UNIVERSITY OF LEEDS

# THE USE OF AL-SI ADDITIVES TO IMPROVE MELTING AND DEPOSITION BEHAVIOUR OF BIOMASS ASH


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BF2RA

EPSRC Engineering and Physical Sciences Research Council

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# Introduction

| Ash Component | Kaolin (%) | Coal PFA (%) | Olive Cake Ash (%) | White Wood Ash (%) |
|---|---|---|---|---|
| Ash Content | - | - | 8.5 | 1.1 |
| $SiO_2$ | 48.3 | 58.2 | 11.2 | 27.1 |
| $Al_2O_3$ | 36.4 | 20.8 | 1.2 | 4.6 |
| $Fe_2O_3$ | 0.9 | 9.3 | 0.9 | 2.3 |
| CaO | 0.04 | 2.9 | 10.3 | 24.8 |
| MgO | 0.4 | 1.4 | 3.0 | 4.7 |
| $Na_2O$ | 0.06 | 2.3 | 0.6 | 1.5 |
| $K_2O$ | 2.6 | 1.70 | 32.3 | 9.2 |
| $P_2O_5$ | - | 0.2 | 5.0 | 2.0 |
| SO3 | - | 0.9 | 2.4 | 0.02 |

# Introduction

- High potassium biomass often contains KCl and potassium silicates

- Al-Si additives have shown strong ability to convert KCl and potassium silicates into potassium aluminoslilcates

# Experiments

- Ash Fusion Testing
  - Indicates effect of additive upon flow temperature of biomass ash

- Sinter Strength Testing
  - To investigate regions of initial particle stickiness/melting (700°C+)

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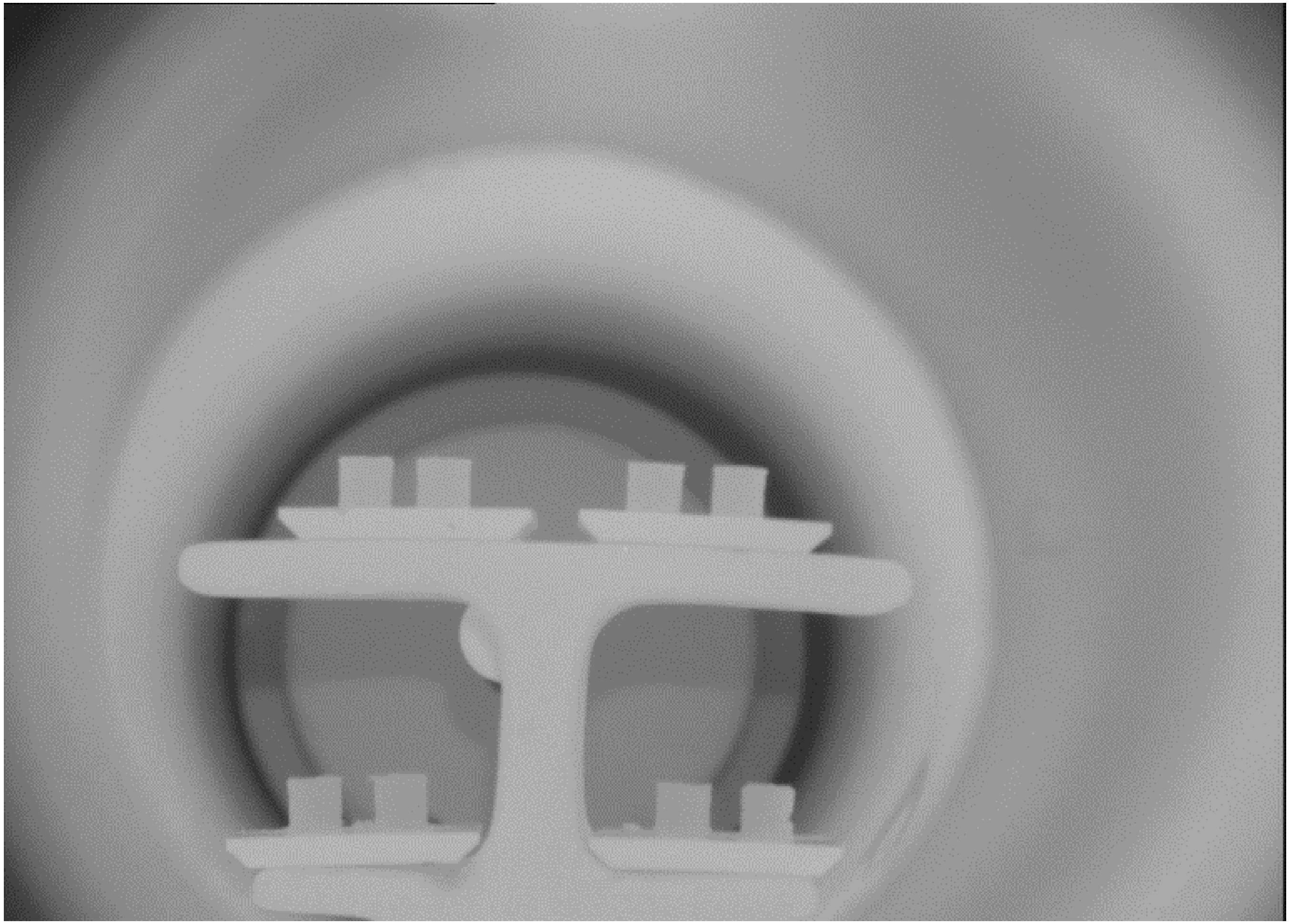
  - Indicates effect of additive upon flow temperature of biomass ash

