Recyclable Structural Supercapacitor Composite with Polymer-Ionic Liquid Electrolyte

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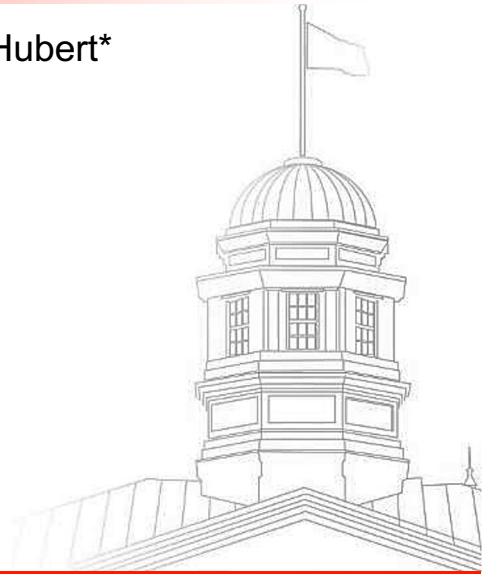
ICCM 2023, Belfast



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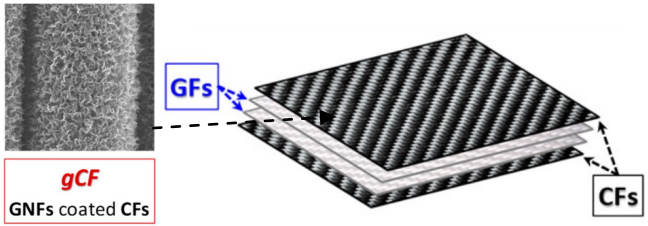
CREPEC
Research Center for High Performance Polymer and Composite Systems

Structural Composite Energy Storage Device

- **Increasing the efficiency and sustainability**
  - Weight
  - Power supply system performance
  - Recyclability
- **Optimizing individual subsystems**
  - Limited saving
- **A holistic approach**
  - Multifunctional composites
  - Electrically active structural material
  - Recyclable components

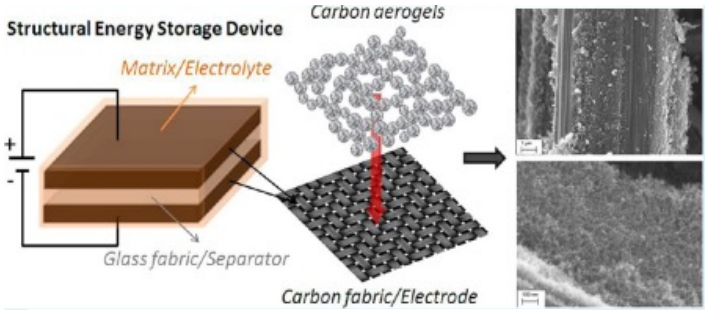
State of the Art Multifunctional Structural Energy Storage Composites

Ganguly, A. et al., ACS Appl. Energy Mater. 2020, 3, 5, 4245–4254



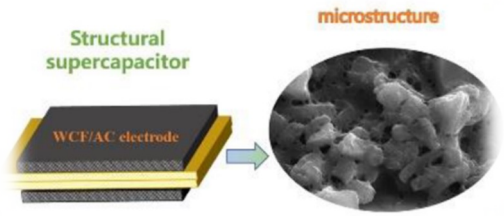
- Graphene nanoflake carbon fibre
- Ionic liquid
- Epoxy

Qian H. et al., ACS Appl. Mater. Interfaces 2013, 5, 13, 6113–6122



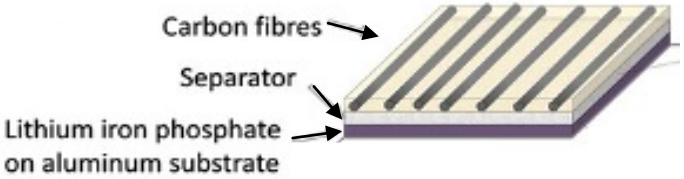
- Carbon aerogel carbon fibre
- Ionic liquid
- Epoxy

Ding, Y. et al., Energy Fuels 2022, 36, 2171–2178



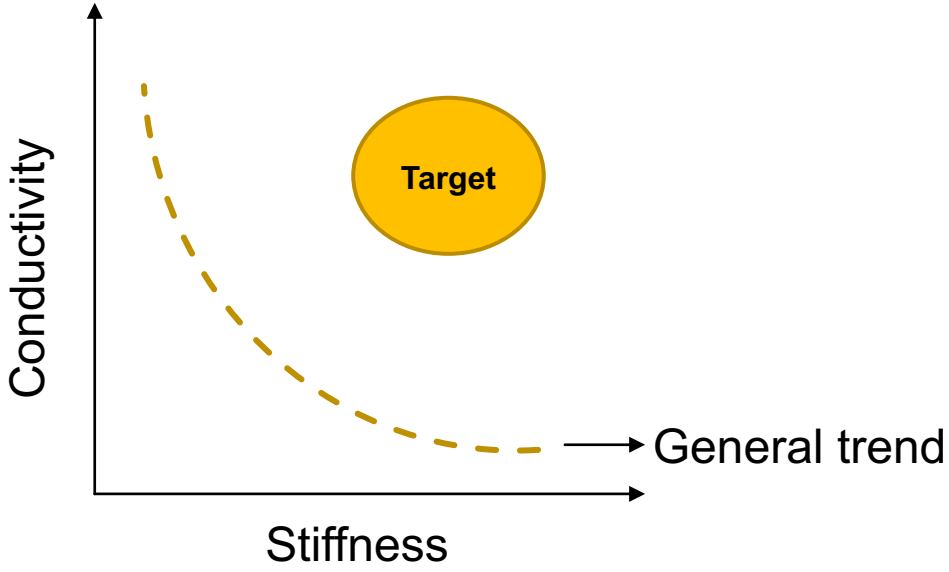
- Activated woven carbon fibre
- Ionic liquid
- Epoxy

