Spring 5-16-2012

A Cost Effective Screening Technique for Testing UHTC Materials Using an Oxyacetylene Torch Flame

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Ultra-High Temperature Ceramics Conference - Hernstein, Austria

May 13 – 18, 2012

Outline

- Introduction to oxyacetylene flame
- Test rig at Loughborough
- Testing of UHTC composites
- Testing of UHTC monoliths and issues
- Long duration testing
- Multi flame testing and argon/nitrogen quenching

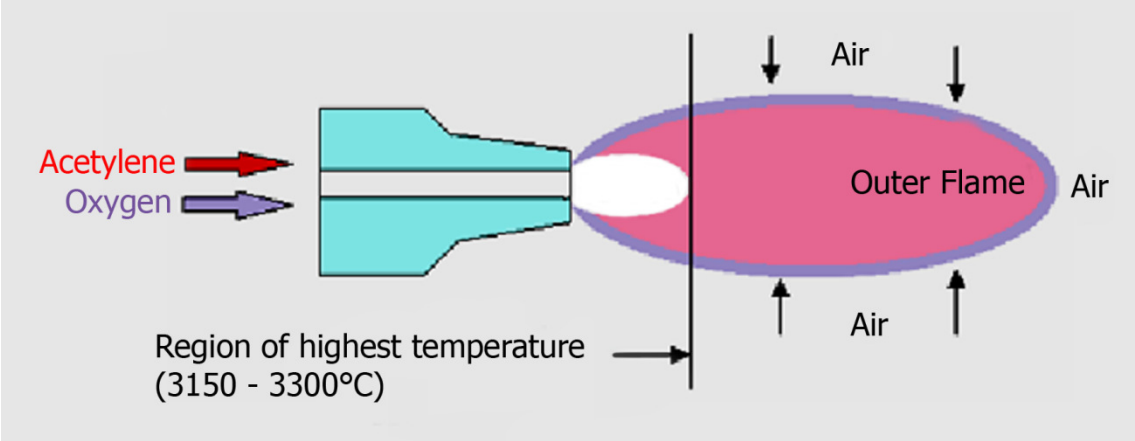
High Temperature Testing of UHTCs

Method	Imposed condition	Merits	Demerits
Air furnace	T*tot*	Ease of use	Ignores flow, no thermal gradients, no catalytic recombination
Laser	Calculated heat flux	High temperature, heating rates	Ignores mechanical effects, ignores emissivity changes, no catalytic recombination effects, no flow, ignores mechanical effects
Hypersonic wind tunnel	Hypersonic fluid flow	Very high fluid velocities	Imposes low T*tot*, wrong gas chemistry
Plasmatron (arc jet)	Calculated heat flux	Catalytic recombination	Expensive, imposes low flow, uses mainly dissociated gases, ignores mechanical effects
Scramjet wind tunnel	Hypersonic combustion	Meets most conditions	Rare, inaccuracies in gas chemistry, inaccuracy in degree of dissociation at high Mach numbers
Real hypersonic flights	Real conditions	Real conditions	Rare, expensive

Parthasarathy et al., Int. J. Appl. Ceram Technol., 8 [4] 832-847, 2011

Oxyacetylene Torch Testing

- Preliminary screening of UHTC materials
- Samples exposed to a high temperature flame produced by the combustion of oxygen and acetylene gases
- Cost effective, less complicated
- Possibility to test wide variety of sample sizes and shapes



Oxyacetylene flame

Oxyacetylene Flame

- Nature of flame depends on the gas flow rate and ratio

Carburizing flame (excess acetylene)

Neutral flame (excess acetylene)

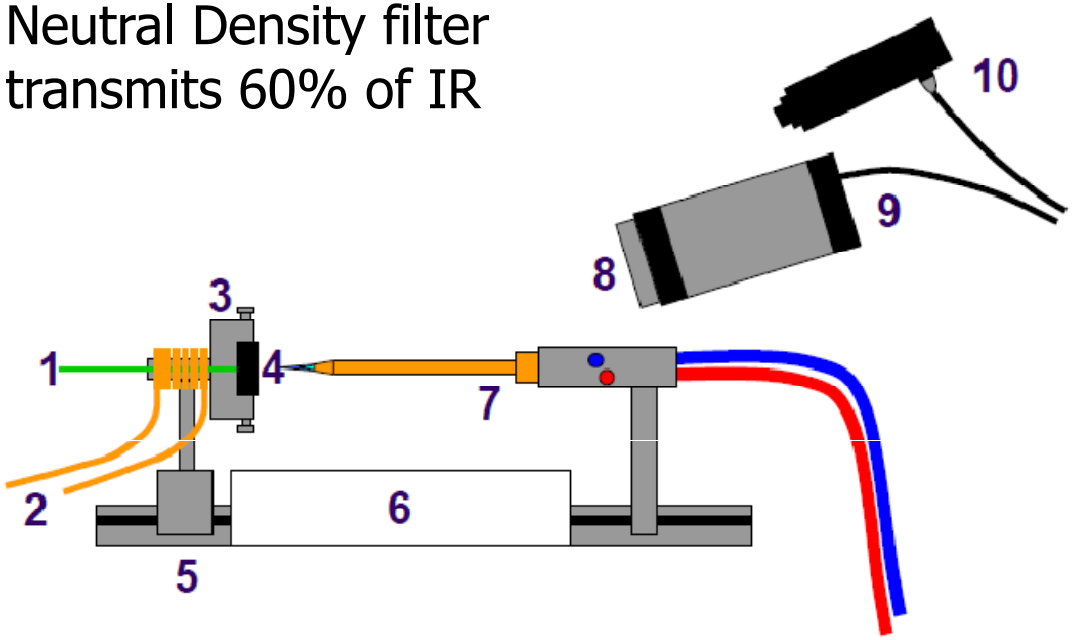
Oxidizing flame (excess oxygen)

