Additive Manufacturing of Carbides using Renewable resources

Monsur Islam
Clemson University

Rodrigo Martinez-Duarte
Clemson University

Follow this and additional works at: https://tigerprints.clemson.edu/grads_symposium

Recommended Citation
https://tigerprints.clemson.edu/grads_symposium/135
Additive Manufacturing of Carbides using Renewable resources

Monsur Islam and Rodrigo Martinez-Duarte
Mechanical Engineering Department, Clemson University, Clemson, SC, USA

Introduction

WHAT? A novel additive manufacturing process of carbides using a biopolymer-metal oxide composite as the precursor material.

WHY:
- Renewable biopolymers replace petroleum-based ones as carbon source;
- The temperature needed for carbide formation is drastically reduced due to the colloidal proximity of the reactants.
- Additive manufacturing of a precursor gel composite could enable complex shapes, especially those currently challenging for powder pressing or machining of bulk carbides.

Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>What it is</th>
<th>General Application</th>
<th>Role in our work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iota-carrageenan</td>
<td>Polysaccharide extracted from red edible seaweeds</td>
<td>Food industry</td>
<td>Carrier</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Polysaccharide, linear long chain of D-glucose</td>
<td>Paper and Paperboard</td>
<td>Bio-filler</td>
</tr>
<tr>
<td>Chitin</td>
<td>Long-chain polymer of a N-acetylglucosamine, a derivative of glucose.</td>
<td>Exoskeleton of shrimp, crab and lobsters</td>
<td>Bio-filler</td>
</tr>
<tr>
<td>Silica nanoparticle</td>
<td>5-10 nm amorphous nanoparticles</td>
<td></td>
<td>Metal oxide nanoparticle (MONP)</td>
</tr>
</tbody>
</table>

Experimental Process

- **SONICATION**
  - Power ~ 35W
  - Time ~ 15 min
- **BIOPOLYMER MIX**
- **COMPOSITE GEL**
- **MANUAL EXTRUSION**
- **HEAT TREATMENT UNDER N2**
  - Heating Ramp: 5 °C/min
  - 75 min dwell at 1300 °C

Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>A) Iota-carrageenan/cellulose</th>
<th>B) Iota-carrageenan/chitin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EDX</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>XRD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BET</strong></td>
<td>399.6723 m²/g</td>
<td>232.0953 m²/g</td>
</tr>
</tbody>
</table>

Conclusion

- Amorphous, Porous, carbonaceous material with many impurities
- Water is the expected source of contaminants. Switch to high purity water.
- Explore higher carbonization temperatures and/or more reductive environments.
- Precursor shape is maintained during carbonization. Shrinkage happens.
- High surface area.

Towards Additive Manufacturing

- **Additive manufacturing**
  - Rheology of gels
  - Scale of manufacturing, Structural, Extrusion rate, Layer bonding? Overhang?
  - Different weight ratio of gel components
- **Heat treatment**
  - Temperature: Carbothermal reaction
  - T>1300 °C
  - Dwell time: Complete reaction
  - Longer dwell time
- **Precursor Composition**
  - Amount of MONP
  - Avoid localized reaction
  - Increase % MONP
  - Water source
  - To avoid contamination
  - Ultra-pure water
  - MONP dispersion
  - Single particle dispersion
  - Use surfactant

Acknowledgements

- Electron Microscopy Laboratory
- Dr. Colin McMillan, X-ray Facilities of The Molecular Structure Centre
- Prof. Stephen Creager and Jamie Shetzline

Visit: www.multiscalemanufacturing.net