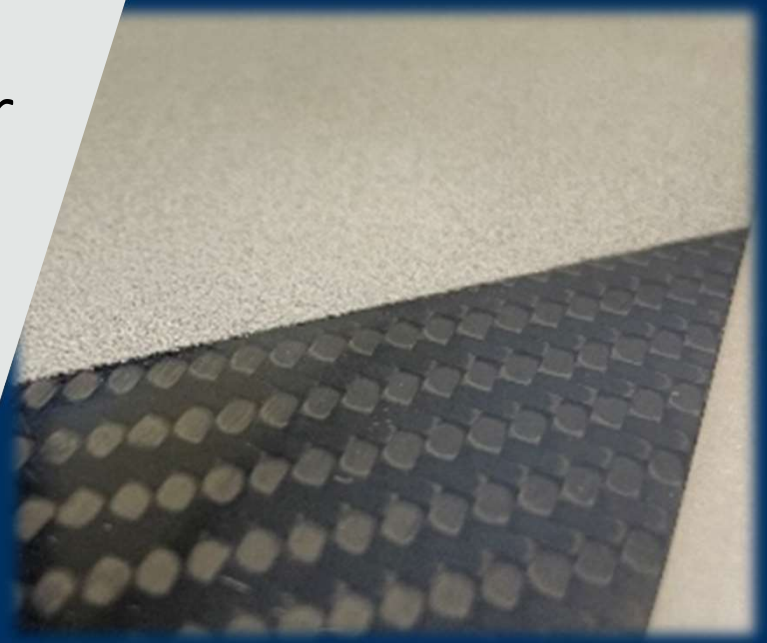
University of BRISTOL
Bristol Composites Institute

NATIONAL COMPOSITES CENTRE

EPSRC Industrial Doctorate Centre in
COMPOSITES MANUFACTURE

Behaviour of Ceramic Coatings on Polymer Composites against Laser Exposure



George Holiday[1,2] - EngD (Sep 2023 – Sep 2027)

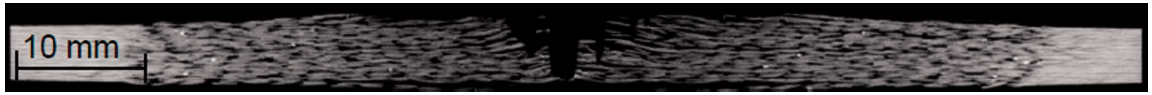
Sean Cooper[1], Konstantina Kanari[1], Richard Trask[2], Ian Hamerton[2], Lilly Liu[3]

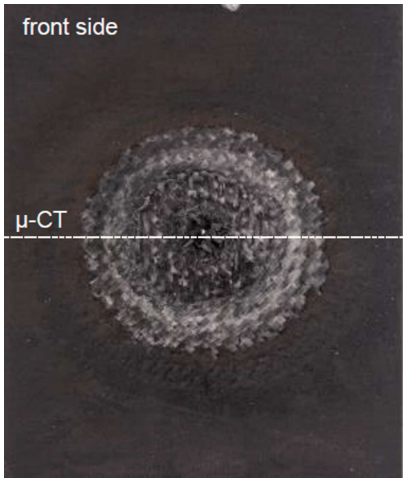
National Composites Centre[1], University of Bristol[2], University of Oxford[3]

Introduction

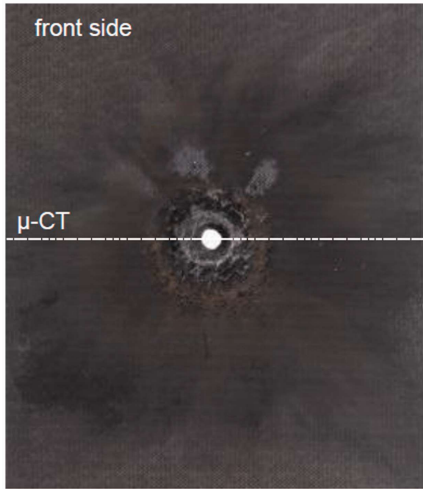
- CFRP is **highly vulnerable** to laser exposure due to poor:

1. Thermal stability of matrix
2. Thermal conductivity
3. Fire retardance
4. Reflectance/Absorbance





30mm Beam



10mm Beam

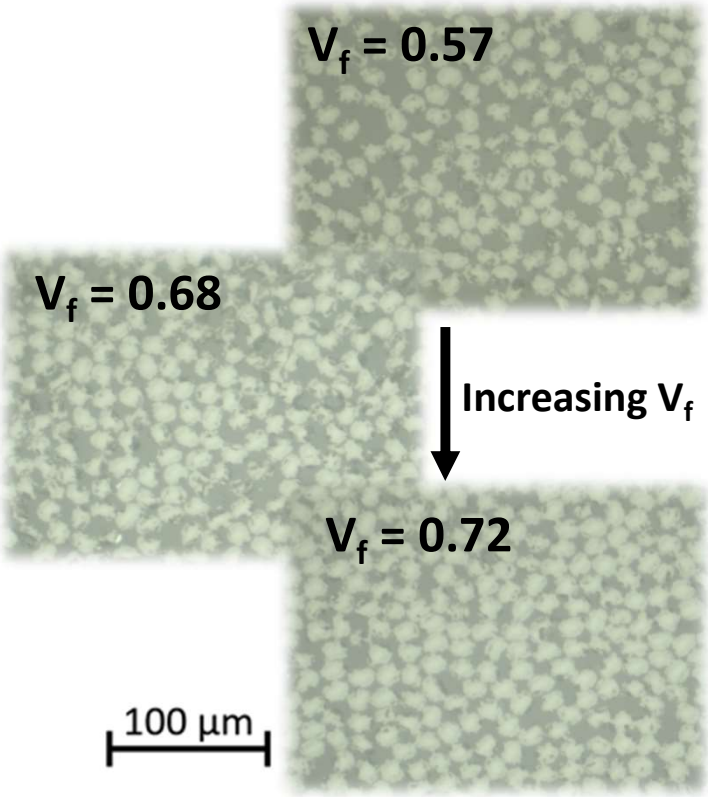
J. Wolfrum *et al*, **High-energy laser effects on carbon fiber reinforced polymer composites with a focus on perforation time.** Journal of Composite Materials. 2021;55(16):2249-2262.

