# Sustainable Replacements for Coal Tar Pitch (CTP) Binders

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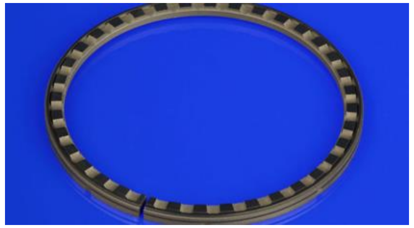
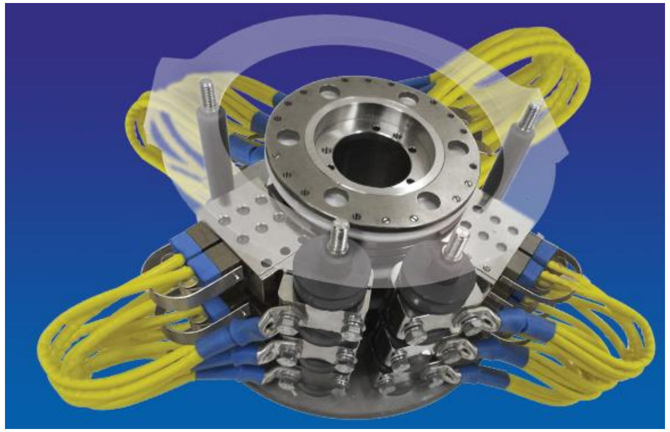
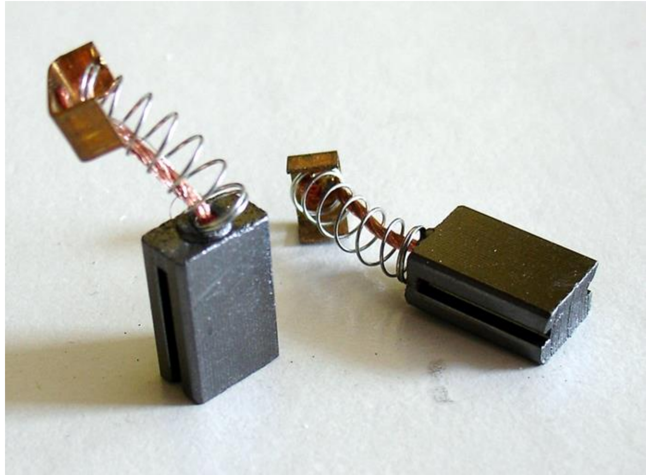
# Coal Tar Pitch (CTP)

- **Coal Tar Pitch (CTP)** is a residue formed from the distillation of coal tar.

- **Carbonisable/graphitisable binder** to form carbon electrodes (*e.g.* for aluminium smelting), seals, specialty graphites for electric brushes, current collectors, etc.





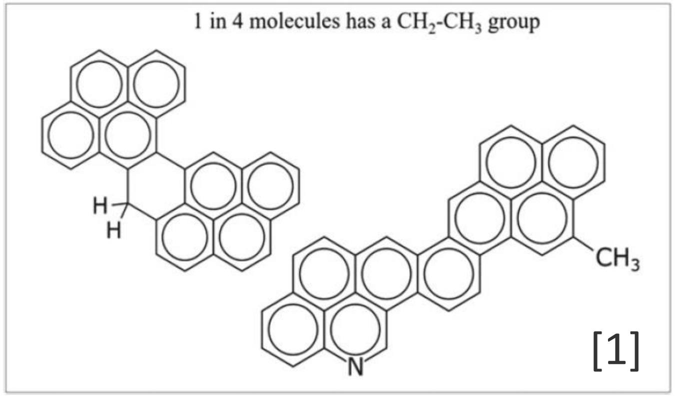


# Current issues with CTP use

## However:

- CTP is fossil-derived and **toxic** (recently classified as a ‘sunset’ status material under REACH).
- Increasing **environmental regulations** raise concerns about the long-term **availability** and supply of CTP.

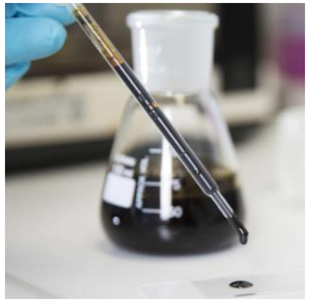
Sustainable alternatives need to be urgently identified for the Foundation Industries dependent on these materials




[1] S. Senanu *et al*. Biocarbon in the Aluminium Industry: A Review. Light Metals (2021), 649.