# Ash Fusion Testing

## White Wood Ash – 900°C

White
Wood Ash
w/ 15% coal
PFA

100 %White
Wood Ash



White
Wood Ash
w/ 5% coal
PFA

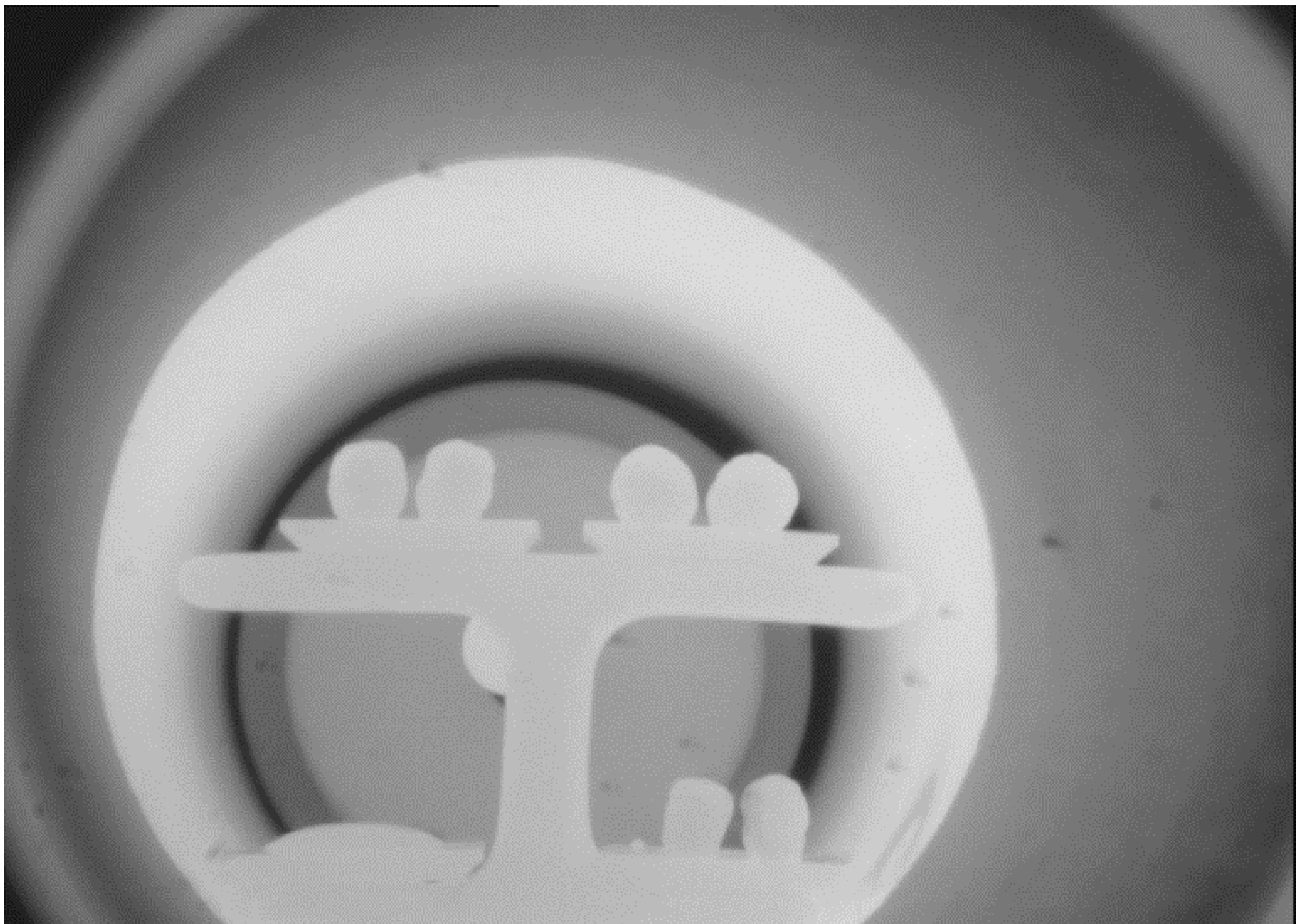
White
Wood Ash
w/ 25% coal
PFA

# Ash Characterisation

## White Wood Ash – 1280°C

White
Wood Ash
w/ 15% coal
PFA

100 %White
Wood Ash

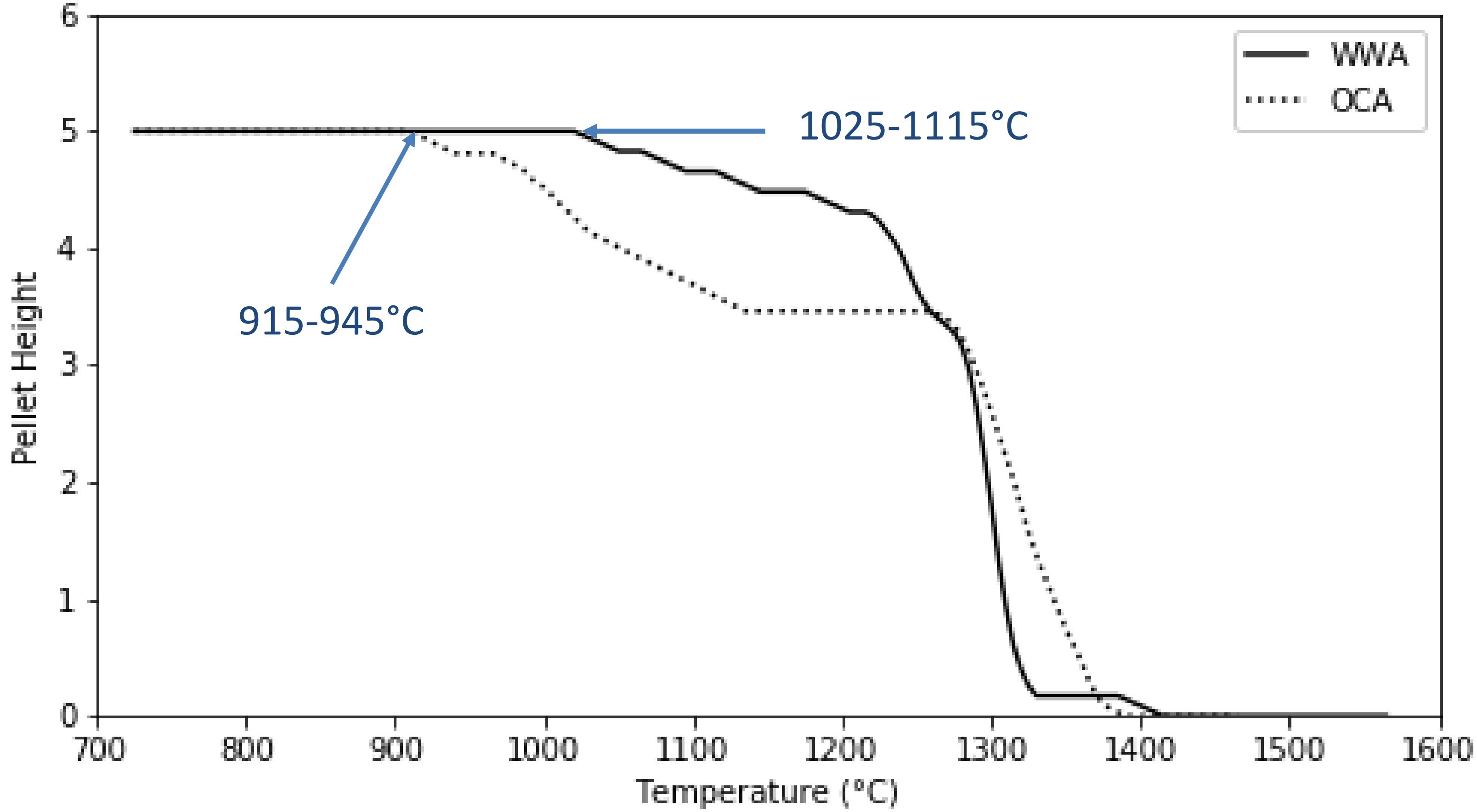


White
Wood Ash
w/ 5% coal
PFA

White
Wood Ash
w/ 25% coal
PFA

# Ash Fusion Testing

# Biomass Ashes - Comparison



# Experiments

- Ash Fusion Testing
  - Indicates effect of additive upon flow temperature of biomass ash

- Sinter Strength Testing
  - To investigate regions of initial particle stickiness/melting (700°C+)

# Experiments

- Sinter Strength Testing
  - To investigate regions of initial particle stickiness/melting (700°C+)

# Sinter Strength Testing

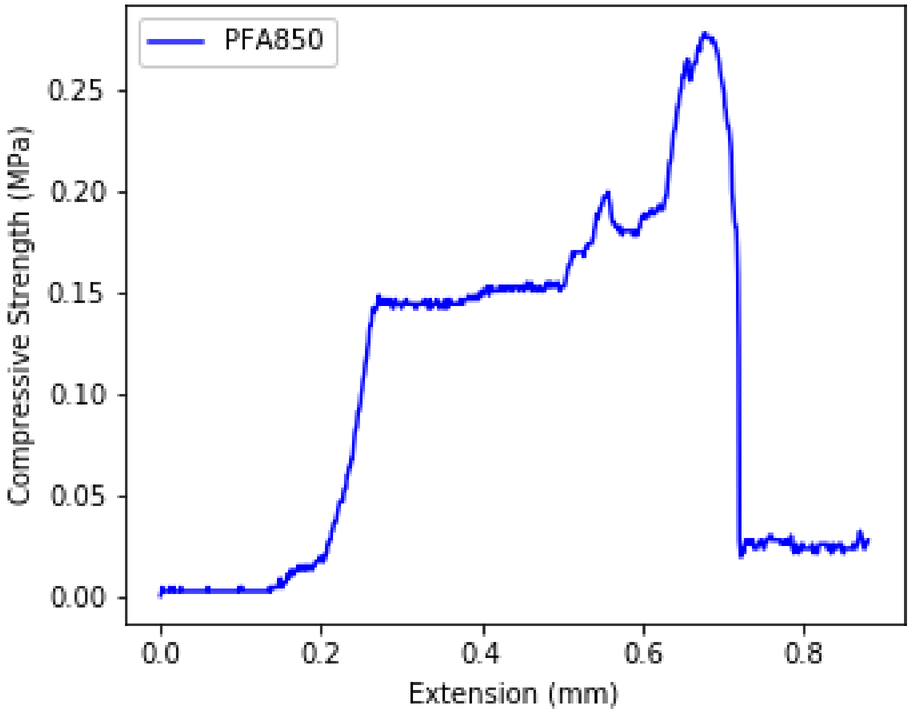
1. **Pelletising** – 1.37 MPa used to best simulate deposit formation [1]

2. **Exposure to Heat -** 5°C/min heating rate to avoid thermal shock, 3 hour hold time

3. **Sinter Strength Test -** Pressure applied gradually: arm extension of 5mm/s

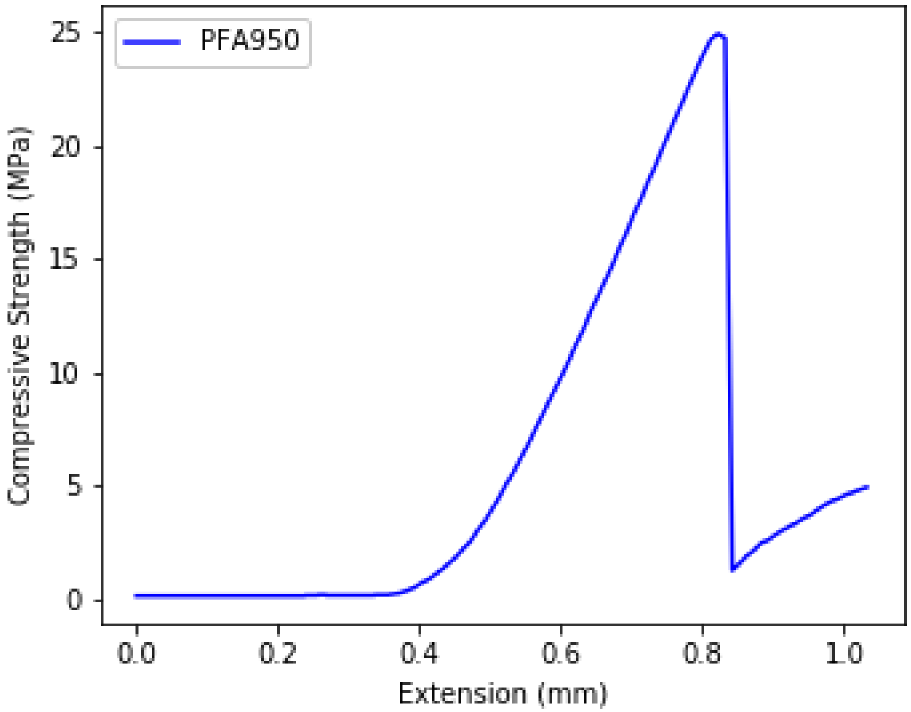
[1] Gibb, W. H. : The Slagging and Fouling Characteristics of Coals - II. A Sintering Test for the Determination of Fouling Propensity (1981)

