

14th International Planetary Probe Workshop

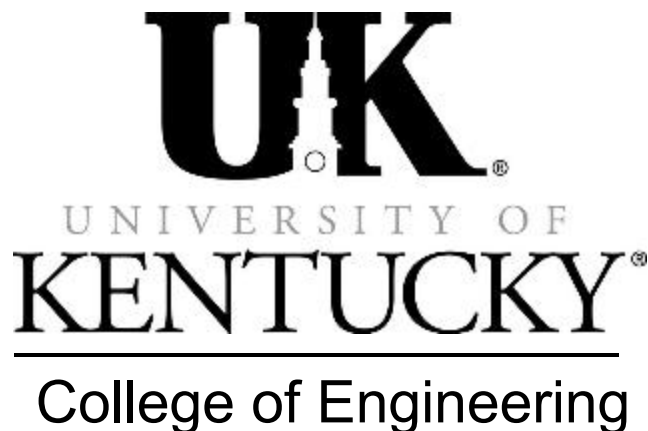
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Remote Recesson Measurements of Seeded PICA

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Student Presentation

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Objective

Characterize a passive thermal protection system sensing approach by seeding the heatshield material at defined positions and depths with tracer materials which are identifiable by their spectral signatures.

Application

The spectral signature of the post-shock plasma is monitored

- Arc jets or during entry, external observation or on-board

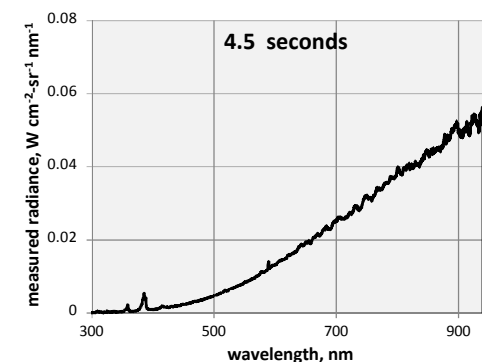
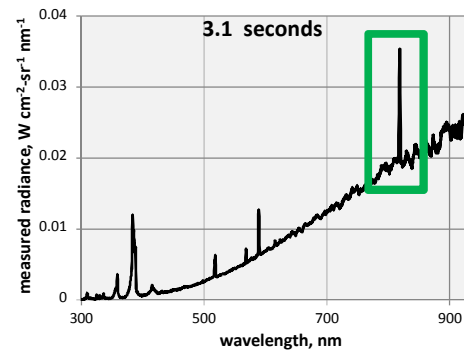
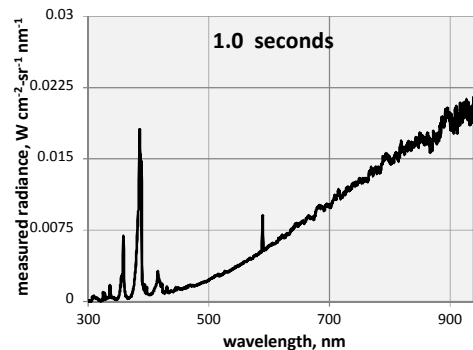
When TPS pyrolysis or recession reaches the seeding depth, the tracer signature appears in the emission spectra

- Time resolved recession and charring measurements in TPS

Remote Recession Measurement - Working Principle

■ Tracer element

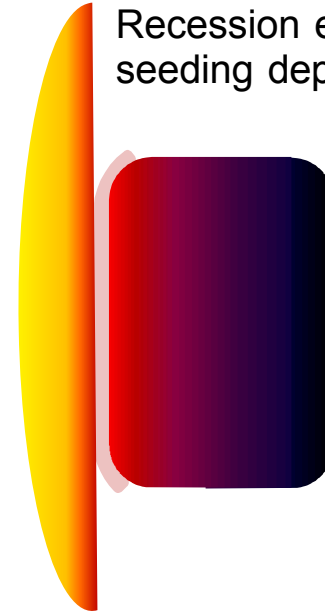
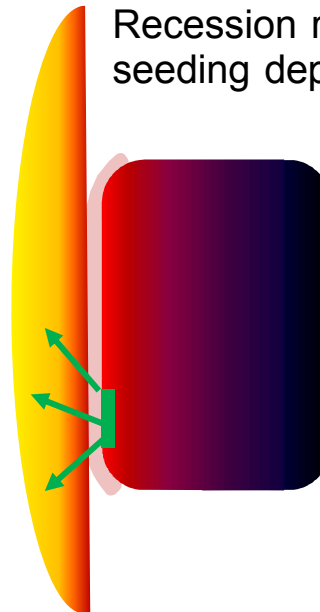
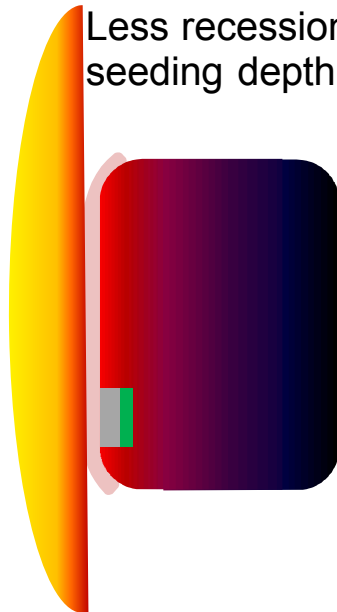
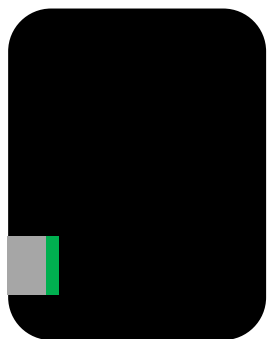
■ Plug (FiberForm, PICA, etc)

