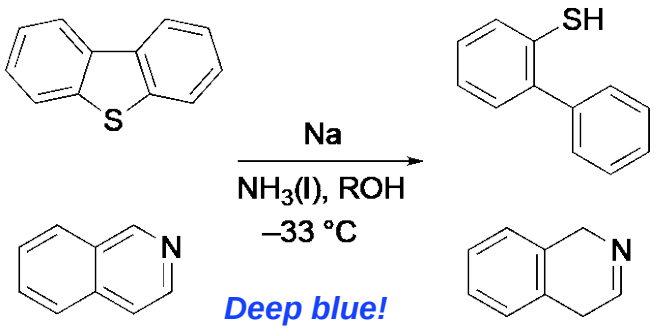
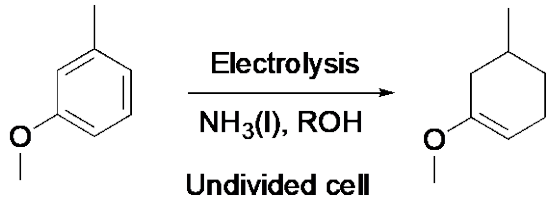
Carbon Upcycling of Bitumen and Waste Biomass

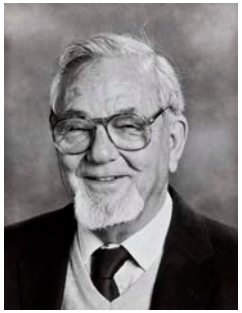
Metallic sodium reduction of heteroaromatics – 1944



Deep blue!



1946 – *Electrochemical Birch reduction*



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

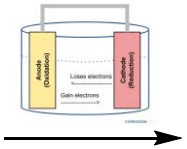
Mesophase asphaltenes, graphenes, quantum dots, reinforced carbon fibres

Adding Value to Bitumen Asphaltenes

Hydrogen-free, ambient temperature upgrading to maltenes

Maltene-free asphaltenes

New electrochemical extrusion



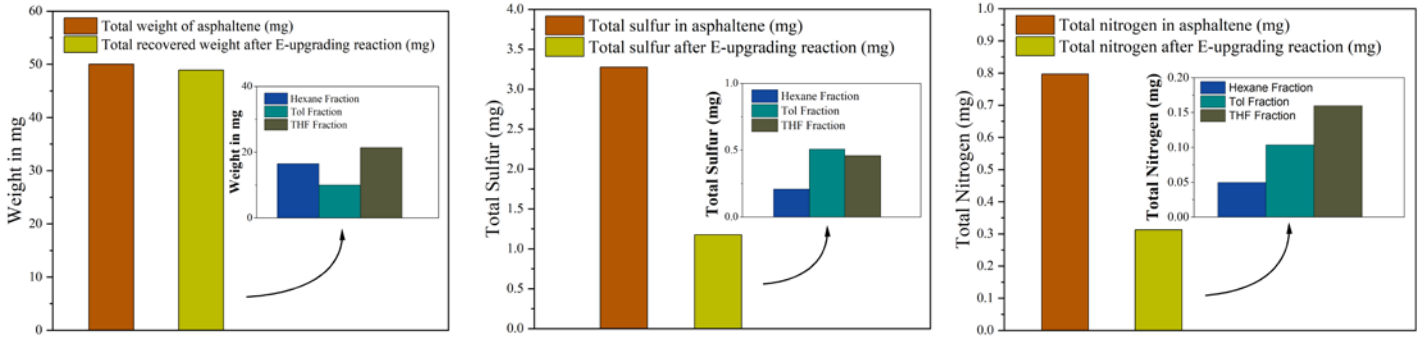
Earth-abundant catalyst

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**

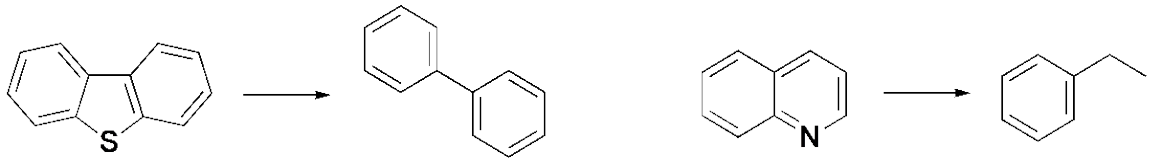
Optimal conditions give > 70% asphaltenes – sulfur and nitrogen below detection limits

Dramatic reduction in heteroatom content, high mass balance



Mass balance ~98%

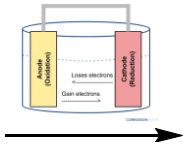
No H_2S – sulfates from anodic oxidation!



