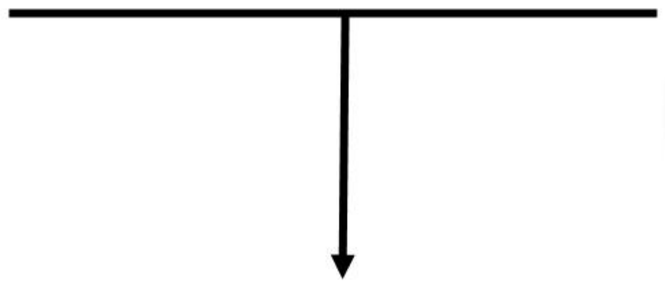
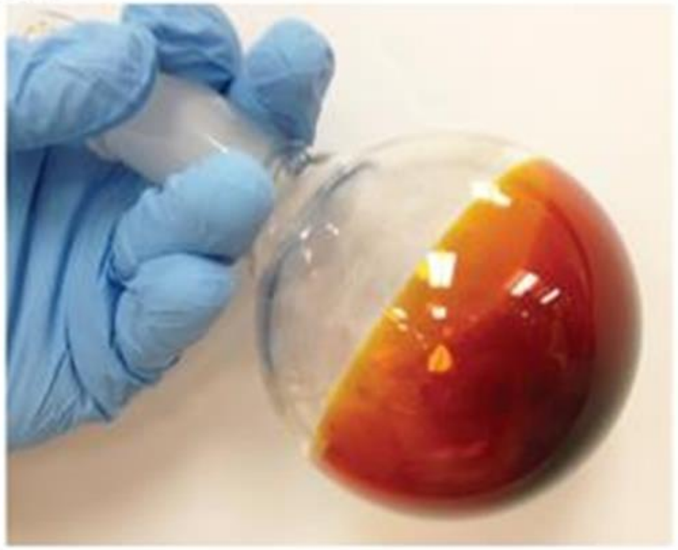
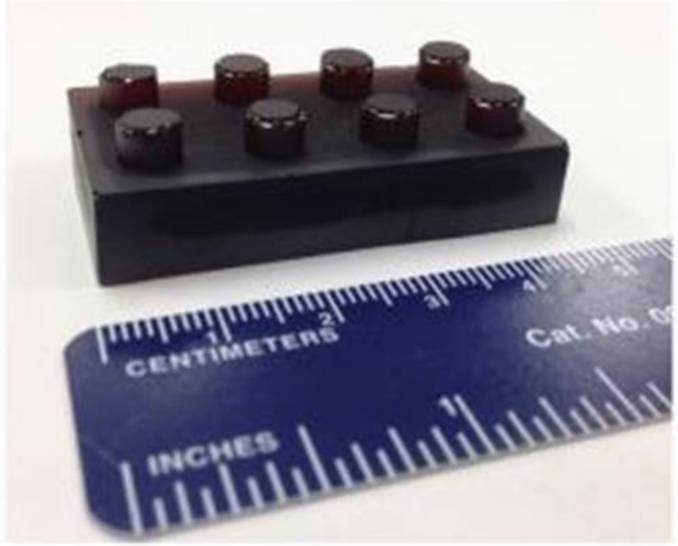
Sulfur-Limonene Polysulfide:
A New Material Synthesised Entirely from Industrial Waste and Its use in Removing Mercury from Water







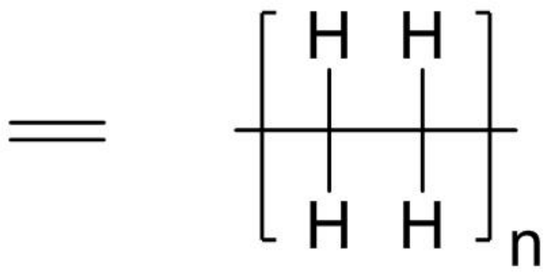
Dr Justin M. Chalker
Flinders University

justin.chalker@flinders.edu.au
www.chalkerlab.com

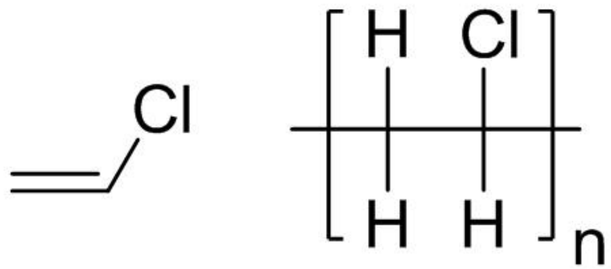
Flinders UNIVERSITY
inspiring achievement