EngD Project Overview

Materials of Investigation

High V_f Composites

Testing & Analysis



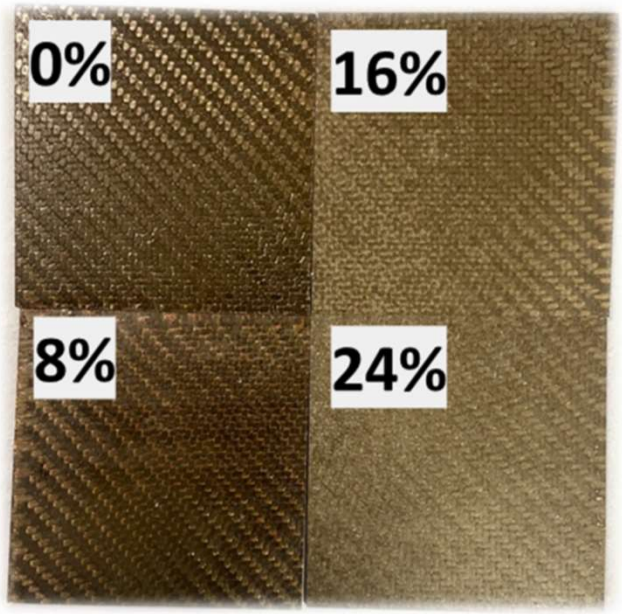
EngD Project Overview

Materials of Investigation

High V_f Composites

Modified Benzoxazine Composites

Testing & Analysis



X% ZrB_2 Modified Benzoxazine

EngD Project Overview

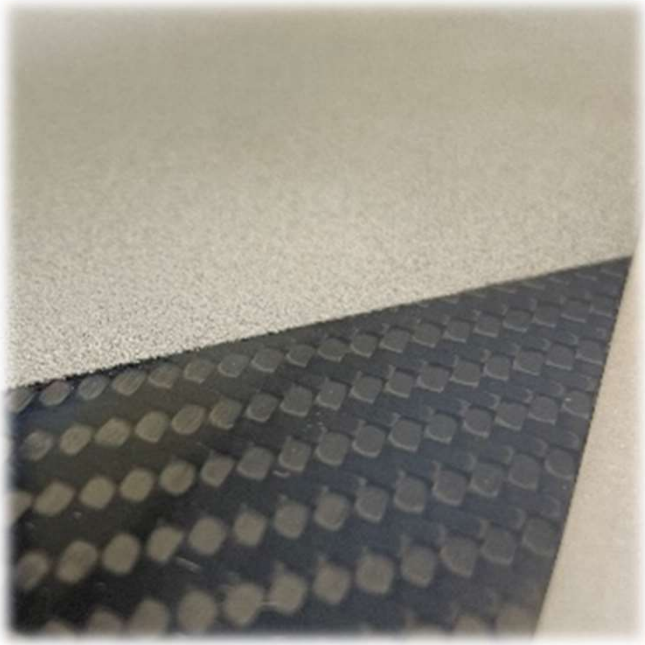
This Presentation

High V_f Composites

Modified Benzoxazine Composites

Ceramic CFRP Coatings

This Presentation

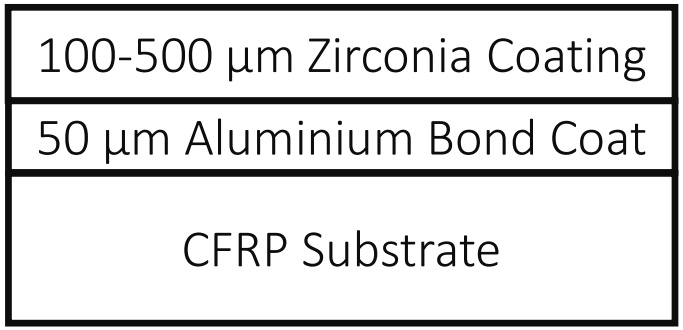


Ceramic CFRP Coating

Why Zirconia Coatings?

1. High **melting point** (~2700 °C) [1]
2. High **infrared reflectance** (70-92%) [2]
3. Low **thermal conductivity** (0.4-2.1 W/mK) [3]
4. **Lightweight** plasma sprayed 100-500 µm layer
5. **Sparse literature** on ceramic CFRP coatings, less on (laser) ablation testing [4]

