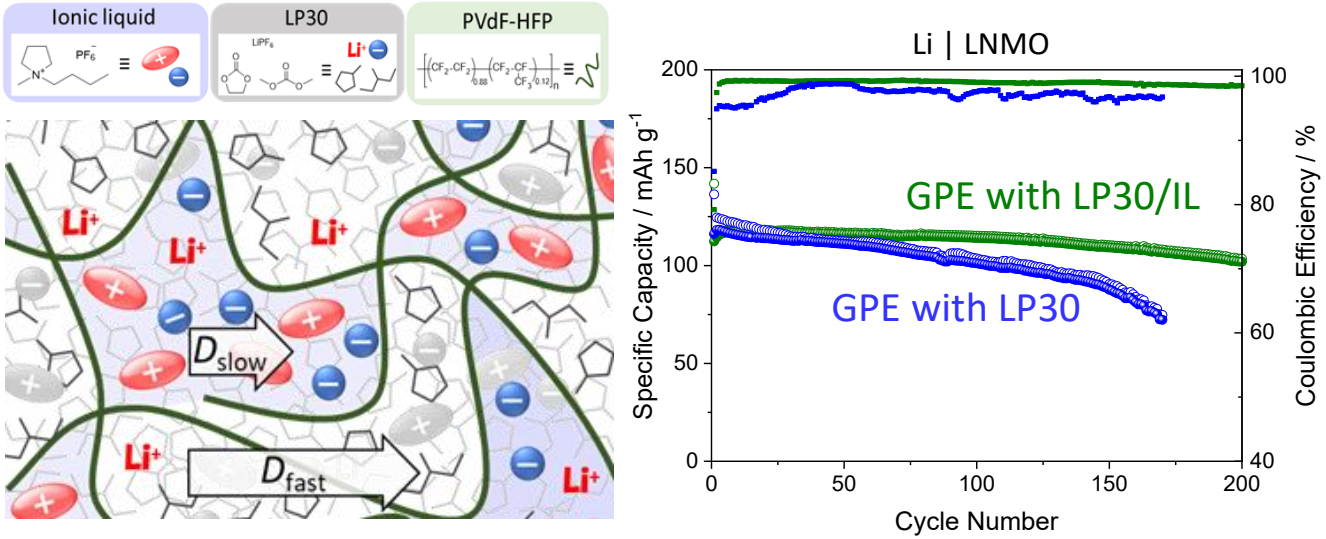
IL-in-electrolyte



- ✓ A few amount (<10wt%) of task specific ILs is added as an additive
- ✓ Addition of BOB-IL improved battery cycling stability because BOB anions form protective cathode-electrolyte interphase
- ✓ DOI:10.1016/j.electacta.2019.04.190

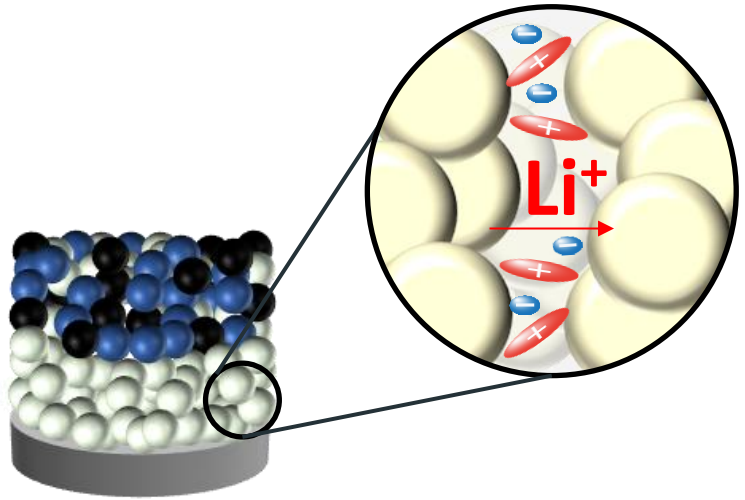
At the ENAM group: ILs with solid framework

With polymer network



- ✓ IL-electrolyte mixtures were used to form gel polymer electrolytes (GPEs) with PVdF-HFP
- ✓ ILs in the GPE enabled longer cycle life due to improved electrochemical stability with ILs
- ✓ DOI:10.1016/j.electacta.2021.139470