Oxy – acetylene welding manual, Lieut. Lorn Campbell Jr., John Wiley and sons, 1919

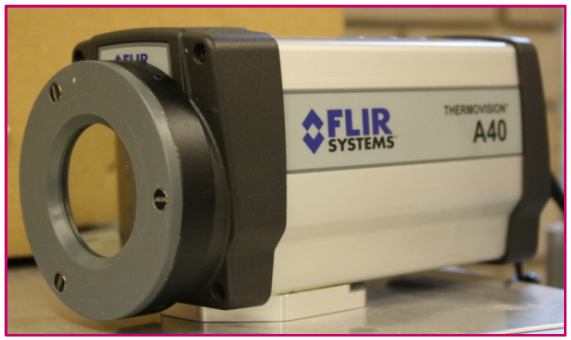
- The distance of the sample from the nozzle and the nature of the flame are crucial
- An oxidising flame is employed for the testing of UHTCs

Oxyacetylene Torch Test Setup

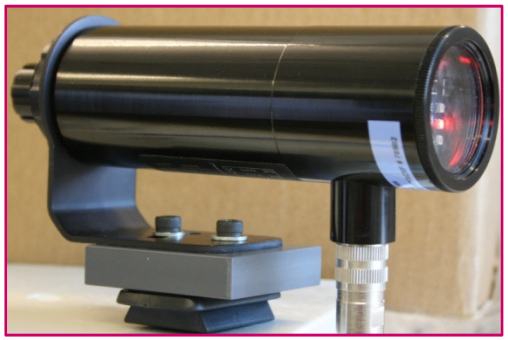
Neutral Density filter transmits 60% of IR



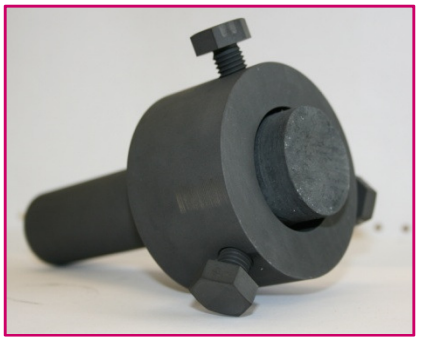
1. Back face thermocouple
2. Water cooling
3. Sample holder
4. Sample
5. Guide rail
6. Protective insulation
7. Oxyacetylene torch
8. Neutral density filter
9. Thermal imaging camera
10. Two colour pyrometer