Coated Coupons

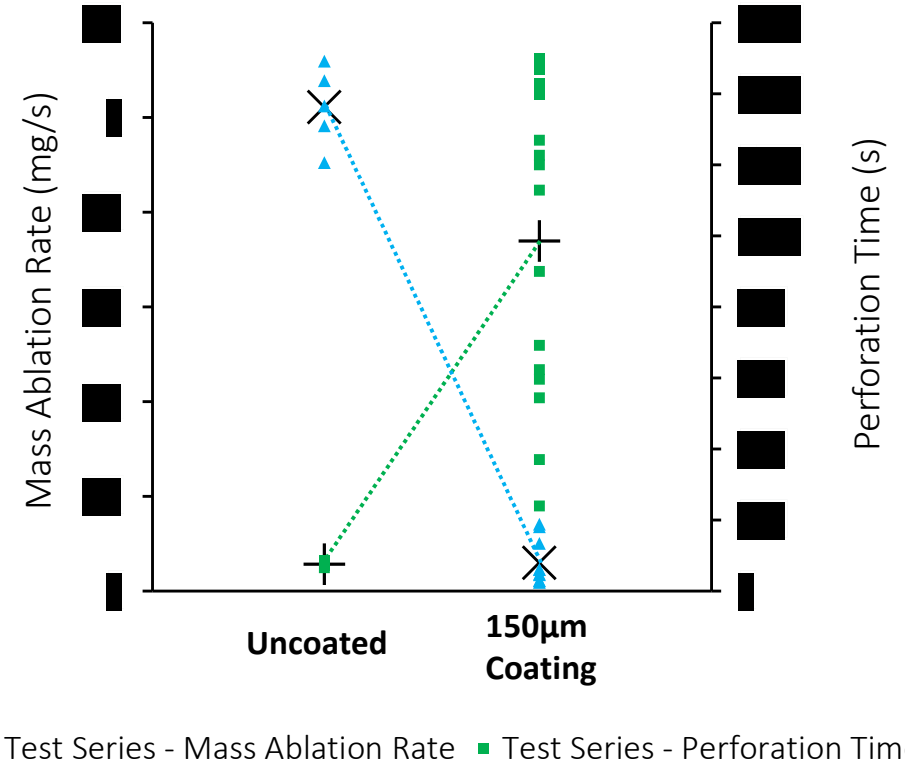


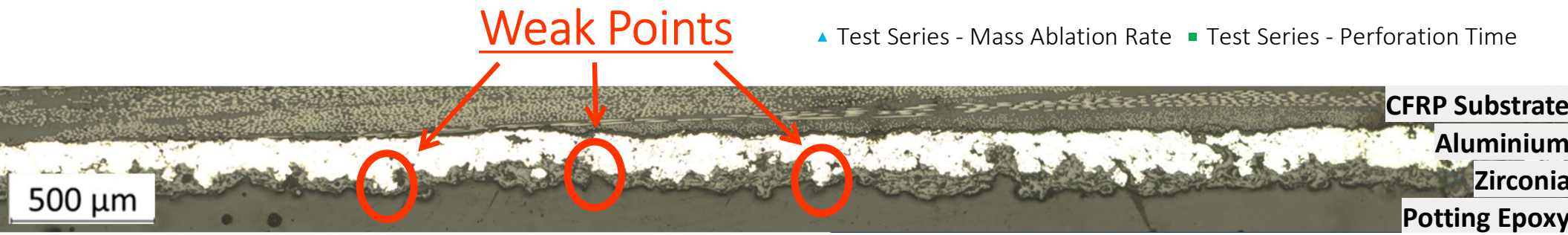
Coating Schematic

[1] R. Vassen *et al*, American Ceramic Soc, (2000) 83(8), 2023 - 2028
[2] G. Darut *et al*, J Therm Spray Tech (2023) 32, 2778–2801
[3] R.B.B. Dinwiddie *et al*, Turbo expo: Power for Land, Sea and Air. 1996
[4] W. Huang *et al*, Surface and Coatings Tech, (2012) 207(25), 421-429

Coating Laser Testing – Hand Sprayed Samples

- Tested **uncoated** CFRP against **coated**
  - **~10x** increase in perforation time
  - **94%** drop in mass ablation rate
- Extremely **high variance** in the perforation times of the coated coupons

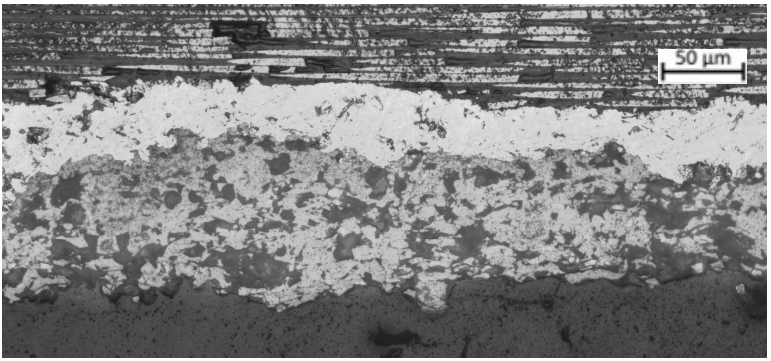




Coating Laser Testing – Robotically Sprayed Samples

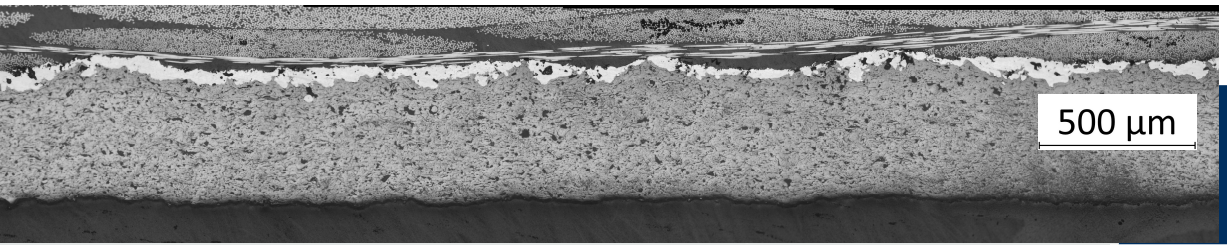
Thicknesses of 100, 200, 300, 400 & 500 µm were tested:

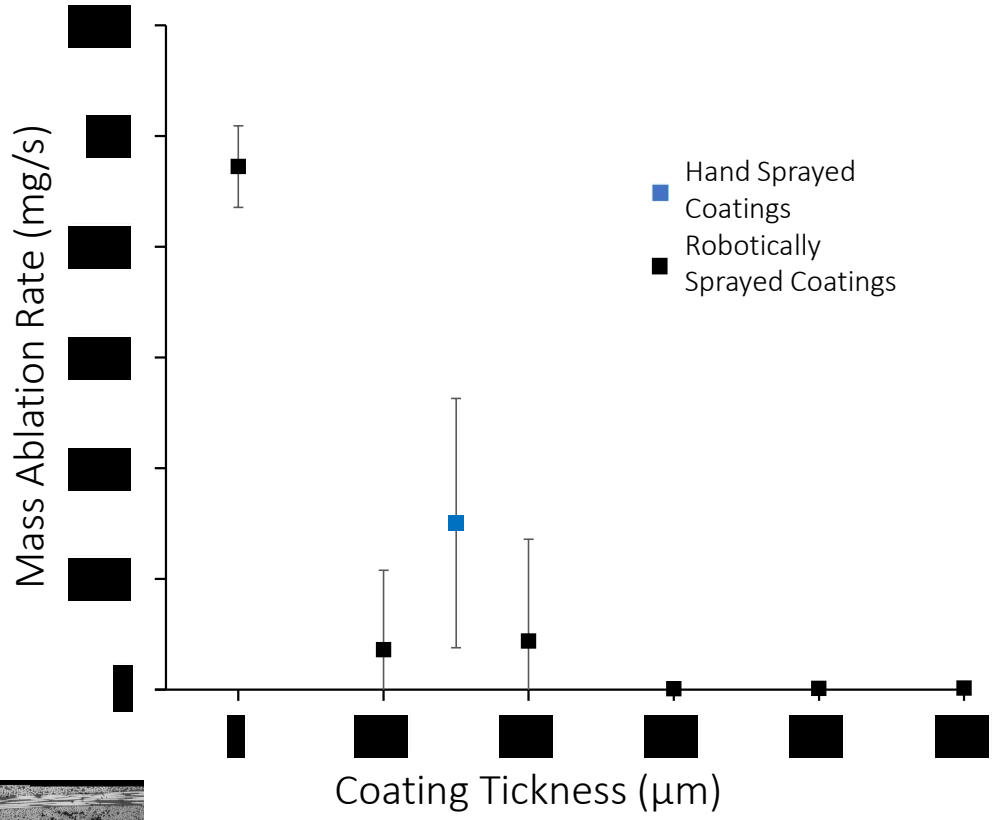
- **No coupon perforated** before 20 min mark
- Some 100 & 200 µm **coatings were breached** although the substrate held