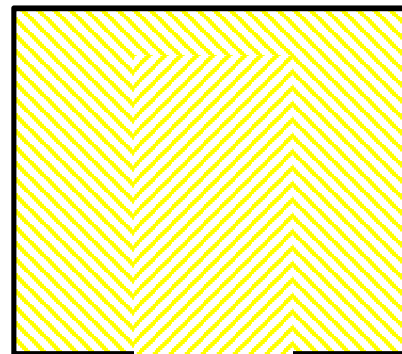


Less recession than seeding depth

Recession reaches seeding depth

Recession exceeds seeding depth





HYMETS – Optical Emission Spectroscopy

HYMETS Operating Conditions

Heat Flux, W/cm ²	200	400	Stellarnet Black Comet miniaturized spectrometer
Max Temperature, K	2450	2860	
Air, SLM	275	150	
Stagnation Pressure, mbar	44	31	

Optical Spectroscopy

Stagnation Line:

Andor Spectrometer with PIXIS CCD

~18 mm with an effective spatial resolution of ~0.3 mm

204 nm to 555 nm range

~0.25 nm resolution

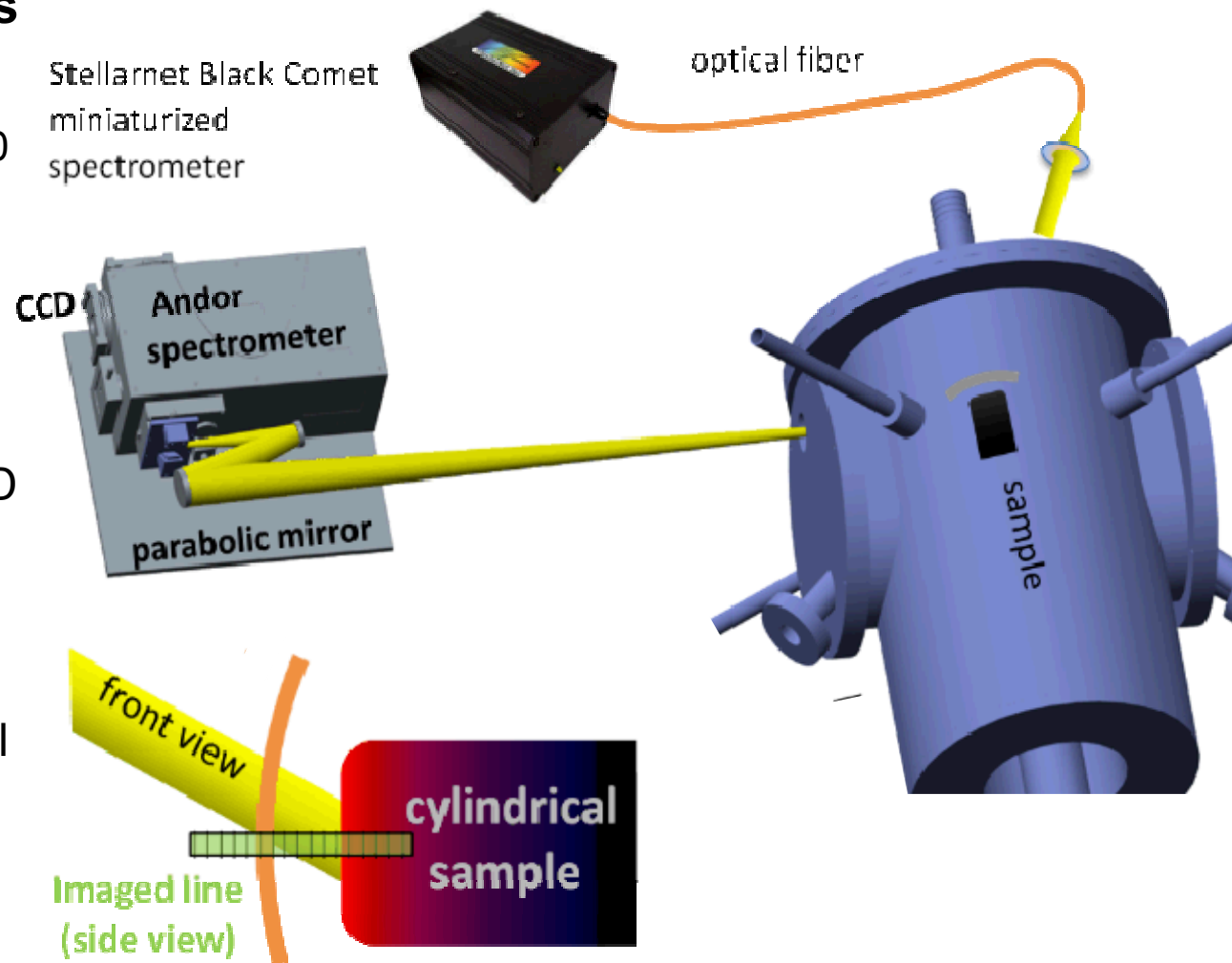
Presented spectra were fully vertical binned, no spatial data shown