# Wood Tar Bio-pitch (WTB)

Wood

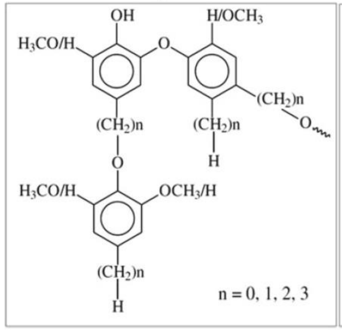


Bio-oil

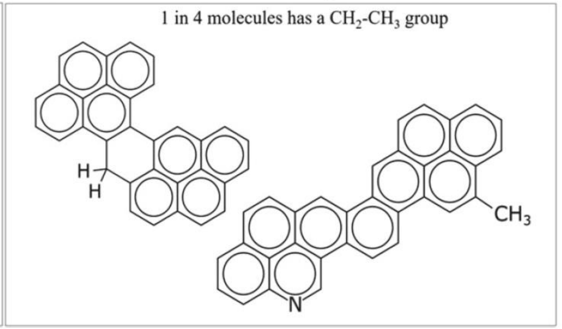
Bio-Pitch

WTB obtained from distilling sawdust shows promise as a safe and renewable binder.

**Eucalyptus Bio-Pitch**




**Coal Tar Pitch**




[1] S. Senanu *et al*. Biocarbon in the Aluminium Industry: A Review. Light Metals (2021), 649.

## Our Objective:

To evaluate the potential of WTB as a less toxic, more sustainable carbonizable/graphitizable binder that can replace CTP

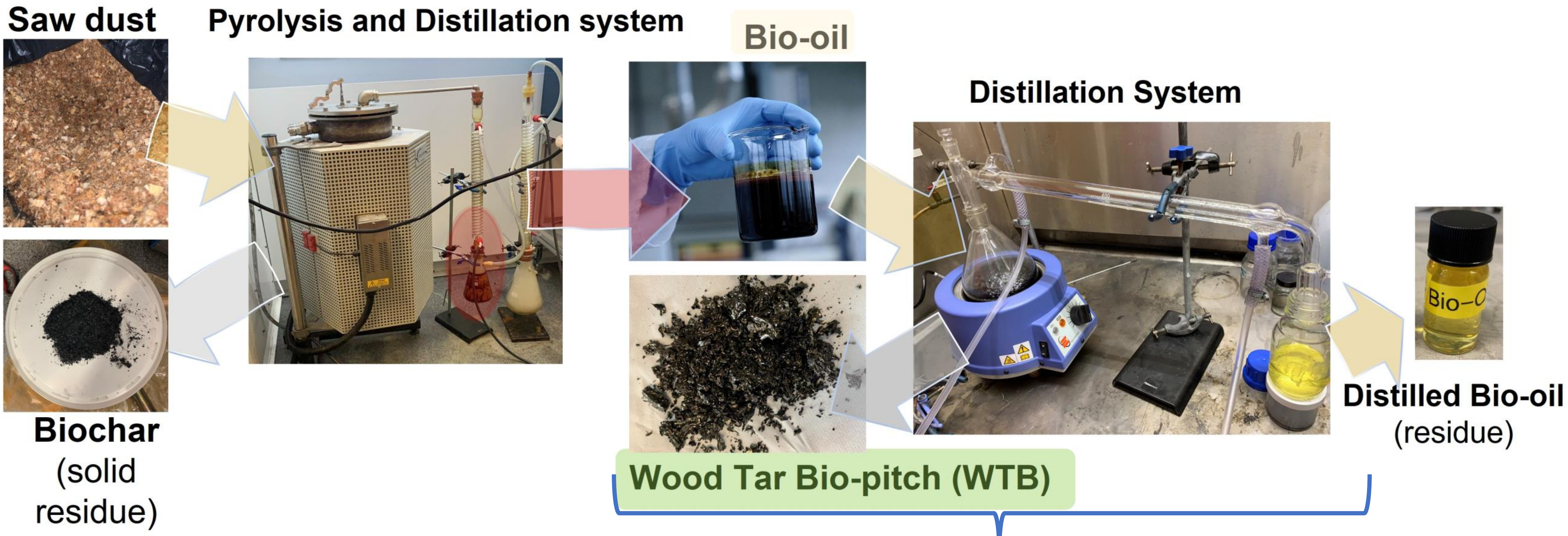
HFi NETWORK+ Small project funding (March-Sept. 22)