~2830℃



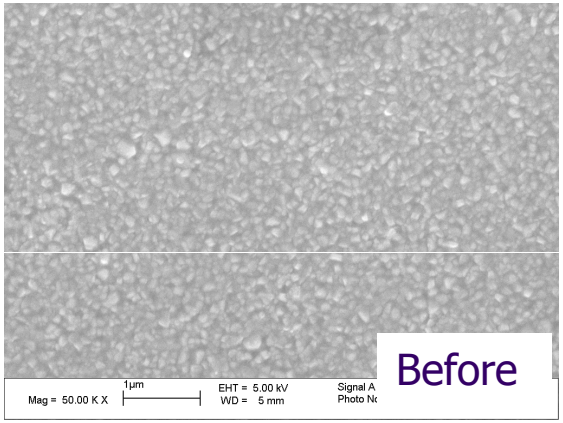
3000℃

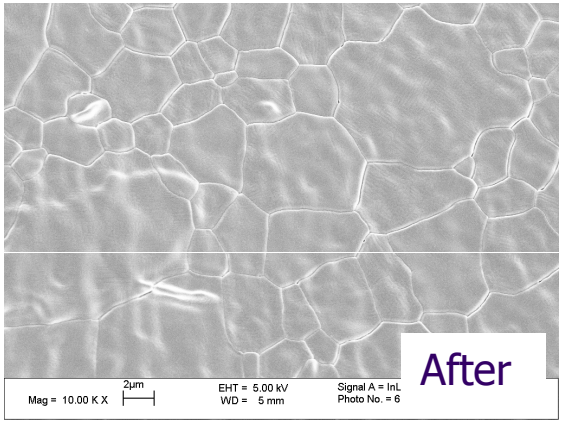


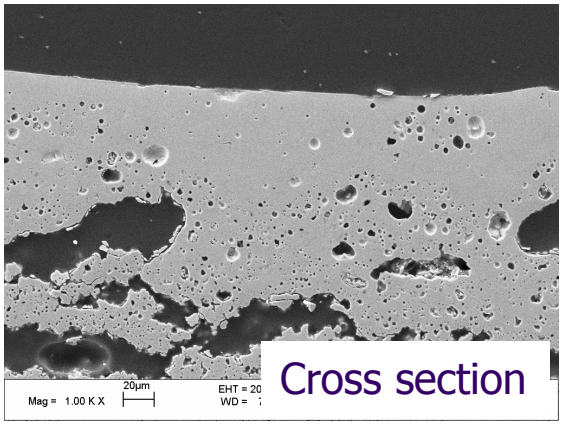
Graphite Holder

Preliminary Testing Using Zirconia

- To verify the temperature capability of the set up
- 3YSZ has a melting point of ~2715℃