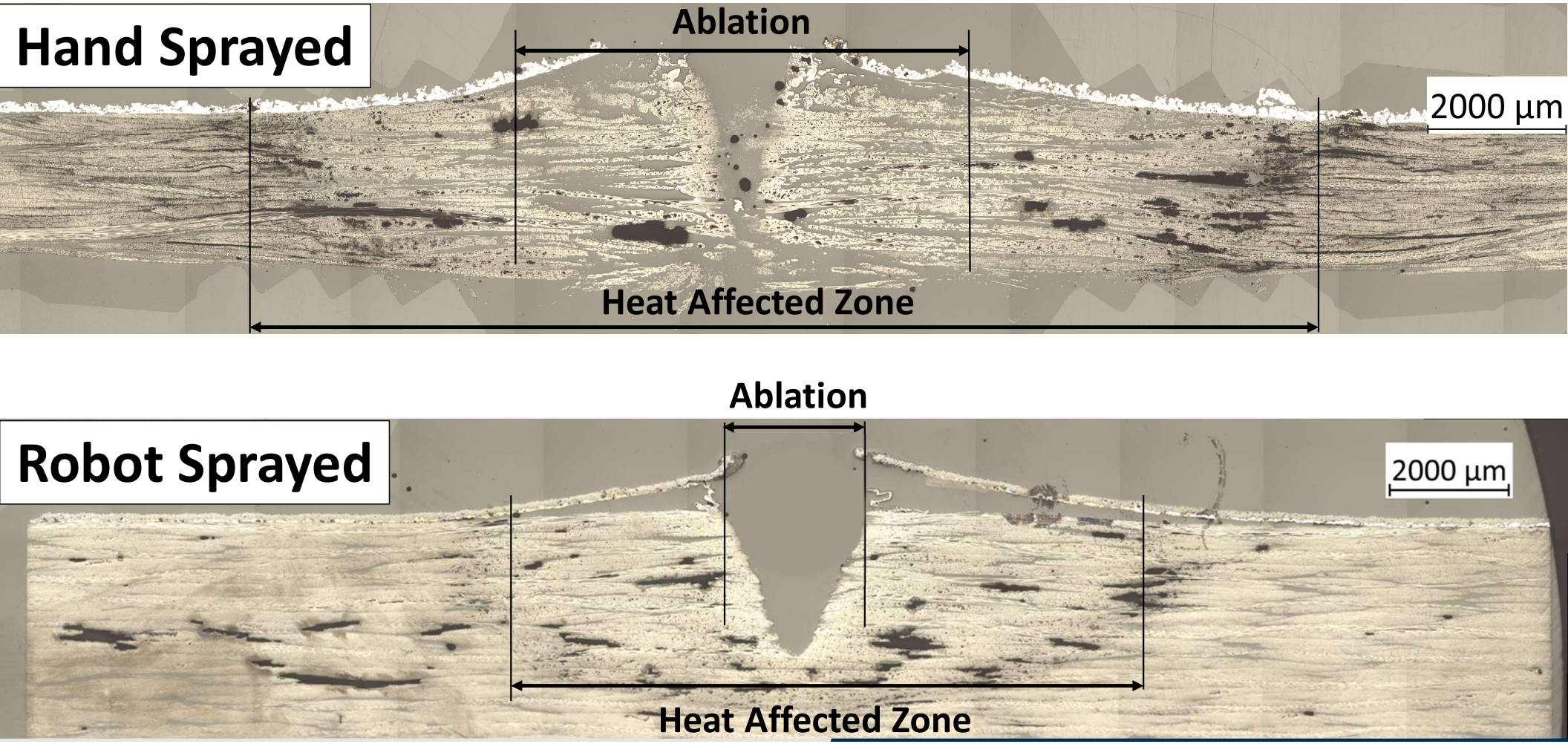
100 µm Coating

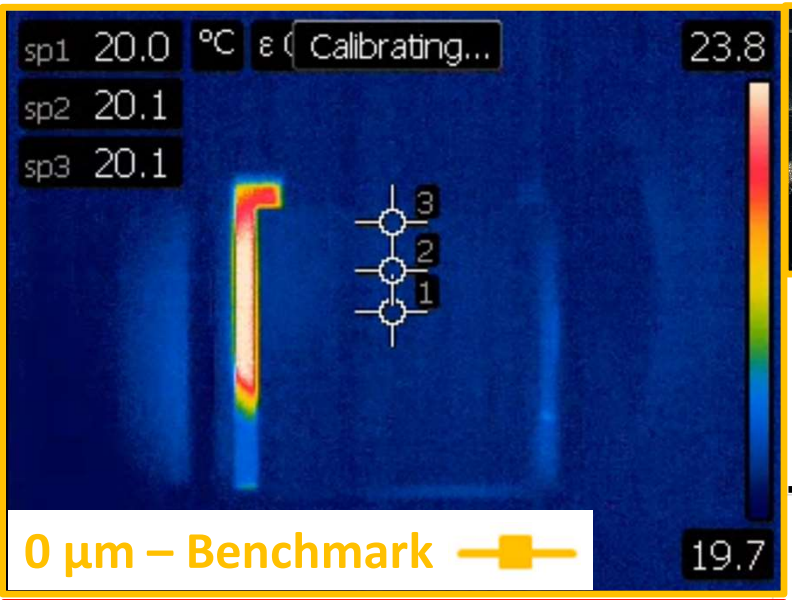
500 µm Coating



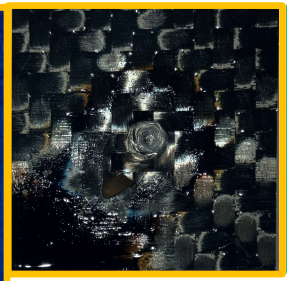


Ablation Pit Cross-sections

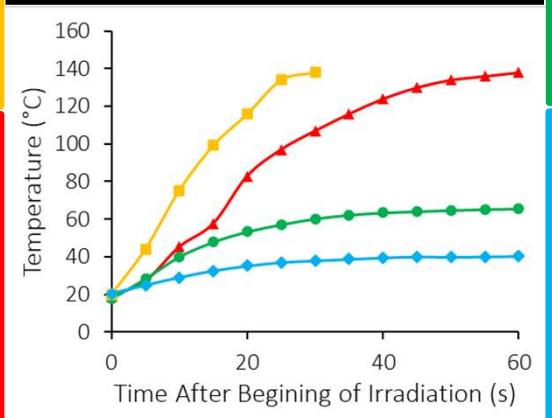


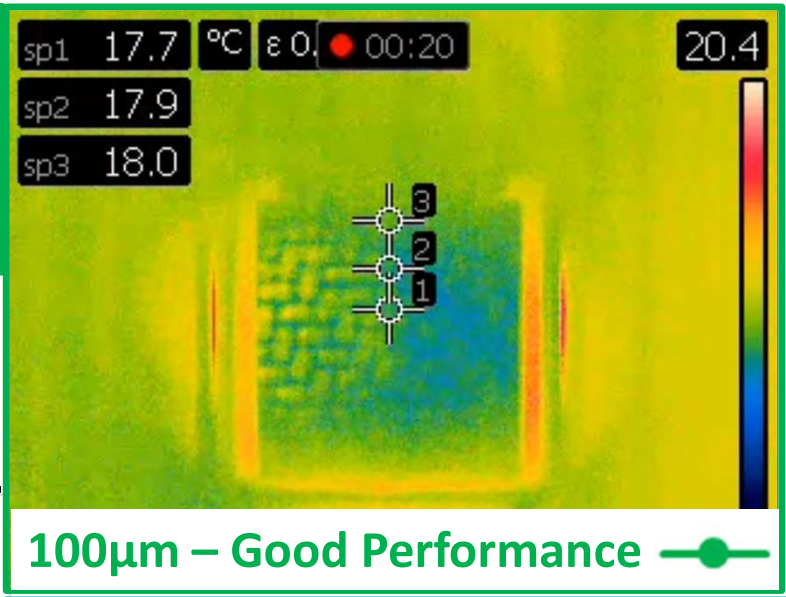


0 µm – Benchmark

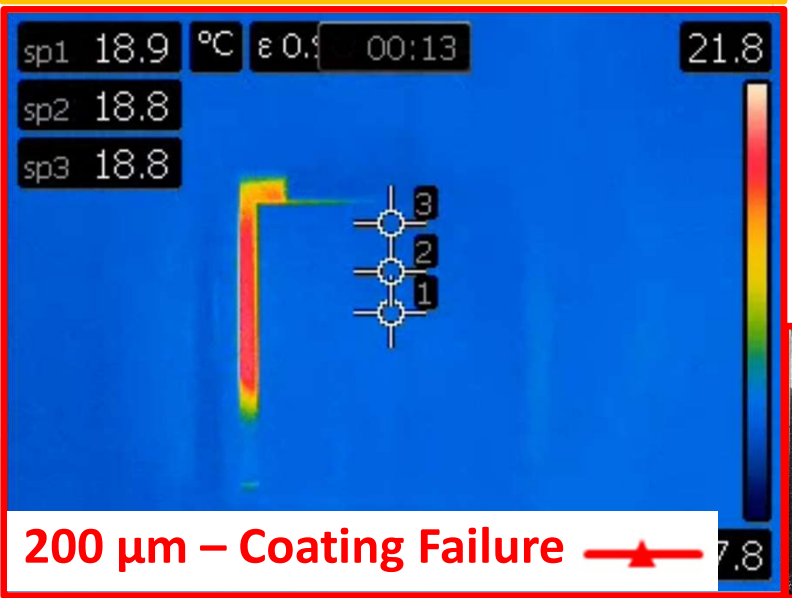


Back Face Temperature Measurements

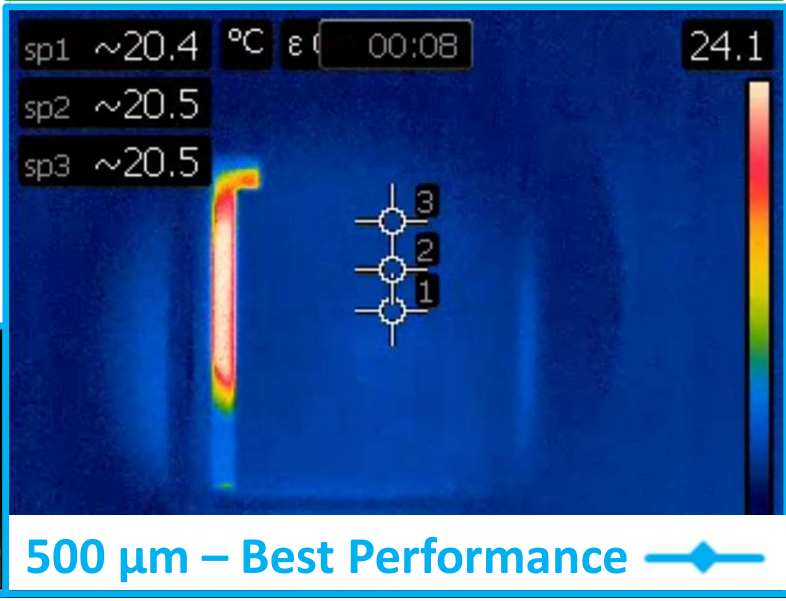




