Laser-Induced Porous Graphene Sponge for Oil Sorption

Katherine M. Atwater¹, Eric J. Bailey¹, Allen C. Chang¹, Griffin L. Godbey¹, John Mecham¹, Amine Oueslati¹, James M. Tour², Chandra Thamire³, Ray J. Phaneuf¹
¹Department of Materials Science and Engineering, University of Maryland, College Park, MD
²Department of Chemistry, Rice University, Houston, TX
³Department of Mechanical Engineering, University of Maryland, College Park, MD

Motivation

- Oil spills have significant environmental, economic, and societal impacts
- Carbon-based materials show promise for oil sorption [1]
- Current technology for oil removal is not selective [1]
- A scalable, comparatively inexpensive fabrication technique for laser-induced porous graphene (LIG) was developed [2]

Objectives

- Develop a tunable porous graphene material for oil sorption
- Create atomistic and fluid flow models for oil sorption in porous graphene
- Determine a relationship between pore size and oil sorption

Background

<table>
<thead>
<tr>
<th>Materials for Oil Sponges</th>
<th>Polyurethane and Polypropylene</th>
<th>99% porous Carbon Nanotube (CNT)</th>
<th>&gt;90% porous Spongy Graphene (SG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can absorb up to 90 grams of oil per gram of polymer [3]</td>
<td>Can absorb 80 grams of oil per gram of CNT with selectivity [4]</td>
<td>Can absorb up to 70 grams of oil per gram of graphene [1]</td>
<td></td>
</tr>
</tbody>
</table>

- Selective only with coating
- Environmentally harmful
- High volume needed
- Very expensive
- Complex, resource intensive processing

Laser-Induced Graphene

A novel method of producing porous graphene by irradiating polyimide (PI) film with a 3.6W IR laser was recently developed [2]

- Laser ablation breaks non-carbon-carbon bonds
- Leaving porous graphene behind
- LIG porosity, pore size, and film thicknesses are controllable with process parameters
- LIG is cost effective and scalable

Table 1: Porosity data for 3.6W-LIG [2]

<table>
<thead>
<tr>
<th>Diameter (Å)</th>
<th>Density (g/cm³)</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.6</td>
<td>137.5</td>
<td>47</td>
</tr>
<tr>
<td>36.8</td>
<td>92.5</td>
<td>31.6</td>
</tr>
<tr>
<td>53.7</td>
<td>47.5</td>
<td>16.2</td>
</tr>
<tr>
<td>89.4</td>
<td>15</td>
<td>5.1</td>
</tr>
<tr>
<td>Total</td>
<td>292.5</td>
<td>100</td>
</tr>
</tbody>
</table>

Experimental

<table>
<thead>
<tr>
<th>Materials</th>
<th>Sample: 25µm thick, 2 m² m⁻² LIG on polyimide substrate</th>
<th>Oil: 99% antihydrous n-octane</th>
<th>Microbalance: 0.001 ± 0.001 mg</th>
</tr>
</thead>
</table>

- Porous graphene only absorbs nonpolar octane and not polar water
- The sorption capacity of LIG is about 8 grams of oil per gram of graphene
- Samples exhibit capillary action when partially submerged in octane
- Absorption may be surface-only due to linear dependence with time

Conclusions

- LIG absorbs fewer grams of oil per gram of graphene
- Oil sorption is independent of pore size
- Distinct octane layers formed over porous graphene sheets
- Sheet spacing is not sufficient for bulk oil sorption
- In its current state, LIG is not a marketable oil sponge

Future Work

- Fabricate ideal design using open backside of LIG
- Test LIG with different pore characteristics
- Implement crude oil in sorption tests
- Increase sheet spacing of LIG
- Investigate mechanical stability of LIG

References


Acknowledgements

We would like to thank Dr. S. Eleanor, Dr. J. Kludra, Dr. P. Kohler, Dr. D. Liu, Dr. Y. Mo, Dr. R. Phaneuf, Dr. S. Philip, Dr. C. Presley, Dr. C. Thomas, Dr. J. Testo, A. Kemp, S. Lacey, K. Pellet, H. Walschom, UMD Deepthought, UMD OTC for their guidance, resources, and time. We also thank the Materials Science and Engineering (MS&E) department for support and everything in the last 4 years.