HENRY ROYCE INSTITUTE ICP (Royce Industrial Collaboration Programme) (Oct. 22-April 23)

Morgan Advanced Materials

# Synthesis of WTB

- ➢ Commercial supply chain is very nascent: bio-oil & WTB extremely hard to purchase
- ➢ We established an **internal supply of bio-oil & WTB** from sawdust within our lab



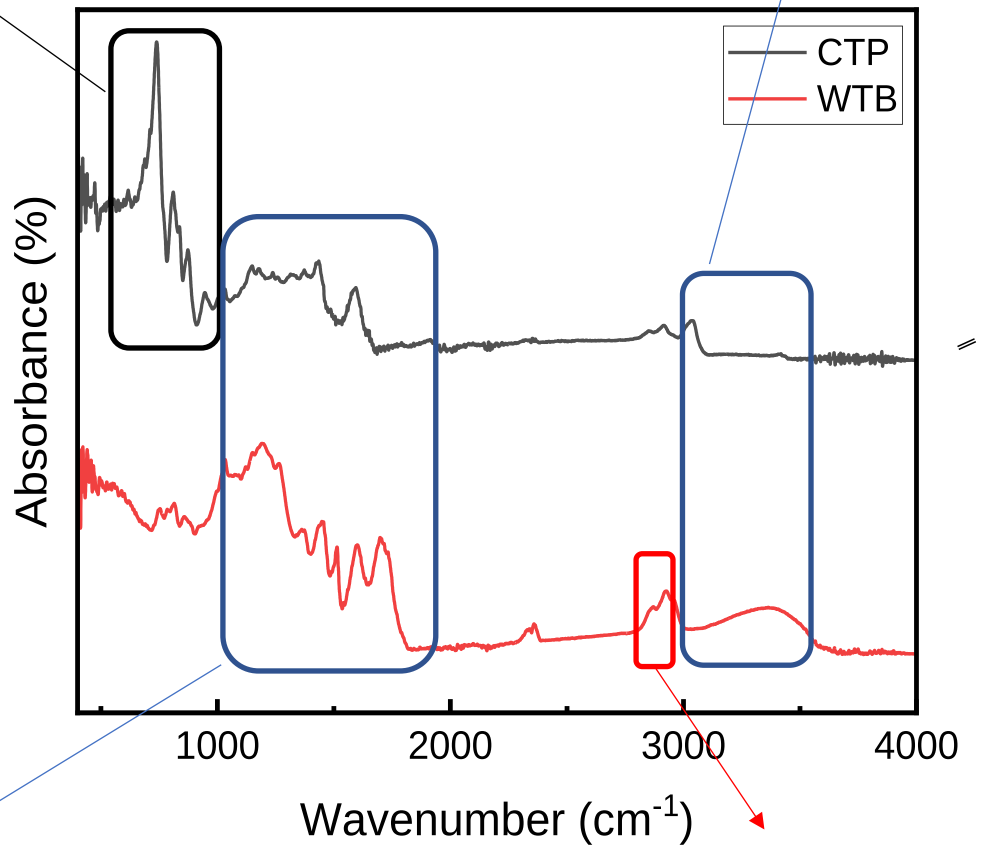

- **Wood tar bio-pitch (WTB)** was produced from our internal bio-oil following a second distillation process