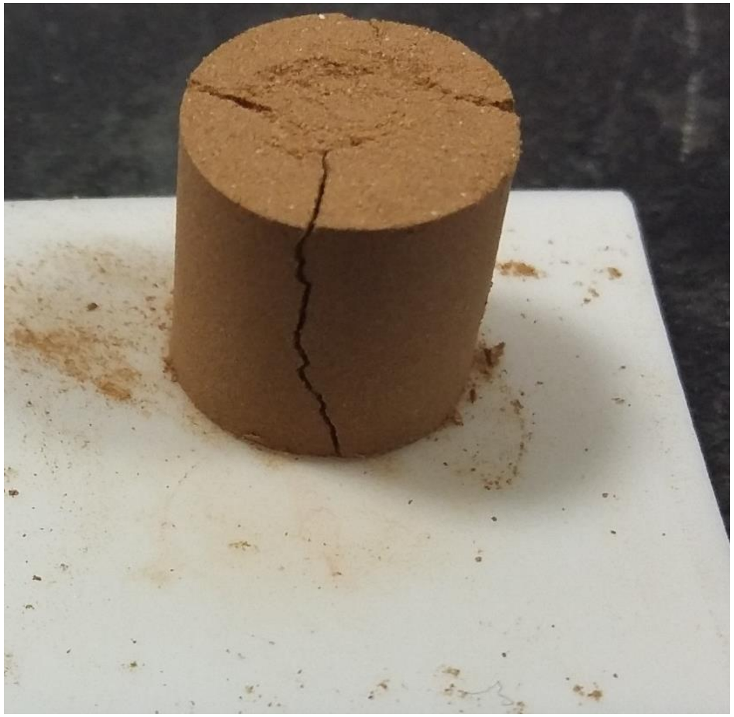
# Sinter Strength Testing




**Ideal Compression Profile** – Pellet crumbles under initial application of pressure

# Sinter Strength Testing



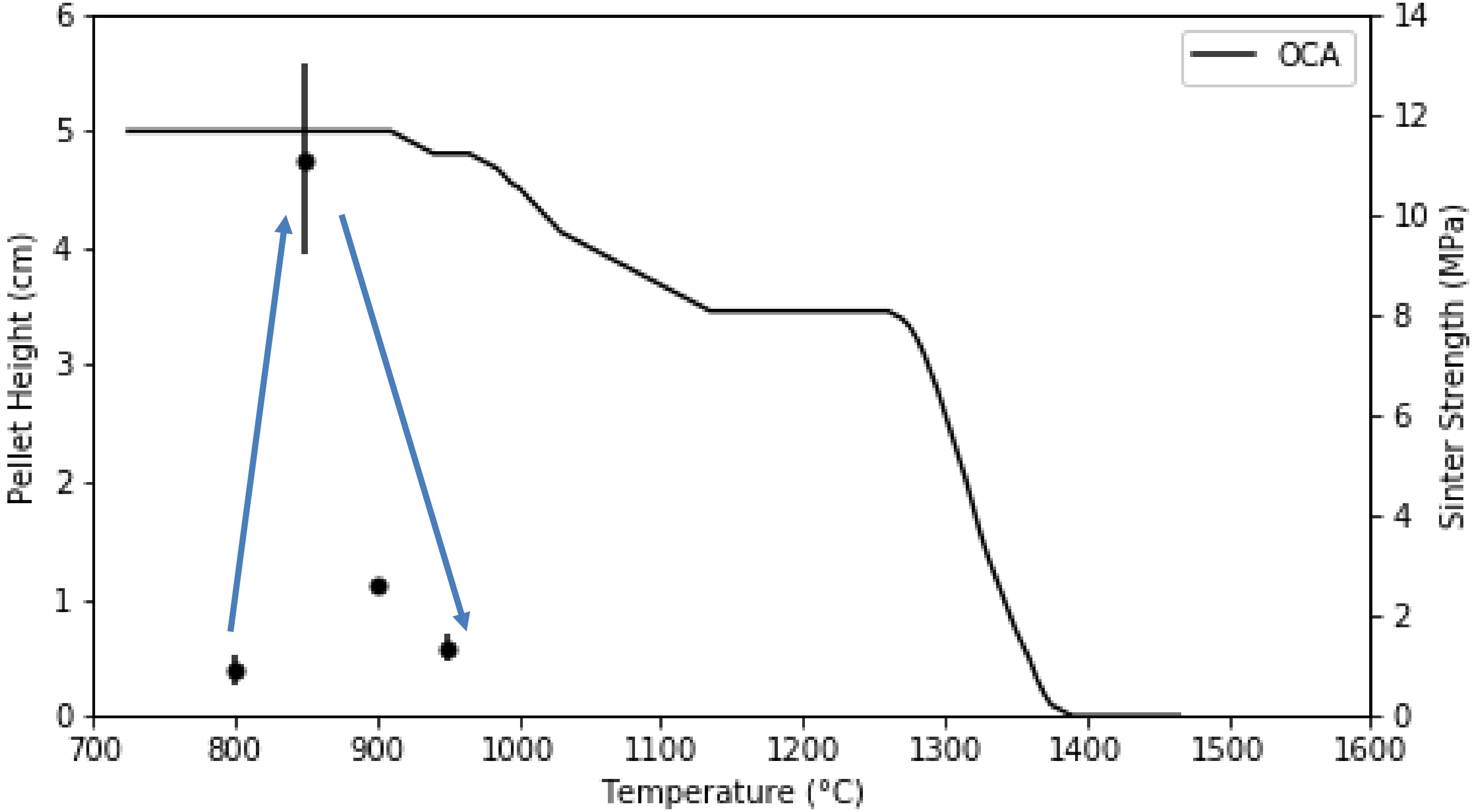



**Ideal Compression Profile** – Pressure increases at constant rate, clean fracture

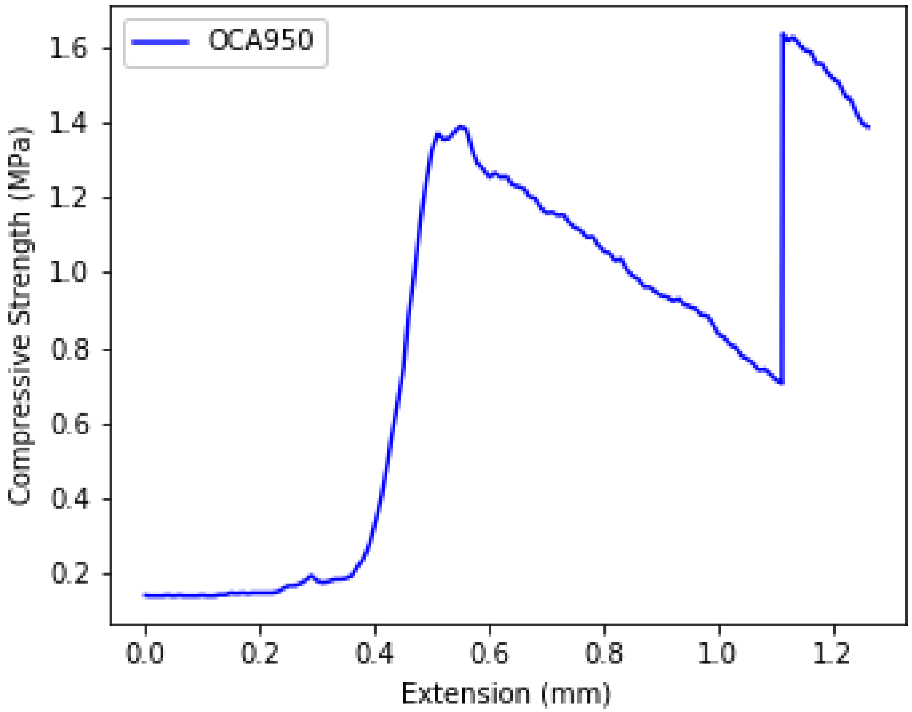
**Non - ideal sinter strength!**

# Sinter Strength & AFT Comparison

## Olive Cake Ash

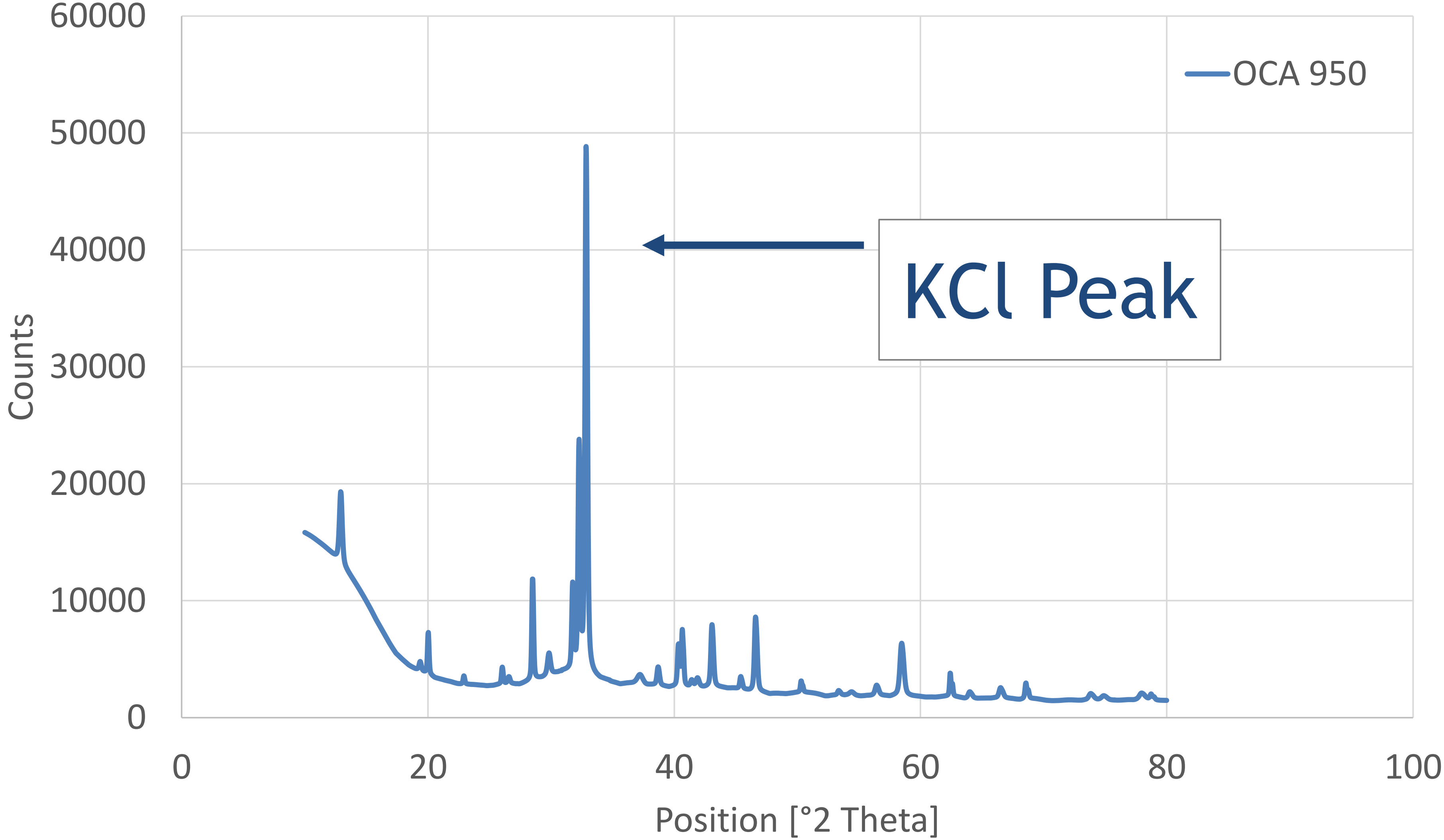


# Sinter Strength Testing



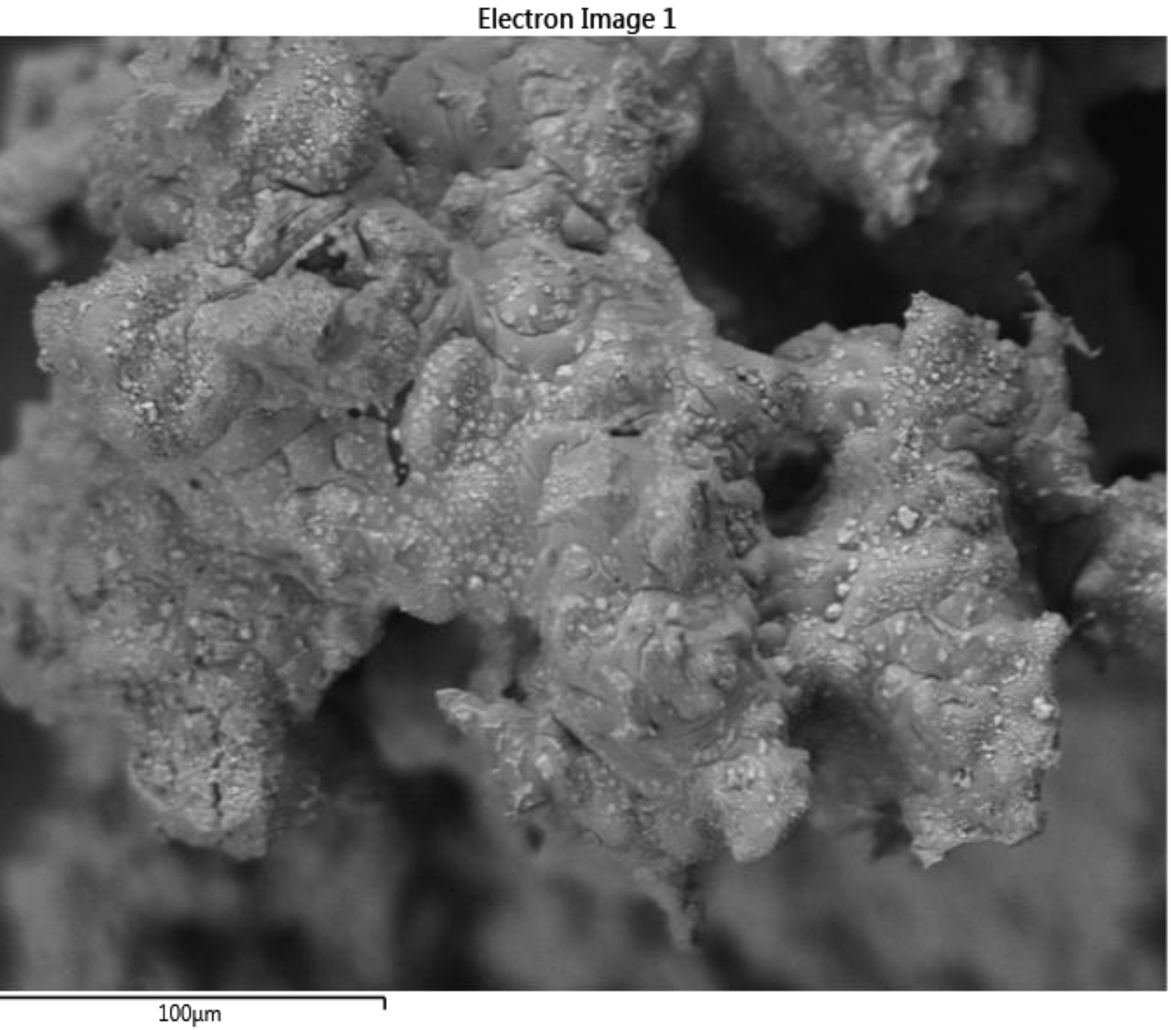

**Worst case scenario -** Pellet compresses under pressure, rather than fracture – False sinter strength readings, indicates sootblower removal will fail