Asp, L. E., Adv. Energy Sustainability Res.2021,2, 2000093

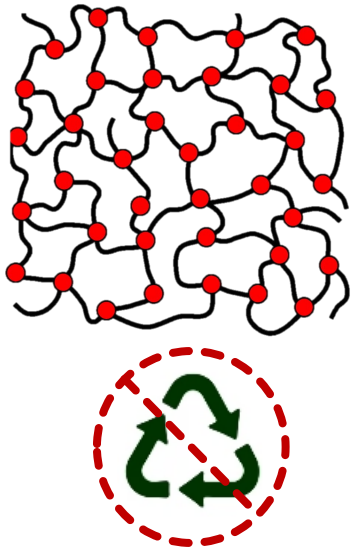


- Carbon fibre
- Lithium salt
- Bisphenol a ethoxylate dimethacrylate

Challenges

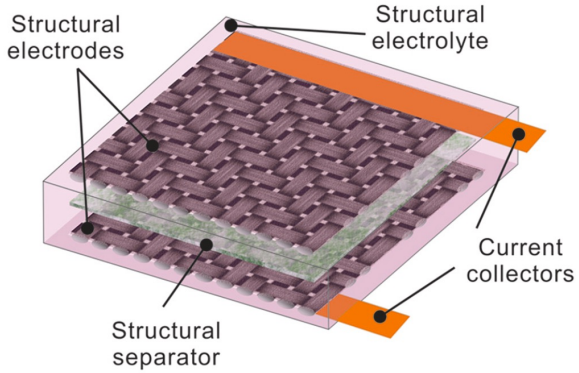


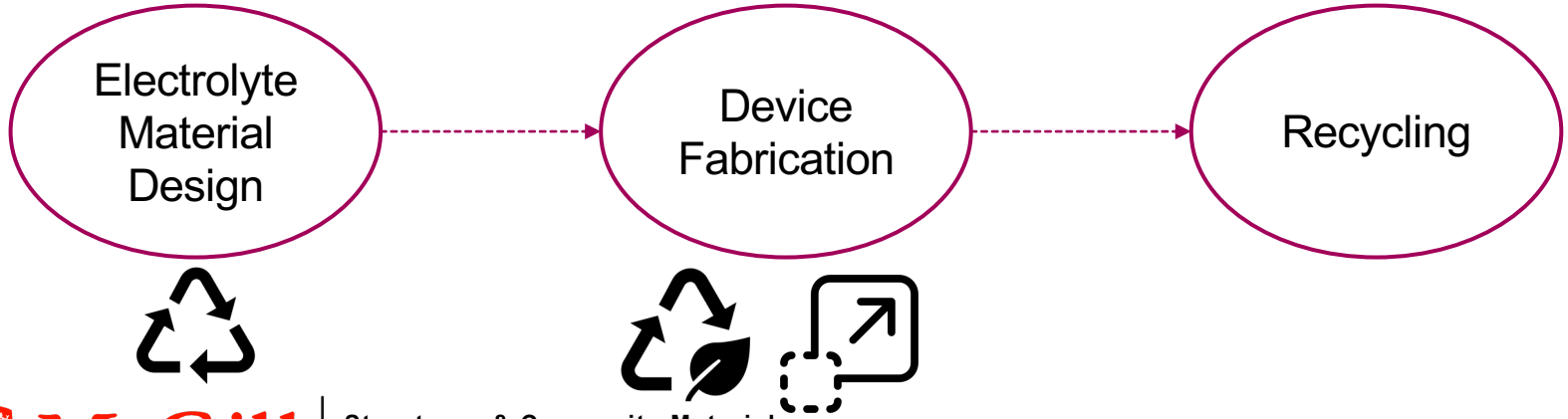
Thermosets



Objective

- Incorporation of the sustainability and recyclability in the design
- Designing the appropriate material system and compatible recycling method

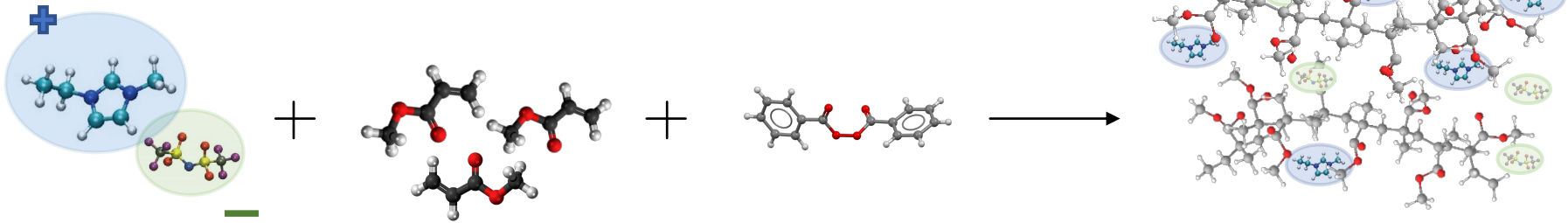




*Navarro-Suárez A. M. et al., Front. Chem. 9:810781

Electrolyte-Synthesis Process

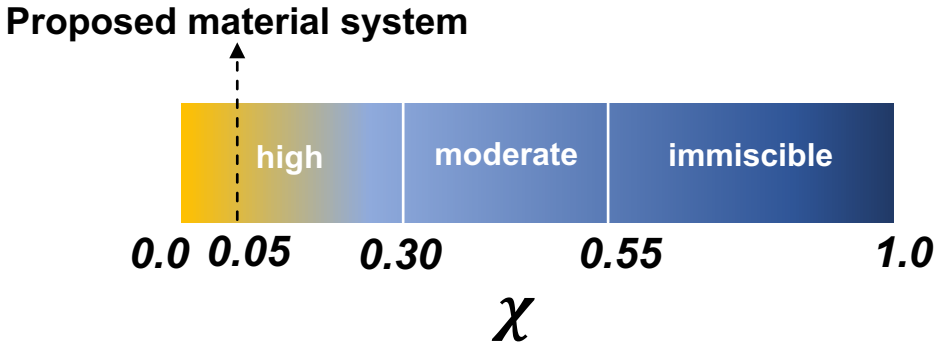
- Combining thermoplastic polymers with ionic liquids:
  - recyclable, high conductivity, good mechanical performance electrolyte
- *In-situ* polymerization at room temperature



