High-Temperature Composite Materials for Aircraft Engine Applications

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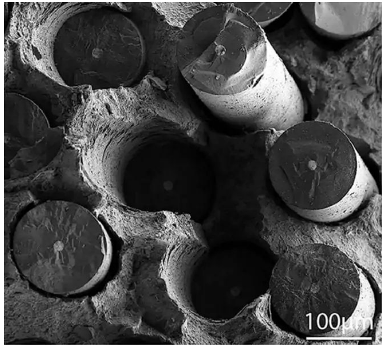
Introduction

Why composites for high temperature applications?

- Ability to tailor the properties of the material used to the specific environmental conditions.
- Increased resistances to erosion, corrosion, oxidation, thermal and physical fatigue, impact resistance, and creep vs traditional materials.

Material types for high temperature use:



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Metal Matrix Composite

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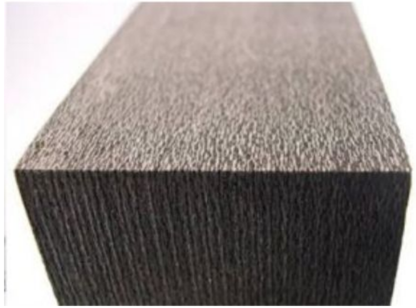
Carbon-Carbon Matrix Composite



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Ceramic Matrix Composites

Metal Matrix Composites

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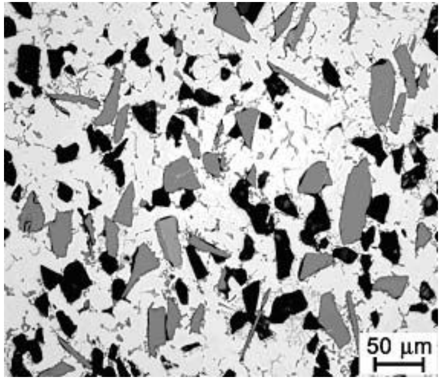
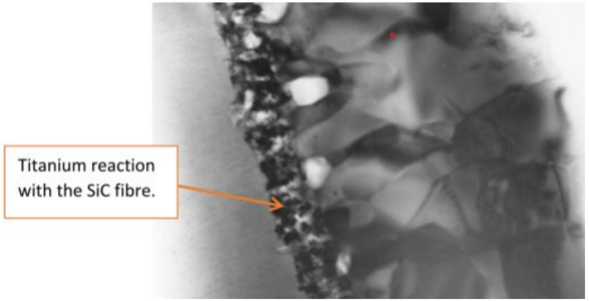


- Excellent thermal properties and strength for engine applications
- Good wear and creep resistance



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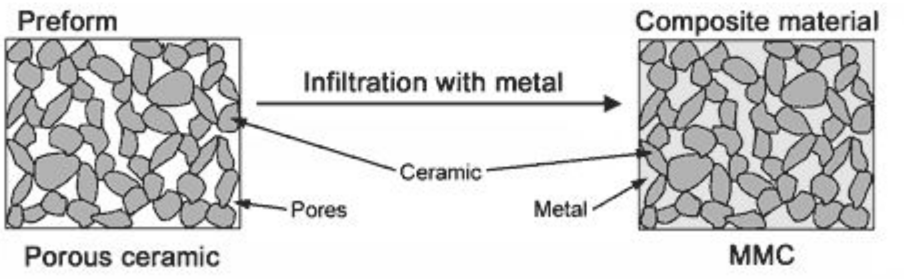

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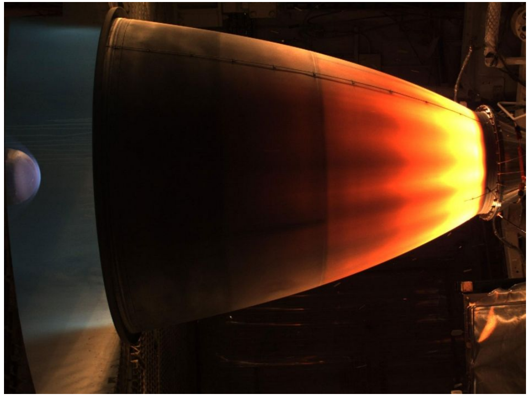
- Unwanted interaction between matrix and fiber requires coating or new manufacturing technique to prevent
- Manufacturing improvements needed to reduce cost

Carbon-Carbon Matrix Composites

- Currently used in ablative heat shields and rocket nozzles
- Most expensive high temperature composite
- Extremely lightweight, high strength/stiffness



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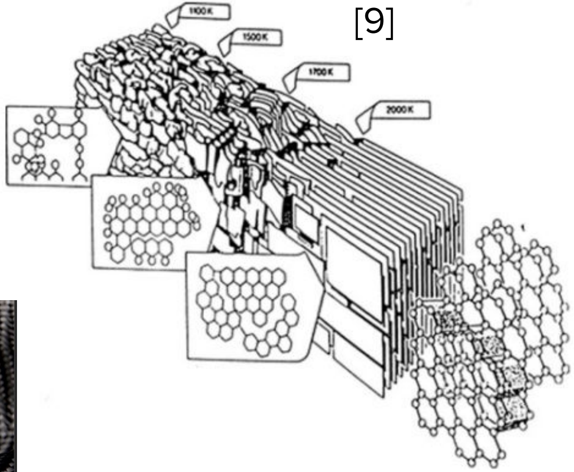