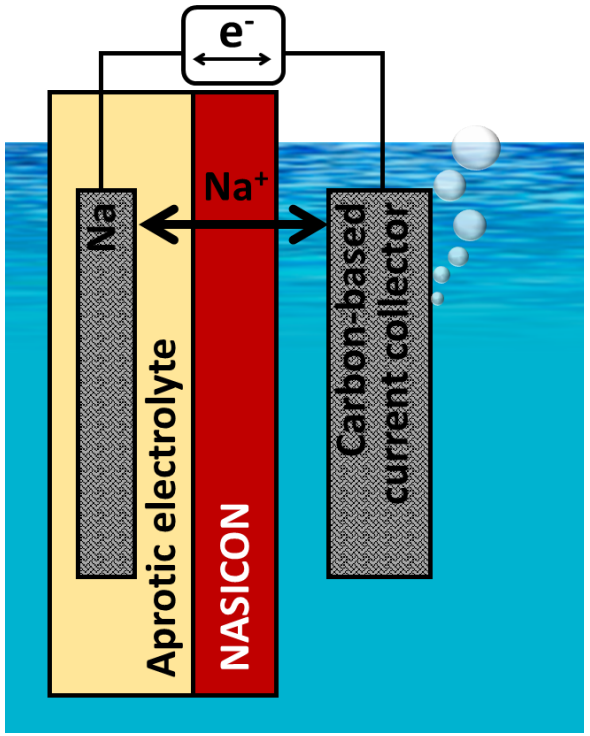
With inorganic solid-state electrolytes



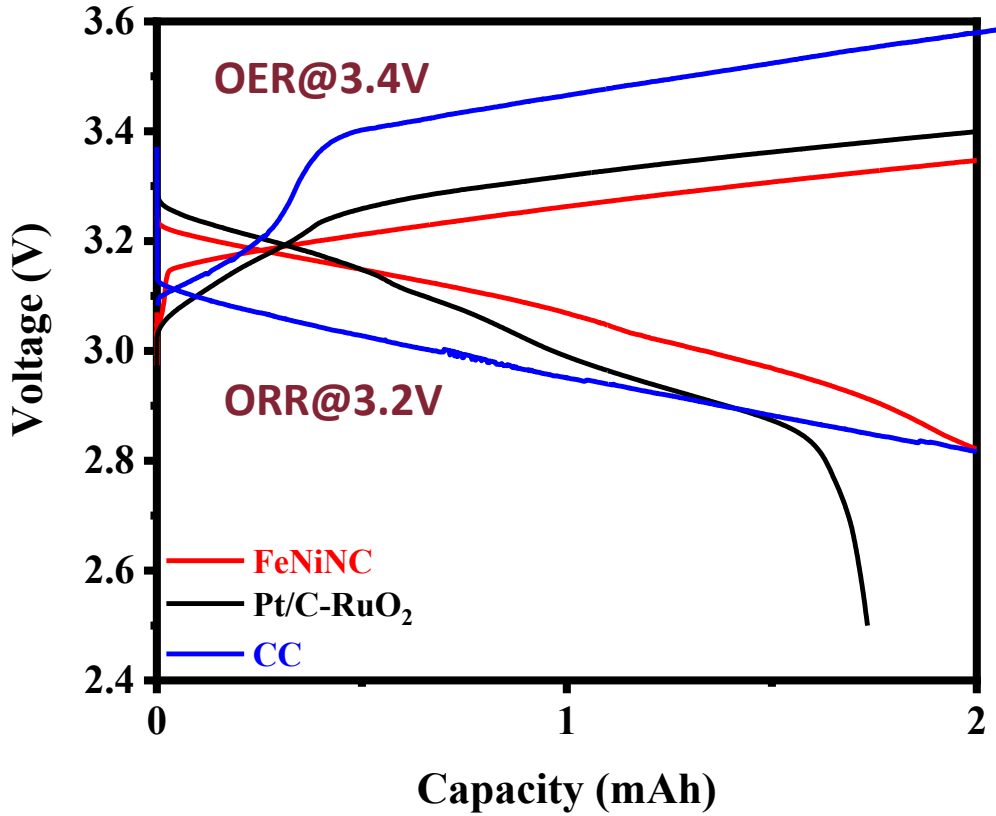
- ✓ By adding ILs to oxide-type electrolytes (LLZO), their grain boundary resistance was successfully eliminated
- ✓ Without sintering, room temperature ionic conductivity about 10^{-3} S/cm was achieved with ILs
- ✓ DOI:10.3390/app12147318

New topic: Seawater batteries

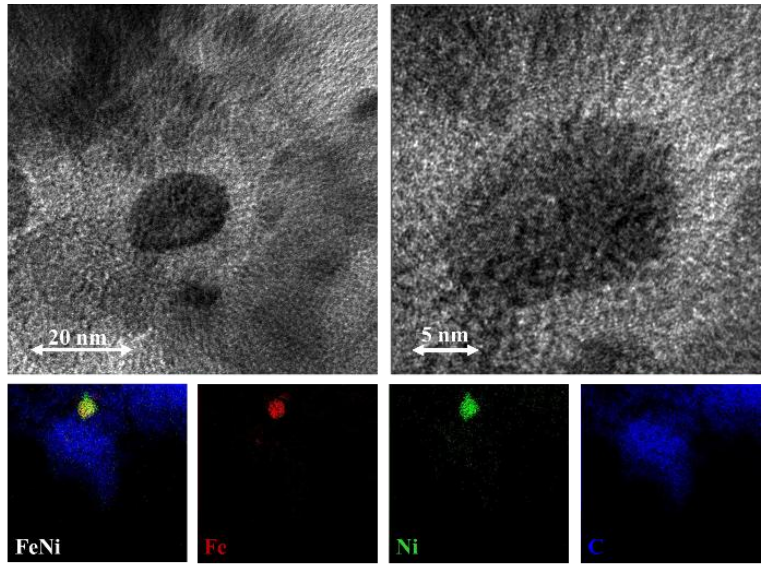
Electrocatalysts for oxygen evolution and reduction reaction (OER and ORR)



