Progress in Manufacturing & Characterizing Domestic Lyocell PICA and Comparison to Heritage PICA

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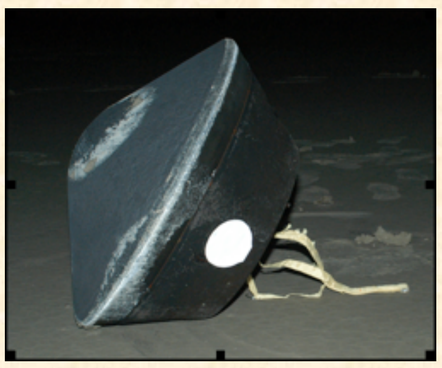
Background – PICA and PICA Sustainability

State of the Art Low Density Carbon Phenolic Ablators

- Phenolic Impregnated Carbon Ablator (PICA) is a low density (~ 0.27g/cm^3) ablator first used as the forebody heatshield for the Stardust sample return capsule where it was used as a single piece heatshield
- Since Stardust, PICA was used on the Mars Science Lab (MSL) in a tiled configuration, on the OSIRIS-REx sample return capsule as a single piece and slated for Mars 2020 as a tiled configuration.



Stardust SRC post flight with PICA forebody heat shield (0.8m max. diameter)

- NASA ARC recently learned that heritage rayon utilized in PICA has stopped production leading to a flight-qualified PICA sustainability challenge.
- NASA ARC is funded by SMD to address PICA rayon sustainability
- Two approaches are being pursued:
  - ***Secure the remaining heritage (Sniace) rayon.***
  - ***Develop and implement plans to certify a Lyocell based PICA***

Feasibility of Sustainable Domestic Lyocell PICA

Lyocell is being evaluated as a "rayon alternative" FiberForm® precursor – Lyocell is a sustainable domestic source and previous work indicates Lyocell is a feasible alternative

SMD-PSD funded ARC to manufacture and perform limited property and aerothermal characterization of Lyocell based PICA

- Fabrication of PICA billets & a near net shape heatshield using Lyocell based FiberForm®. Activity supports tiled heatshield & smaller scale single piece heatshield designs. Target drop-in replacement for heritage PICA
- Characterization includes thermal /mechanical properties and arc jet testing of instrumented coupons - NASA ARC worked with NF proposing orgs to ensure arc jet testing is at mission relevant conditions

PICA Processing Steps

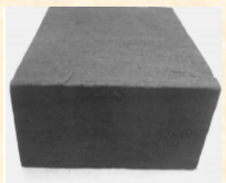
Role of Rayon/Lyocell in PICA Manufacturing

Rayon or Lyocell Raw material sustainability concern

Conversion to carbon

Near net shape preform

Single piece PICA heatshield (< 1.00 m max diameter)

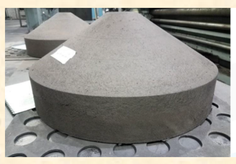


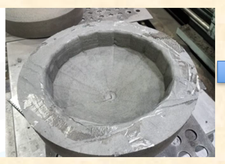
FiberForm® billet preform

Tiled PICA heat shield (> 1.00 m max diam)

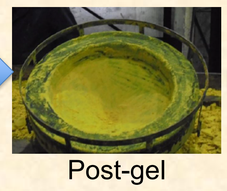
Status - Net Casting, Billet Fabrication and Infusion

- 7 billets of fiberform manufactured to optimize the process using lyocell fibers – billets span the spec density range – fiberform target densities achieved
- Development and fabrication of 1 relevant scale, net-shaped FiberForm heatshield blank (OSIRIS REx scale) completed – density targets in net cast achieved
- Process refinements and lessons learned have been documented
- Limited Non Destructive Evaluation (NDE) completed on the lyocell near net shape fiberform unit to evaluate fiber alignment and check for off-nominal features





Trimmed prior to infusion



Post-gel

Post-infusion

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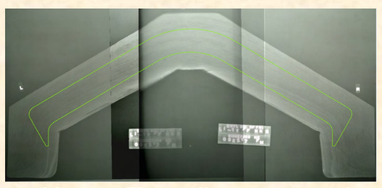