Sample Surface:

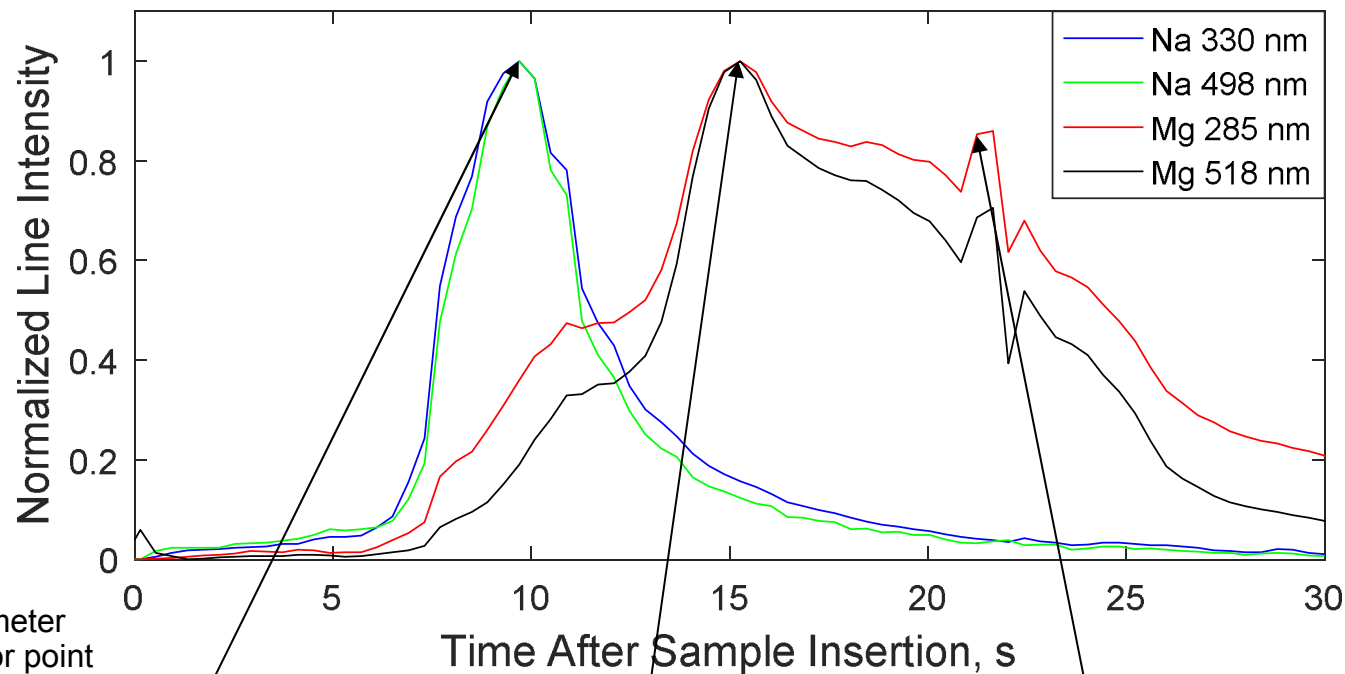
Stellarnet 200 nm to 1100 nm range

~0.5 nm resolution

Note: Data not in this presentation



Epoxy Seed Encapsulation (200 W/cm²)

