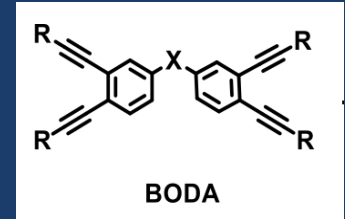


Compression Molding Fabrication of C/C Composite Produced via Highly Processable BODA-Derived Precursor Resin System

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2025 Region II Student Conference, 4-5 April 2025



Introductions



Josh Brown
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Joshua Griffin
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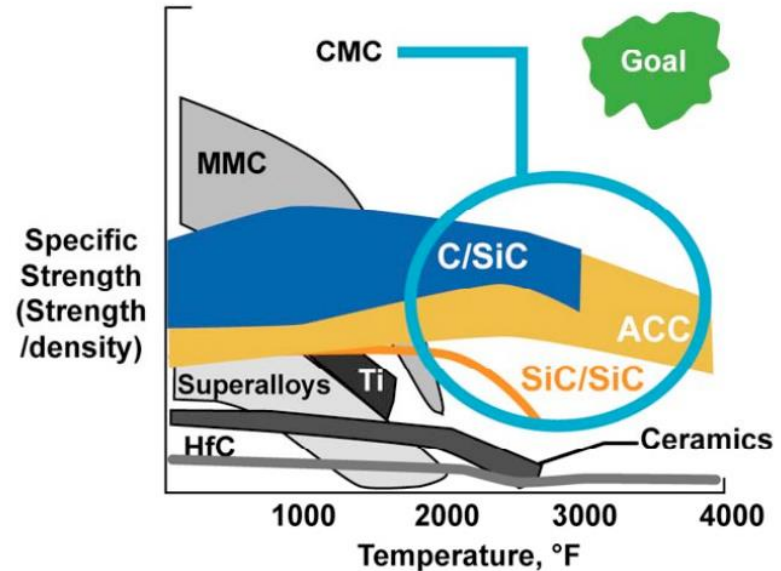


Patrick Madden
Senior (Astronautics)
Manaus, Brasil

What is Carbon/Carbon?

Carbon Fiber/Carbon Matrix

- Material Properties
 - High Specific Strength
 - High Thermal Stability
 - Low CTE
- Applications
 - Leading Edge of Space Shuttle
 - High Performance Brakes
 - Rocket Motor Nozzle Throats
 - Nuclear Fusion



D. E. Glass, "Ceramic Matrix Composite (CMC) Thermal Protection Systems (TPS) and Hot Structures for Hypersonic Vehicles," 15th AIAA Space Planes and Hypersonic Systems and Technologies Conference, Dayton, OH, Apr. 28–May 1, 2008, AIAA-2008-2682.

Carbon Matrices Are Expensive...

➤ Carbon/Carbon (C/C) manufacturing

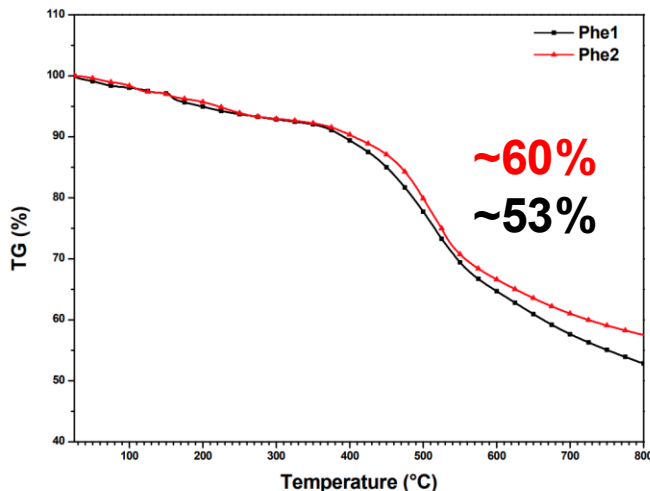
- Long Manufacturing Time
- Decades Old Precursor Technology