# Chemical composition of WTB & CTP

High number of aromatic groups in the CTP

Moisture, hydrogen bonds, amines, −COOH

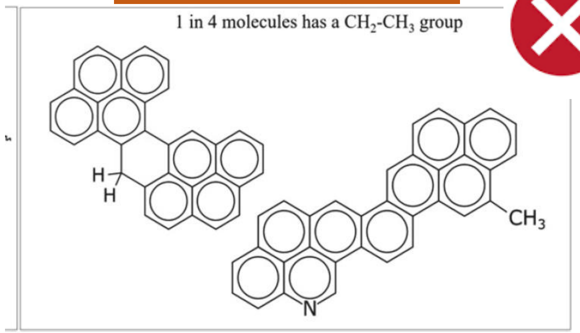
**FT-IR:**



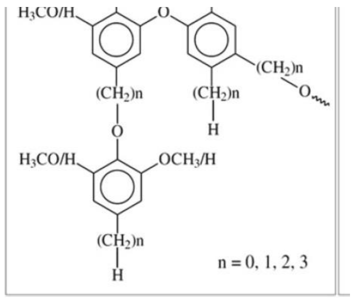

Different proportions of aliphatic hydrocarbons and O-containing non-aromatic compounds

C=O containing chemical compounds (ketones, aldehydes) in WTB

**Coal Tar Pitch**




**Eucalyptus Bio-Pitch**



# WTB/graphite & CTP/graphite Composites

**Our WTB represents a much less toxic binder than the CTP typically used in industry, but … does it show promise for industrial applications?**

**WTB/CTP**

**Graphite**

**Elemental S**

**Green Composites:**

- WTB/Graphite (50/50)
- CTP/Graphite (50/50)

+ Sulphur (1.5, 3, 5 wt.%)

**Carbonisation (850 °C):** to remove the oxygen, hydrogen, etc., and leave a purely carbon network.

**Graphitization (2,500 °C):** carbon re-arrangement to form graphite crystals

- ➢ Microstructure & physical properties
- ➢ Electrical & mechanical properties

} Carbonized/Graphitized composites

# WTB-based & CTP-based Composites

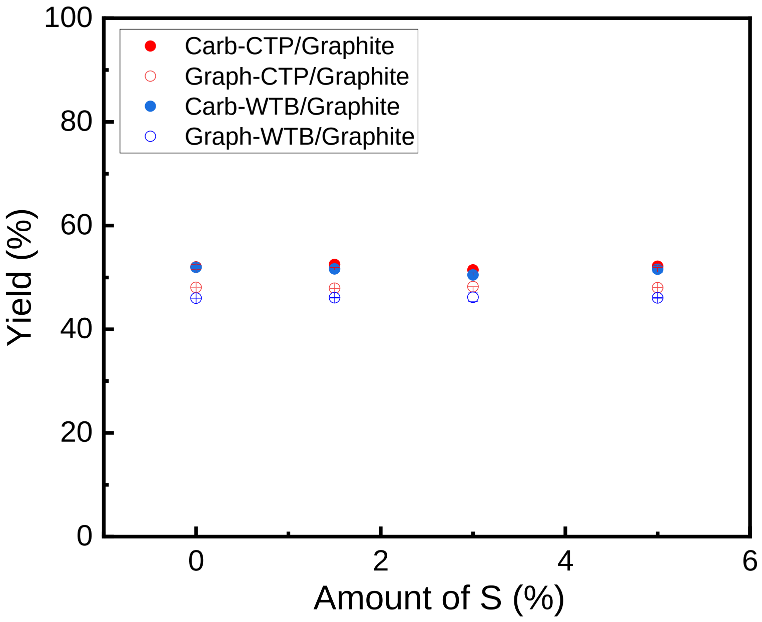
## ➢ Role of S?

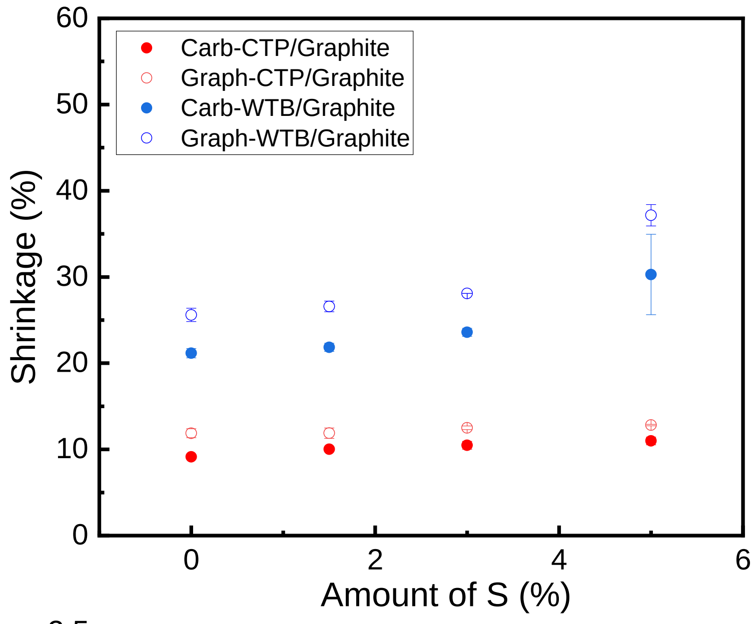
Decreased porosity
(hence, increased density)

