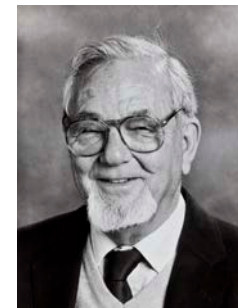
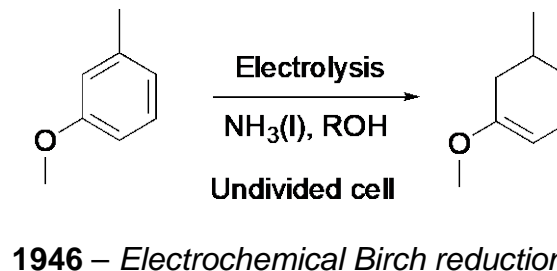
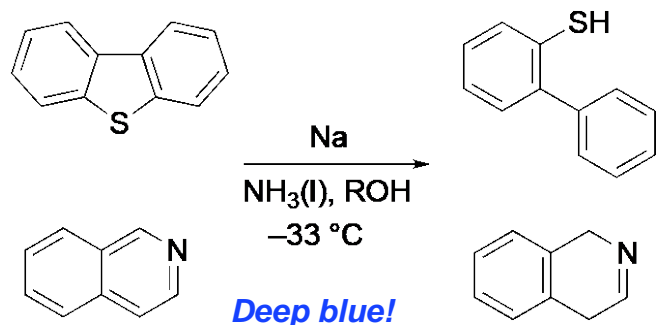


Metallic sodium reduction of heteroaromatics – 1944



Birch, A. J. 117. Reduction by Dissolving Metals. Part I. *J. Chem. Soc.* **1944**, No. 0, 430–436. <https://doi.org/10.1039/JR9440000430>.

Birch, A. Electrolytic Reduction in Liquid Ammonia. *Nature* **1946**, 158, 60. <https://doi.org/10.1038/158060b0>.

Hypothesis: Electrocatalysis for hydrogen-free bitumen upgrading?



Electrocatalysis
 Solvent, salts, RT
 Undivided cell
 low overpotential

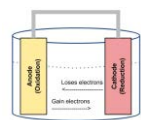
Reductive electrocatalysis – HDS, HDN, HDO
Low sulfur, low nitrogen maltenes from asphaltenes

Oxidative electrocatalysis – Cold coking
Mesophase asphaltenes, graphenes, quantum dots, reinforced carbon fibres

Hydrogen-free, ambient temperature upgrading to maltenes



Maltene-free asphaltenes
New electrochemical extrusion

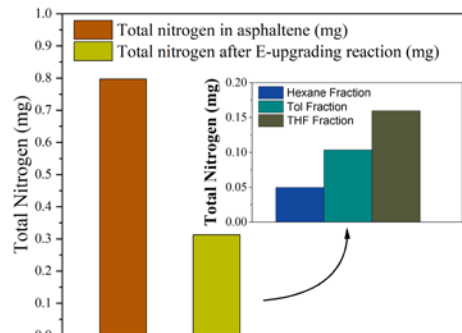
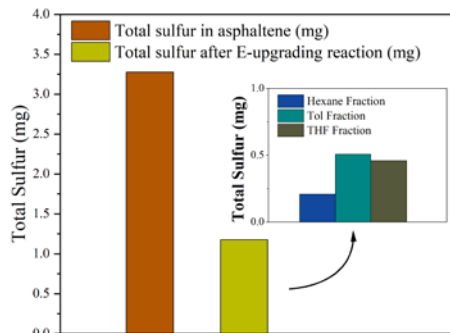
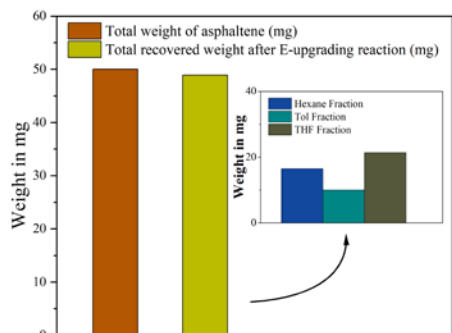


Earth-abundant catalyst
Low overpotential

Material	%N	%C	%H	%S
Athabasca asphaltene	1.59	83.64	5.74	7.18
Maltenes post reaction	0.33	81.76	12.31	1.3
Asphaltenes post reaction	0.59	78.72	9.14	2.17

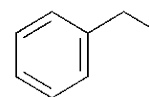
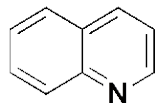
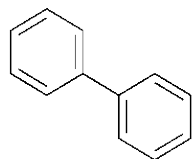
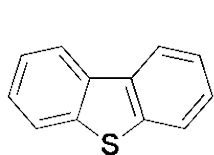
Optimal conditions give > 70% asphaltenes – sulfur and nitrogen below detection limits

Dramatic reduction in heteroatom content, high mass balance



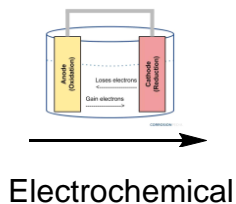
Mass balance ~98%

No H₂S – sulfates from anodic oxidation!