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- Requires repeated manufacturing cycles in order to reach needed density
- Usually requires secondary heat treating processes after manufacturing
- Quality assurance for carbon fibers increases costs

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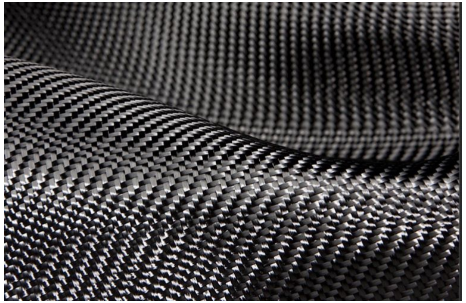

Ceramic Matrix Composites

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- Newest High-Temperature composite
- Ceramic has excellent properties for use in extreme conditions except very brittle
- Reinforcing ceramic with fibers makes this composite very promising for engine components
- Oxide/Oxide and Non-Oxide composites

- Prohibitively expensive manufacturing for widespread use
- More research needed for accurate lifetime and failure predictions
- New combinations of materials being researched

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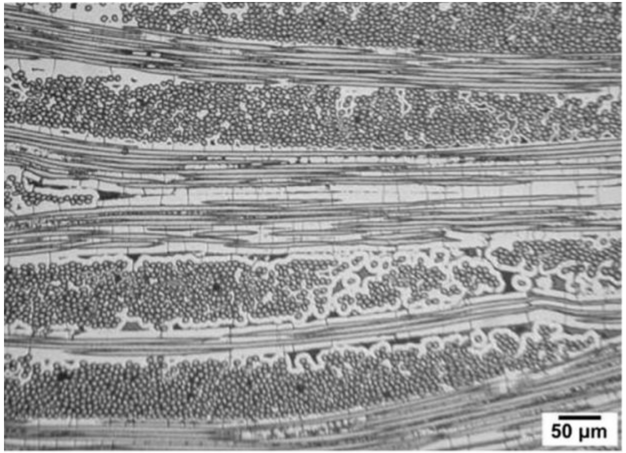

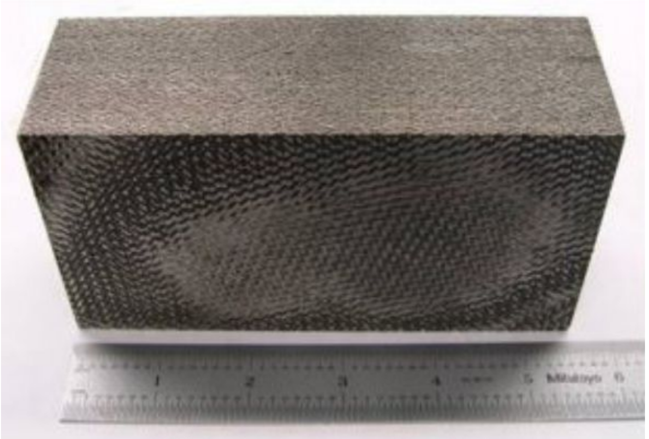

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The future of High-Temperature Composites...

- Continue to become stronger and lighter, more resistant to corrosion, erosion and thermal stress.
- Optimized through research on material selection and manufacturing processes for lowered costs and consistent materials with known performance and failure data.
- Improving specific drawbacks for each type of material, e.g. fiber matrix interactions in MMCs.

Possibly...

- Integration of different types of materials within high-temperature composites, electronic components, microprocessors, sensors
- Nanotechnology
- Materials that can self-assess for damage

Image Credits:

[1] https://doi.org/10.1002/adem.201700027
[2] https://www.cfccarbon.com/news/thick-walled-constructions-of-carbon-carbon-cc-composite.html
[3] https://ultramet.com/ceramic-matrix-composites/material-systems/
[4] Doorbar, Phillip J. et al. (2018). “Development of Continuously-Reinforced Metal Matrix Composites for Aerospace Applications”, Comprehensive Composite Materials II Vol 4. Elsevier.
[5] http://www.keramverband.de/brevier_engl/3/4/4/3_4_4_2.htm
[6] https://www.machinedesign.com/materials/article/21835569/the-future-of-metal-is-in-matrix-composites
[7] https://www.nasa.gov/audience/foreducators/rocketry/imagegallery/rparts_engine.jpg.html
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[9] Taylor, R. et al. (2018). “Carbon Matrix Composites”, Comprehensive Composite Materials II Vol 5. Elsevier
[10] Shinavski, Roberset al. (2018). “Non-Oxide/Non-Oxide Ceramic Matrix Composites - Composite Design for Tough Behavior”, Comprehensive Composite Materials II Vol 5. Elsevier.