Polymers: Essential Materials from Finite Resources

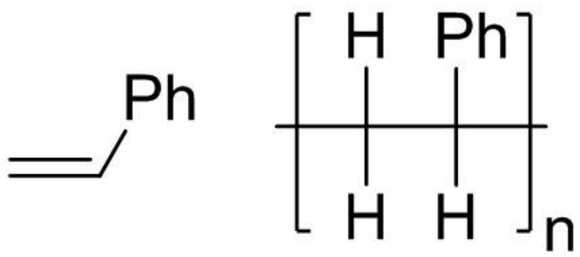
Polyethylene



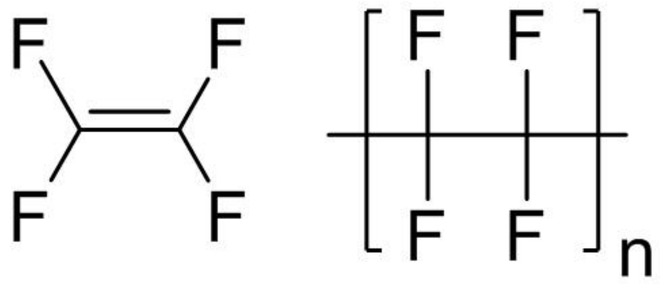
Polyvinylchloride



Polystyrene

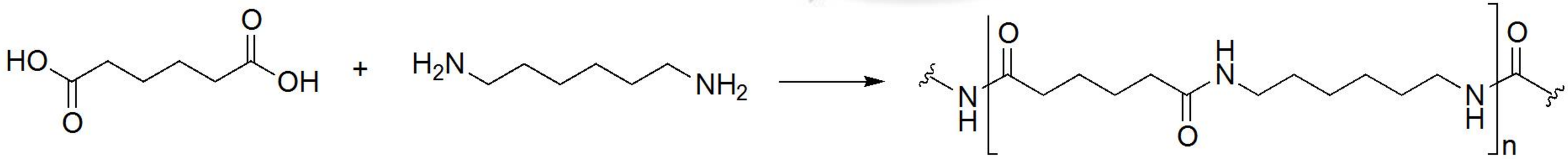


Polytetrafluoroethylene - Teflon®

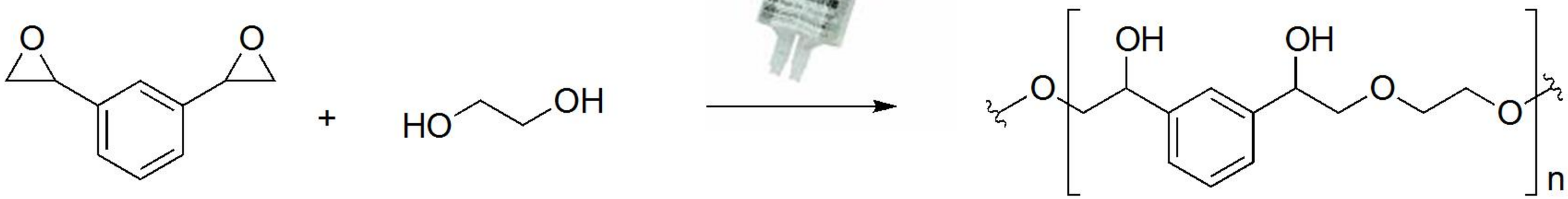


Polymers: Essential Materials from Finite Resources

Nylon

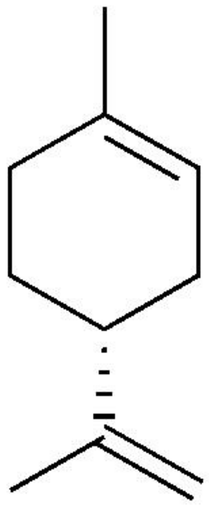


Epoxy resins and adhesives

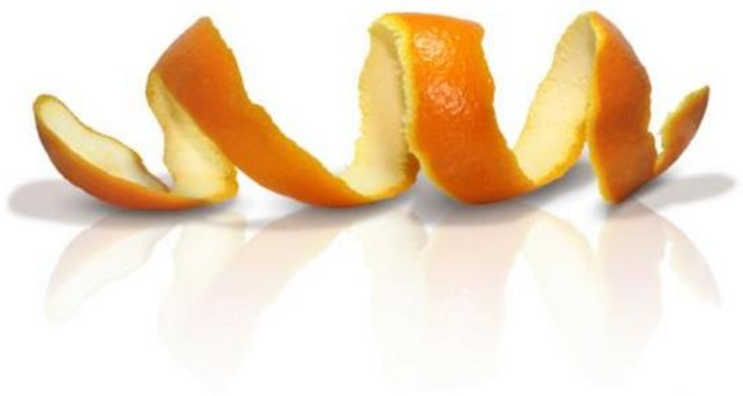


Limonene: By-product of Citrus Industry

- **Renewable plant oil**
- **Natural handle for polymerization**
- **70,000 tons per year** (citrus industry)
- **< $7 AUD / L**
- Current uses: solvent, fragrance