Ionic liquid (IL) + Vinylic monomer + Initiator → Thermoplastic polymer + Ionic liquid

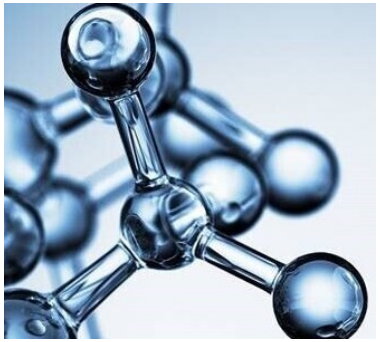
Material Selection- Compatibility Study

- Flory- Huggins's parameter, χ
  - **Cohesive** force (in polymer) *vs.* ***Adhesive*** force (polymer and ionic liquid)
  - Polymethyl methacrylate (PMMA) and Ionic liquid (EMIM-TFSI)



*Langer, E., et al. "Essential quality parameters of plasticizers." Plasticizers derived from post-consumer PET (2020): 45-100.
*Mohan, M., et al. Green Chem., 2022, 24, 1165
* Yoo, B., et al. Ind. Eng. Chem. Res. 2012, 51, 29, 9913–9917

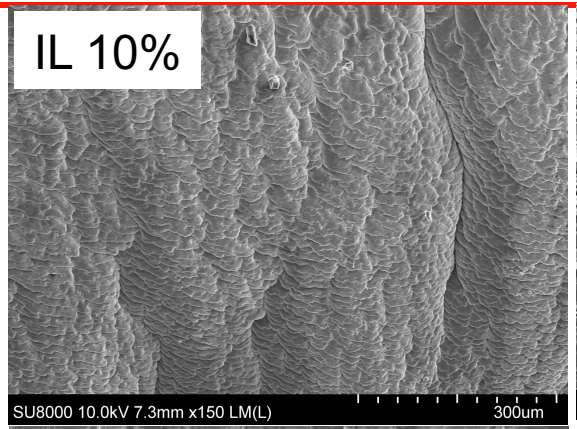
Electrolyte Synthesis Process

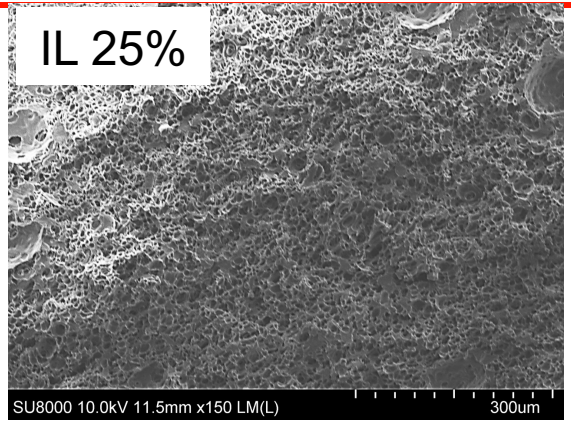


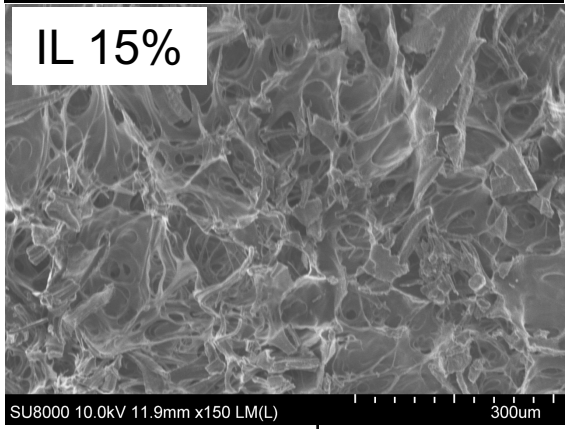
ELIUM® ARKEMA

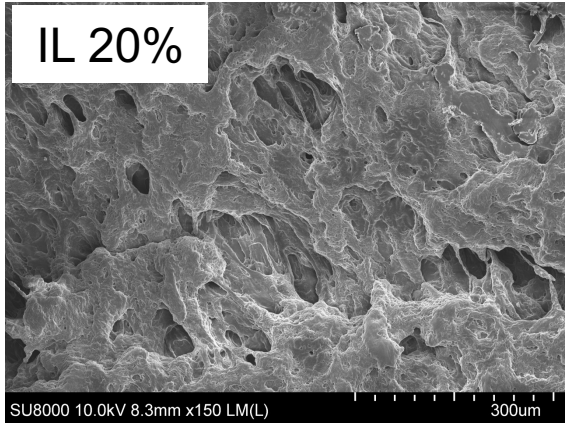
- Polymer: Elium 188 O resin (Methyl methacrylate, MMA)
- Ionic liquid: EMIM-TFSI
- Initiator: Dibenzoyl peroxide (1.6% w/w)
- Lithium salt (Li-TFSI)
- Fumed silica (SiO_2)
- Process:
  - Mixing of Elium®, IL, and additives adding initiator (IL:PMMA (w/w%): 10:90 to 60:40)
  - Curing at 35 °C for 2 hrs
  - Post-curing at 80°C for 1 hr