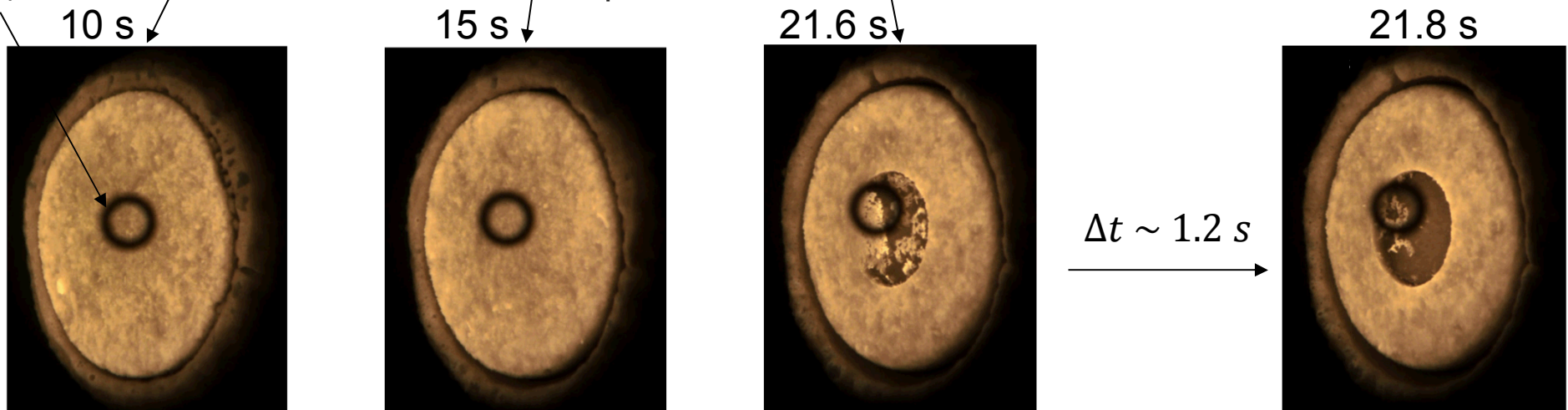


Seeding Depth: 1.69 mm

Seed Thickness: 0.9 mm

Seeds: MgCl and NaCl

- Epoxy disk not suitable and a step face is created



Phenolic Seed Impregnation (200 W/cm^2)

Seeds: Al_2O_3 , SiO_2 , HfC , TiC

Aluminum appears at about 10 seconds

- Related to diffusion of seed through matrix
- Alumina melting point 2345 K
- Also seen with Aluminum (melting point 930 K) in a different sample

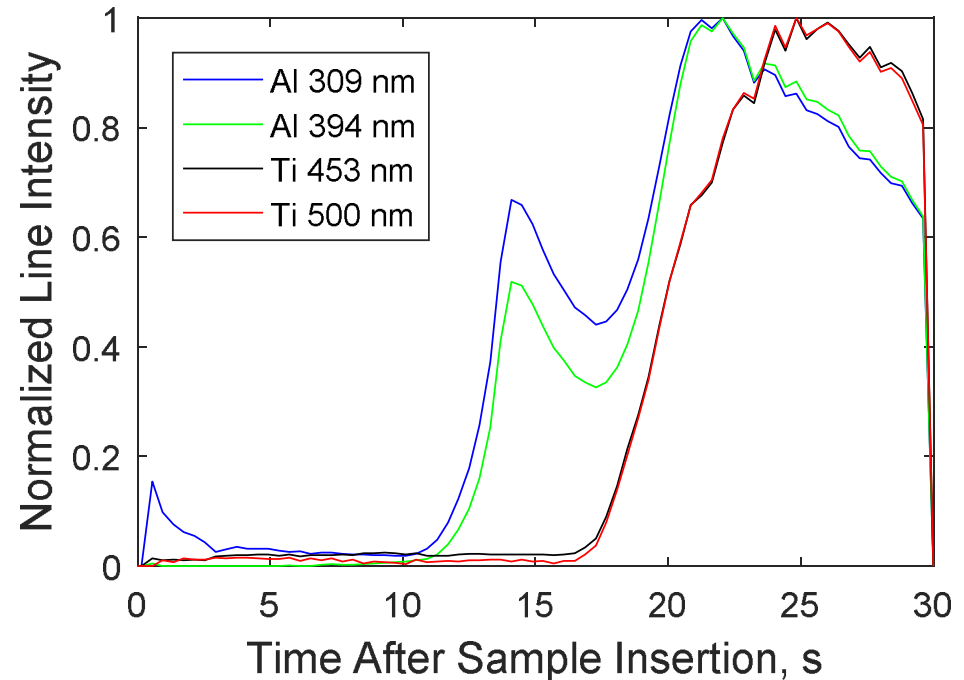
Titanium appears at about 17 seconds

- Related to material recession
- Titanium Carbide melting point 3430 K

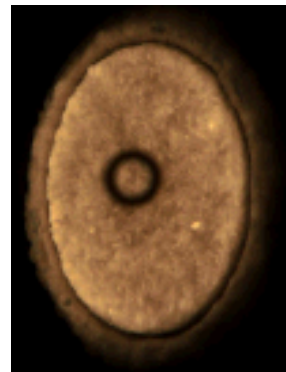
Max pyrometer surface temperature 2400 K