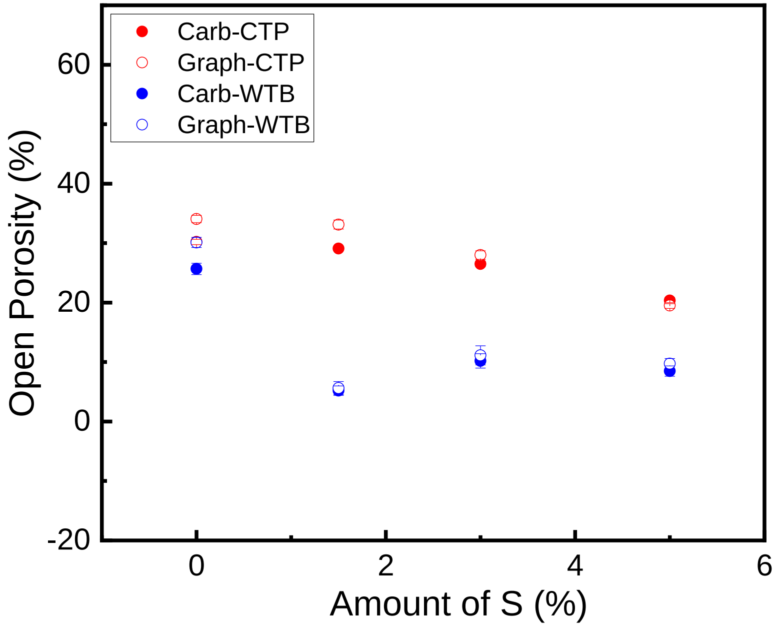
Role in cross-linking particles while chemical compounds are removed during carbonization and carbon atoms are reorganized during graphitization

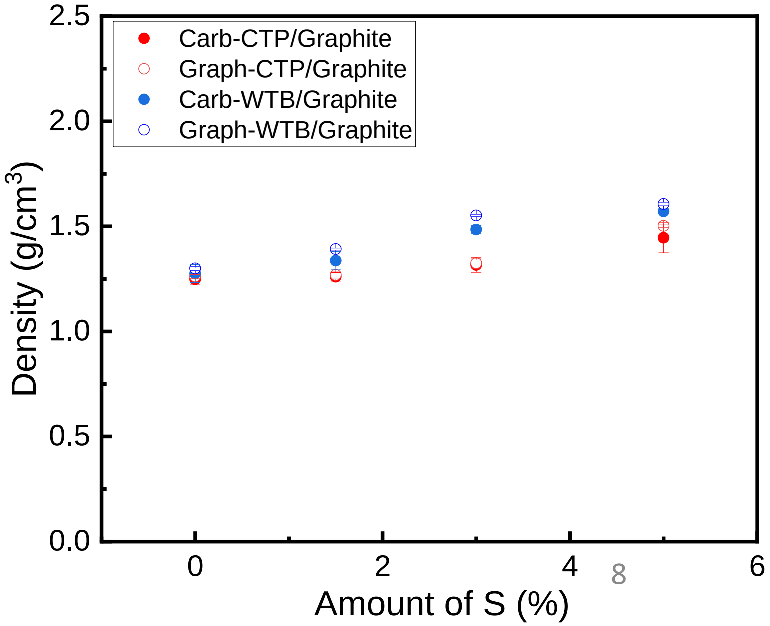
## ➢ WTB vs. CTP?