Some ring hydrogenation observed in both reactions

Mesophase synthesis at room temperature

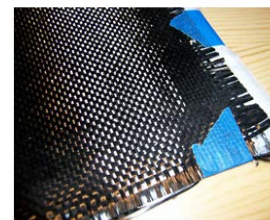


Mesophase
luminescence
(Quantum dots!)



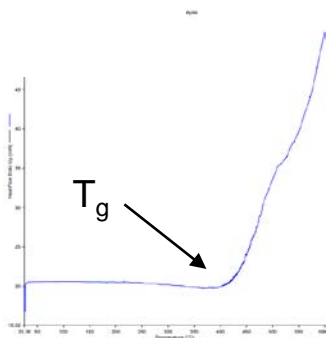
200 g asphaltenes; 4 L plastic bucket; electrodes purchased from Amazon.ca

90% pyridine insoluble (mesophase)

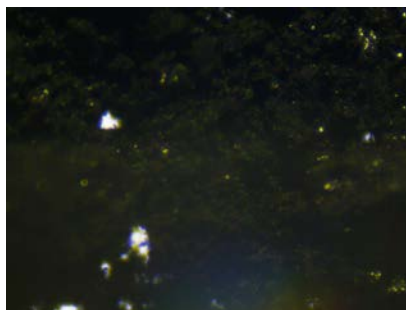


Carbon
fibres

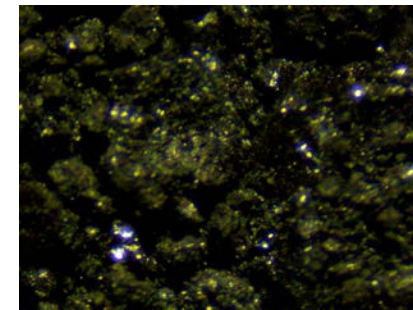
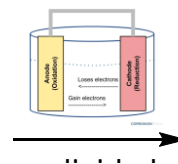
Removes occluded maltenes and isotropic asphaltenes



DSC (exothermic down)



InnoTech asphaltenes
(mild heat-treated)

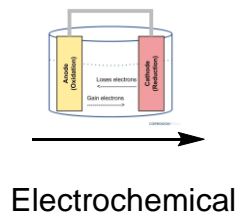


Polarized microscopy

Cold coking of asphaltenes – not much to look at....



Maltene-free asphaltenes
(e-treated)



Toluene solubles
(recovered asphaltenes)

+

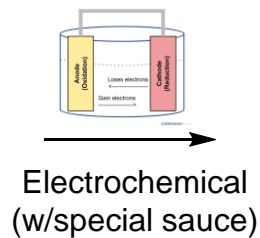


Petcoke (mostly
pyridine insoluble)

Facile bitumen deasphalting



Whole bitumen



Hexane solubles <10%

+

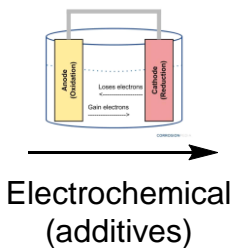


Toluene solubles >85%

Graphenes from black and blue (hydrogen) cokes



Amorphous carbon
(3 anodes, 1 cathode)



Spent anode (~12 h)



Graphenes

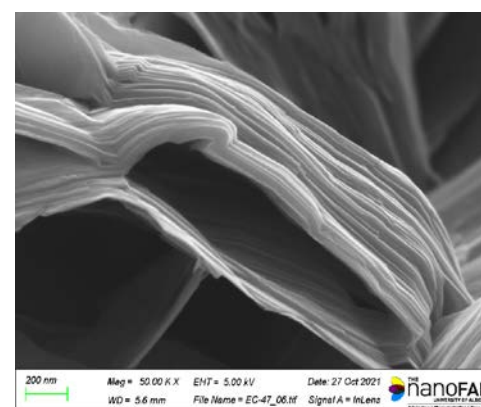
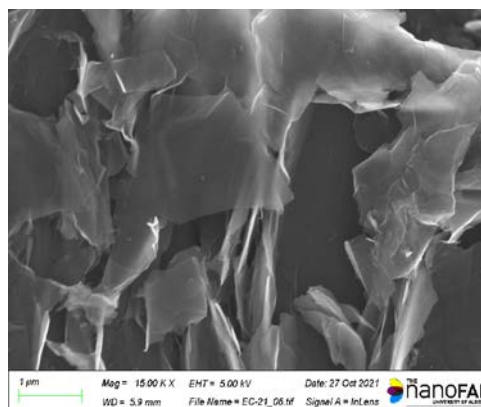
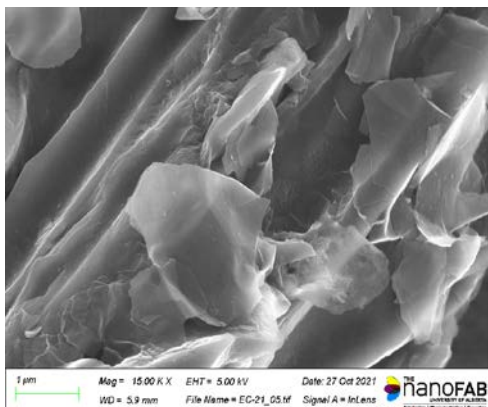
16 g of graphene
(150 beaker, ON)