Some ring hydrogenation observed in both reactions

Asphaltene Upgrading

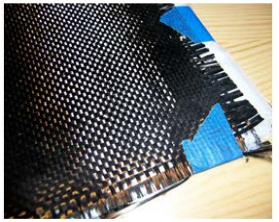
Mesophase synthesis at room temperature



Electrochemical

Mesophase luminescence

(Quantum dots!)

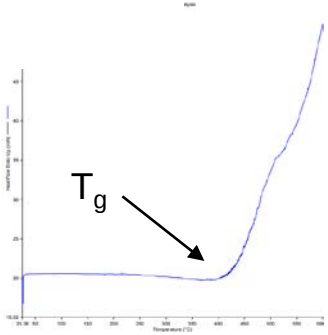


Carbon fibres

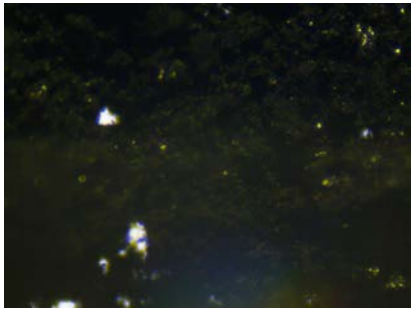
200 g asphaltenes; 4 L plastic bucket; electrodes purchased from Amazon.ca

90% pyridine insoluble (mesophase)

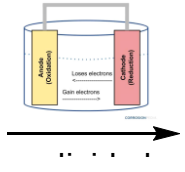
Removes occluded maltenes and isotropic asphaltenes

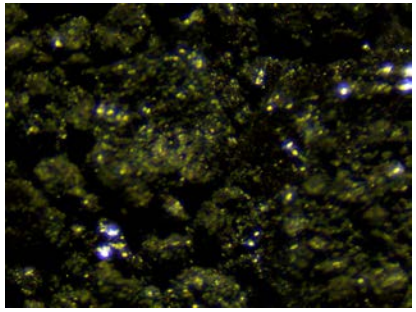


DSC (exothermic down)



InnoTech asphaltenes
(mild heat-treated)



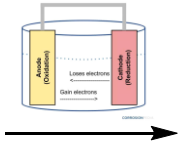


Polarized microscopy

Cold Coking and Bitumen Deasphalting

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

Maltene-free asphaltenes
(e-treated)



Electrochemical

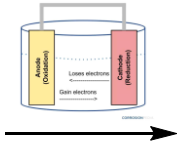
Toluene solubles
(recovered asphaltenes)

+

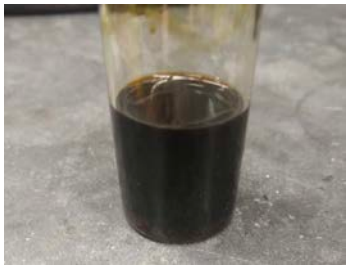
Petcoke (mostly
pyridine insoluble)

Facile bitumen deasphalting

Whole bitumen



Electrochemical
(w/special sauce)



Hexane solubles <10%

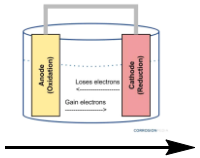
+

Toluene solubles >85%

Adding Value to Petcoke and Amorphous Carbon

Graphenes from black and and blue (hydrogen) cokes

Amorphous carbon
(3 anodes, 1cathode)



Electrochemical
(additives)

Spent anode (~12 h)

Graphenes

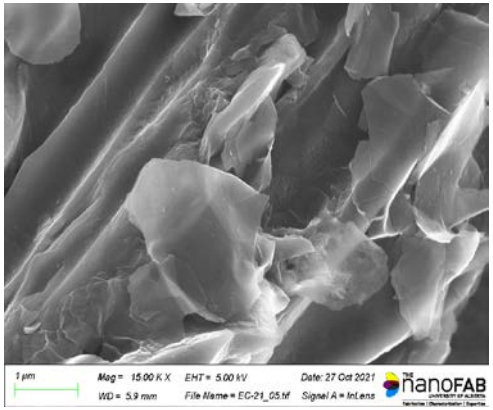
16 g of graphene
(150 beaker, ON)