100µm – Good Performance

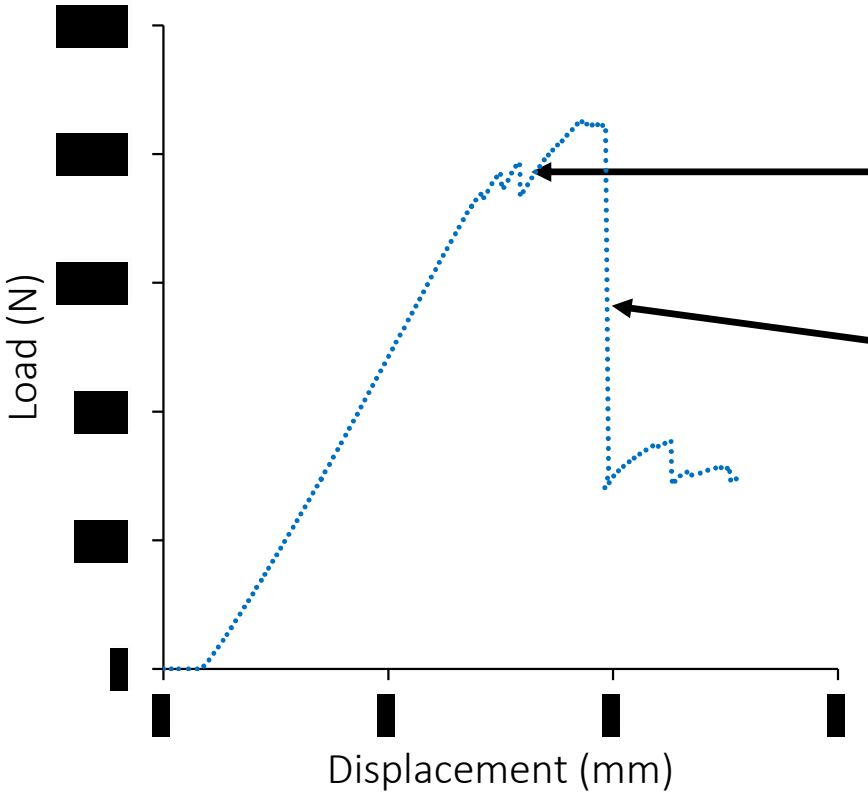


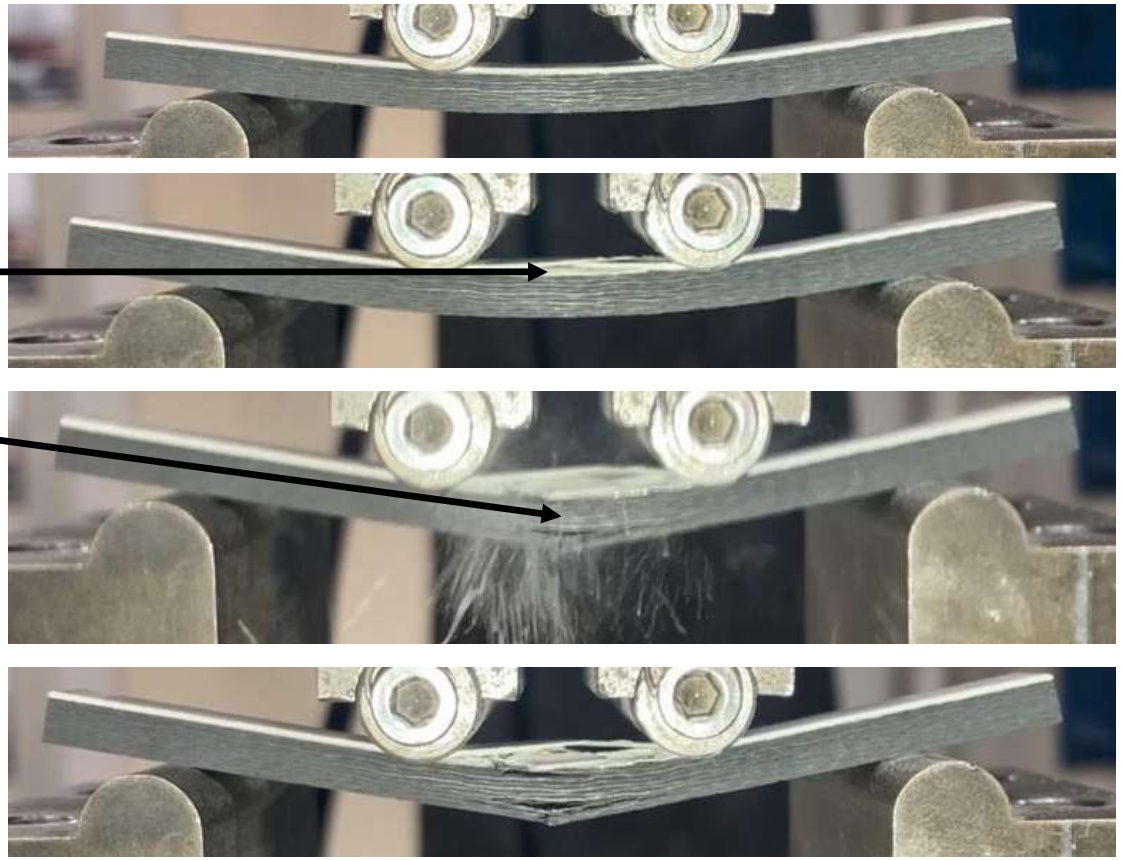
200 µm – Coating Failure



500 µm – Best Performance

4 Point Bending

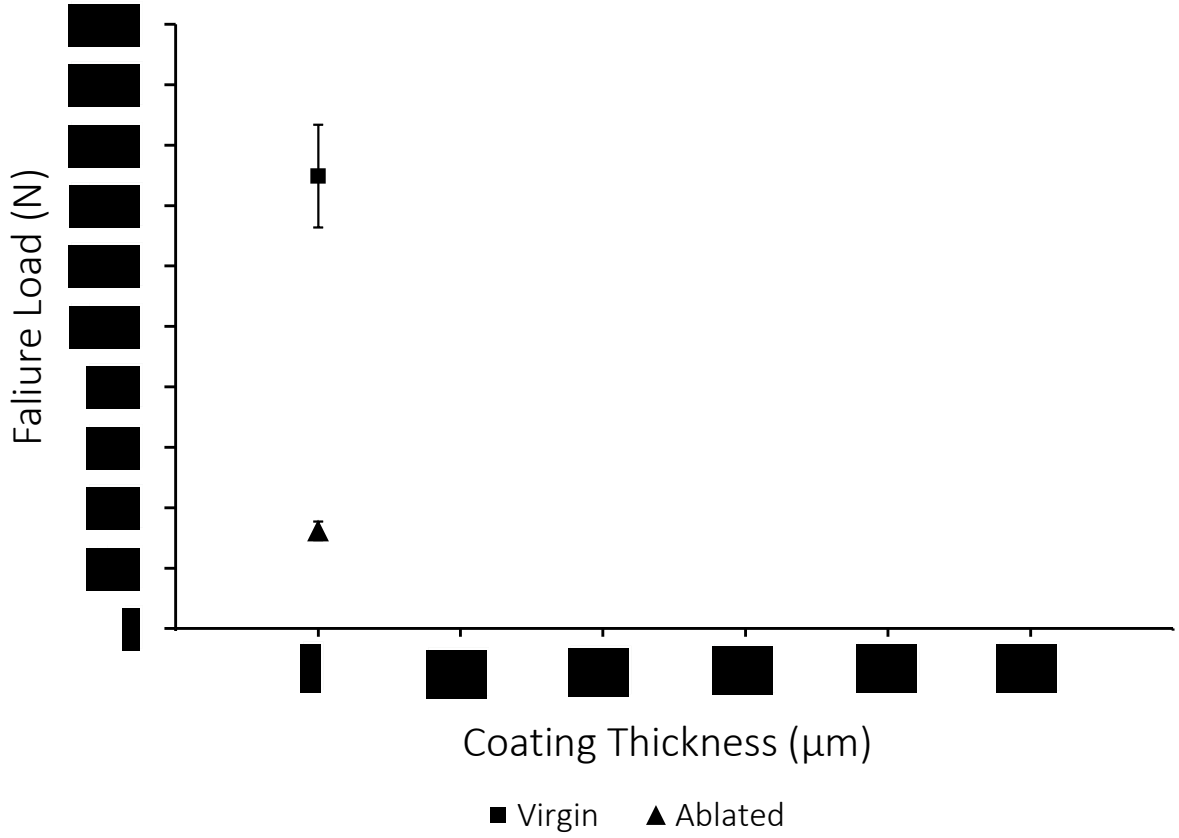




- ASTM 6272 Standard

4 Point Bending Results

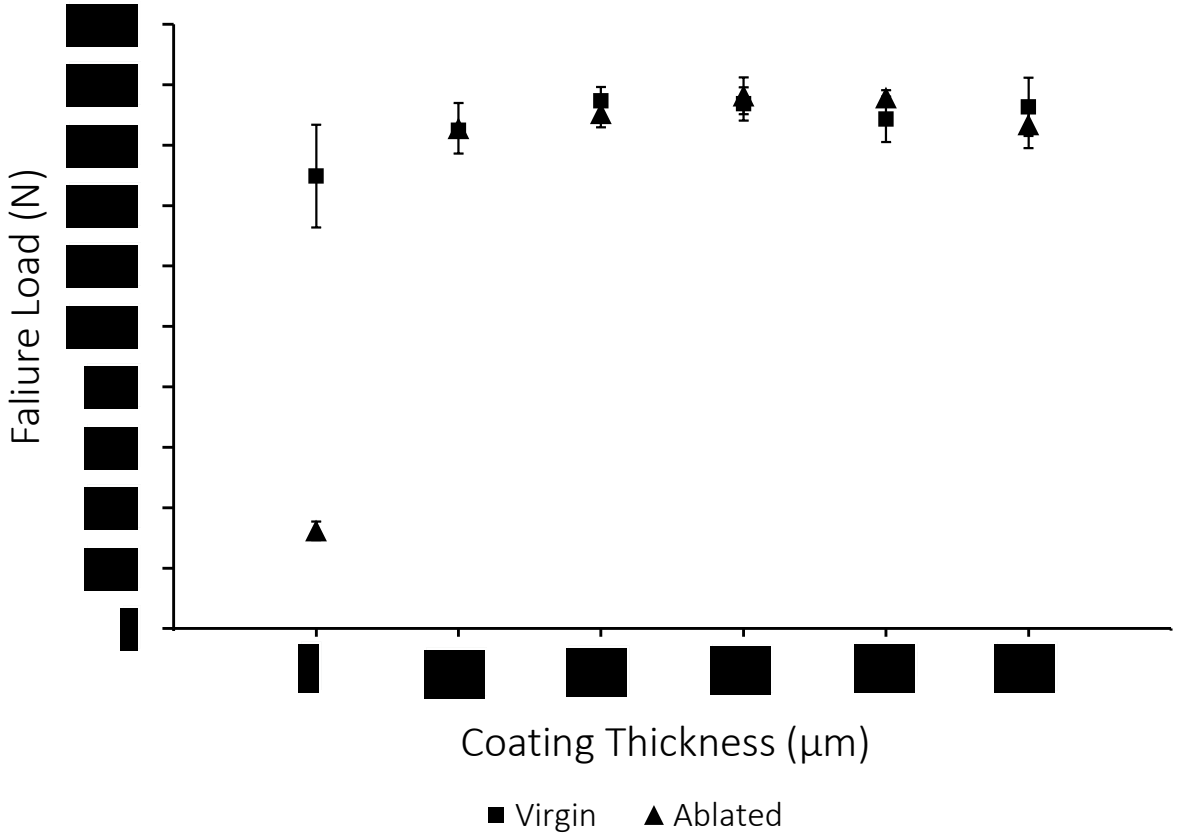
- 80% drop in strength for uncoated



4 Point Bending Results

- **80%** drop in strength for uncoated
- No drop for any coating