Similar structure & physical properties



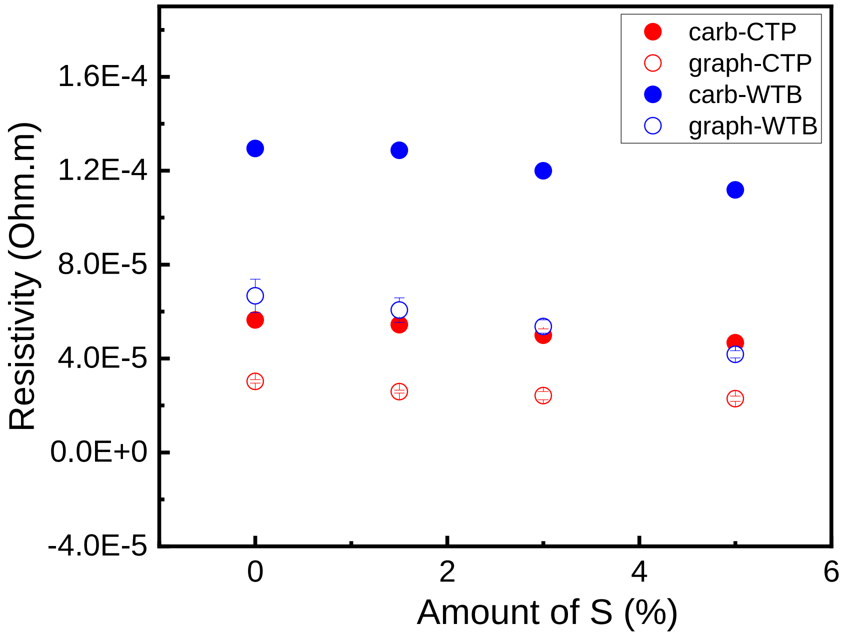



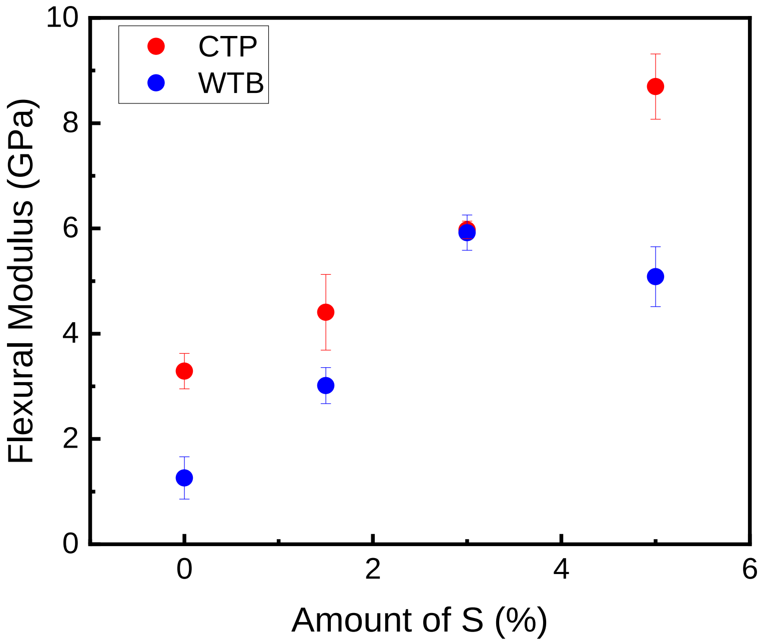
# Properties of the CTP & WTB composites