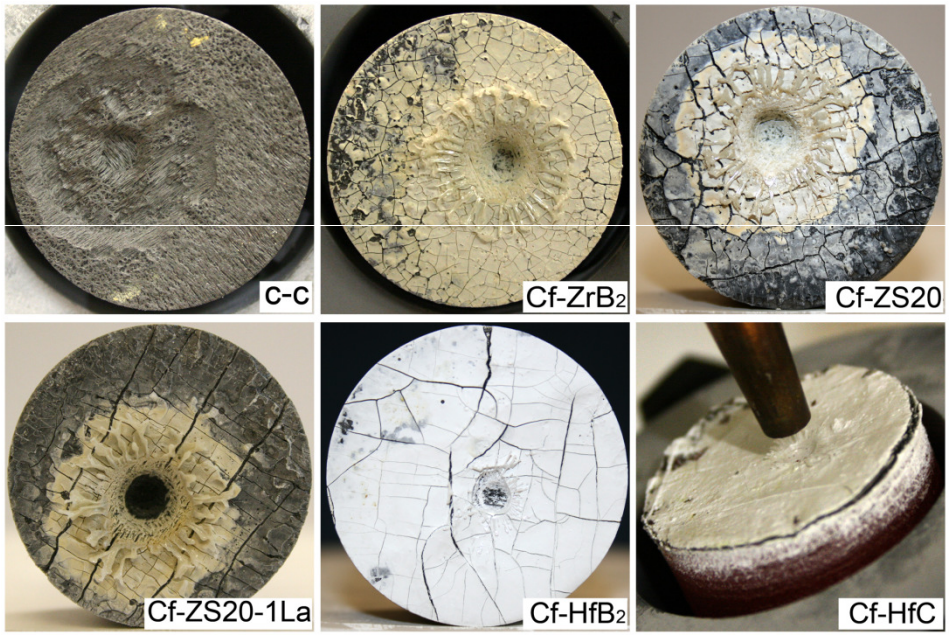


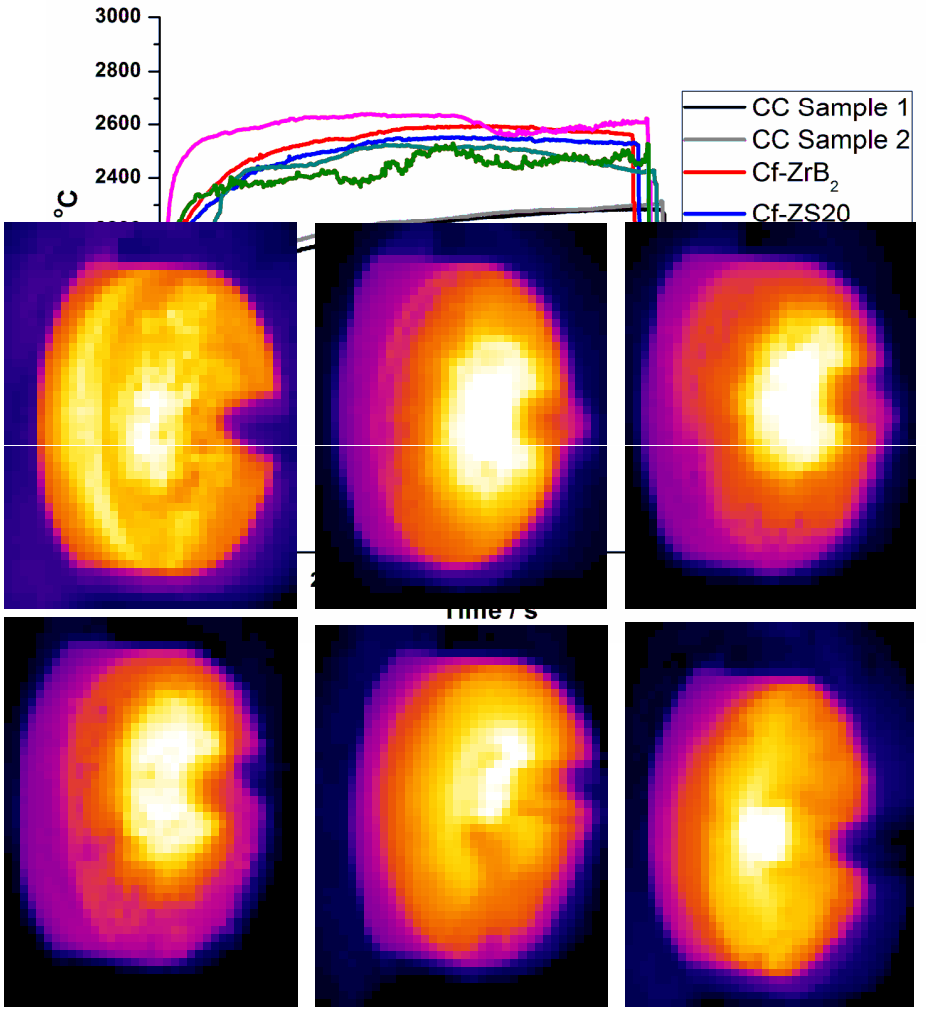


Melting, rapid grain growth and formation of a porous microstructure

Oxyacetylene Testing of UHTC Composites

- Cf-UHTC powder composites prepared by slurry impregnation





- Temperature distribution on the sample

Problem with Monolithic Samples

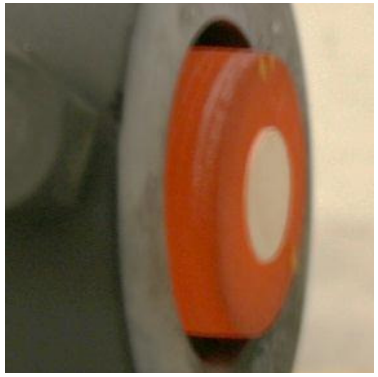
- Samples shattered due to thermal shock and gradients

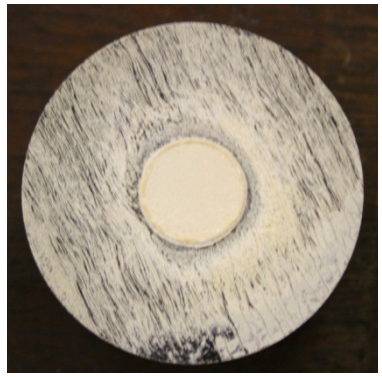
35 mm ZrO_2

32 mm TaC

- Reduce heating rates, increase distance between sample and nozzle
- Reduce sample size, 10 and 15 mm dia TaC

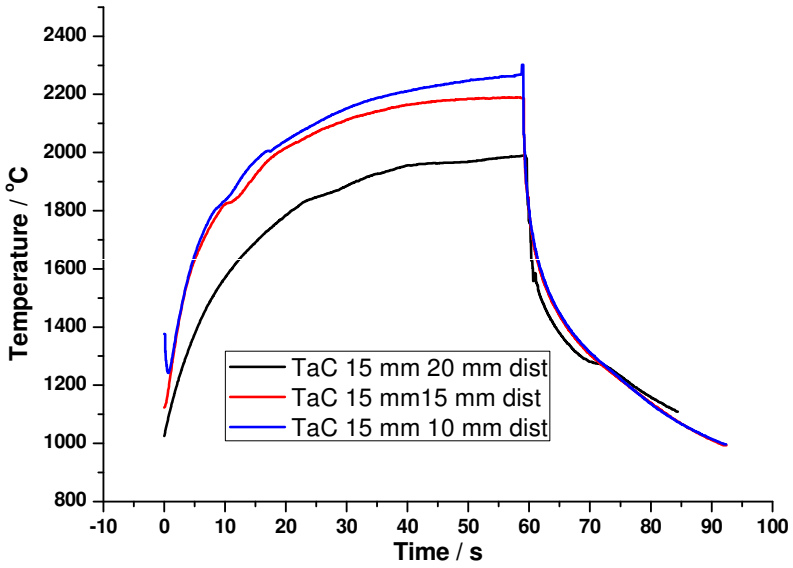
TaC Sample	Test Duration / s	Peak temperature / °C
		Front face
10 mm	60	2110
15 mm		1990

