A New Generation of Activated Carbon Adsorbent Microstructures

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Priority Topic Area: **Responsible Production, Innovation and Industry**

Introduction

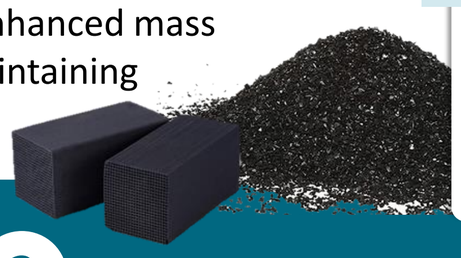
Activated carbon (AC) is the most frequently used adsorbent[1].
It is ✔ **Cheap** ✔ **Abundant** ✔ **Renewable**

Some structures of activated carbon include monolithic and granulated (GAC)

Drawbacks from monolithic and GAC structures are

- ✔ **Prone to channelling**
- ✔ **High pressure drop**
- ✔ **Premature breakthrough**

Complex geometries offer enhanced mass transfer properties while maintaining a lower pressure drop.

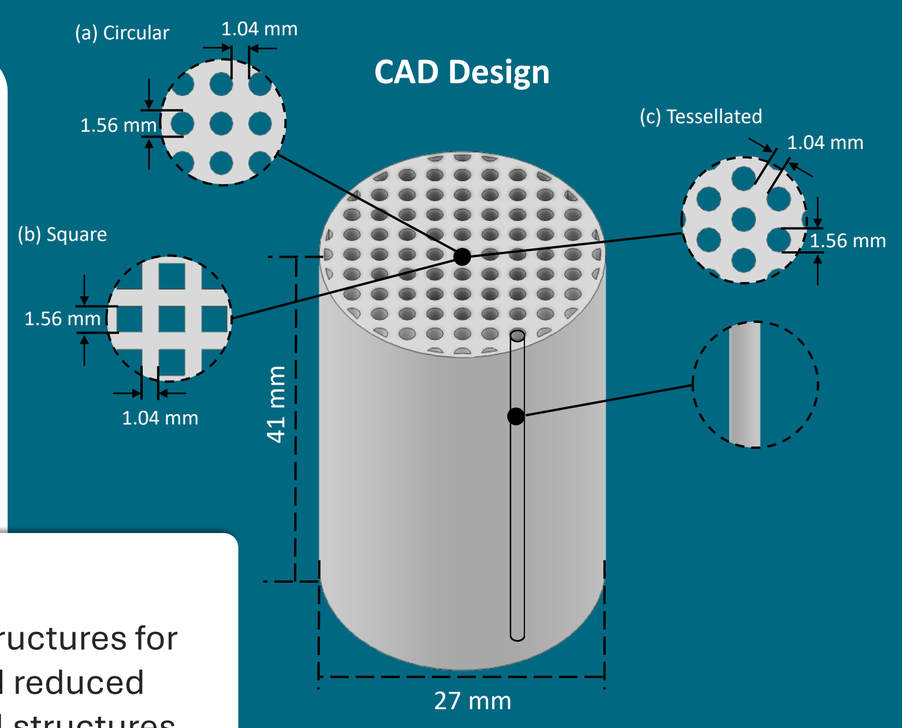


51.3%

Market share of global activated carbon attributed to gas processes in 2023[2].

100,000 tonnes/yr

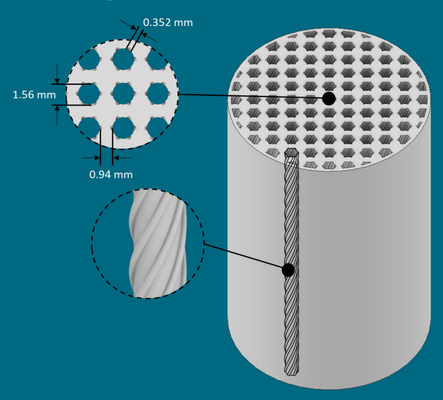
Mass of activated carbon produced annually[3].



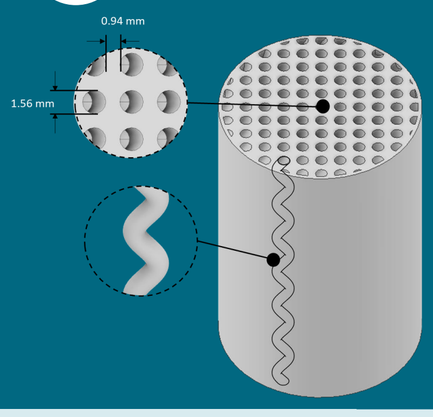
Aim

Develop novel 3D printed AC microstructures for improved adsorption dynamics and reduced pressure drop compared to traditional structures.