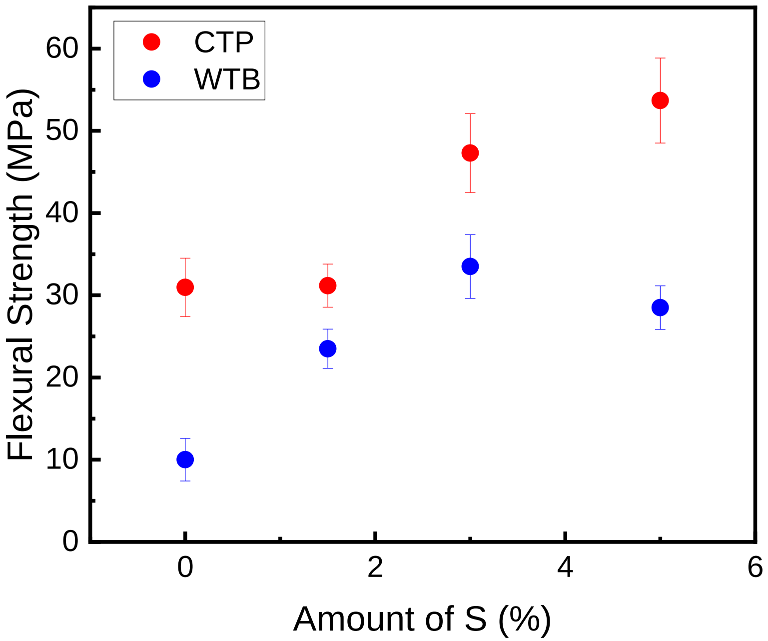
- **Electrical Resistivity**




- Resistivities ~$10^{-4}$-$10^{-5}$ Ω·m (good for most applications)

- **Mechanical Properties (3-point bending)**




- Adding S improves flexural moduli and strength
- Higher values found for the CTP system (small differences though)

# Key results

- WTB was produced at the UoM, mixed with graphite particles and then carbonised and graphitized to produce carbon-carbon composites.
- The carbon yield and electrical and mechanical performance of the graphitized WTB based composites was close to those derived from CTP, showing enormous promise as a more sustainable alternative to CTP.
- The addition of S led to more compact structures and to higher levels of graphitization through a cross-linking between particles, hence improving the mechanical properties of the composites.

# Key results

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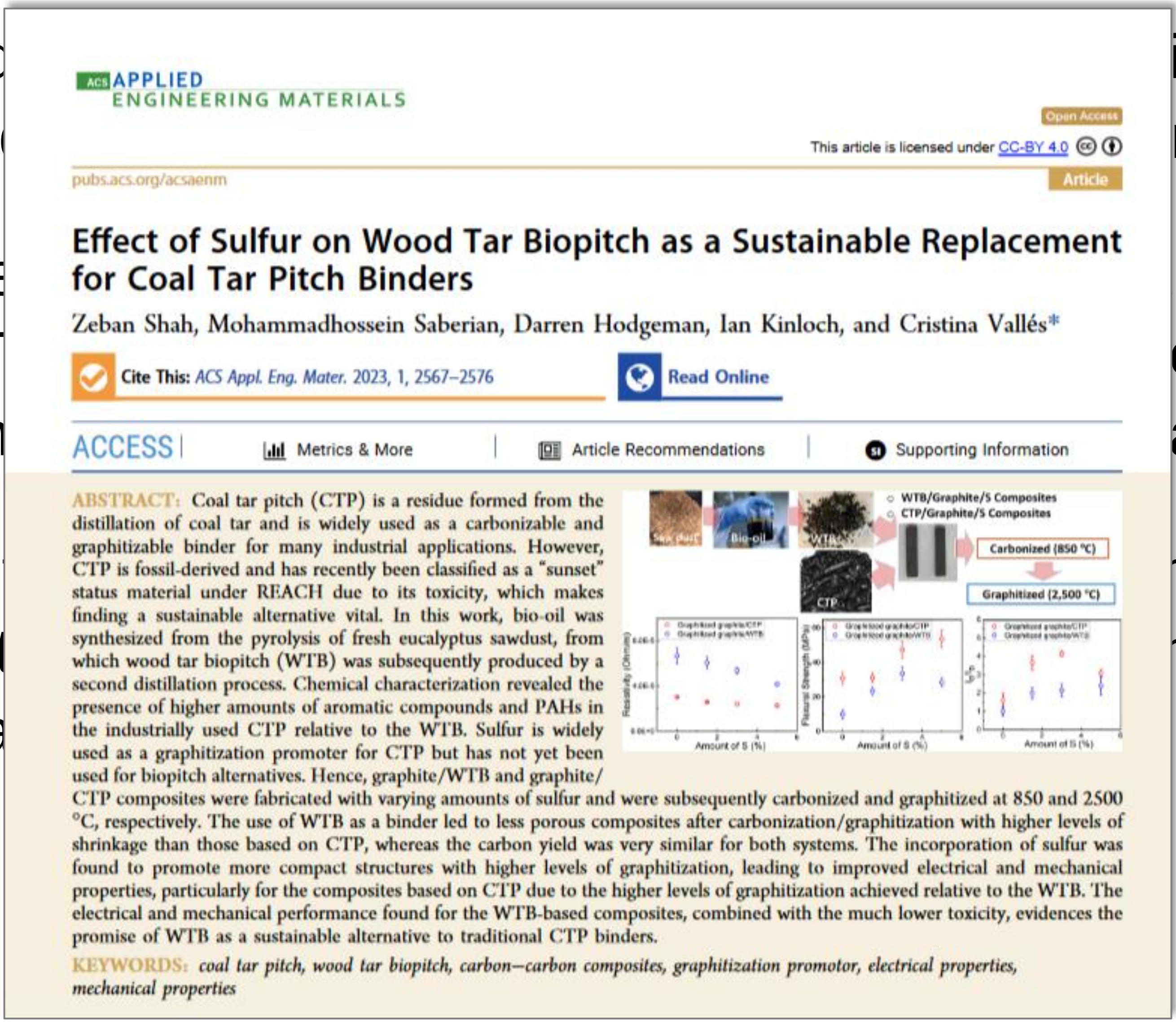