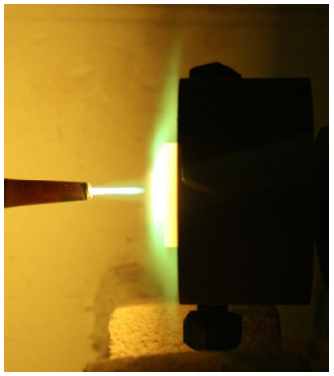




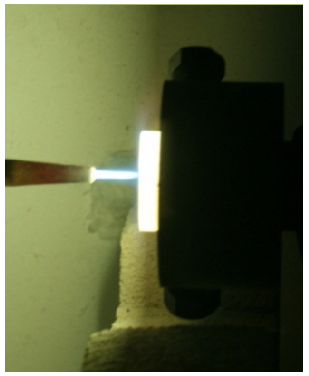
Effect of Distance

- 15 mm dia TaC disc

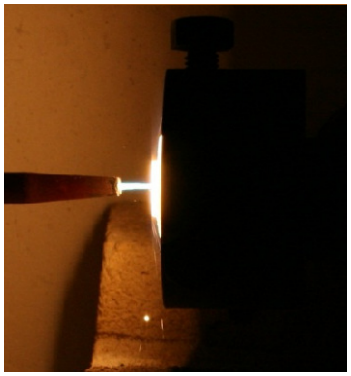




20 mm



15 mm



10 mm

1990℃

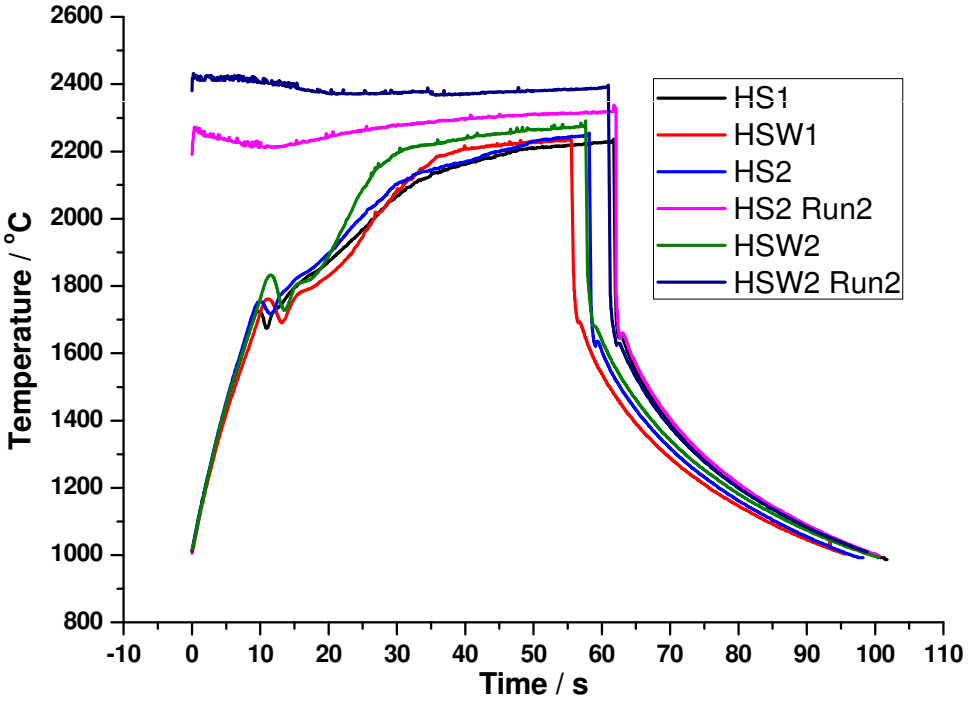
2190℃

2300℃

- Distance between the sample and nozzle affects the heating rate, peak temperature and surface erosion