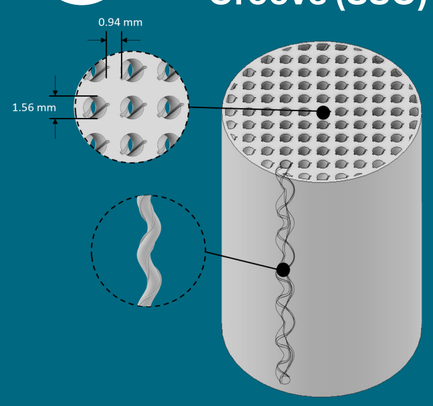
1 Rifled Spiral (RS)



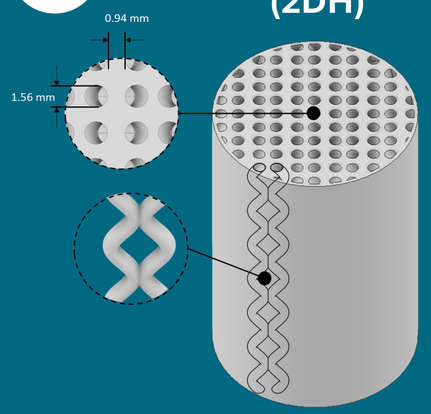
2 Simple Serpentine (SS)



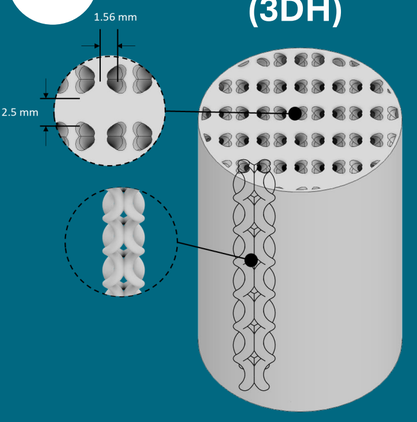
3 Serpentine Spiral Groove (SSG)



4 2-Dimensional Helix (2DH)



5 3-Dimensional Helix (3DH)



Results and Discussion

Complex geometries had a 20% increase in breakthrough time at constant Re=80 and a 10% increase in equilibrium loading compared to simple geometries.

- ✔ **Extended residence time**
- ✔ **Enhanced turbulence**
- ✔ **Elongated true path lengths**

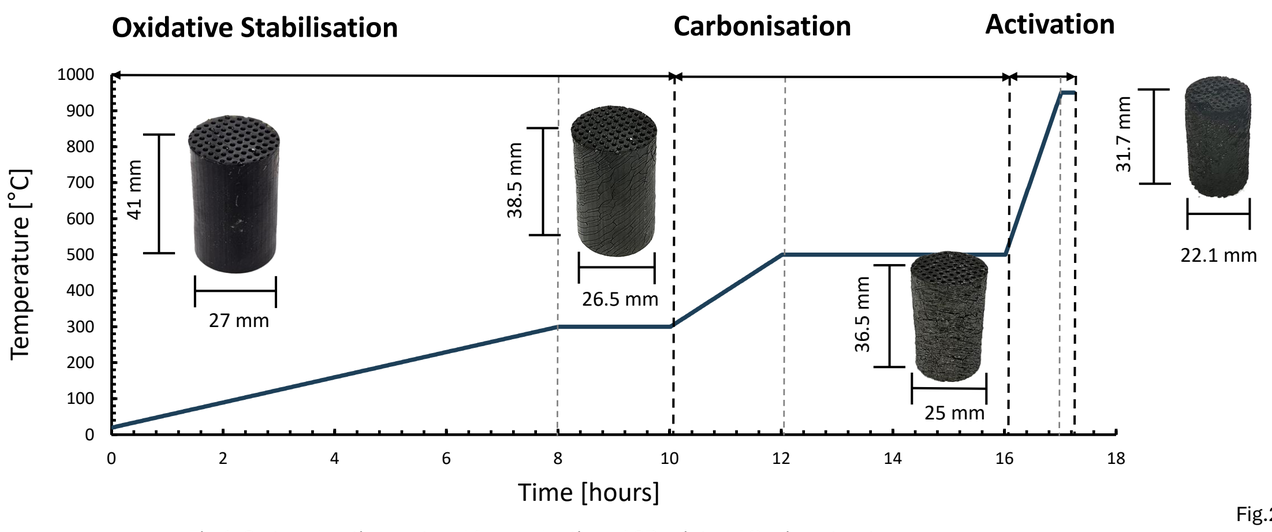


Fig.1. 3-stage heating protocol for production of 3D printed AC microstructures.