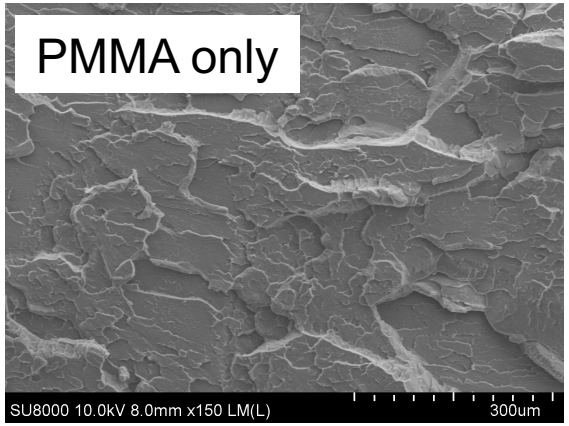
Electrolyte - SEM





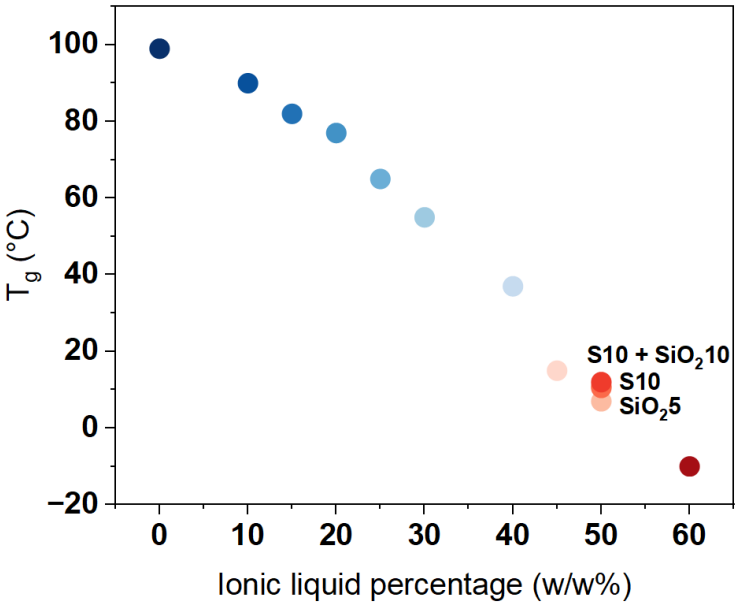




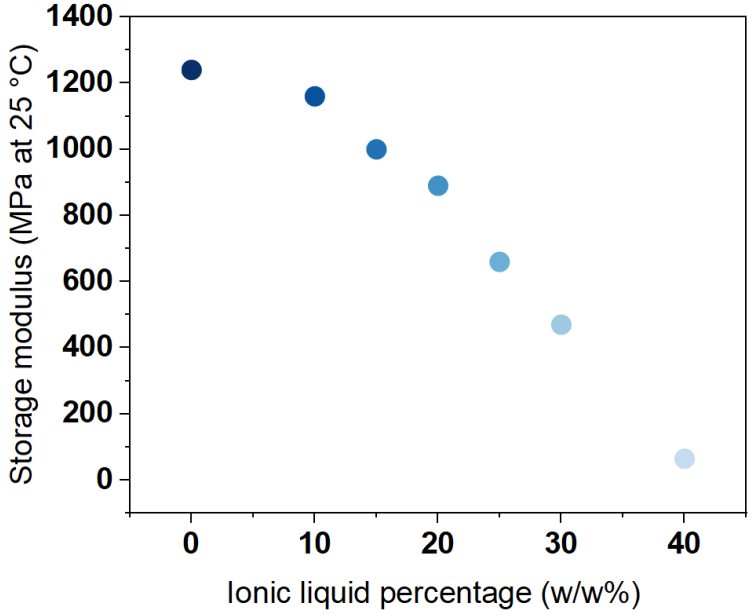


Electrolyte - Material characterization

DSC



DMTA

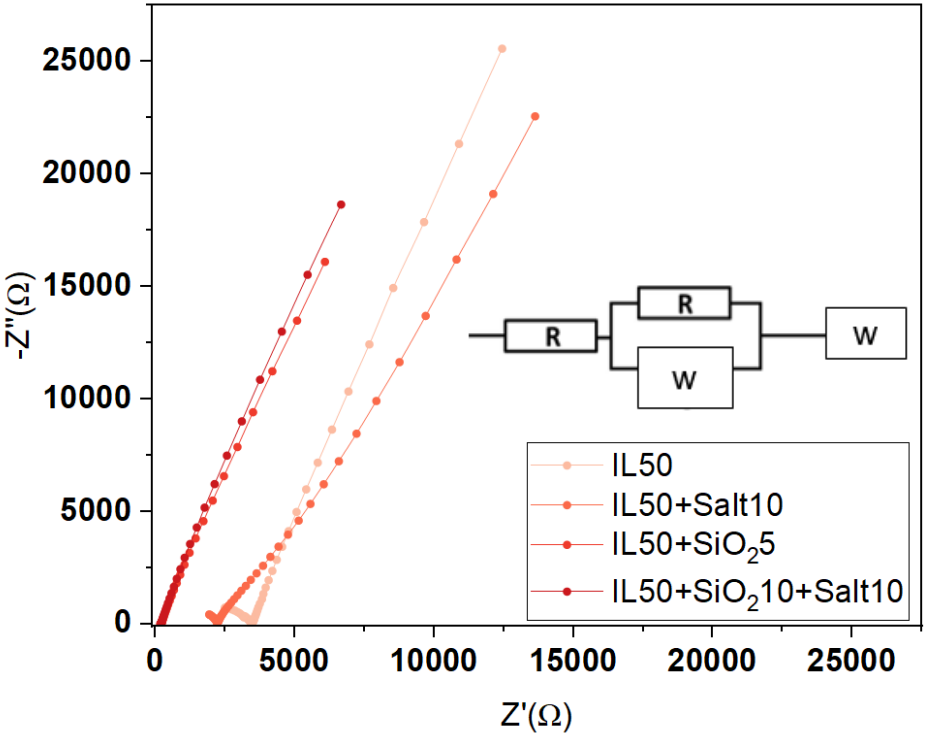


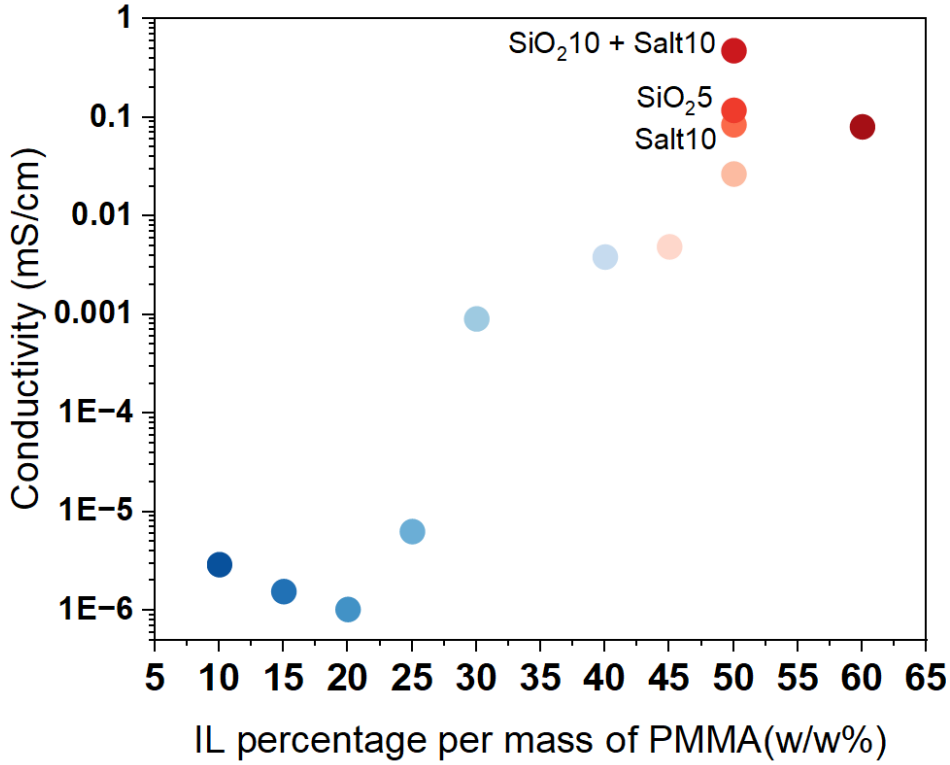
Tensile test

Ionic liquid %	Tensile modulus (GPa)
0	2.63
10	2.55
25	2.34
20	2.06
25	1.70
30	1.12