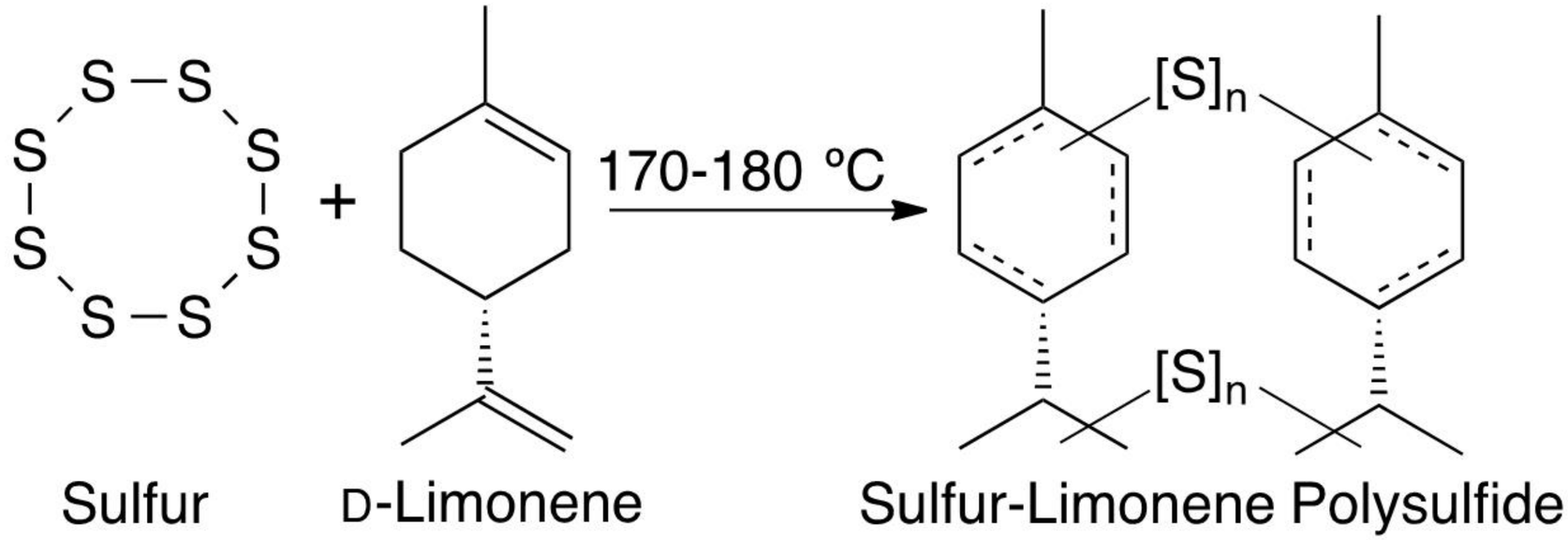
Limonene

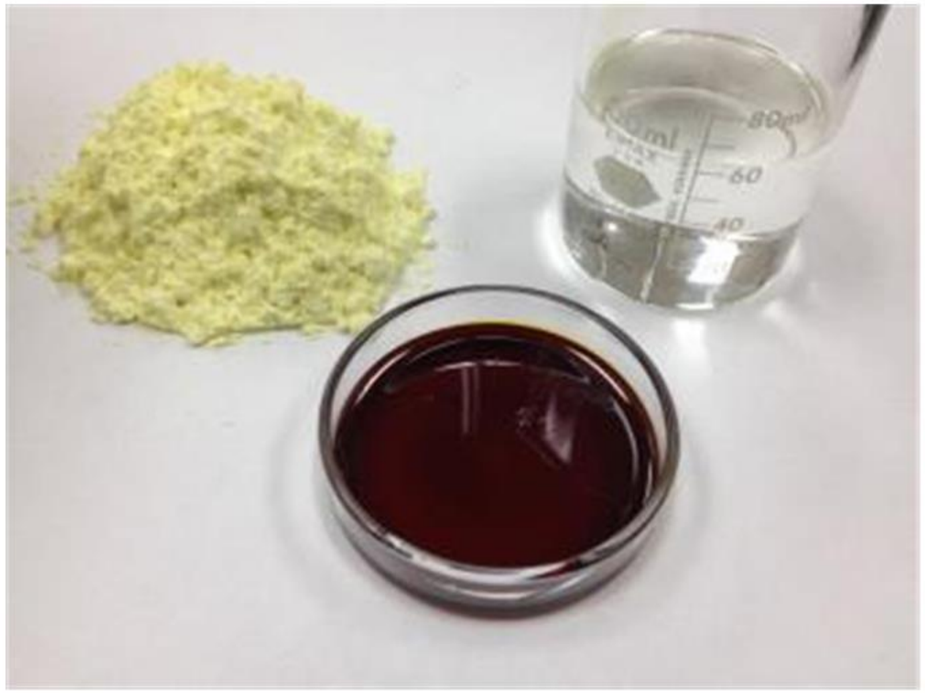


Sulfur: By-Product of Petroleum Industry

- **70 million tons per year** (petroleum refining)
- **< $1 AUD per kilogram**
- Current uses: sulfuric acid synthesis, fertilizer