HfB_2 Based UHTCs - AFRL

- Samples from WPAFB, USA
- 15 mm dia x 15 mm thick



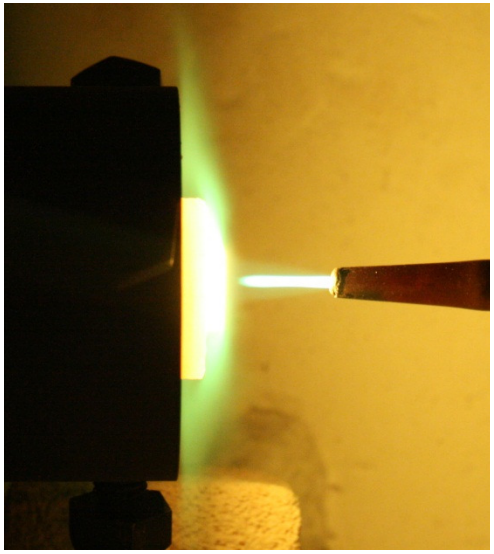
HfB_2-SiC 1 min

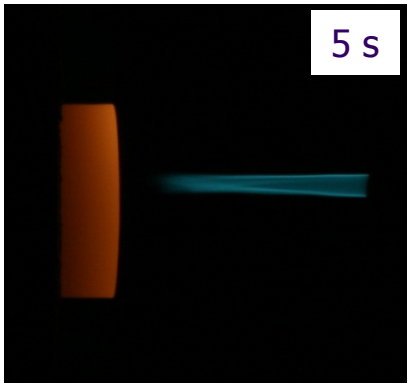
HfB_2–SiC 2 x 1 min

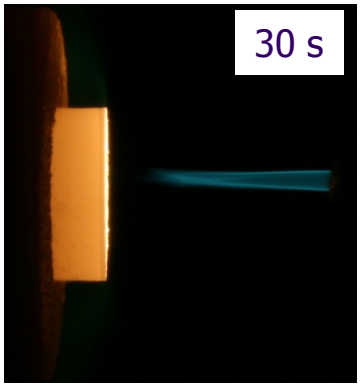
HfB_2-SiC-WC 1 min

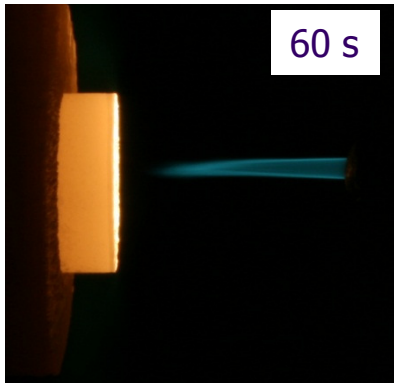
HfB_2-SiC-WC 2 x 1 min

HfB_2 Based UHTCs - AFRL

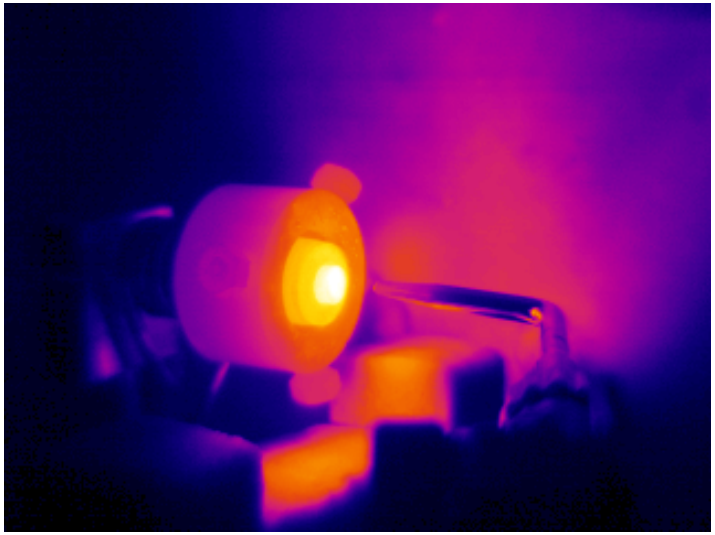