ASTM D638- type V

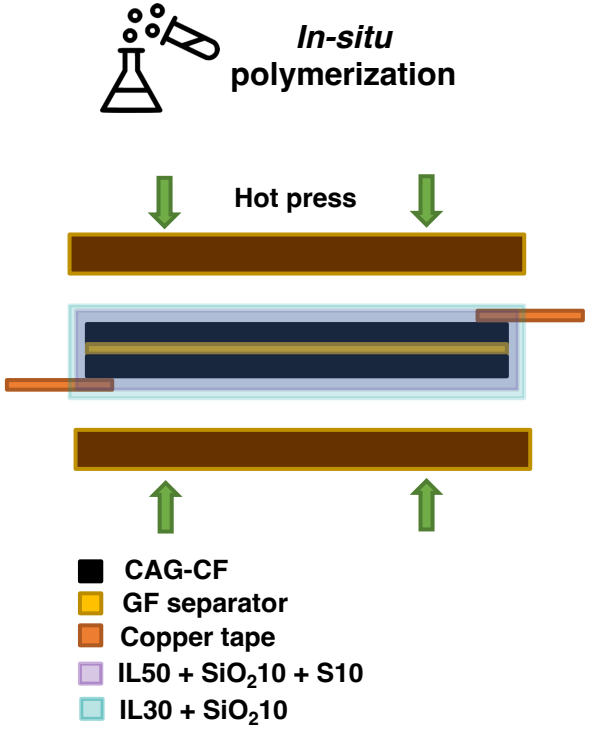
Electrolyte - Conductivity - EIS





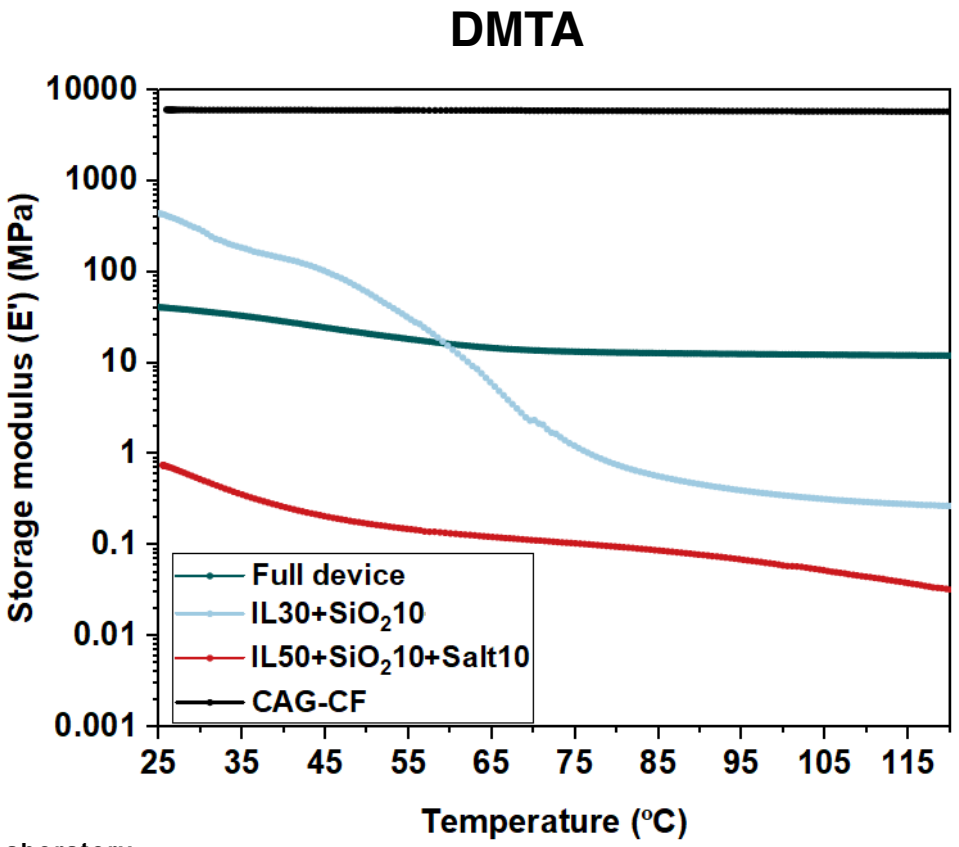
Supercapacitor Device Fabrication

- Electrode and separator (*Greenhalgh's group**)
  - Carbon fibre: Carbon-aerogel-modified carbon fibre (C-weave, 200 gsm), CAG-CF
  - Separator: Glass fibre, GF
- Thin films of *IL50%+additives* is *in-situ* polymerized on the CAG-CF and GF.