Sulfur-Limonene Polysulfide Synthesis





Features:

Operationally simple

No exogenous solvents

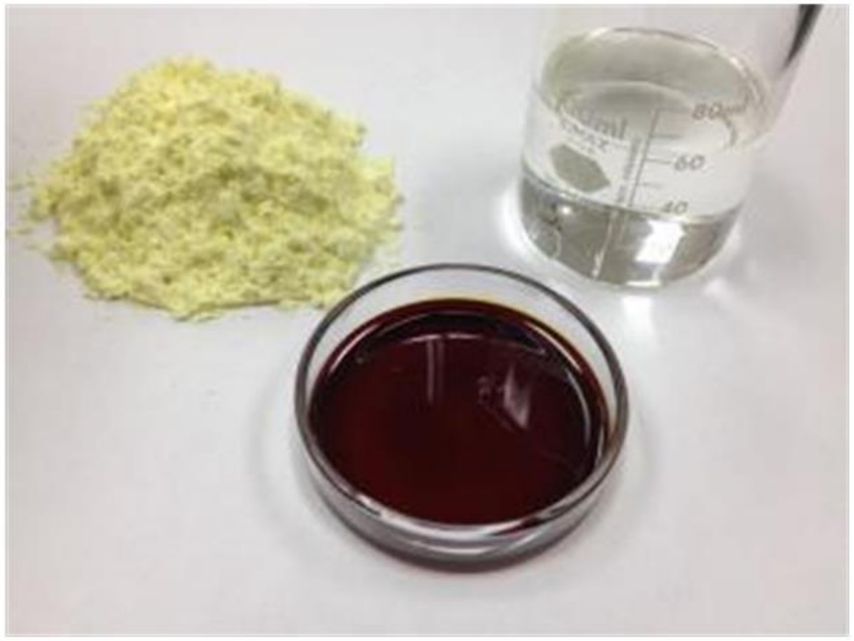
No exogenous reagents

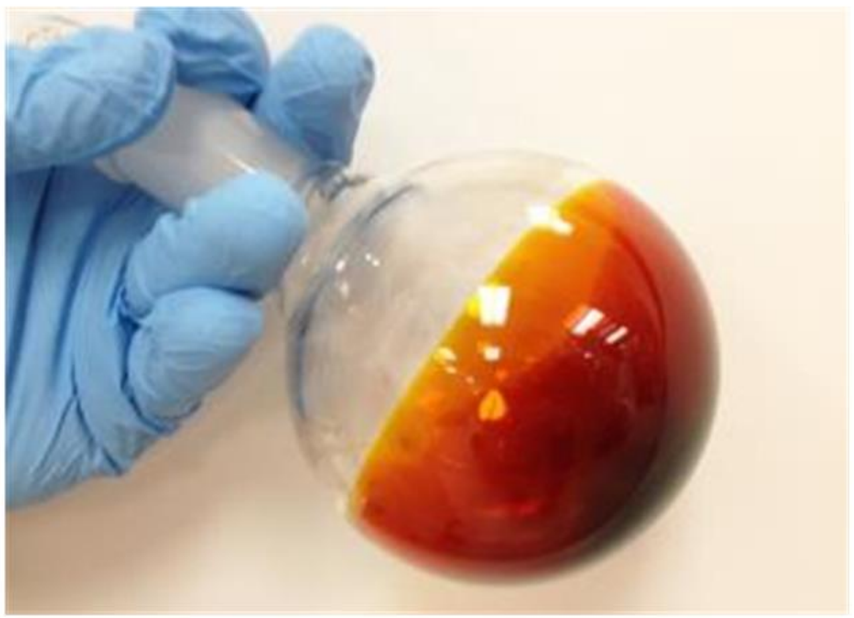
Scalable (100 g batches routine)