X-ray (fiber alignment and FOD/void check

Cast unit density coupon cut plan

Status – Property Testing

- 3 billets of PICA manufactured to support testing -these represent the material's density varying through the range of specification limits on billet density
- Limited In-plane (IP) tension, through-thickness (TT) tension, and through thickness thermal conductivity at 100F and 350F were conducted and compared to heritage rayon PICA
- Overall these results are in family with production rayon PICA – however additional testing is needed as limited coupons were evaluated

Mechanical Property Comparison

	Density (g/cc)	Failure Stress (psi)
Average Lyocell IP properties	0.28	246.48 *(vs 190 for rayon PICA)*
Average Lyocell TTT properties	0.28	44.03 *(vs 49.6 for rayon PICA)*

Thermal Property Comparison

Billet ID	Specimen ID	Thermal Conductivity (BTU-in/hr-ft^2-°F) at 100°F	Thermal Conductivity (BTU-in/hr-ft^2-°F) at 350°F
Average Lyocell TTT properties		0.939	1.32
Average Rayon TTT properties		1.22	1.66

Status - Arc Jet Characterization

- 3 conditions targeted – testing completed in Oct 2017
- NF proposers provided guidance on test conditions

Rayon Derived PICA

Pre test

Post test

Lyocell Derived PICA

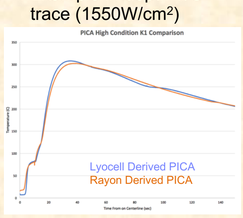
Pre test

Post test

Arc Jet Test Matrix

Target Conditions	Objective	Comments
~ 220W/cm^2 and 0.08 atm (4" iso-q)	thermal response, recession	Instrumented coupon, calibration included **Testing in Oct 2017**
~ 400W/cm^2 and 0.3 atm (4" iso-q)	thermal response, recession	Instrumented coupon, **Testing complete Aug 2017**
~ 1550W/cm^2 and 1.3 atm (4" iso-q)	Failure mode evolution, thermal response, recession	Instrumented coupon, **Testing complete Aug 2017**

Example in-depth T/C trace (1550W/cm^2)



Recession Comparison

Material	Average centerline recession (1550W/cm^2 and 1.3 atm)	Average centerline recession (400W/cm^2 and 0.3atm)	Average centerline recession (220W/cm^2 and 0.08atm)
Lyocell Derived PICA	4.0mm	6.02mm	3.79mm
Rayon Derived PICA	4.2mm	5.97mm	3.89mm

- For a given test condition (same run time) initial results indicate recession and in-depth temperature between a lyocell-derived and a rayon-derived PICA are comparable.

Summary

- NASA ARC is working with SMD-PSD to address PICA rayon sustainability concerns
- Remaining Sniace heritage rayon has been procured by NASA and is being stored for future SMD-PSD mission – enough heritage rayon available to support a single mission (OSIRIS-REx scale)
- NASA is also evaluating a domestic rayon alternative (Lyocell) for qualifying a replacement PICA thereby providing a sustainable domestic source that is more certain for long-term availability
- Limited initial testing and property dataset indicate that Lyocell derived PICA is a ***potential*** drop in replacement for rayon derived PICA

Future Work – 2 Focus Areas

PICA for NF, Discovery and Mars Missions with Expanded Capabilities:

- Recommend that SMD/PSD initiate a tasks for drop in replacement for heritage PICA
  - Comprehensive property database, complete arc jet testing (including shear testing) on multiple samples at NF relevant conditions demonstrating we have a drop in replacement for heritage PICA
- Evaluate single piece PICA manufacturing scale-up (up to 1.5m uni-piece heatshield)
- Identify PICA expanded capability limits:
  - Current recommended use based on flight (~ 1000W/cm^2, 0.5 psi and ~ 600Pa)
  - Potential PICA use limit (heat flux, pressure, shear) (~1700W/cm^2 ? , ~1.3 atm ? and 1200Pa ?).

Acknowledgements

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