Hafnium spectra were not seen during either test

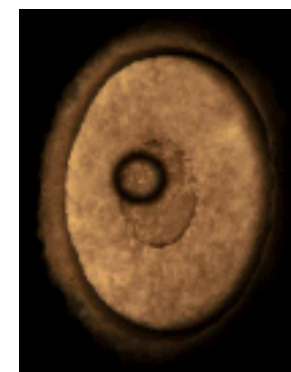
Rate of recession $\sim 0.10 \text{ mm/s}$ from Titanium



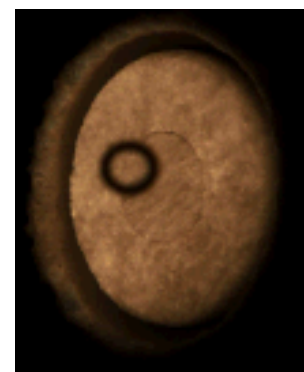
10 s



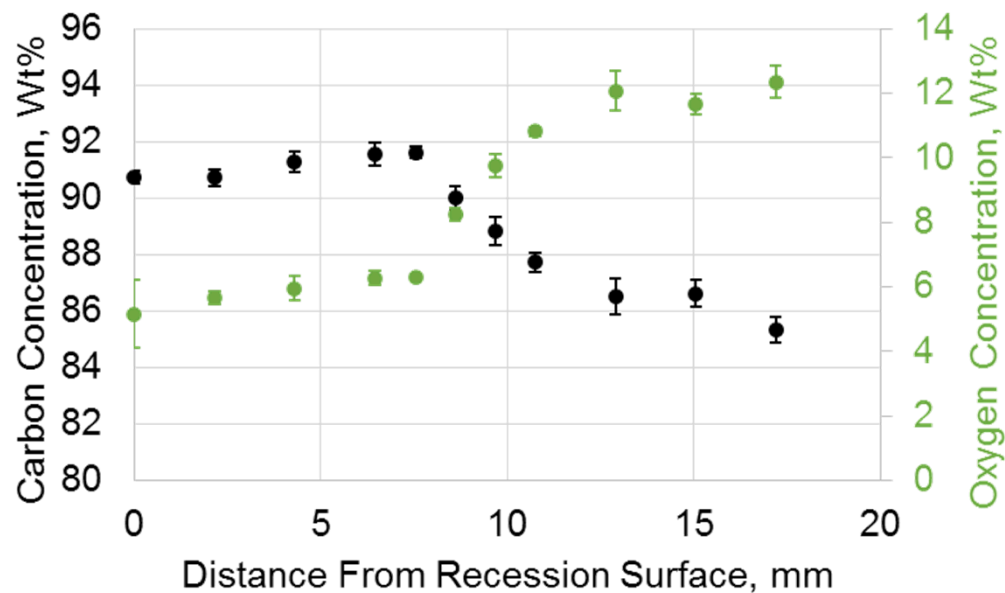
17 s



30 s



Post Test SEM/EDX of Seed Impregnation Sample

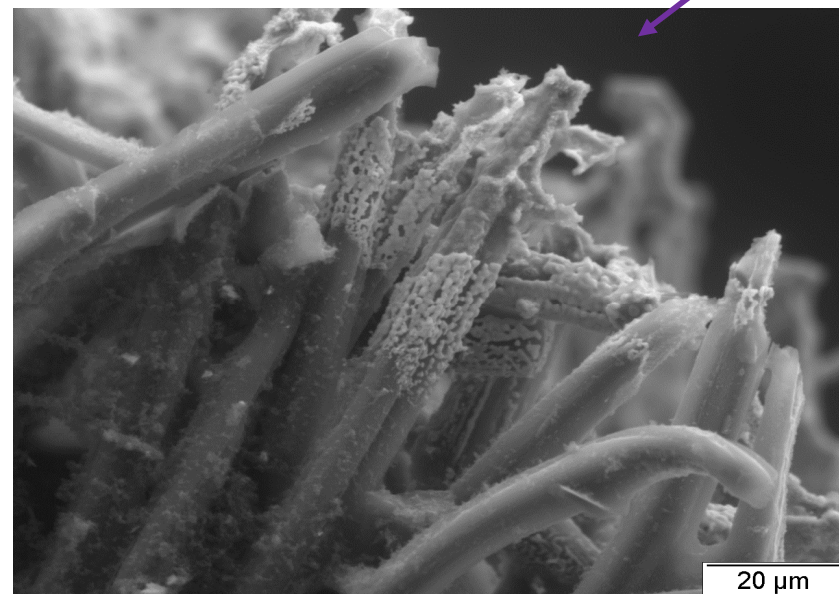
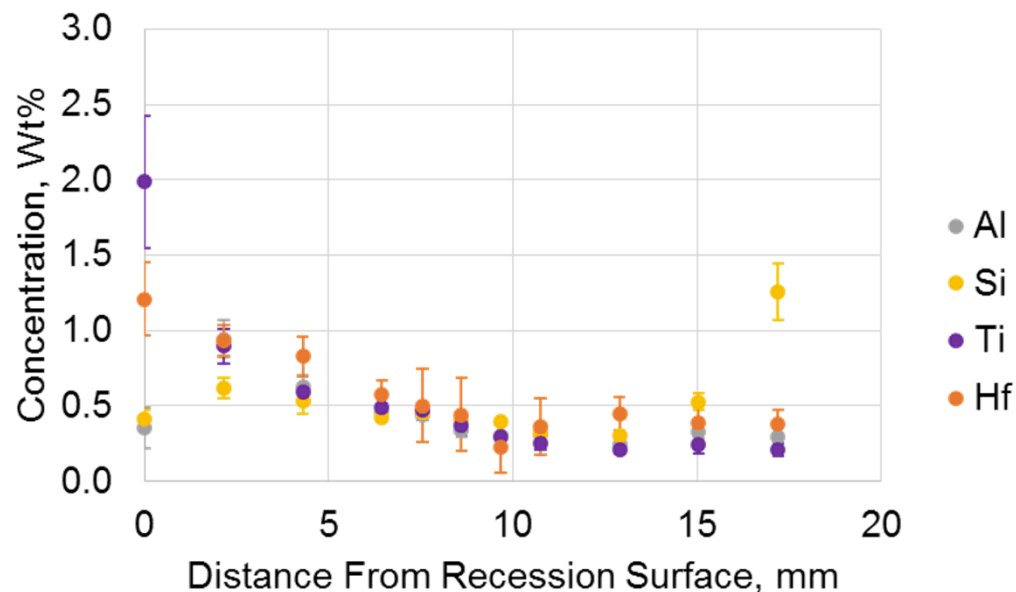


