A New Generation of Activated Carbon Adsorbent Microstructures

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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 channeling ✅ High pressure drop ✅ Premature breakthrough

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

1 Rifled Spiral (RS) 2 Simple Serpentine (SS) 3 Serpentine Spiral Groove (SSG) 4 2-Dimensional Helix (2DH) 5 3-Dimensional Helix (3DH)

Aim

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

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

3D printed AC microstructures had

3x longer n-butane breakthrough times.*
> 80% Reduction in pressure drop.*
> 65% Increase in equilibrium loading.*

Table of Mass of activated carbon produced annually[2].

<table>
<thead>
<tr>
<th>Structure</th>
<th>Mass of Activated Carbon</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS</td>
<td>37.3%</td>
<td>26.5 mm</td>
</tr>
<tr>
<td>SS</td>
<td>45.3%</td>
<td>22.1 mm</td>
</tr>
<tr>
<td>SSG</td>
<td>45.4%</td>
<td>38.5 mm</td>
</tr>
<tr>
<td>2DH</td>
<td>41.8%</td>
<td>41 mm</td>
</tr>
<tr>
<td>3DH</td>
<td>47.2%</td>
<td>33.7 mm</td>
</tr>
<tr>
<td>TES</td>
<td>34.7%</td>
<td>31.7 mm</td>
</tr>
<tr>
<td>SQR</td>
<td>41.9%</td>
<td>43.1 mm</td>
</tr>
<tr>
<td>CIR</td>
<td>47.2%</td>
<td>43.1 mm</td>
</tr>
</tbody>
</table>


Notes:
- * Computed as the reduction in approach velocity at constant Re=80.
- ** Computed as the increase in equilibrium loading at constant Re=80.

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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