"Infinitely" scalable,
parallel or series

Low oxygen; no acids
(C/O = 9 : 1)

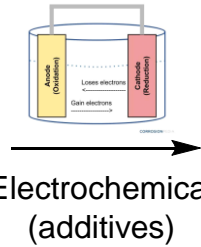
No post-processing
deoxygenation

Low voltage, fast exfoliation (10-100X literature)

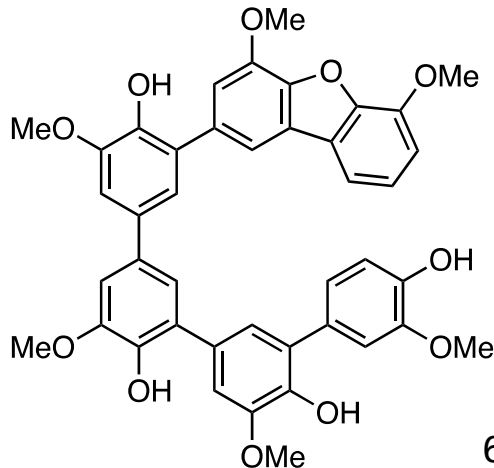


SEM imaging (UofA nanoFAB centre)

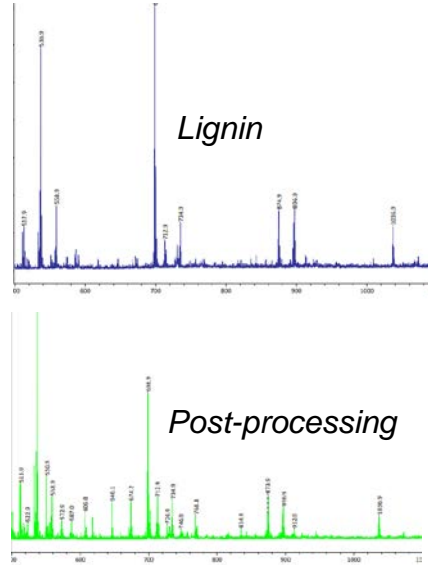
Carbon quantum dots from waste lignin



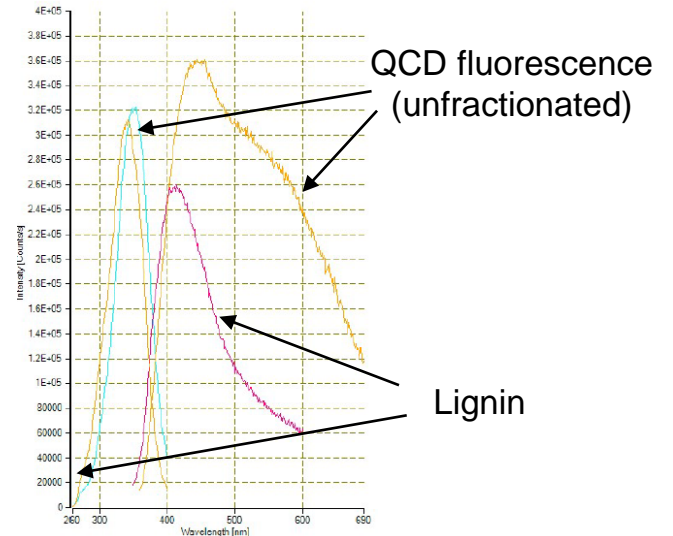
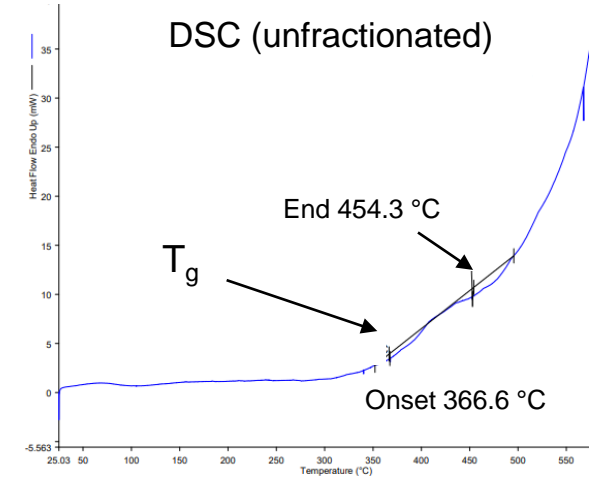
“Organosolv lignin”



