Carbon/carbon composites: manufacturing, structures and property relationships

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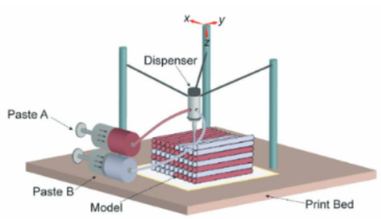
Introduction

A limitation in the aerospace industry is the lack of lightweight materials that could withstand high temperatures without losing their mechanical robustness for applications in supersonic/hypersonic flights. The current generation of carbon fiber-reinforced plastic and titanium alloys fails to sustain their properties at elevated temperatures. Carbon-carbon (C-C) composites have been studied for nearly four decades, but their lead time had hampered their use in industries. We are developing a 3D printing (i.e., direct ink writing) method to produce reinforced C-C composites. This adoption of rapid prototyping would significantly reduce the production time and allow functional and complicated structures to be manufactured.

Materials and Methodology



J2027LV, a phenolic resin is used that is known to have high carbon content[3]. We yielded about 60% carbon yield post pyrolysis. Hyrel 3D printer is used for printing. Post-printing, the sample must be kept inside a tube furnace at about 1300°C. This removes all the other elements from the resin-like hydrogen, oxygen, etc. that are volatile compounds which isn't a part of the C/C composite. Also, this has to be done in an inert atmosphere to prevent the carbon from oxidizing to form CO and CO_2. The final product that we have will be the C/C composite.

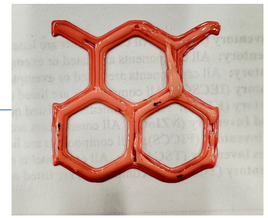
Source: 3D printing- enabled Nanoparticle Alignment: A review of mechanisms and applications, 2021, Xu et al.

Process Development and Results

Phenolic Resin
+
Carbon reinforcement
+
pTSA catalyst

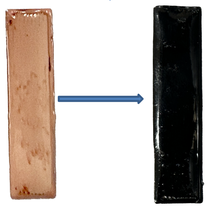
Printing using DIW

Tube Furnace



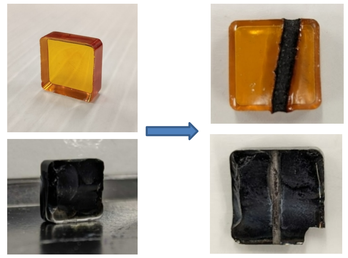
Printed sample

Pyrolysis
@ 1400°C for 24 hrs.



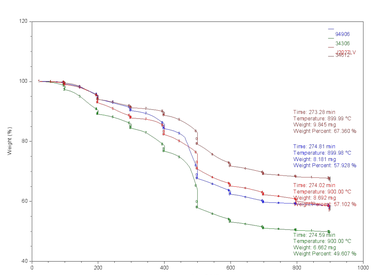
Sample post pyrolysis

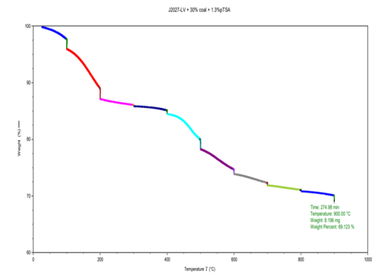
CVD[4] to improve carbon impregnation and surface oxidation resistance



Effect of laser on the composite

Material Analysis





[3]TGA of resins showing the carbon yield post pyrolysis. This can be used as a measure to calculate volumetric shrinkage and carbon yield.

[4]Plain C/C composite is both porous and susceptible to oxidization when exposed to oxygen at high temperatures. So, it is necessary to do CVD to coat the composite with a SiC to prevent this from happening.

Future work.

- Test resin with carbon reinforcement like coal, etc.
- CVD coating of SiC over the composite for additional strength and oxidation resistance.
- High-temperature mechanical test to compare with Al and Ti.
- Test thermal and porous properties for any potential application in energy storage devices.

Acknowledgements

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