Oxide layer formation



~2237℃

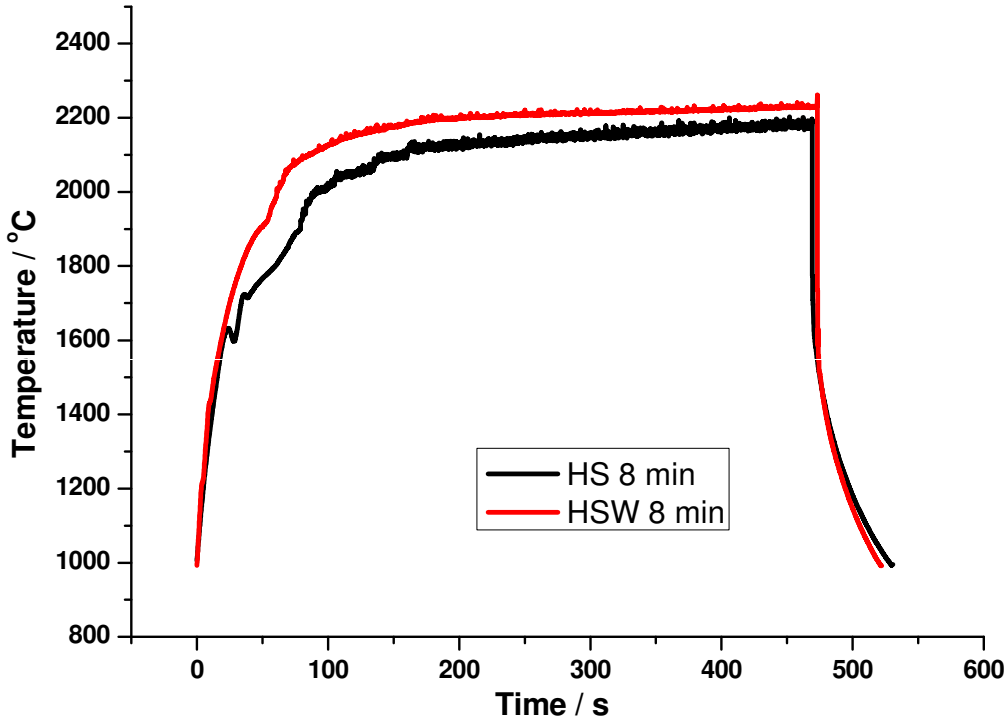
1342.0℃

<300.0℃

Uniform temperature distribution across the sample

Long Duration Testing

- HfB_2 based samples for 8 minutes

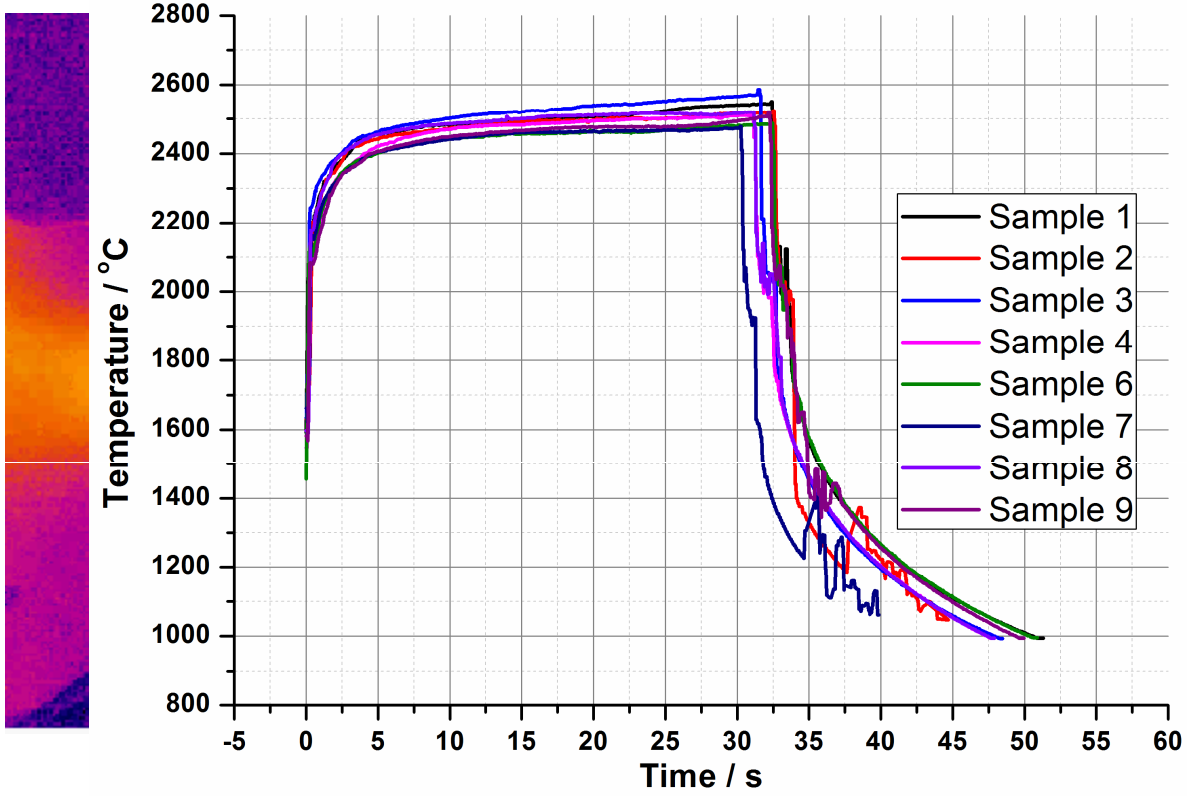


HS ~2200℃

HSW ~2260℃

- Longest test done so far
- Adjusted the test parameters to maintain a lower temperature (~2000℃)