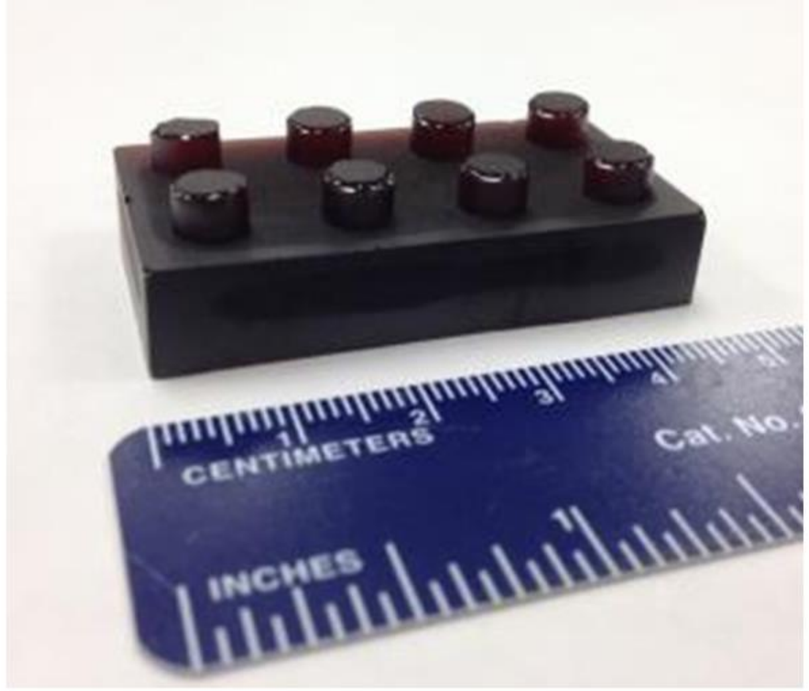
Flinders UNIVERSITY inspiring achievement

Crockett, Evans, Worthington, Albuquerque, Slattery, Gibson, Campbell, Lewis, Bernardes, & Chalker. *Angew. Chem. Int. Ed.* **2015** In Press.

Sulfur-Limonene Polysulfide Processing







Flinders UNIVERSITY inspiring achievement

Crockett, Evans, Worthington, Albuquerque, Slattery, Gibson, Campbell, Lewis, Bernardes, & Chalker. *Angew. Chem. Int. Ed.* **2015** In Press.

Mercury Sequestration and Sensing

$HgCl_2$ in H_2O + Sulfur-Limonene Polysulfide

Reduce Hg^{2+} in solution from **parts per million** to **parts per billion**

1. 24 hr incubation

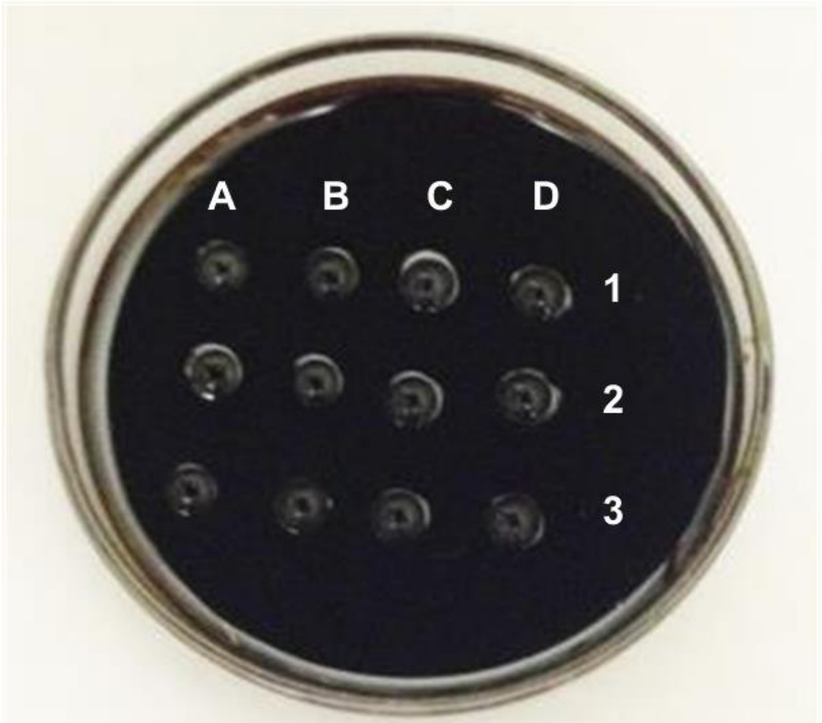
2. H_2O wash

1 = DI H_2O
2 = $HgCl_2$ in H_2O (2 mg/mL)
3 = Arkansas River water
4 = $HgCl_2$ spiked Arkansas River water (2 mg/mL)

Flinders UNIVERSITY inspiring achievement

Crockett, Evans, Worthington, Albuquerque, Slattery, Gibson, Campbell, Lewis, Bernardes, & Chalker. *Angew. Chem. Int. Ed.* **2015** In Press.