3D printed AC microstructures had

3× longer

n-butane breakthrough times.*

> 80%

Reduction in pressure drop.*

> 65%

Increase in equilibrium loading.*

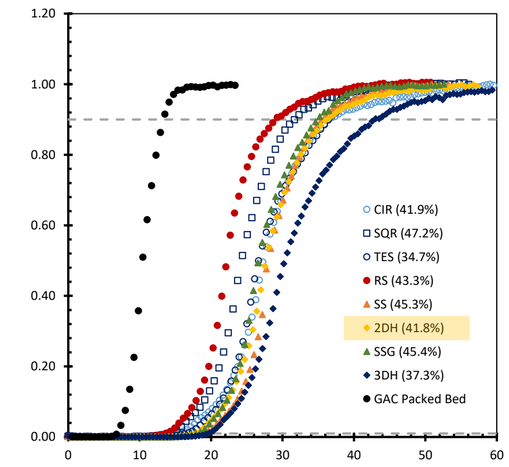


Fig.2. Normalised *n*-butane breakthrough profiles for AC microstructures at constant Re=80 and C_0= 1000 ppm *n*-butane.

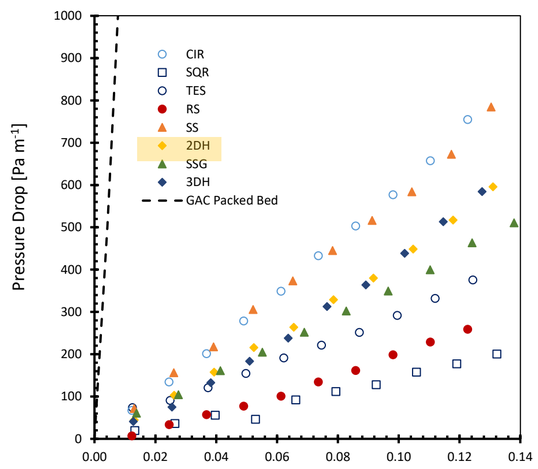


Fig.3. Experimental pressure drop for AC microstructures and GAC packed bed.

* Compared to a commercial packed bed.

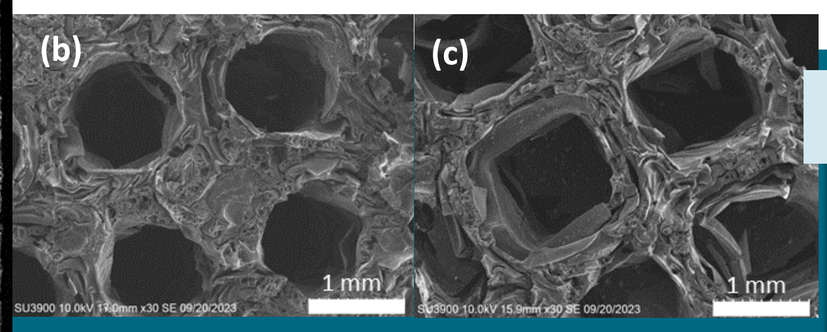


Fig.4. (a) CT scans and (b, c) SEM micrographs channel entrances (a) CIR and (b) SQR, and interior channel structure (c) 3DH.

Benefit to Society and Next Steps

- ✔ These successfully manufactured 3D printed activated carbon microstructures with superior dynamic adsorption performance and lower pressure drop offer a glimpse into the future of high-performance and low energy cost gas separation.
- ✔ Impregnation is the next stage of development of these microstructures to target a wider variety of toxic gases while maintaining high performance and low cost.

References/Acknowledgements

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[1] Ali, M.E., Hoque, M.E., Safdar Hossain, S.K. et al. Nanoadsorbents for wastewater treatment: next generation biotechnological solution. Int. J. Environ. Sci. Technol. 17, 4095–4132 (2020). https://doi.org/10.1007/s13762-020-02785-4

[2] Grand View Research. (2021). Activated Carbon Market Size, Share & Trends Analysis Report By Product (Powdered, Granular), By Raw Material, By Application, By End-use, By Region, And Segment Forecasts, 2024 - 2030. Grand View Research.

[3] Heidarinejad, Z., Dehghani, M.H., Heidari, M. et al. Methods for preparation and activation of activated carbon: a review. Environ Chem Lett 18, 393–415 (2020). https://doi.org/10.1007/s10311-019-00955-0