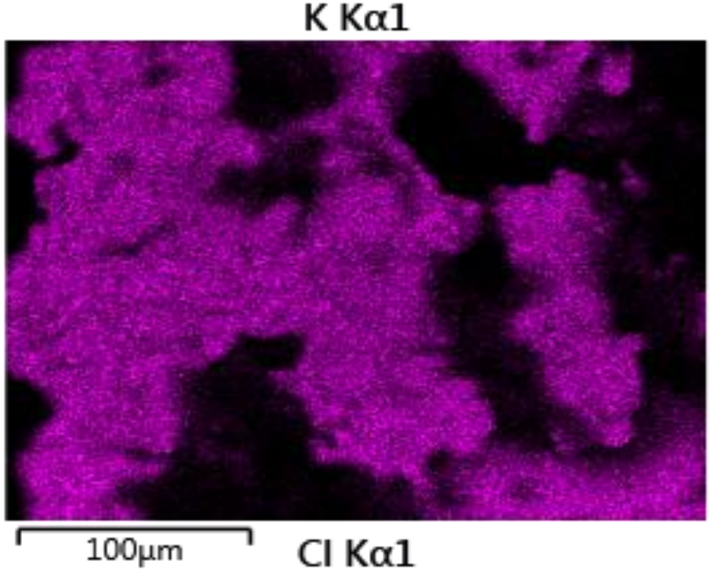
# OCA @ 950˚C - XRD

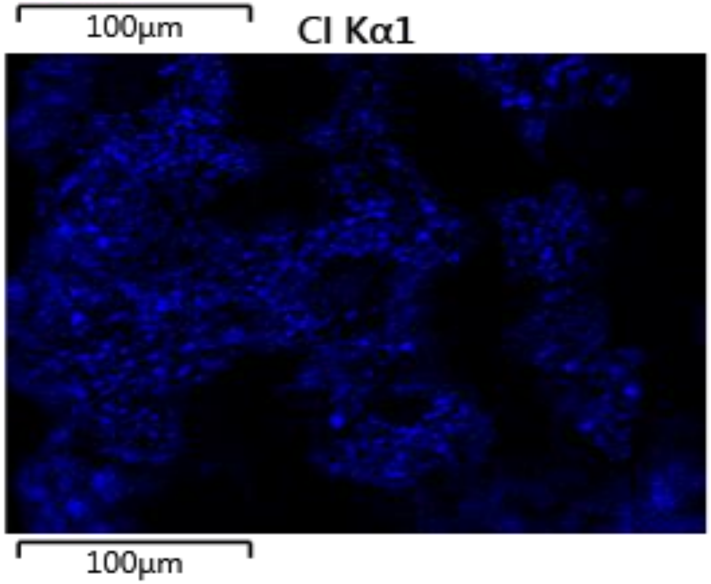


60000
50000
40000
30000
20000
10000
0
Counts
OCA 950
KCl Peak
0
20
40
60
80
100
Position [°2 Theta]