- Thin films of *IL30%+additives* is hot-pressed on the initial device layout.



*Qian H. et al., ACS Appl. Mater. Interfaces 2013, 5, 13, 6113–6122

Supercapacitor Device Mechanical Performance



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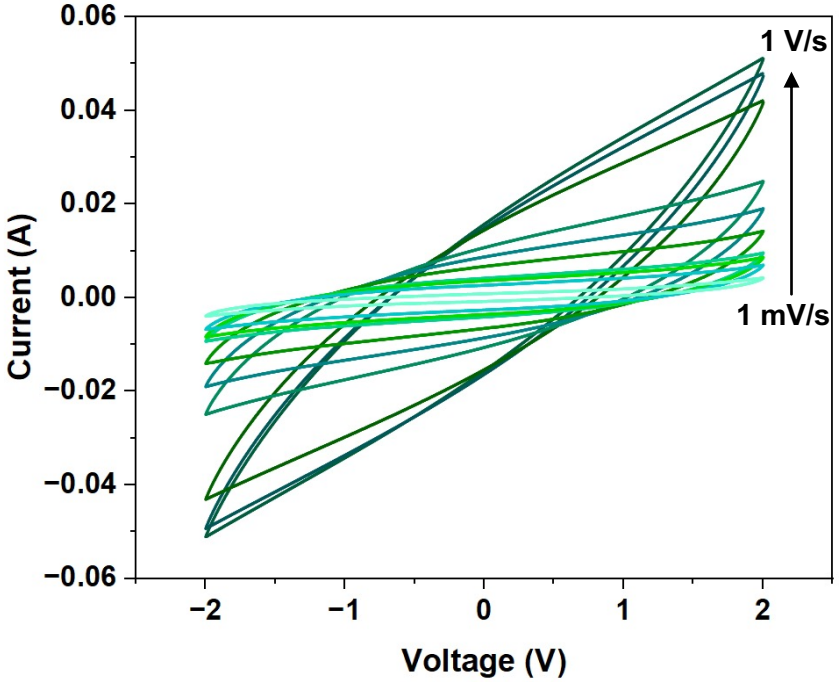
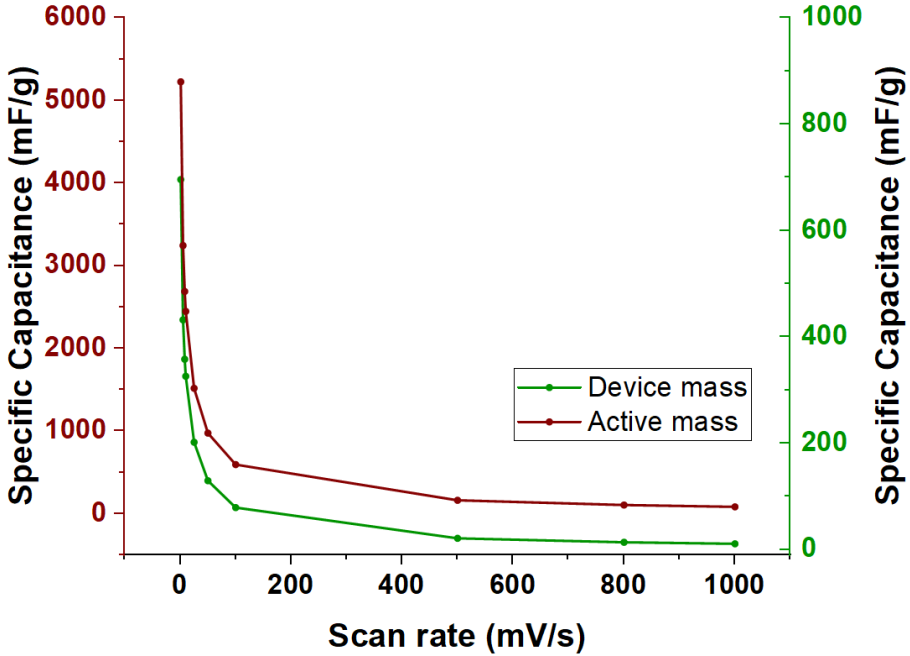
Supercapacitor Device Electrochemical Performance