Non-seeded PICA carbon and oxygen concentrations consistent with Stardust measurements

Seed concentration rather constant in virgin material region

Seed concentration favored the charred region

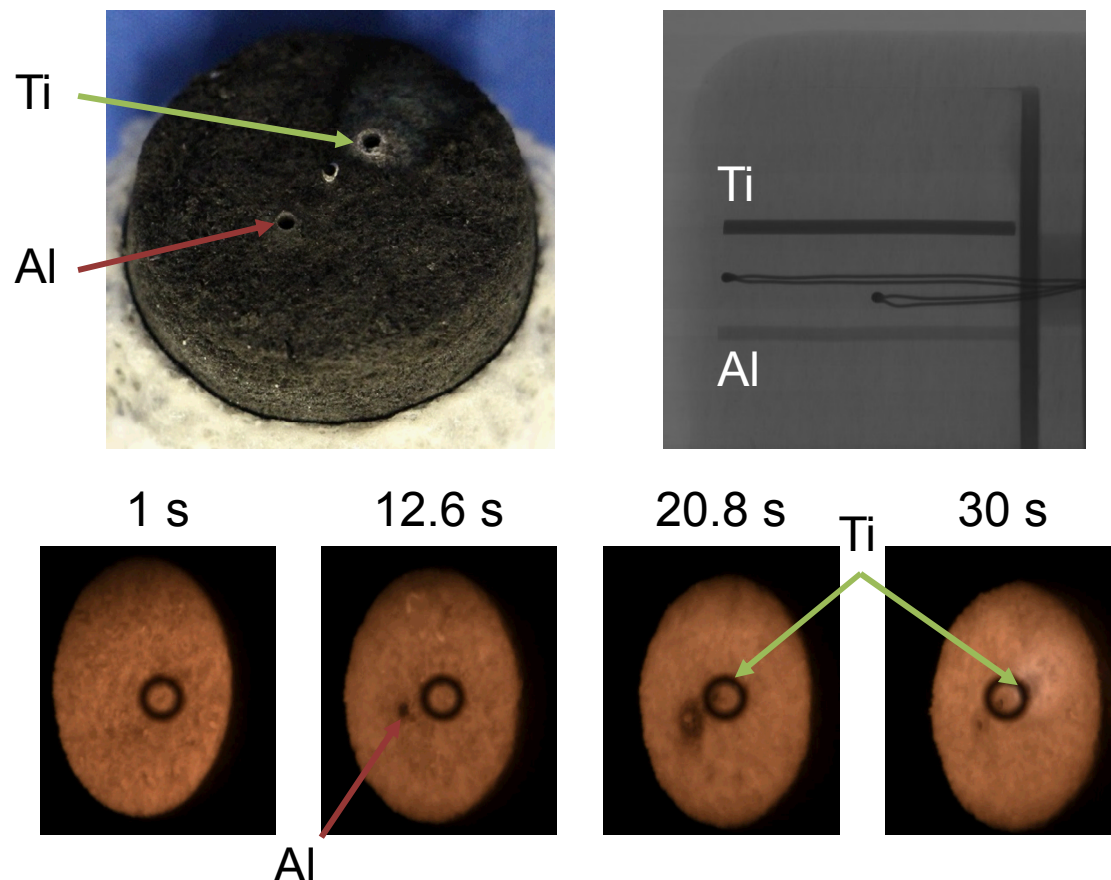
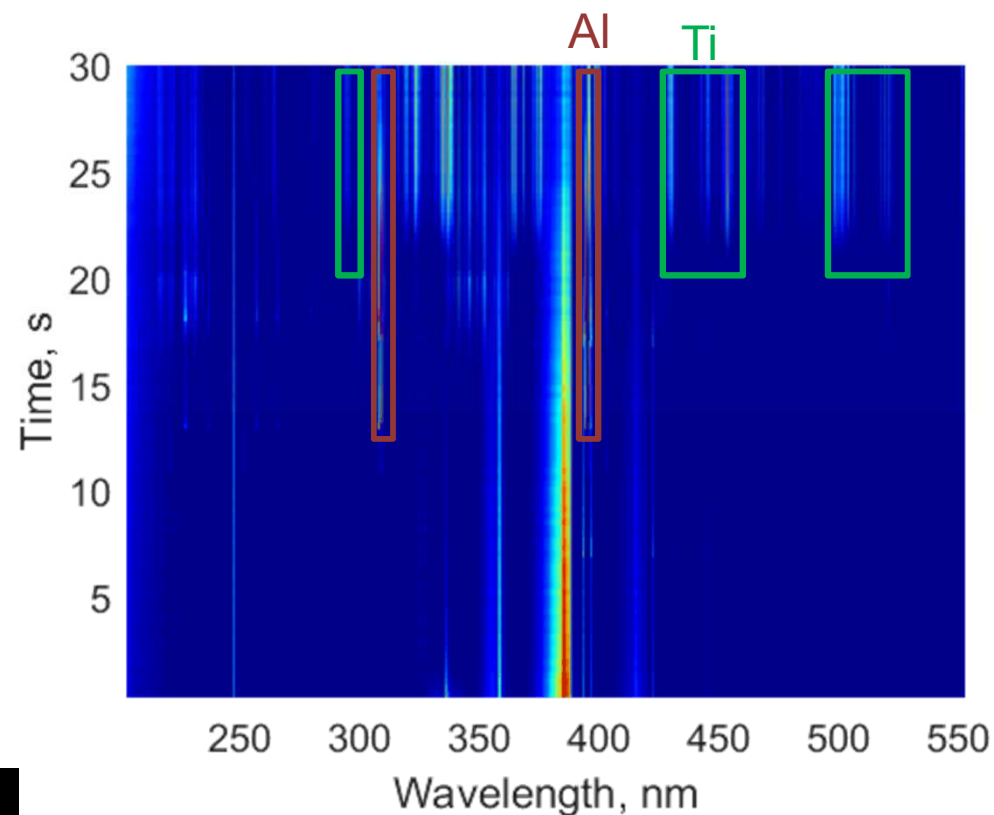
Large clusters of seed particles on charred fiber tips