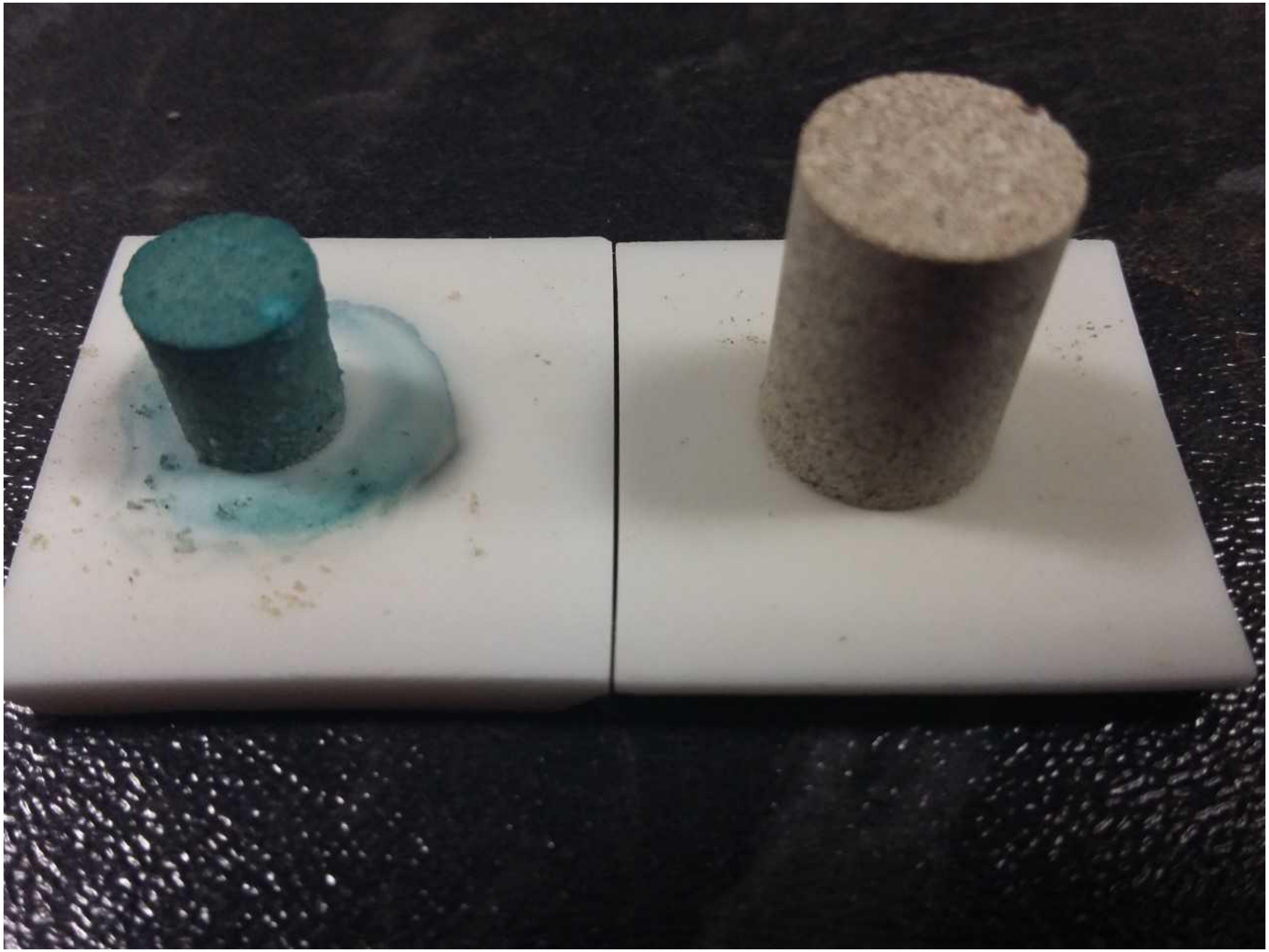
# OCA @ 950°C – SEM-XRF



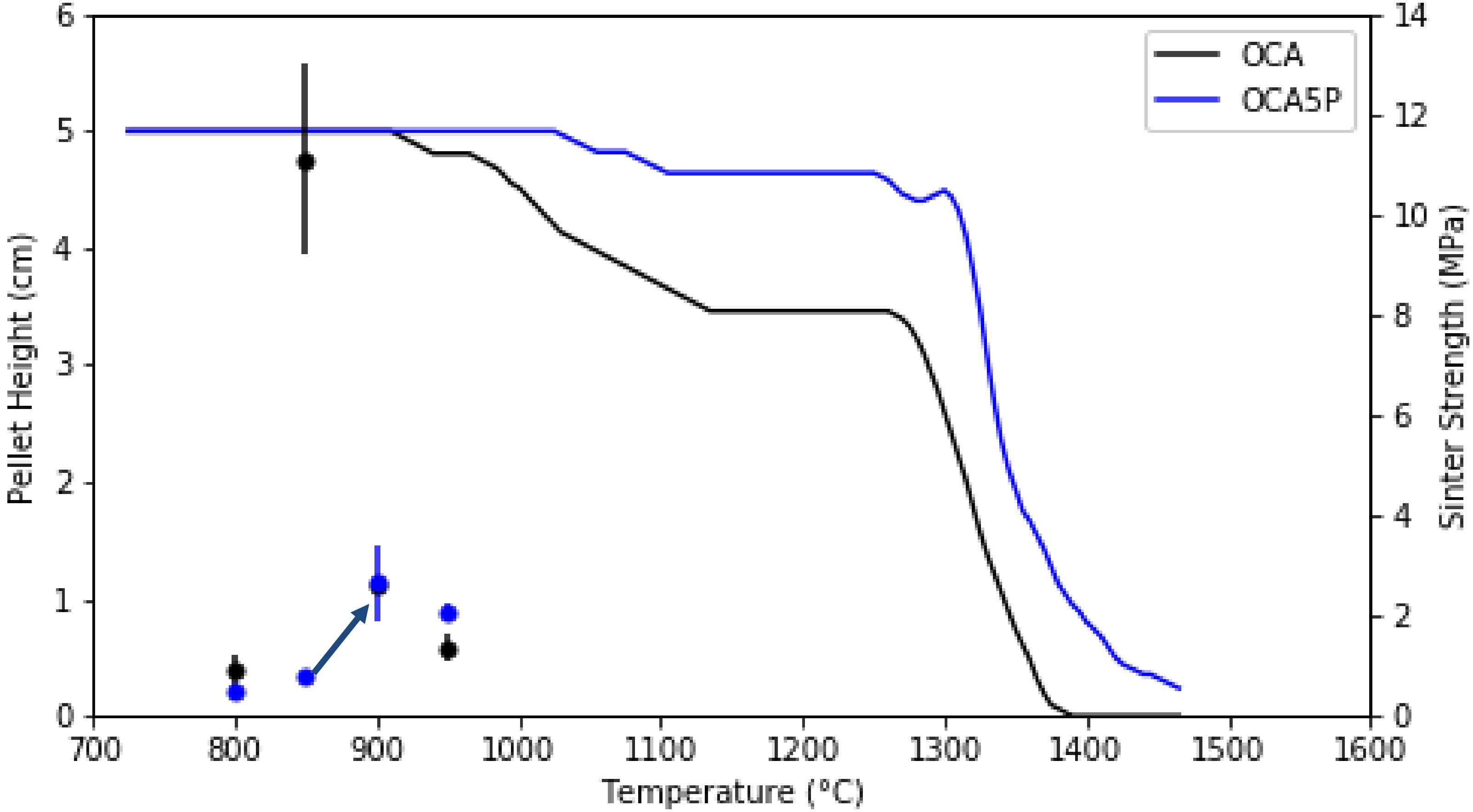



# Sinter Strength Pellets



# Sinter Strength & AFT Comparison

## Olive Cake Ash – 5% PFA addition



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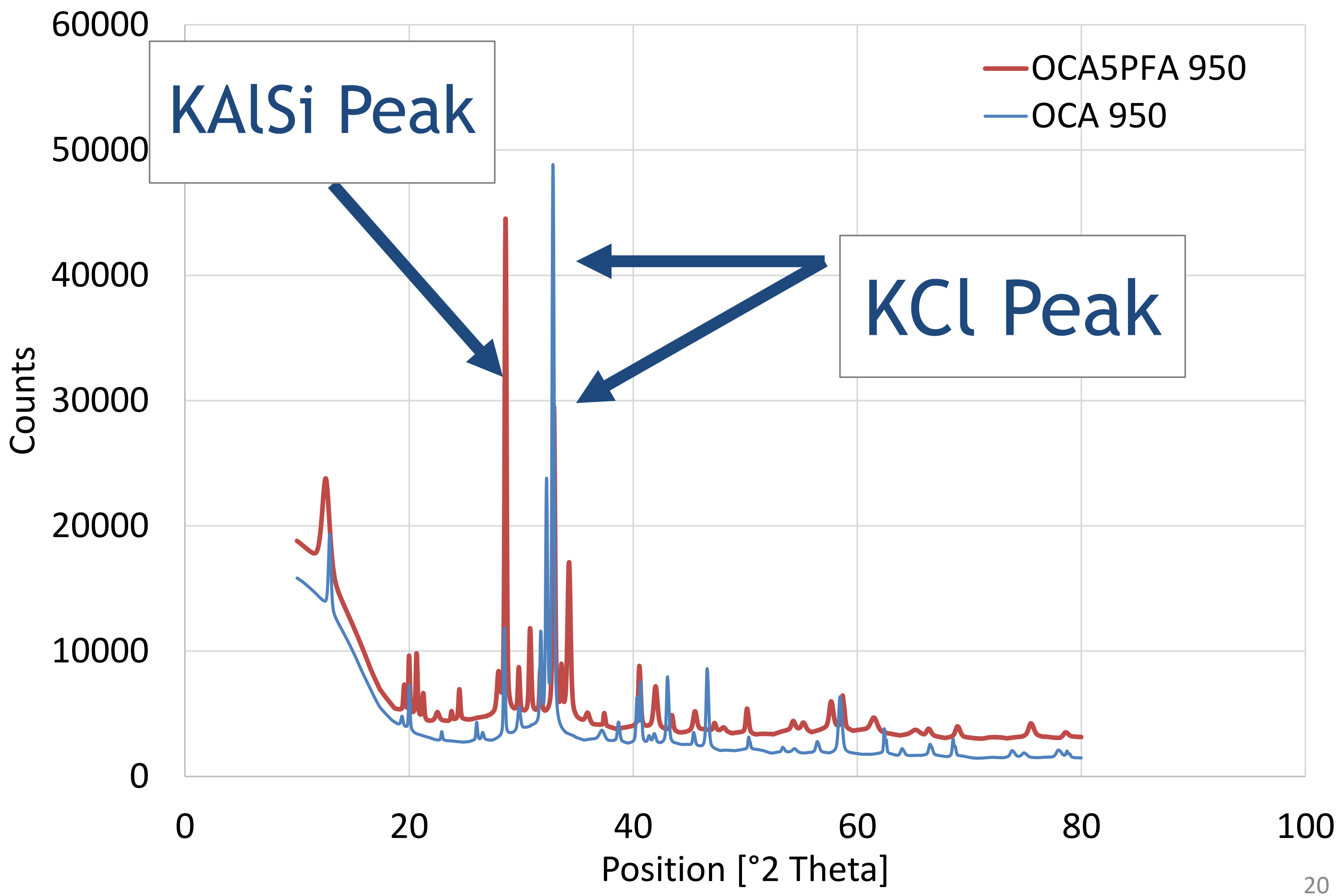

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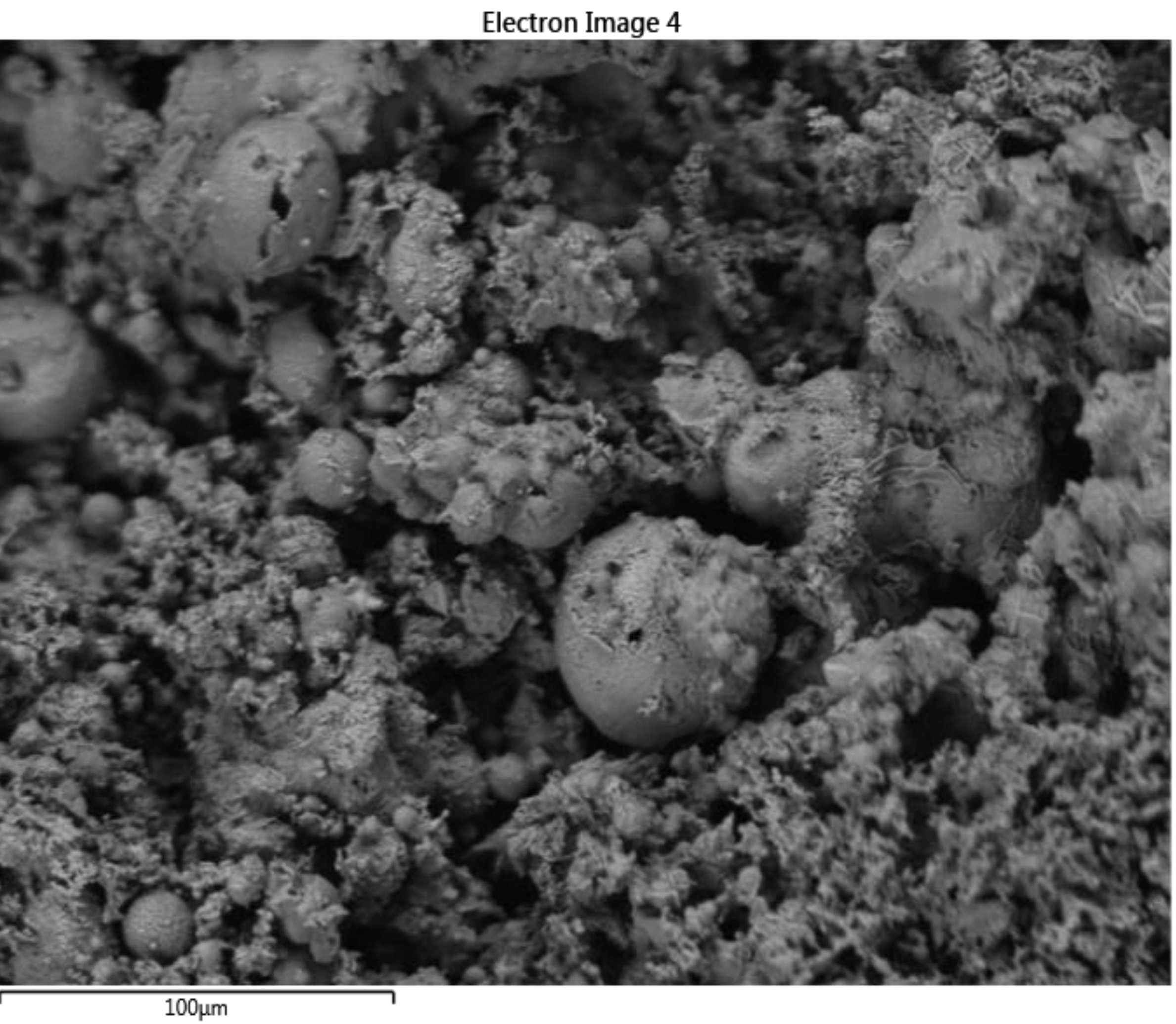


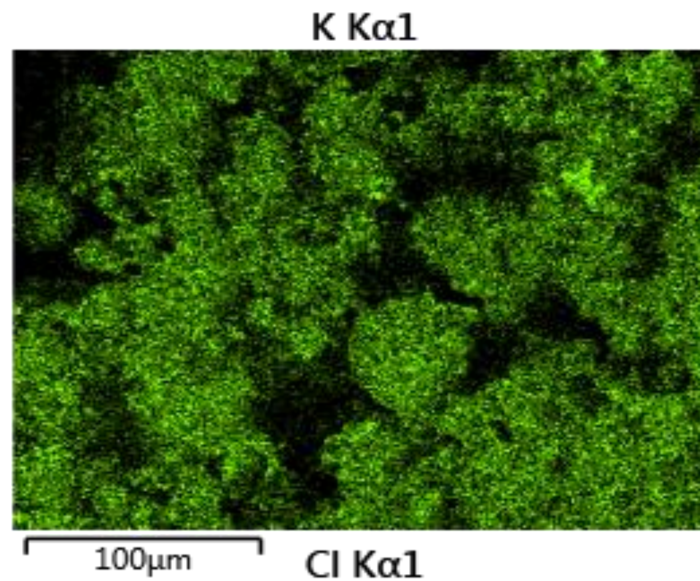


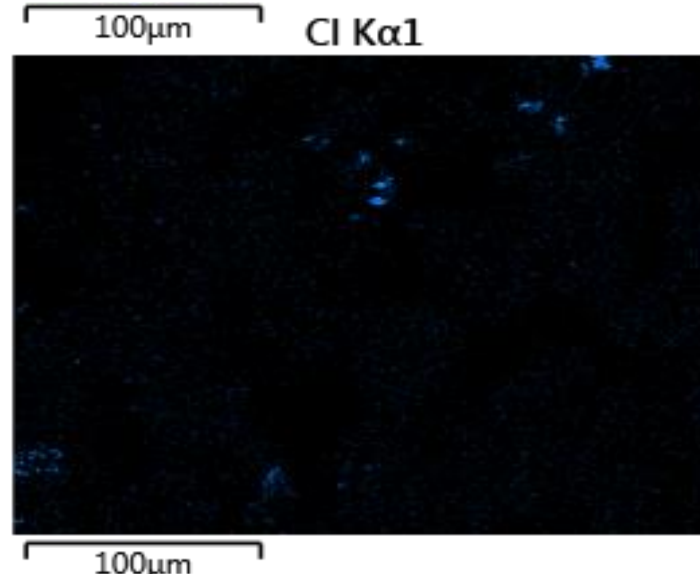

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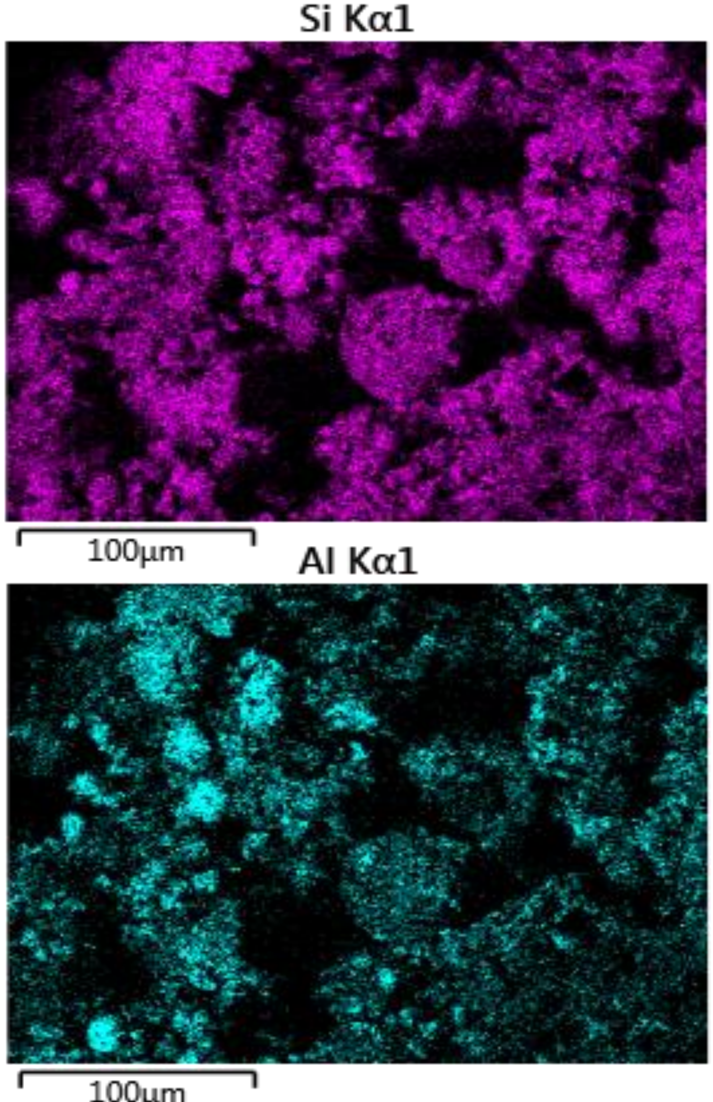