Cyclic voltammetry



Capacitance vs. Scan rate



- 5.2 F/g @ 1 mV/s Active mass
- 0.7 F/g @ 1 mV/s Device mass

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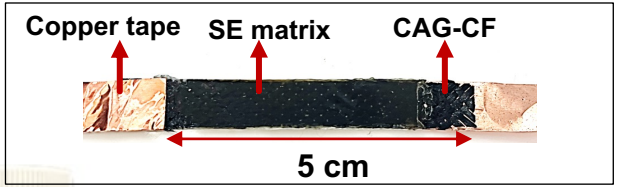
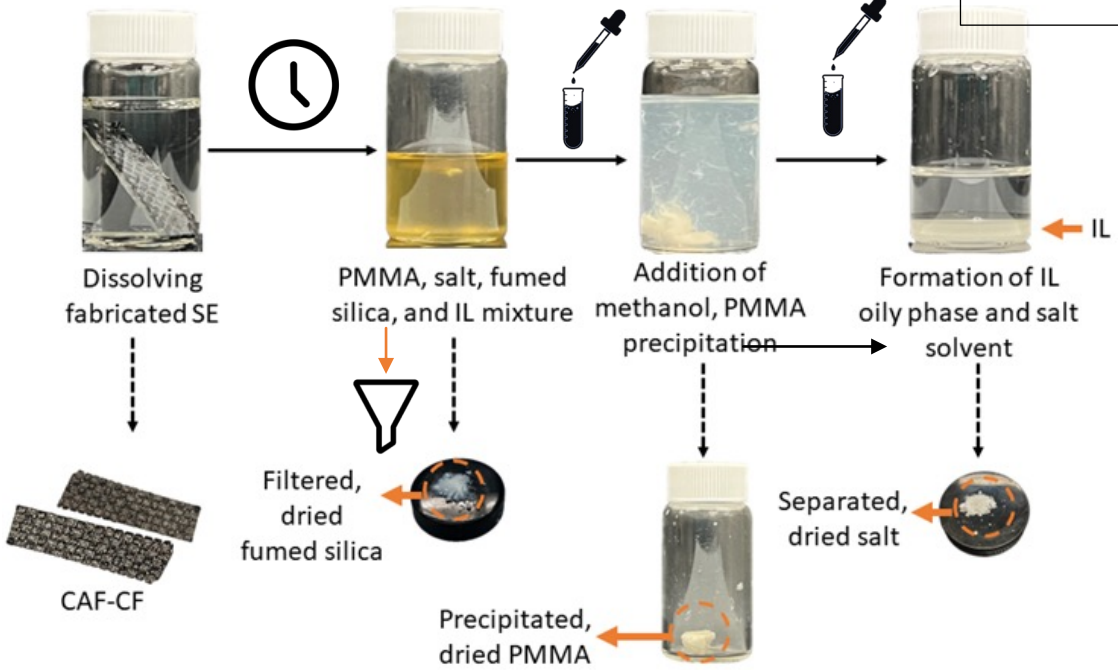
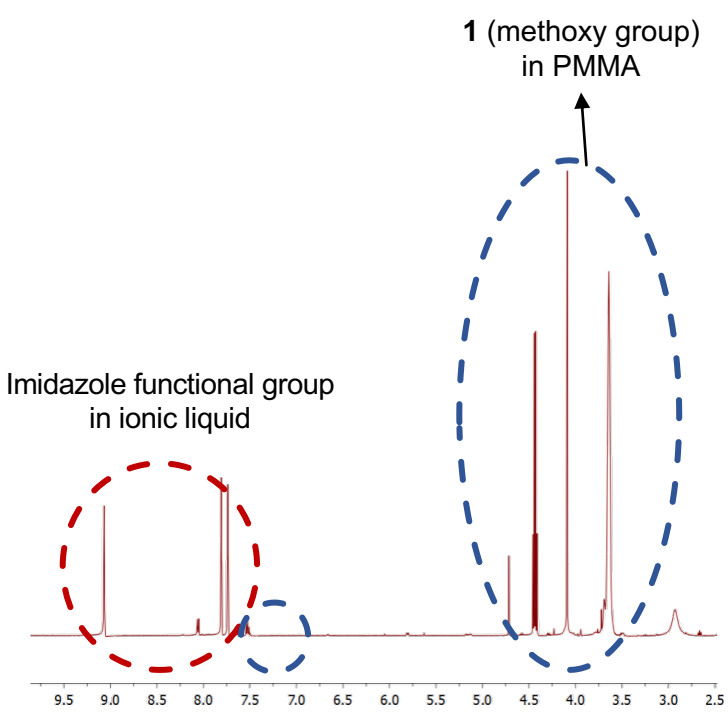
Recycling

- Using ethyl-acetate as a solvent
- Simple and efficient method



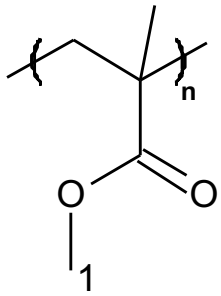


Recycling- NMR

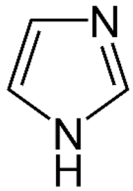


Before recycling (PMMA + IL)