  ⇒ Coating is **insulative** and prevents substrate **strength degradation**



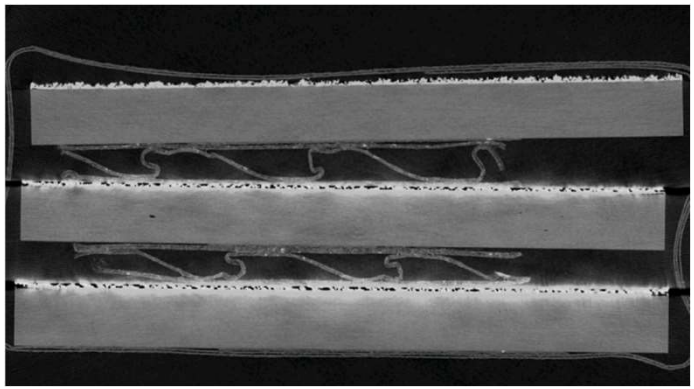
Key Takeaways

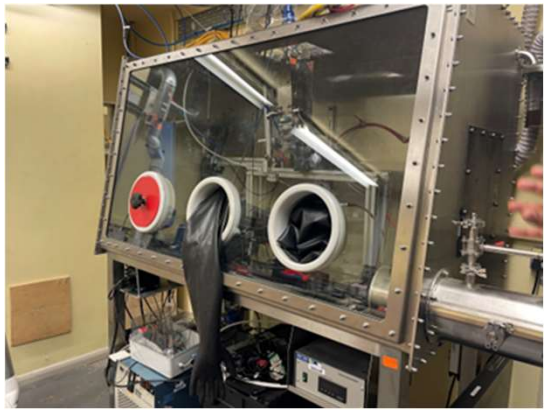
1. Ceramic coatings are highly effective at shielding CFRP against these laser conditions

2. Variability in coating properties determines reliability

Future Plans

1. Further **Analysis** of Ablated Coupons including XCT