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## Effect of Sulfur on Wood Tar Biopitch as a Sustainable Replacement for Coal Tar Pitch Binders

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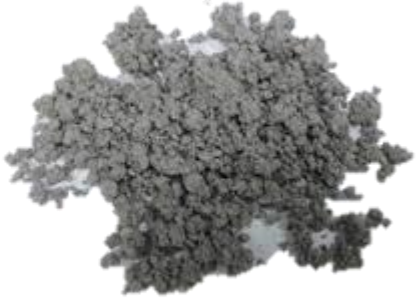
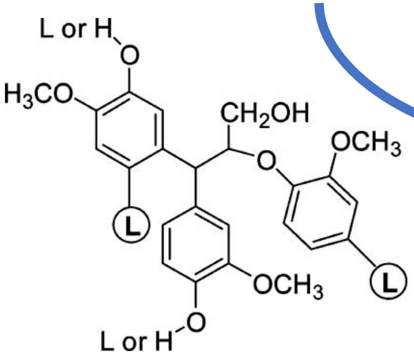
ABSTRACT: Coal tar pitch (CTP) is a residue formed from the distillation of coal tar and is widely used as a carbonizable and graphitizable binder for many industrial applications. However, CTP is fossil-derived and has recently been classified as a "sunset" status material under REACH due to its toxicity, which makes finding a sustainable alternative vital. In this work, bio-oil was synthesized from the pyrolysis of fresh eucalyptus sawdust, from which wood tar biopitch (WTB) was subsequently produced by a second distillation process. Chemical characterization revealed the presence of higher amounts of aromatic compounds and PAHs in the industrially used CTP relative to the WTB. Sulfur is widely used as a graphitization promoter for CTP but has not yet been used for biopitch alternatives. Hence, graphite/WTB and graphite/CTP composites were fabricated with varying amounts of sulfur and were subsequently carbonized and graphitized at 850 and 2500 °C, respectively. The use of WTB as a binder led to less porous composites after carbonization/graphitization with higher levels of shrinkage than those based on CTP, whereas the carbon yield was very similar for both systems. The incorporation of sulfur was found to promote more compact structures with higher levels of graphitization, leading to improved electrical and mechanical properties, particularly for the composites based on CTP due to the higher levels of graphitization achieved relative to the WTB. The electrical and mechanical performance found for the WTB-based composites, combined with the much lower toxicity, evidences the promise of WTB as a sustainable alternative to traditional CTP binders.

KEYWORDS: *coal tar pitch, wood tar biopitch, carbon−carbon composites, graphitization promotor, electrical properties, mechanical properties*

# Beyond sawdust…

## **Adding value to industrial waste** while developing novel **more sustainable materials** for industrial use?






e4 Structures

HENRY ROYCE INSTITUTE

UK Research and Innovation

*Economic Material Innovation for Sustainable and Efficient use of Resources (**EconoMISER**) programme*

HOLMEN

Can we use **paper sludge (industrial waste)** to synthesize bio-oil and bio-pitch?

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