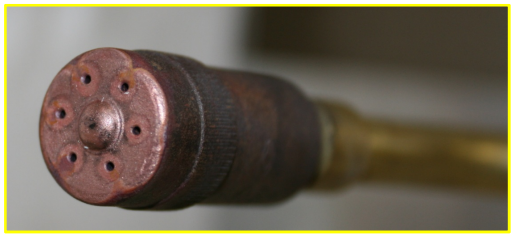
Testing of Polymeric Composites

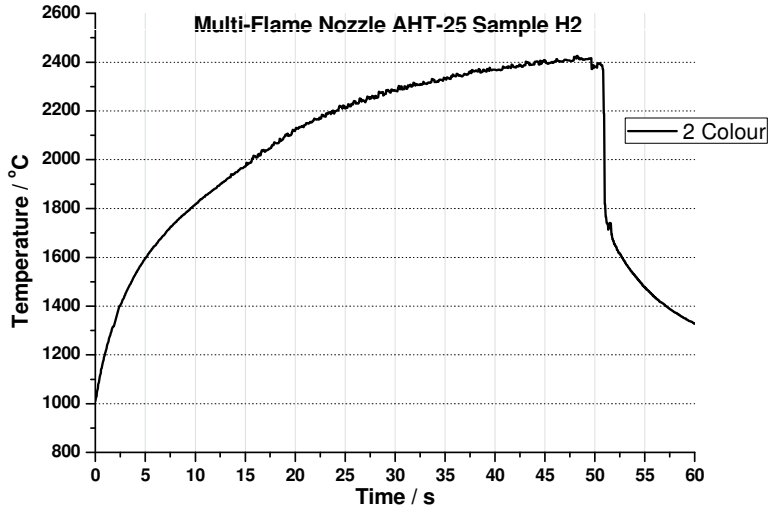


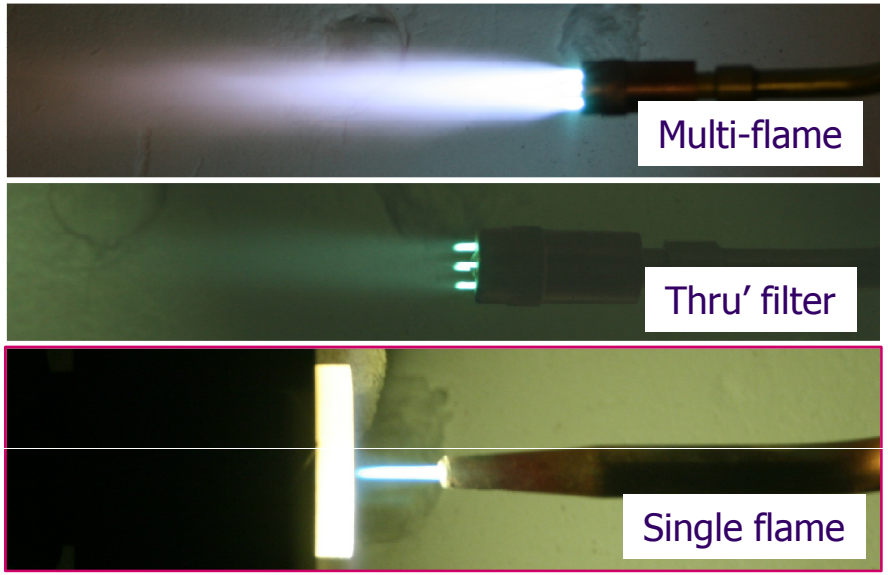
- Sideways sample movement and Ar/N_2 quenching
- Allows the test to be started from room temperature
- Rapid heating (~800 °C s^{-1} for the initial 2400 °C) and high thermal shock

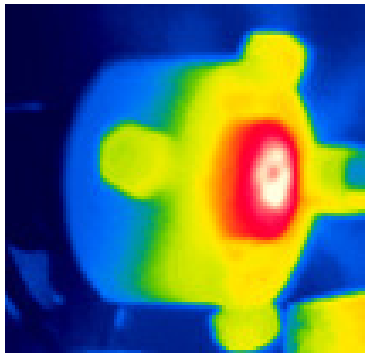
Multi-Flame Oxyacetylene Torch Testing

- To eliminate thermal gradients while testing 30 mm dia samples









- Reduced the heating rate
- Gradients are not completely eliminated

Summary

- An oxyacetylene flame can be used for the preliminary screening of UHTC materials in a cost effective way
- Temperature gradients with single flame nozzles can be reduced by using smaller samples and/or increasing the distance between sample and nozzle
- Multi flame nozzle results in slower heating rates
- The results from oxyacetylene torch testing needs to be compared with the results from other techniques
- Very high heating rates can be achieved using sideways sample movement
- Test needs to be modified to get a better control over temperature

Acknowledgements

- The authors thank the Defence Science and Technology Laboratory, Porton Down, Salisbury, UK for providing financial support for this work under contract no. DSTLX-1000015267.
- The torch testing of samples provided by the Air Force Research Laboratory was performed under a Project Arrangement between the United Kingdom of Great Britain and Northern Ireland Ministry of Defence and the United States of America Department of Defence with the guidance of Professor Peter Brown (Dstl) and Dr. Allan Katz (AFRL/RXLN).
- C. Carney (AFRL) and M. Hallett (Dstl) are thanked for allowing to include some of their results.