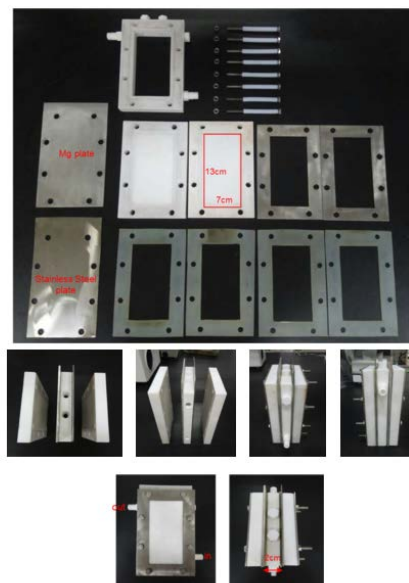
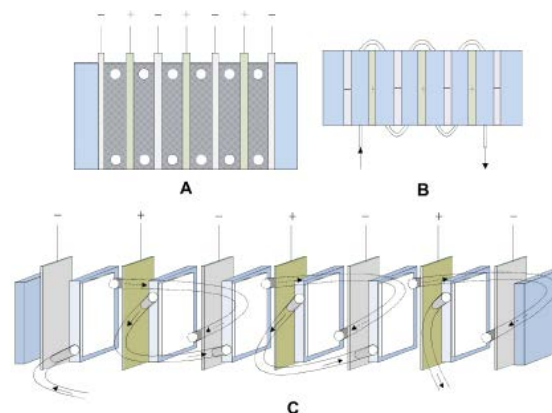
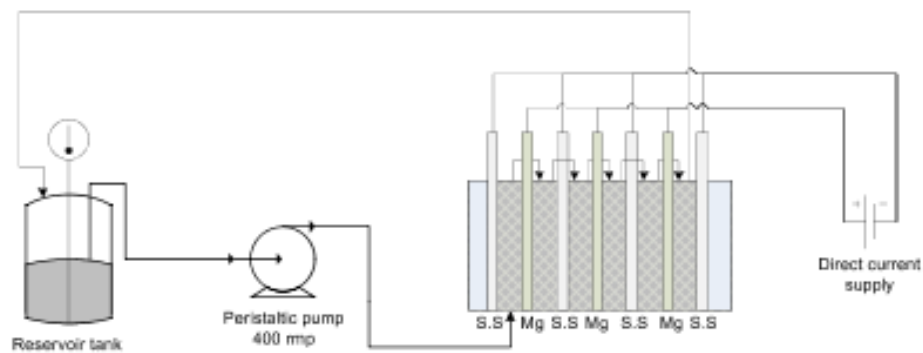
6-mer (from guaiacol)



QCDs (partial conversion)



Engineering and scaling of flow electrocatalytic – *Baran makes it look easy*



B Modular scalability of electrochemical Birch in flow



*Modular
Sustainable
Cheap (3-D printed)
Simple, robust
Water friendly
No clogging*

Phil Baran et al. Scalable and Safe Synthetic Organic Electroreduction Inspired by Li-Ion Battery Chemistry. *Science* **2019**, 363 (6429), 838–845.
<https://doi.org/10.1126/science.aav5606>.

Graphene-reinforced carbon fibres from Athabasca bitumen



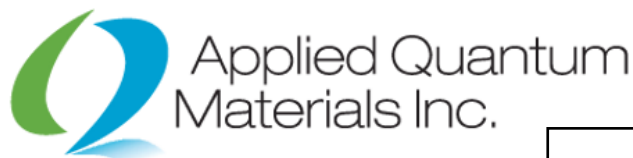
Dark materials matter!

Acknowledgements



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- Dr. Orain Brown
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- Dr. Sanjay Jadhav
- Munashe Chizema
- Amir Rouhi (CME)
- Dominique Hebert
- Mia Dolanjski (NSERC USRA)



Collaborators:

- Dr. Kevin Hodder (CME)
- Dr. Natalia Semagina (CME)



Thanks, Murray!