2. **High-power testing** at Cranfield University
3. Enhance **reflectivity** and **quality** of coatings
4. Long Term: **Hybridise** materials





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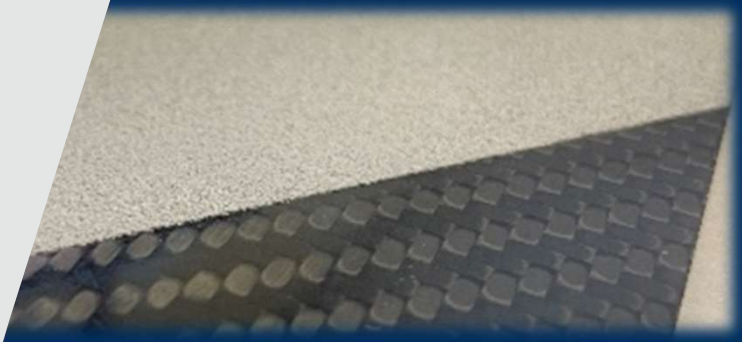
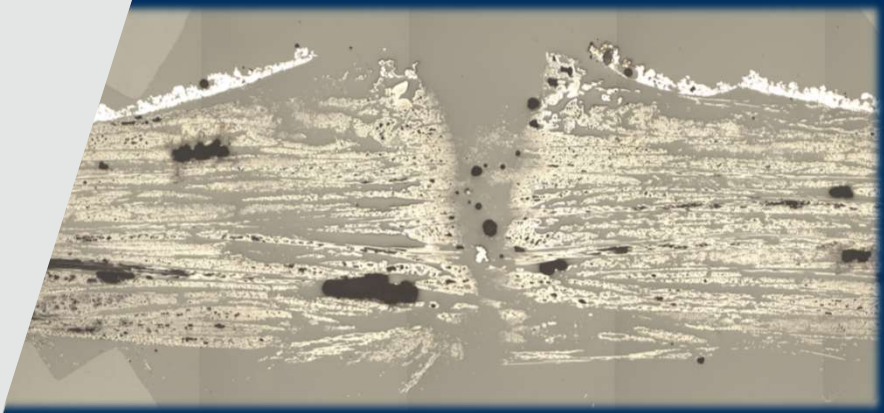
Thanks for listening!

Any Questions?





Can also email questions: george.holiday@bristol.ac.uk

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