# Sinter Strength & AFT Comparison

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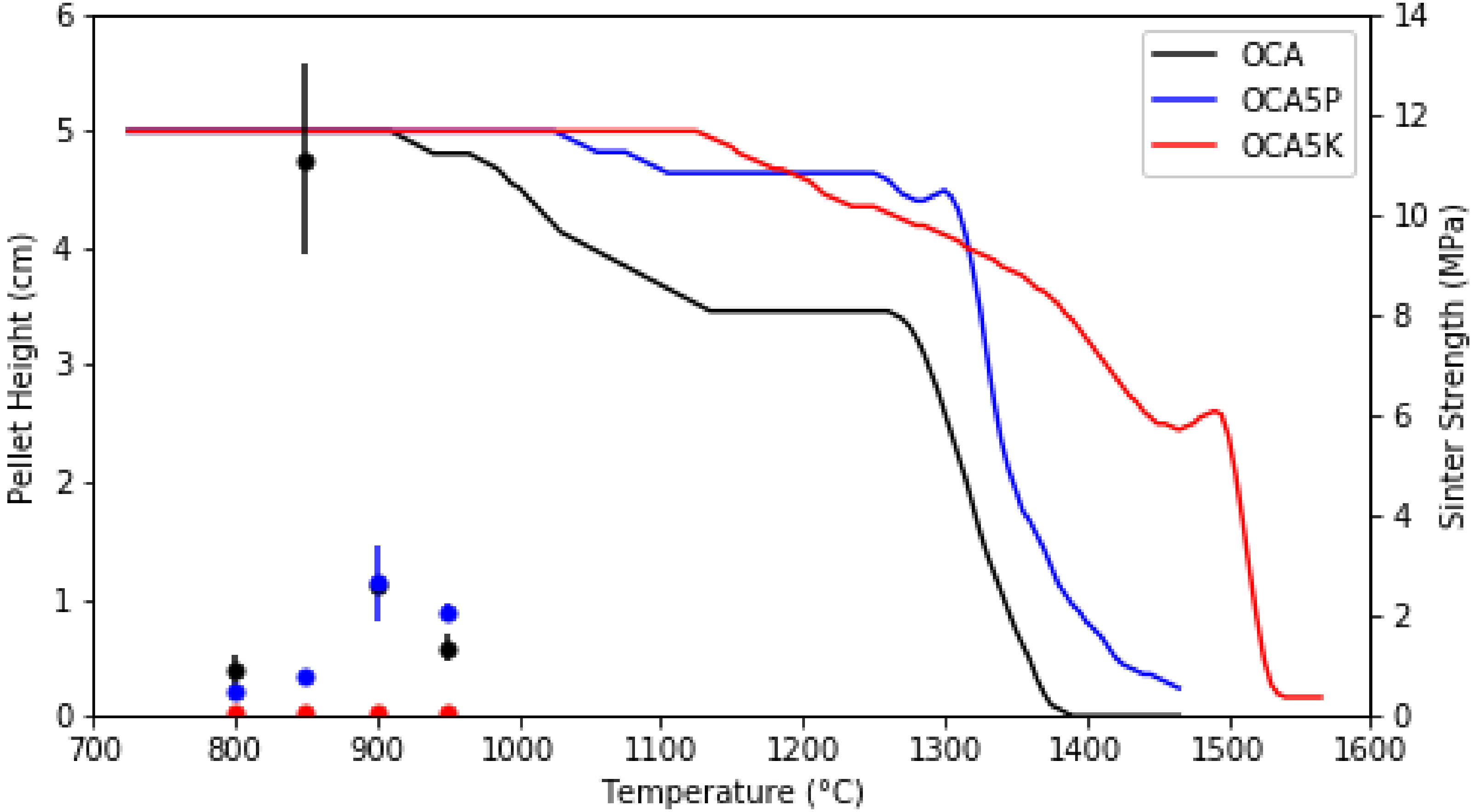

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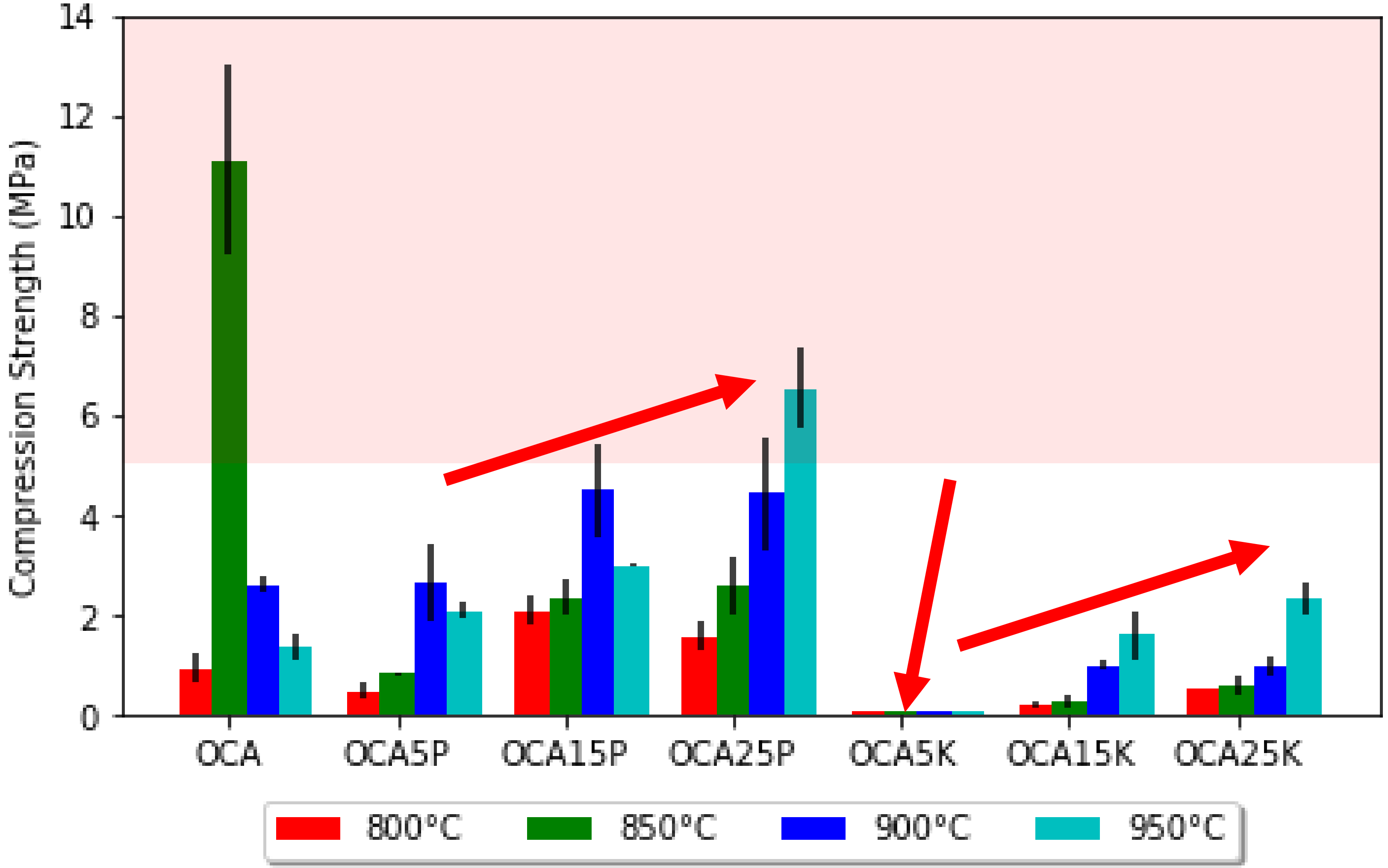

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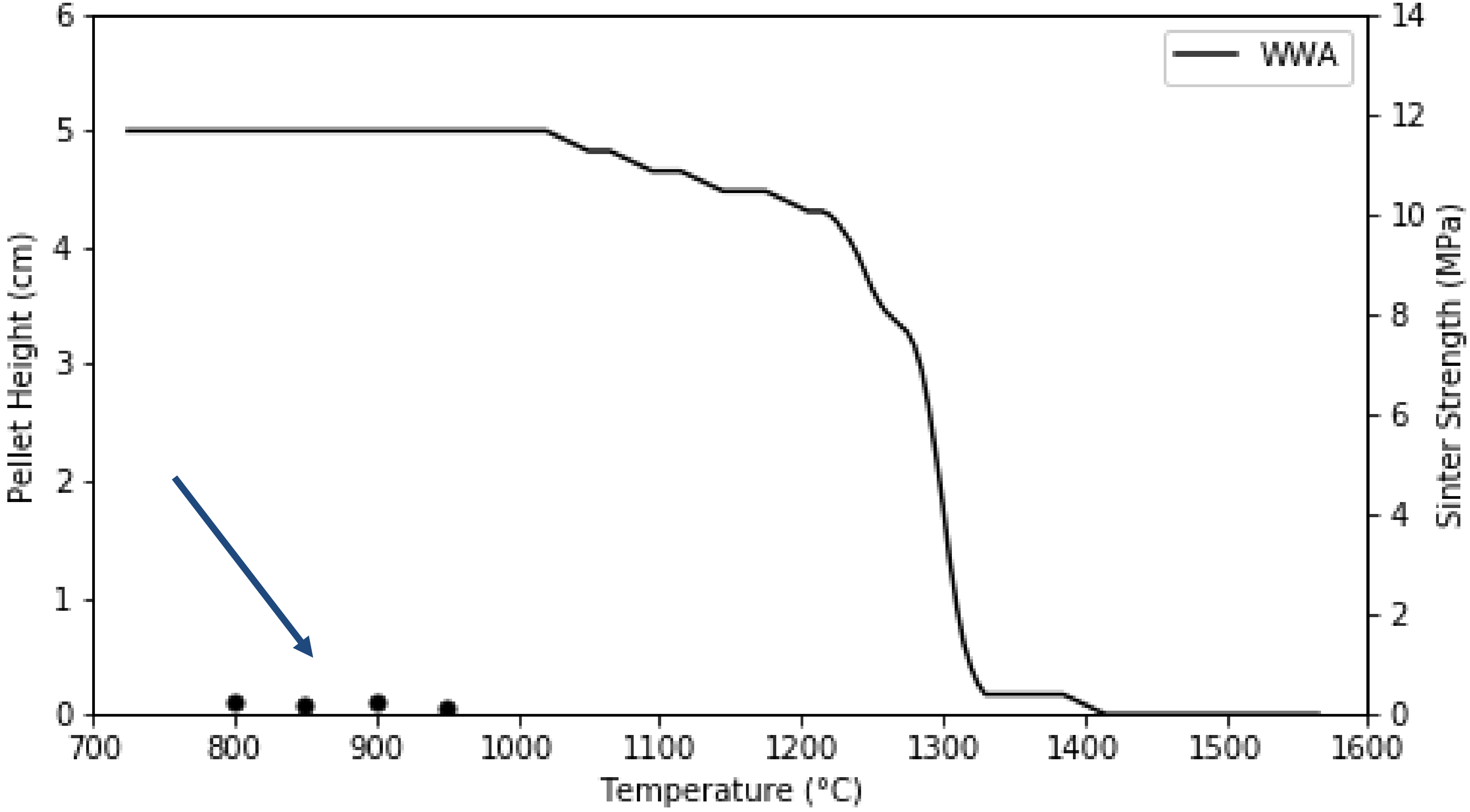