PMMA



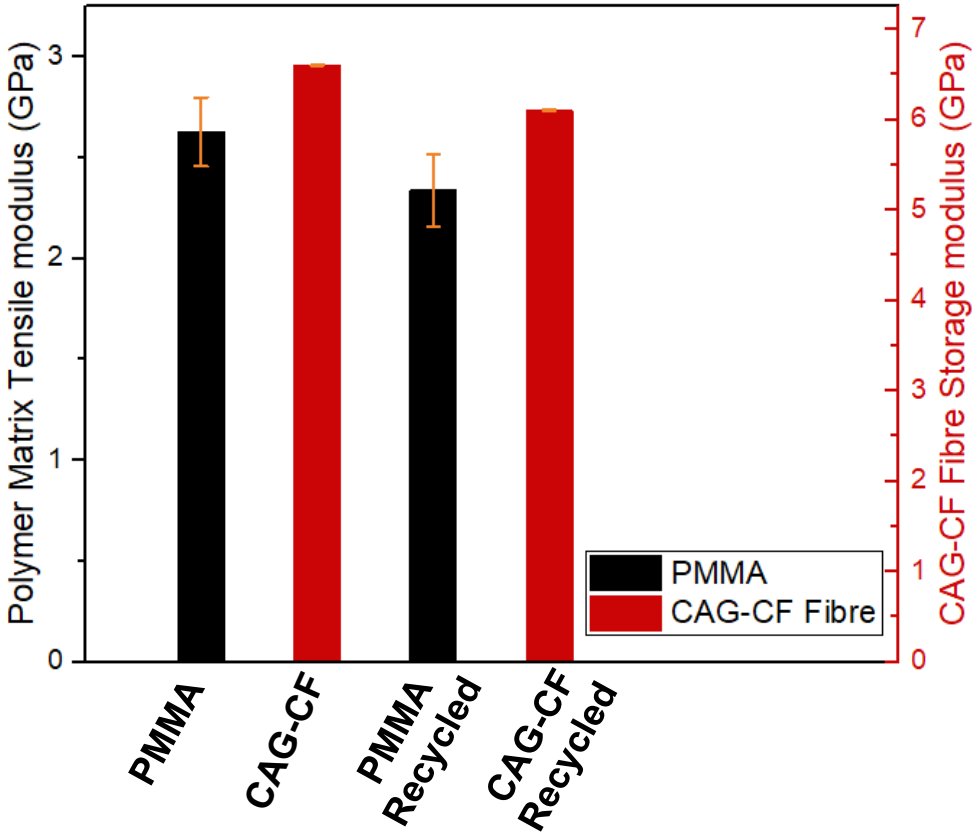
Imidazole functional group



After recycling (PMMA)

Recycling- Mechanical Test

>10% decrease in modulus



Conclusion

- Optimization of the conductivity and mechanical performance should be considered simultaneously for an efficient structural polymer electrolyte.
- The integration of sustainability and recyclability should be seamlessly incorporated into the design process.
- Considering the capability of Elium® resin, the process has the potential of scaling up.

Acknowledgments

- McGill University Werner Graupe Chair
- Natural Sciences and Engineering Research Council of Canada
- Research Centre for High Performance Polymer and Composite Systems (CREPEC)
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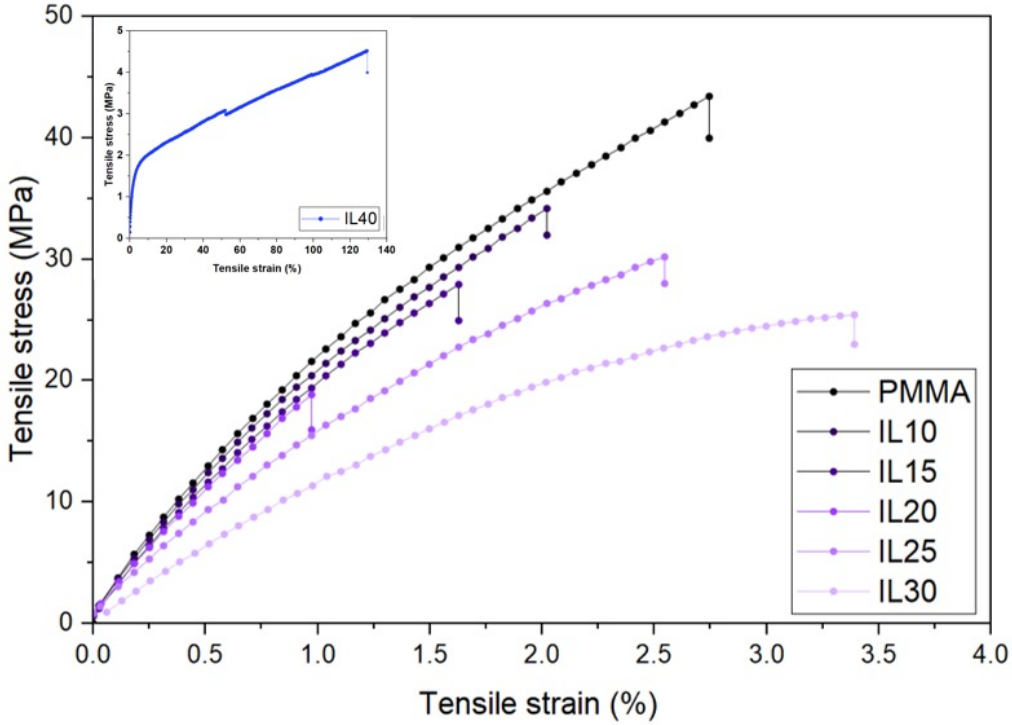
- Prof. Leif Asp, Chalmers University of Technology
- Lucie Riffard and McGill SCML members

Thank you!

Tensile


Tensile stress (MPa)
Tensile strain (%)
PMMA
IL10
IL15
IL20
IL25
IL30
IL40