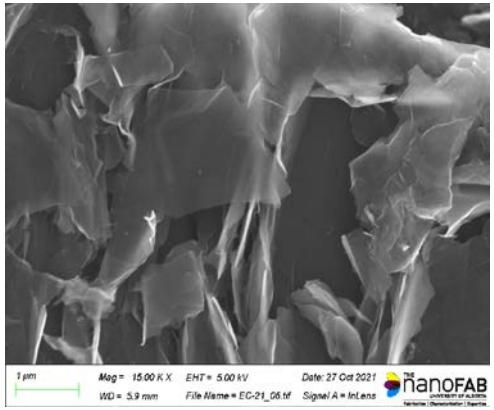
"Infinitely" scalable,
parallel or series

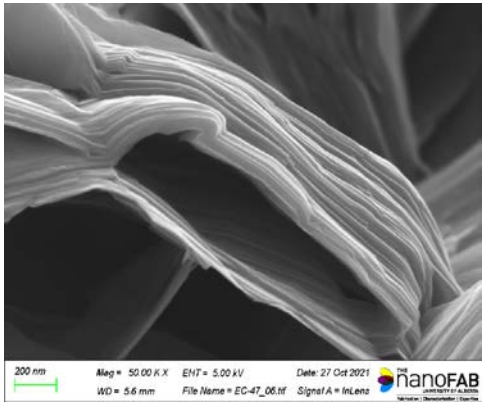
Low oxygen; no acids
(C/O = 9 : 1)

No post-processing
deoxygenation

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





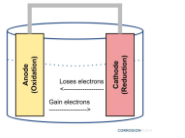


SEM imaging (UofA nanoFAB centre)

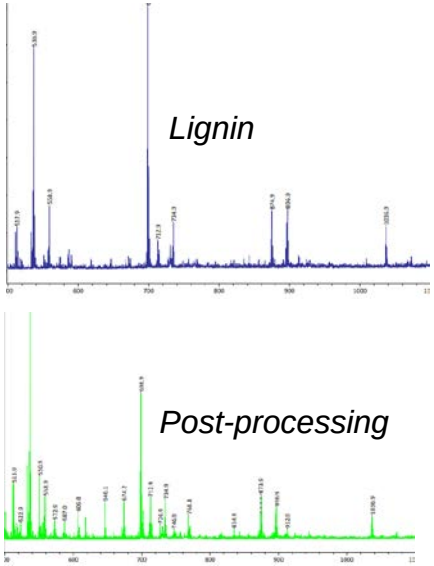
Value added products from lignin and cellulose waste

Carbon quantum dots from waste lignin

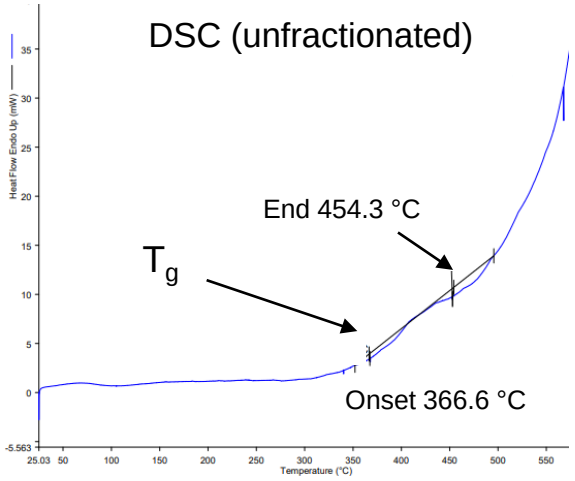
"Organosolv lignin"

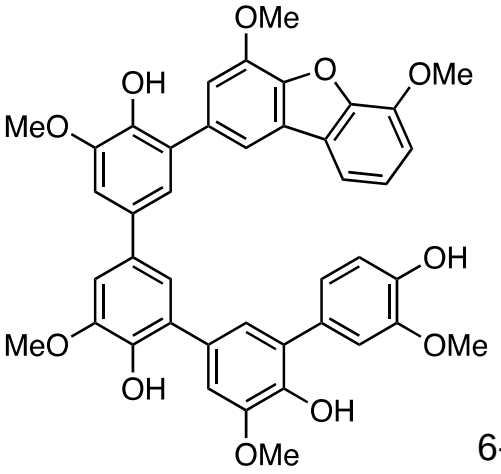


Electrochemical (additives)