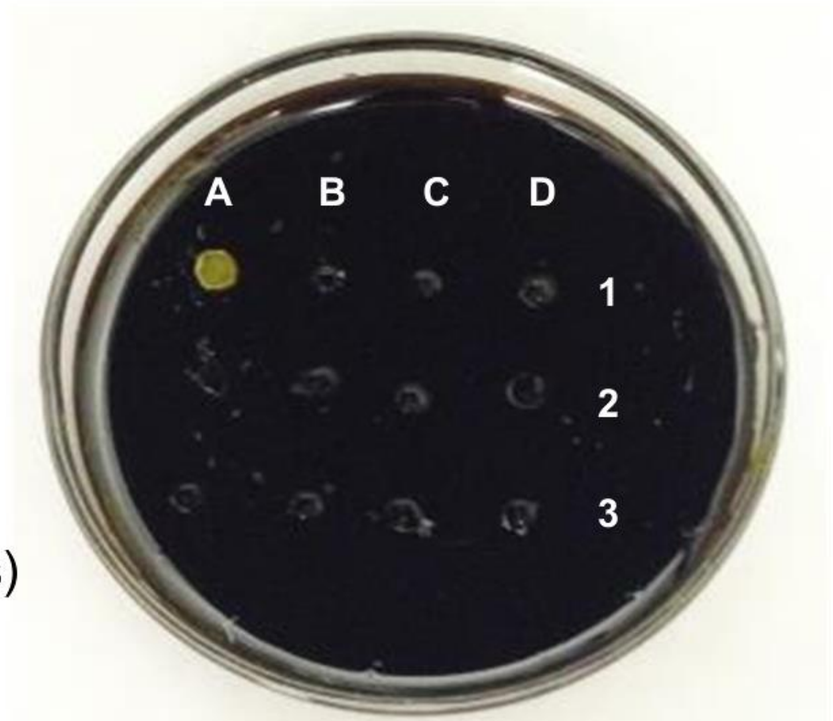
Mercury Sequestration and Sensing



1. 24 hr incubation

2. H_2O wash

(10 μM solutions of metal salts)



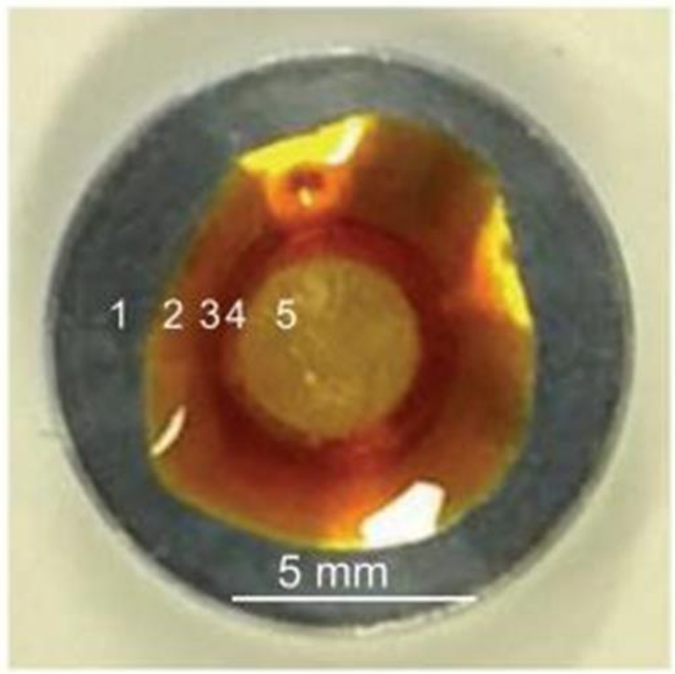
Sulfur-Limonene polysulfide ***selectively*** **indicates** presence of **mercury**

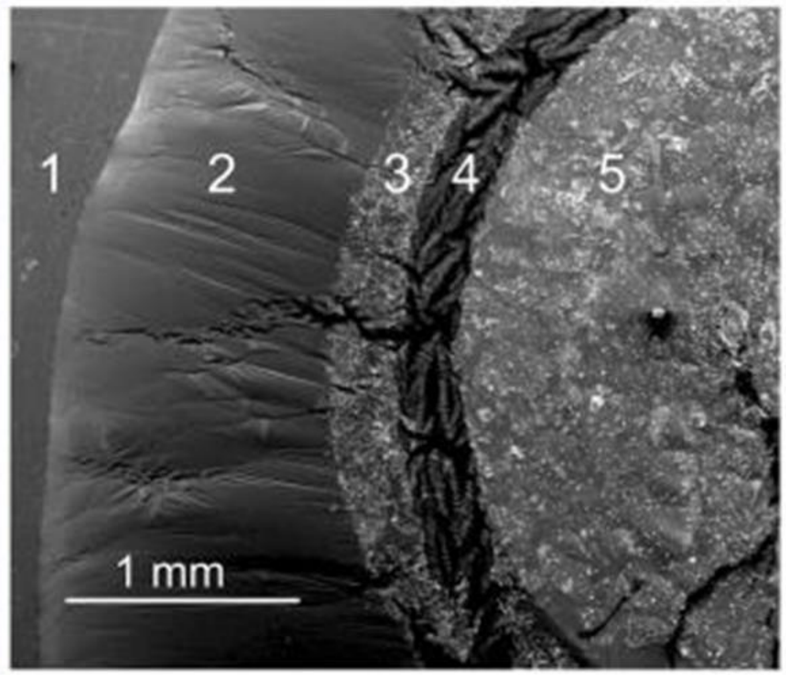
A1 = $HgCl_2$	B1 = LiCl	C1 = $FeCl_3$	D1 = $CaCl_2$
A2 = $CuSO_4$	B2 = $PbCl_2$	C2 = $MgCl_2$	D2 = $ZnCl_2$
A3 = $NiCl_2$	B3 = KCl	C3 = $MnCl_2$	D3 = H_2O only