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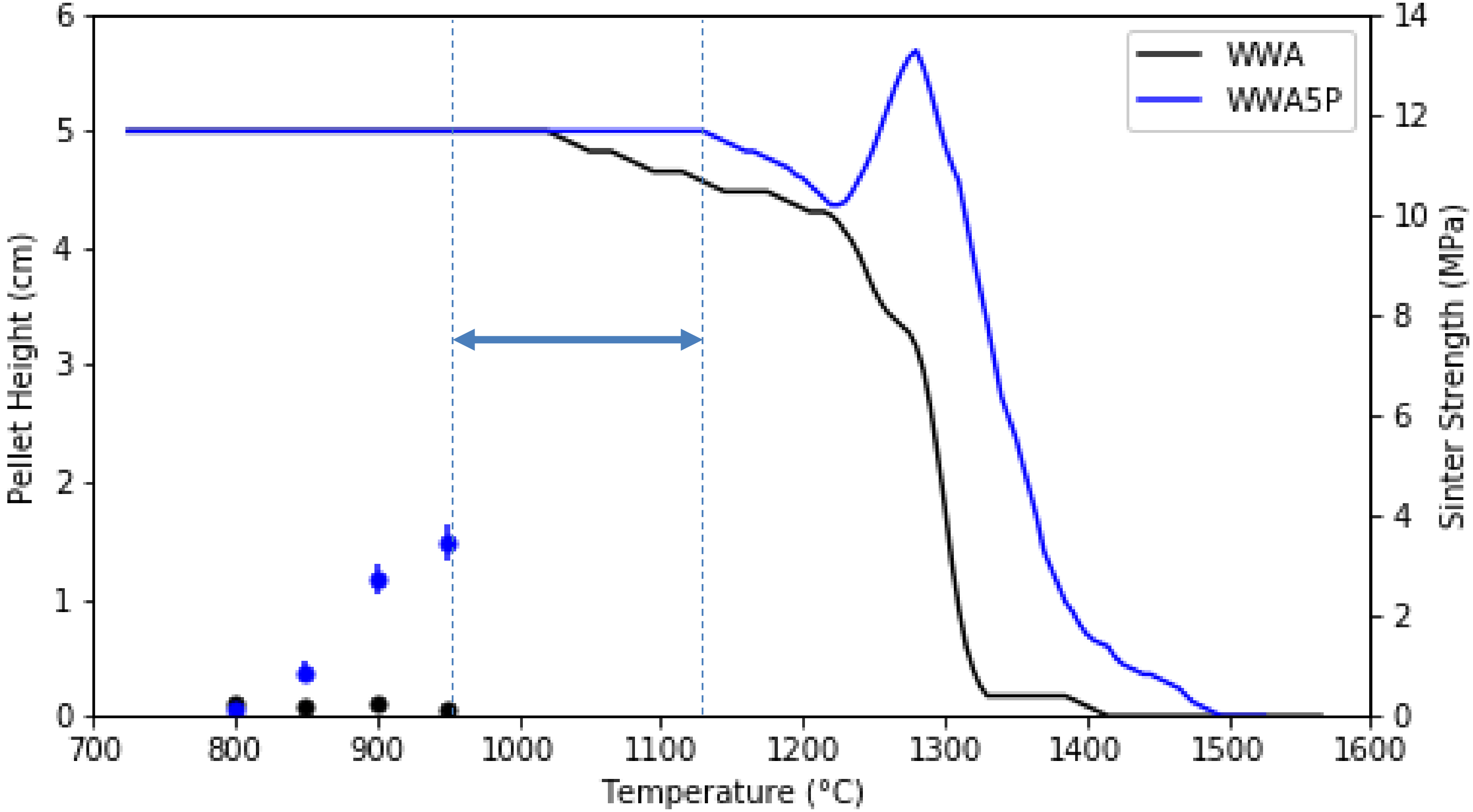

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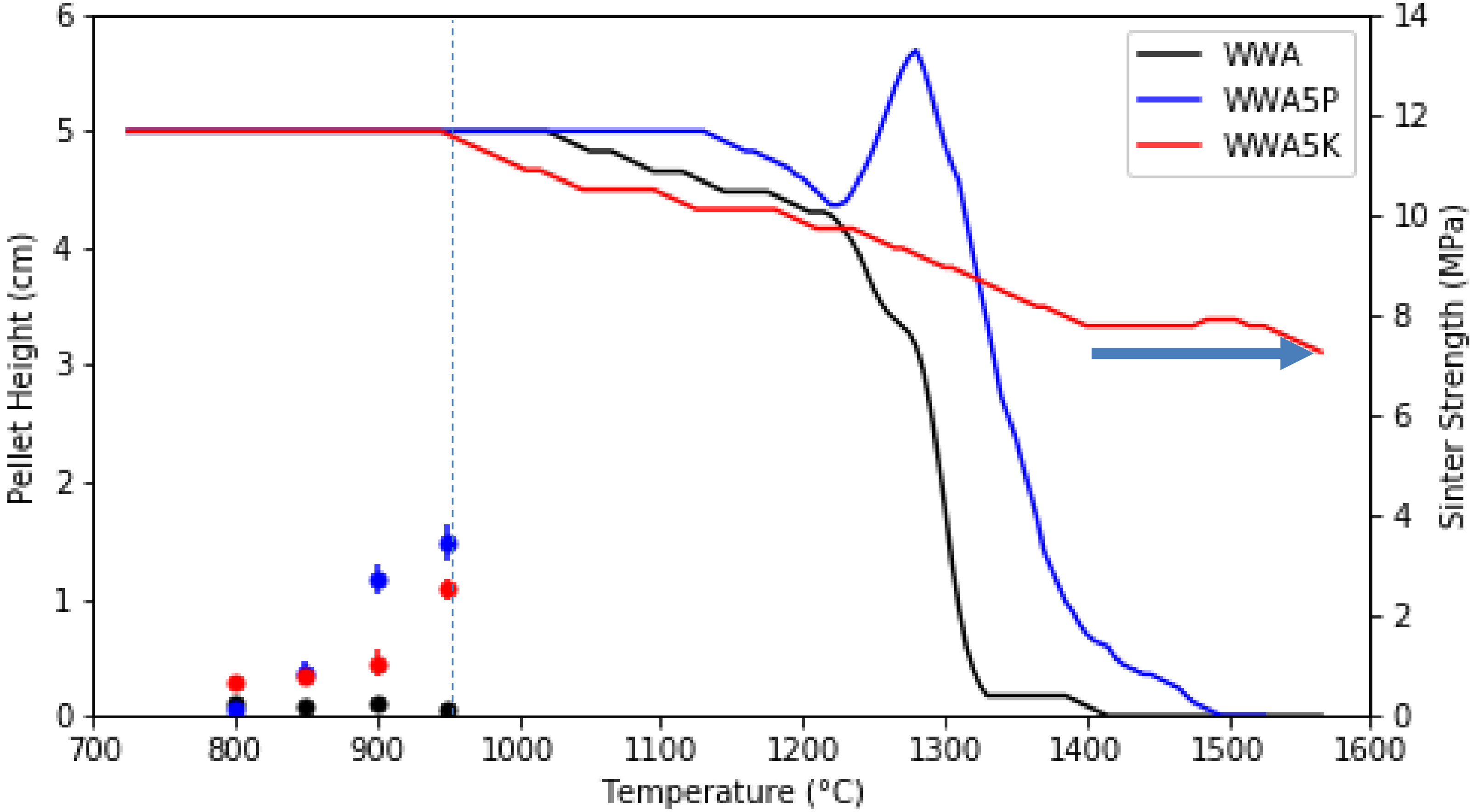

# Kaolinite Transformations

| | |
|---|---|
| 500-925°C | $Al_2O_3.2SiO_2.2H_2O \rightarrow 2H_2O + Al_2O_3.2SiO_2$ |
| 925-1100°C | $2(Al_2O_3.2SiO_2) \rightarrow SiO_2 + 2Al_2O_3.3SiO_2$ |
| >1100°C | $2Al_2O_3.3SiO_2 \rightarrow SiO_2 + 2(Al_2O_3.SiO_2)$ |
| >1400°C | $3(Al_2O_3.SiO_2) \rightarrow 3Al_2O_3.2SiO_2 + SiO_2$ |

Formation of amorphous phase metakaolinite and silica: known sintering mechanism

High melting T mullite (>1800°C) only created above 1100°C

# Sinter Strength & AFT Comparison

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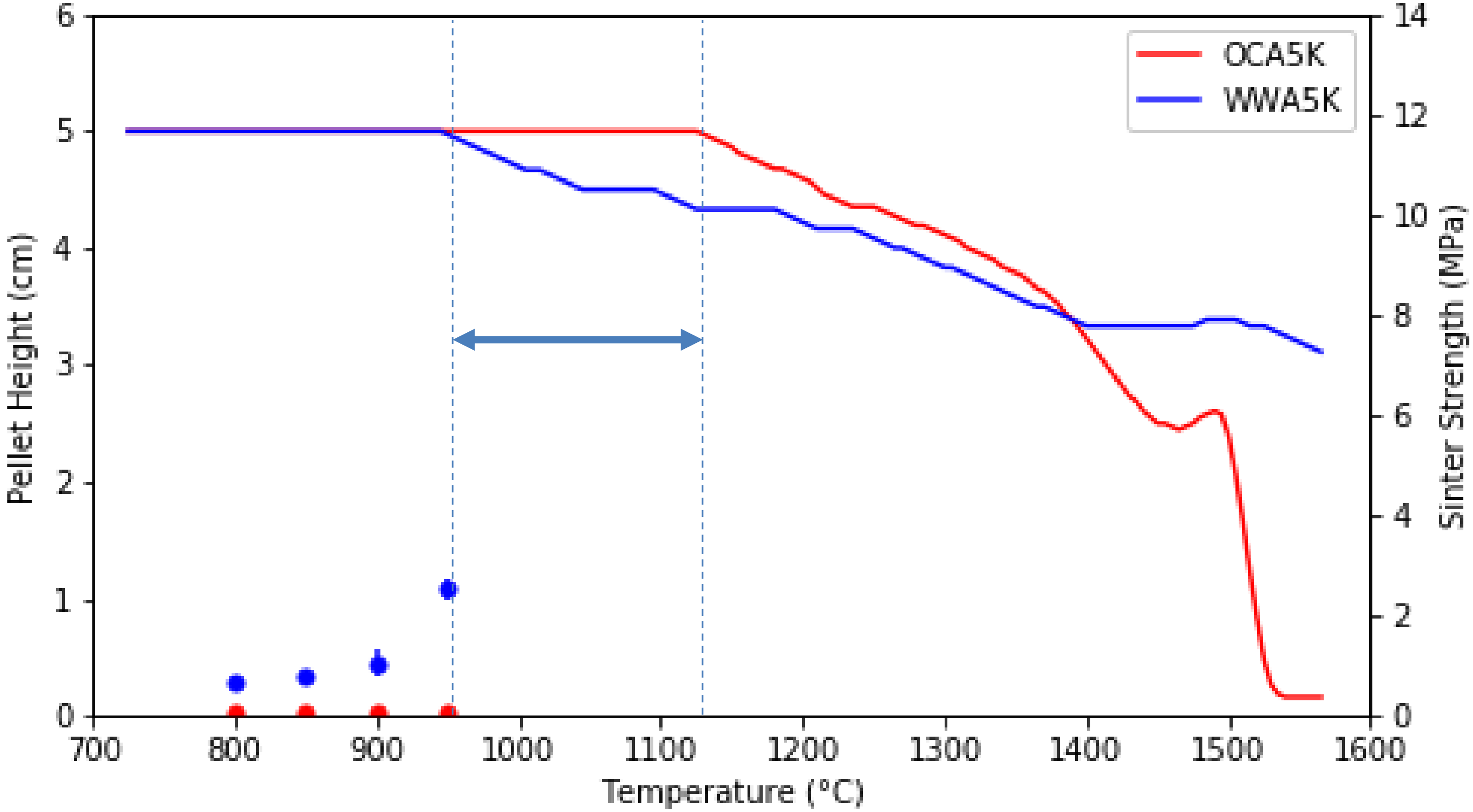