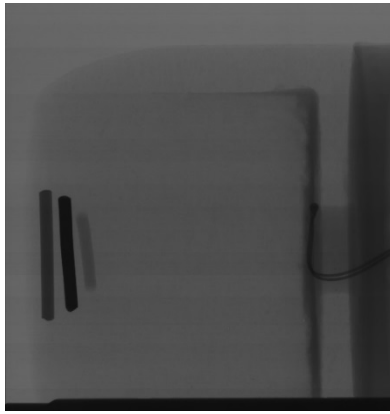
Wire Seeding Method ($400\text{W}/\text{cm}^2$)

Aluminum and Titanium wire 1.6 mm below surface

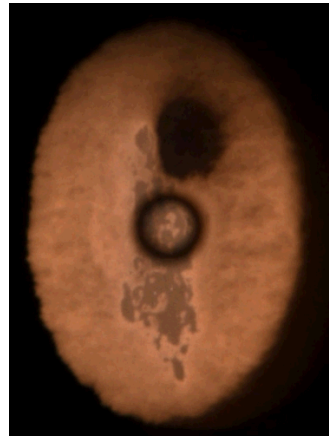
Aluminum appears about 12.6 seconds
 Titanium appears about 20.7 seconds
 Spectra appearance agrees with video



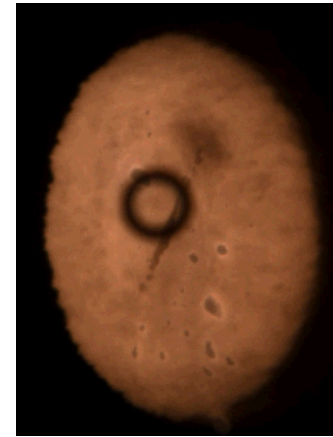
Alternate Wire Seeding Method (400W/cm²)