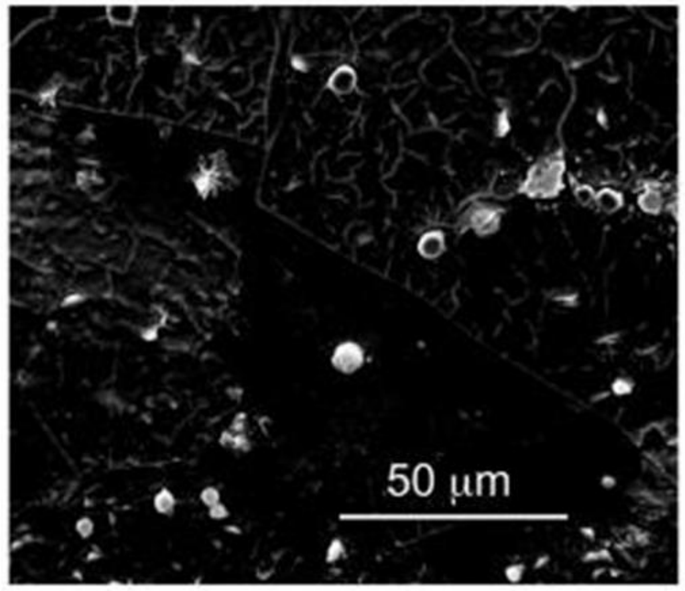
Flinders UNIVERSITY inspiring achievement

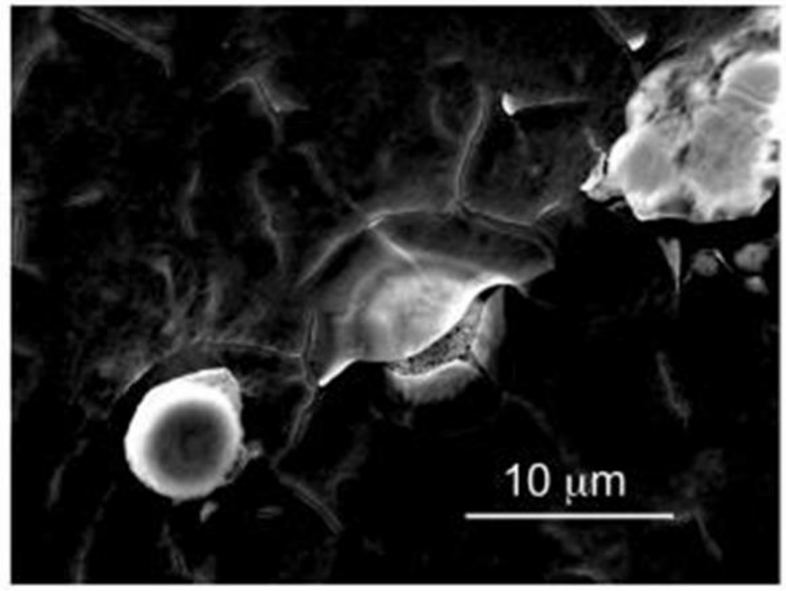
Crockett, Evans, Worthington, Albuquerque, Slattery, Gibson, Campbell, Lewis, Bernardes, & Chalker. *Angew. Chem. Int. Ed.* **2015** In Press.