➤ Manufacturing Methods

- Chemical Vapor Deposition
- Mesophase Pitch
- Synthetic Precursor Resin

➤ Precursor resins have the greatest room for improvement

Phenolic Resin TGA



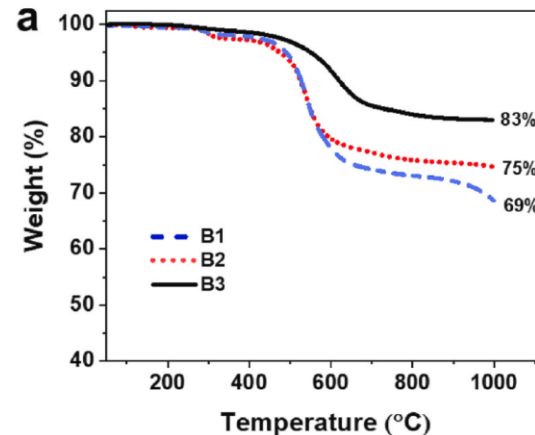
*Di Gregorio, Luca; Ronchetti, Silvia;
Onida, Barbara (2015).*

Bis - *ortho* – diynylarene (BODA)

- BODA-derived resins (BDR) have high char yield and high oxidative stability as a polymer
- Properties allow for **one-step** infusion and carbonization greatly reducing processing time for a finished C/C part.



Borrego et. Al (2022)



**BODA-Resin
TGA**

*10 ° C/min
under Ar flow*

Composite manufacturing w/BODA

- BDR has limited composite manufacturing (TRL 4-5).
- Create a process for compression molding BDR C/C parts
- Get hands-on composite manufacturing experience

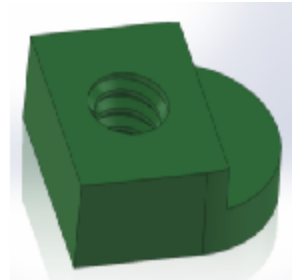
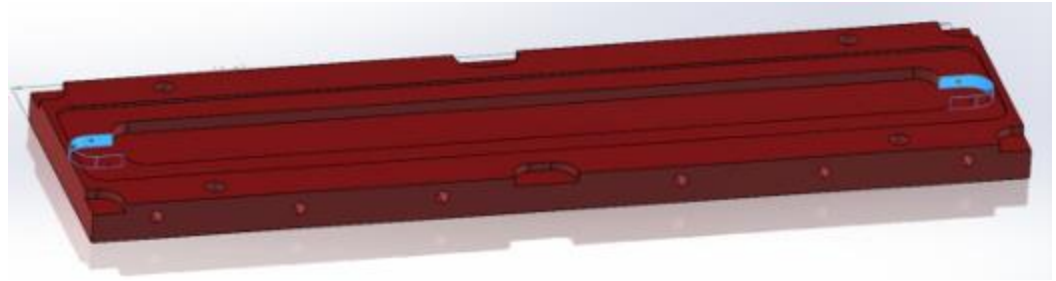
Overview

- "One-step powder-melt infusion and compression molding"
 - Mold (designed for ASTM D3039 coupons and fabricated)
 - Fiber and Resin Layup
 - Cure schedule
 - Co-developed by chemists, iteratively improved by and for ASE students and instrument capability
 - Demolding
 - Processing
 - Carbonization

Mold Design

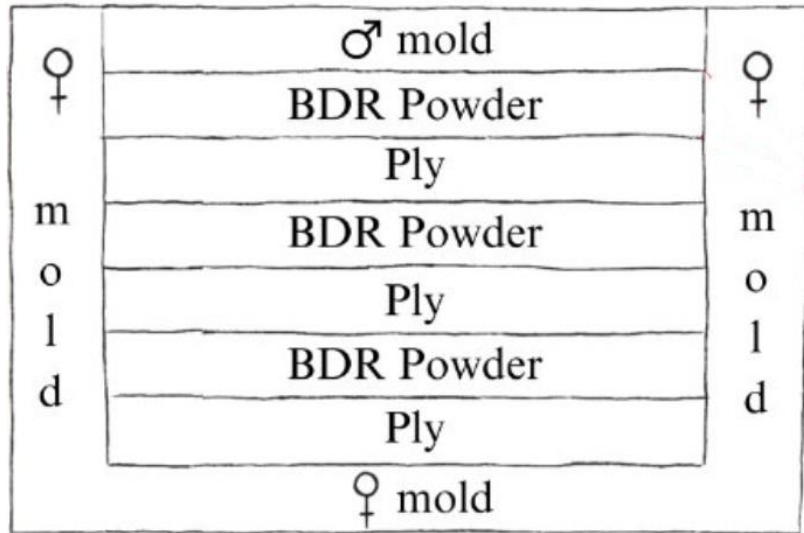
➤ Mold Design Features:

- Draft angle
- Male and female mold
- Thermocouple port
- Access pieces



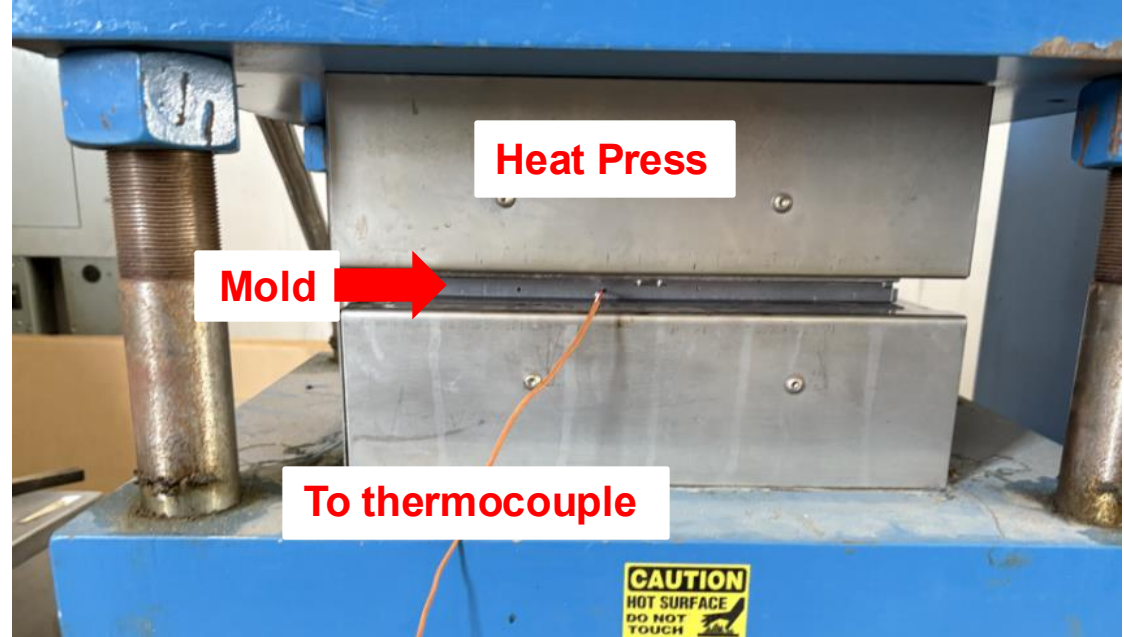
Mold Prep and Fiber/Resin Layup

- Mold prepped with 5 layers of Loctite Frekote 900-NC



Curing for Thermoset

1. 30°C
 2. 200 °C
 3. 220 °C
 4. 250° C + Compression
 5. Extract, at r.t.
-



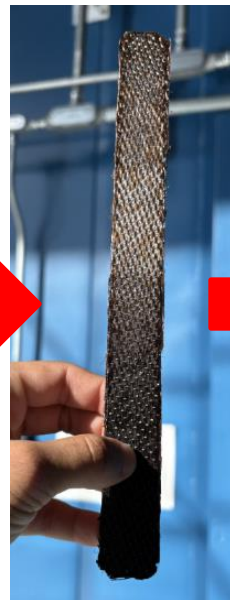
Demolding and Carbonization

- Coupon pried from mold
- Cut to size
- Carbonized at 1000°C in a tube furnace



Results

Trial	Result
1	Resin starved, 1 ply saturated with resin
2	Resin starved; 2 plies saturated with resin
3	Resin starved, delaminated upon carbonization
4	Delaminated upon carbonization
5	Carbonized successfully
6	Carbonized successfully
7	Failure due to wrinkling while cooling
8	Failure due to wrinkling while cooling
9	Failure due to wrinkling while cooling
10	Failure due to wrinkling while cooling
11	Carbonized successfully
12	Carbonized successfully
13	Delaminated upon removal from mold



Challenges



- Demolding
CTE Mismatch Buckling



- Resin starvation



- Delamination

Conclusions

- Novel Undergrad Student-Led C/C Composite Manufacturing Process
- Findings:
 - Machine-cut fiber layers
 - Evenly spread carbon precursor
 - Accurate temperature measurements within the mold
 - Demold part before cooled to room temperature
 - Fabricate large pieces
 - Fall-away mold design
- Future Work
 - Scanning Electron Microscopy
 - Porosity testing
 - Tensile testing



Acknowledgments

- Ernesto Borrego Ph.D., Hand Technologies LLC
- Han-Gyu Kim, Ph.D., Mississippi State University
- Alejandro Martinez, Mississippi State University
- Matthew Roberson, Advanced Composites Institute
- Brandon Warner, Mississippi State University



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Questions?



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