4.5 s



13.6 s



30.0 s



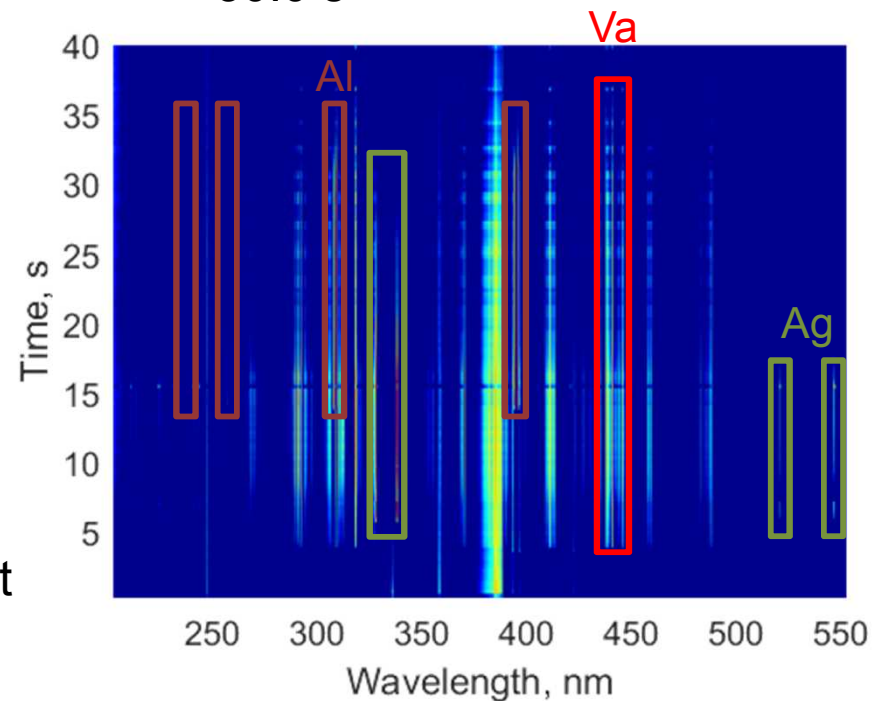
Vanadium 1.5 mm to surface
Silver 3.0 mm to surface
Aluminum 4.6 mm to surface

Vanadium stayed primarily pooled on the surface,
sheer forces drove it downstream during test

Silver appeared about 5.5 seconds into the test with
some spectral lines persisting longer than others

Aluminum appeared about 13.6 seconds into the test

Seed material solidified on surface post-exposure



Conclusions

Epoxy encapsulation of seed material is not appropriate

Through the thickness orientated seeding wires show some promise

Pros: Relatively easy seeding technique, instrumenting PICA with thermocouples is an accepted technology

Cons: Recession rates of metals and PICA are different

Tested specimens were equipped with in depth thermocouples

In-plane orientated seeding wires cause pooling of high melting temperature material

The one tested specimen did not show On/Off signal behavior

Phenolic seed impregnation shows the most promise

Seeded densities are within the specification of PICA

Seeded material recesses at the same rate as regular PICA

High melting materials act as recession indicators

Low melting materials are diffusion driven and emit radiation before recession reaches the seed depth, exact diffusion mechanism to be determined

Choice of seed material would depend upon other instrumentation and surfaces/hardware that would be exposed during atmospheric entry

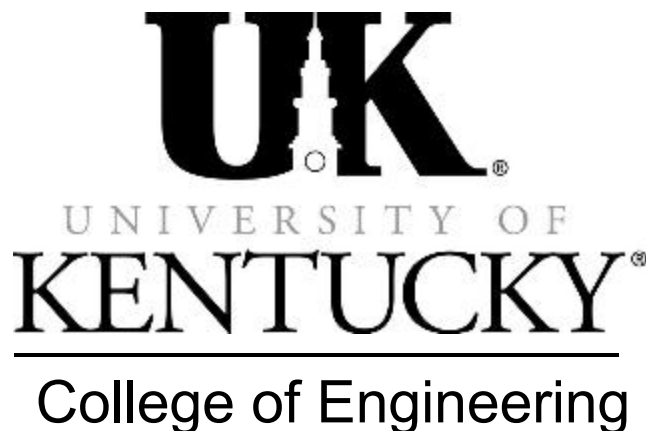
i.e. if thermocouples are used, would need to avoid those materials as seeds

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References:

- Winter, M., Stackpoole, M., Nawaz, A., Gonzales, G., and Ho, T., "Remote Recession Sensing of Ablative Heat Shield Materials," 52nd AIAA Aerospace Sciences Meeting, 2014.
- Butler, B., Winter, M., Panerai, F., Martin, A., Bailey, S., Stackpoole, M., Danehy, P., and Splinter, S., "Characterization of Candidate Materials for Remote Recession Measurements of Ablative Heat Shield Materials," 54th AIAA Aerospace Sciences Meeting, 2016.
- Butler, B., Winter, M., and Stackpoole, M., "Characterization of Virgin and Charred PICA Seeded for Remote Recession Measurements," AIAA Aviation Forum, 2017.