Mercury Sequestration and Sensing









Mercury is trapped on and in polymer as micro- and nanoparticles

Flinders UNIVERSITY inspiring achievement

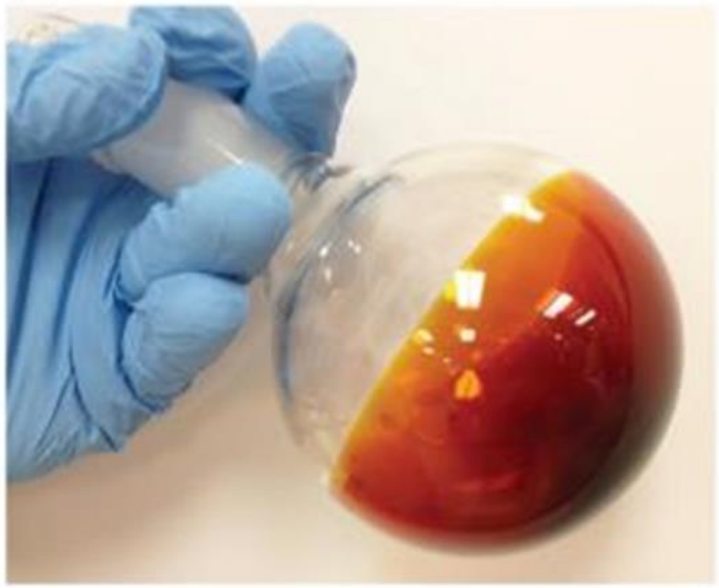
Crockett, Evans, Worthington, Albuquerque, Slattery, Gibson, Campbell, Lewis, Bernardes, & Chalker. *Angew. Chem. Int. Ed.* **2015** In Press.

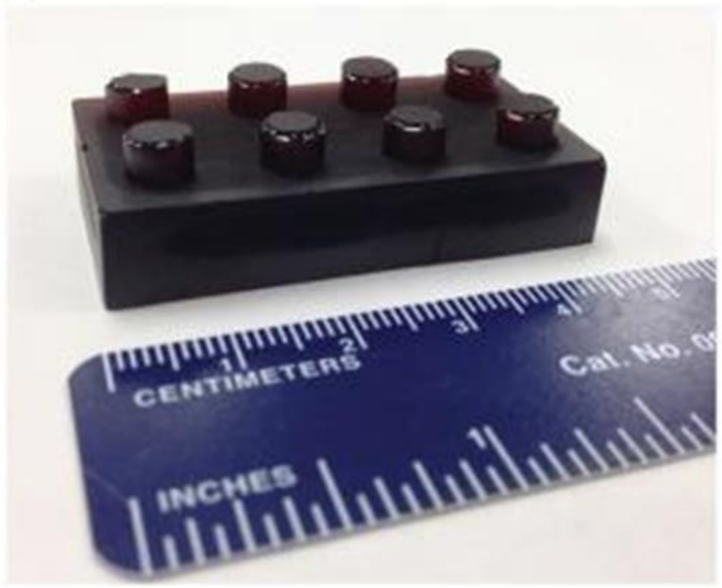
Mercury Sequestration and Sensing

Crockett, Evans, Worthington, Albuquerque, Slattery, Gibson, Campbell, Lewis, Bernardes, & Chalker. *Angew. Chem. Int. Ed.* **2015** In Press.

Conclusions and Outlook

- **New polymer** synthesised entirely from **industrial by-products as starting materials**
- **Scalable**, operationally **simple** synthesis
- **Inexpensive**
- Processable – **coating** or **mold**
- High **affinity for mercury**: applications in **water and soil purification**
- **Mercury sensing** capability
- **Commercialisation** efforts underway





Flinders UNIVERSITY inspiring achievement

Crockett, Evans, Worthington, Albuquerque, Slattery, Gibson, Campbell, Lewis, Bernardes, & Chalker. *Angew. Chem. Int. Ed.* **2015** In Press.

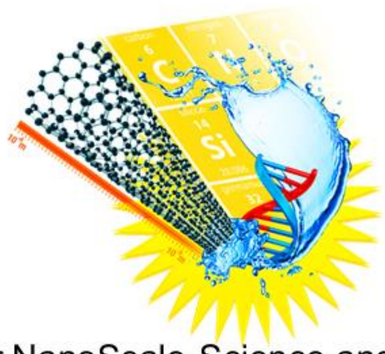
Acknowledgements

Max Worthington
Ashley Slattery
Chris Gibson
Jonathan Campbell
David Lewis

Michael Crockett
Austin Evans

Inês Albuquerque

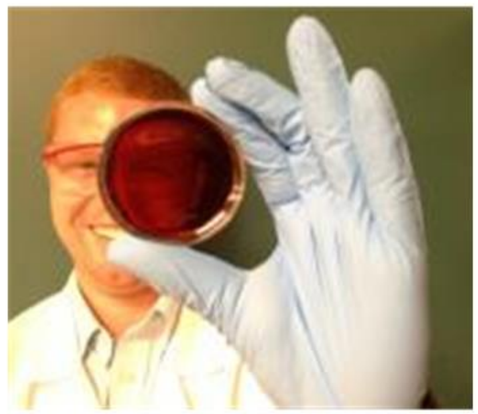
Gonçalo Bernardes



Centre for NanoScale Science and Technology

Max Worthington & Justin Chalker

Michael Crockett



Austin Evans

Funding:

justin.chalker@flinders.edu.au
www.chalkerlab.com