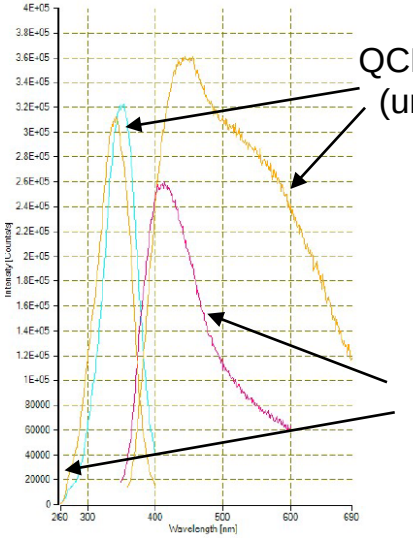


QCDs (partial conversion)



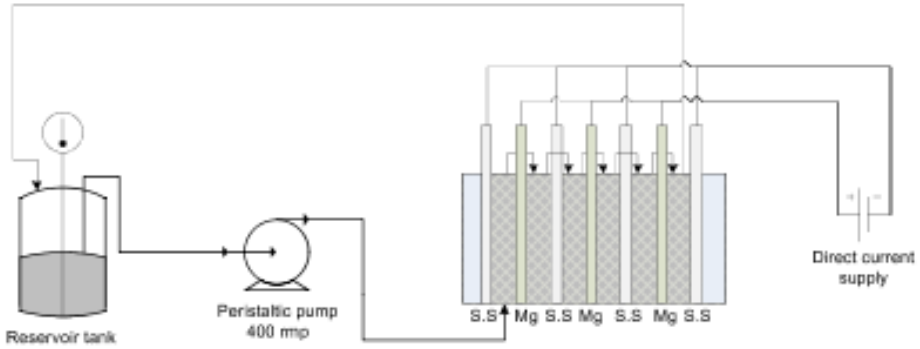


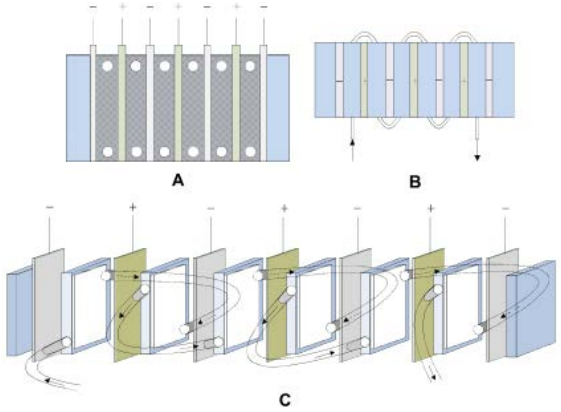
6-*mer (from guaiacol)*

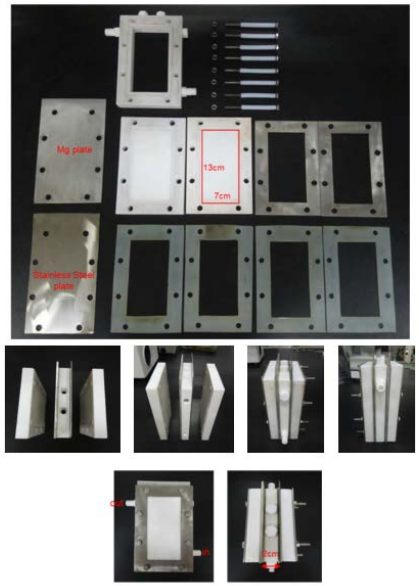


Continuous Processing: E-cat Flow Systems

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







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.

Carbon Upcycling of Bitumen and Waste Biomass

Graphene-reinforced carbon fibres from Athabasca bitumen

Dark materials matter!

Carbon Upcycling of Bitumen and Waste Biomass

Acknowledgements

Stryker/Hamilton Group:

- Dr. Robin Hamilton
- Dr. Orain Brown
- Dr. David Scott
- 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!

UNIVERSITY OF ALBERTA FUTURE ENERGY SYSTEMS

CANADA FIRST RESEARCH EXCELLENCE FUND | APOGÉE CANADA FONDS D'EXCELLENCE EN RECHERCHE

CRIN Clean Resource Innovation Network

ALBERTA INNOVATES

Applied Quantum Materials Inc.

NSERC CRSNG