Seawater batteries



TEM image of FeNi nanocomposites incorporated in mesoporous carbon functionalized with nitrogen



At anode:

$Na^+ \Leftrightarrow Na + e^-$

At cathode:

$O_2 + H_2O + 4e^- \Leftrightarrow 4OH^-$

- Without catalysts, seawater batteries exhibit a huge overpotential,
- The overpotential was effectively reduced with FeNi alloy synthesized with mesoporous carbon as a template

My project idea

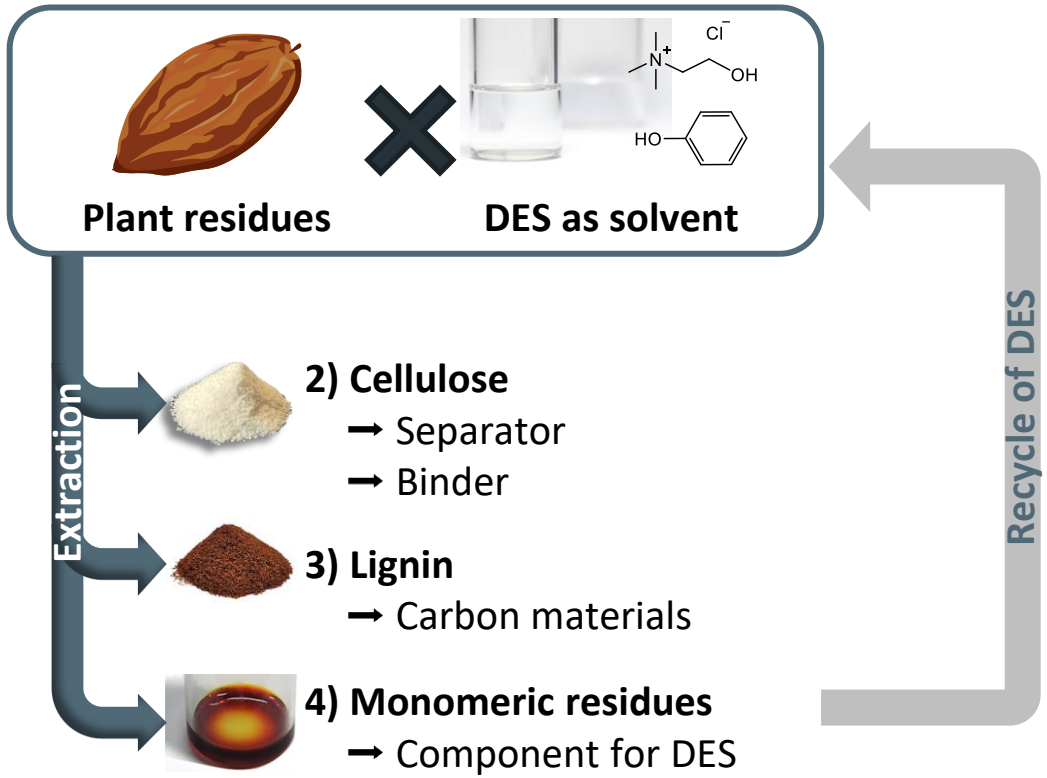
Combination of green chemistry and electrochemistry

Targeted call: HORIZON-CL5-2026-09-D2-01

Main objectives: Utilising Bio-based Raw Materials for Battery Electrode Materials

Current problem: Isolated case studies and weak communication between energy and forest/agriculture sectors.

- Extraction of biomass from agricultural or forest industry residues with green solvent (like DES) and their recycling
- Utilization of extracted biomass for the synthesis of graphite or carbon materials
- Show strategy to synthesize appropriate carbon for diverse battery system from the viewpoint of biomass composition of plants and synthesis procedure
- As one extent, synthesize carbon material from black liquor, which is currently combusted to create energy in industry



Conclusion

- **If my project idea is feasible, we are looking for:**
  - Any partners in academia to develop and assess green materials together
  - Industrial partner in forest or agriculture industry
- **We are open for any kind of collaborations, and we can provide:**
  - Electrochemical and physico-chemical analyses
  - Provide battery components, both electrodes and electrolytes

ENAM lab is active on LinkedIn!

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