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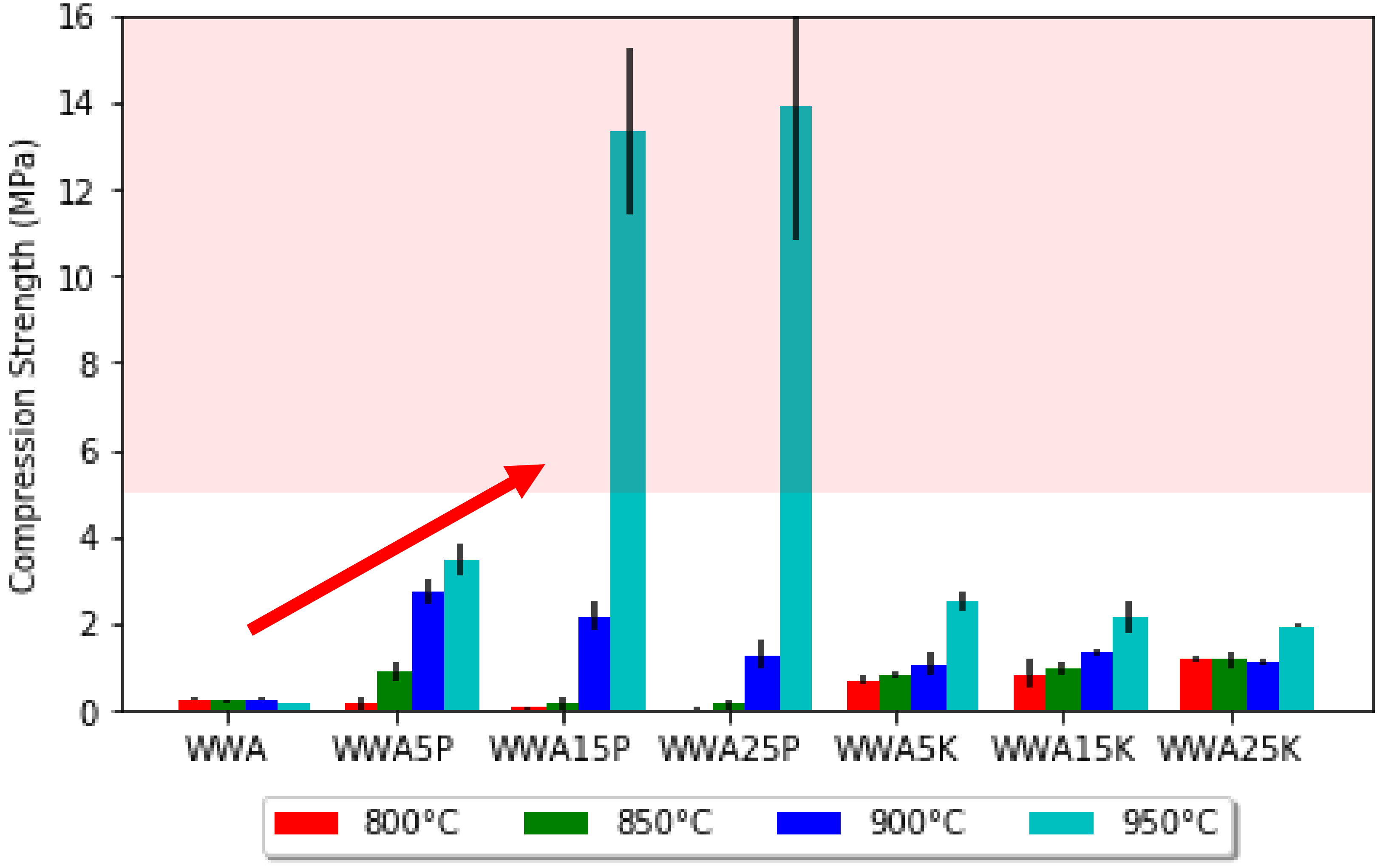
| >1400°C | $3(Al_2O_3.SiO_2) \rightarrow 3Al_2O_3.2SiO_2 + SiO_2$ |

KCl release occurs ~ 800°C, before formation of amorphous phases occurs

Higher melting T KAlSi formed instead

# Sinter Strength Testing



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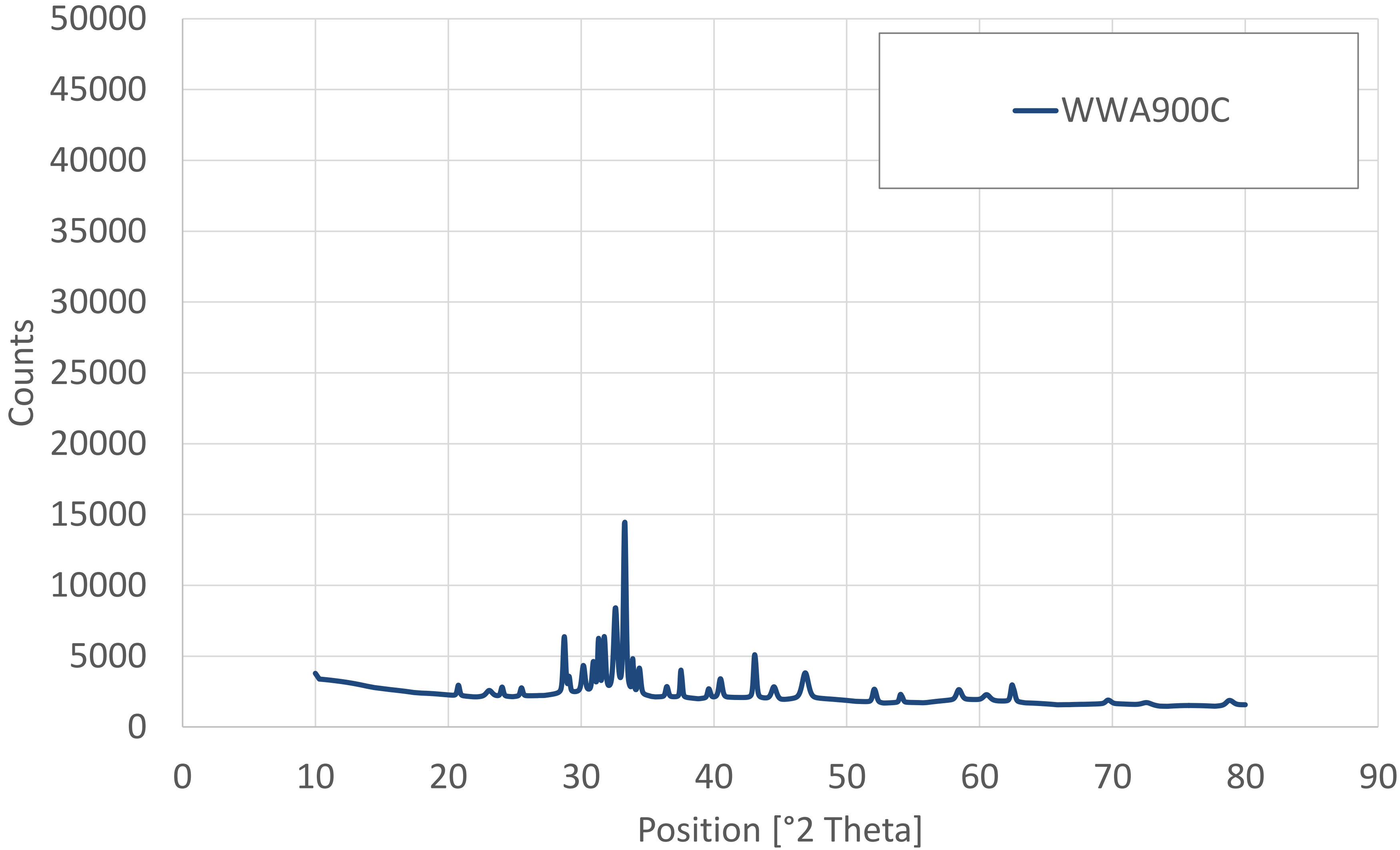

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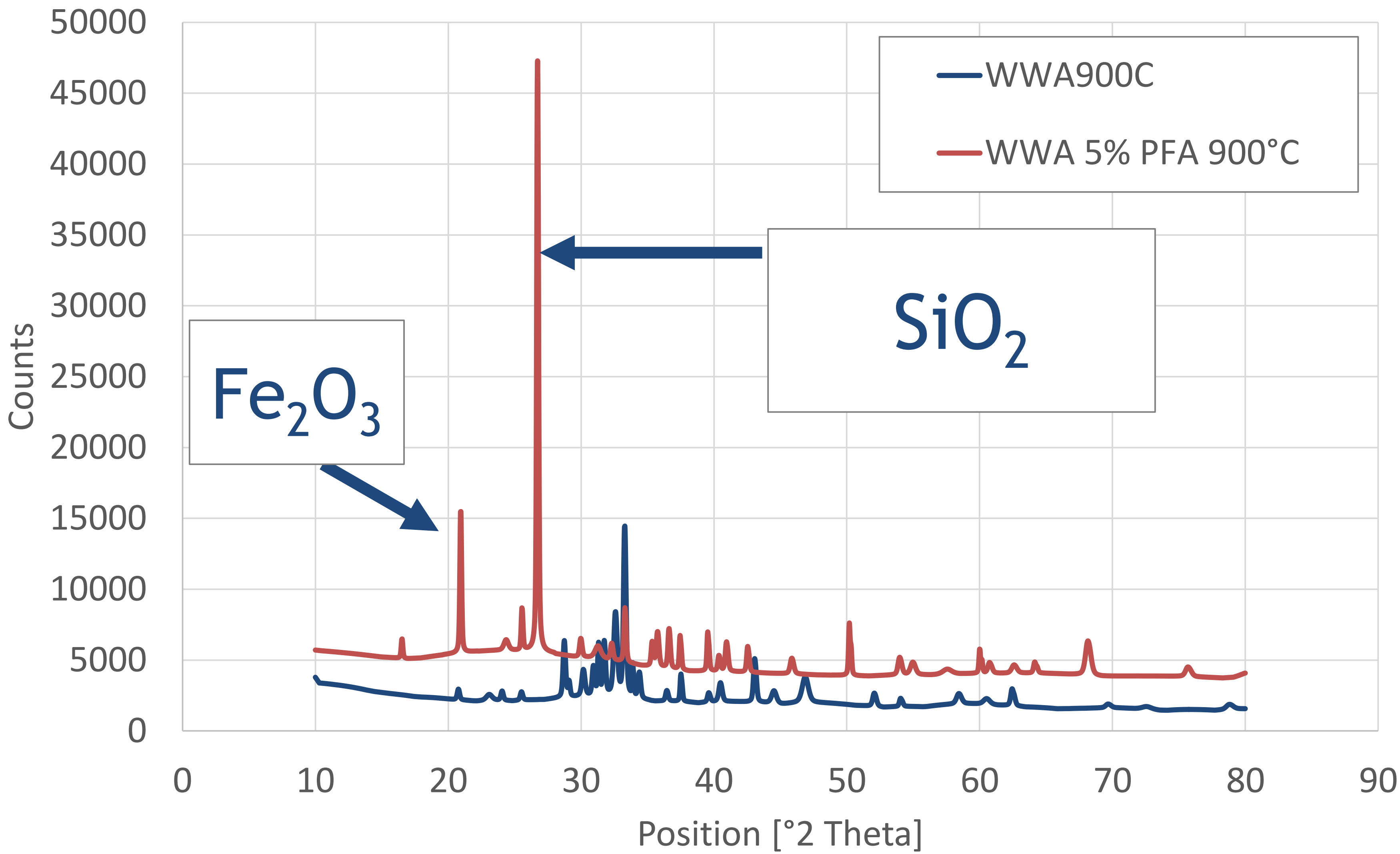

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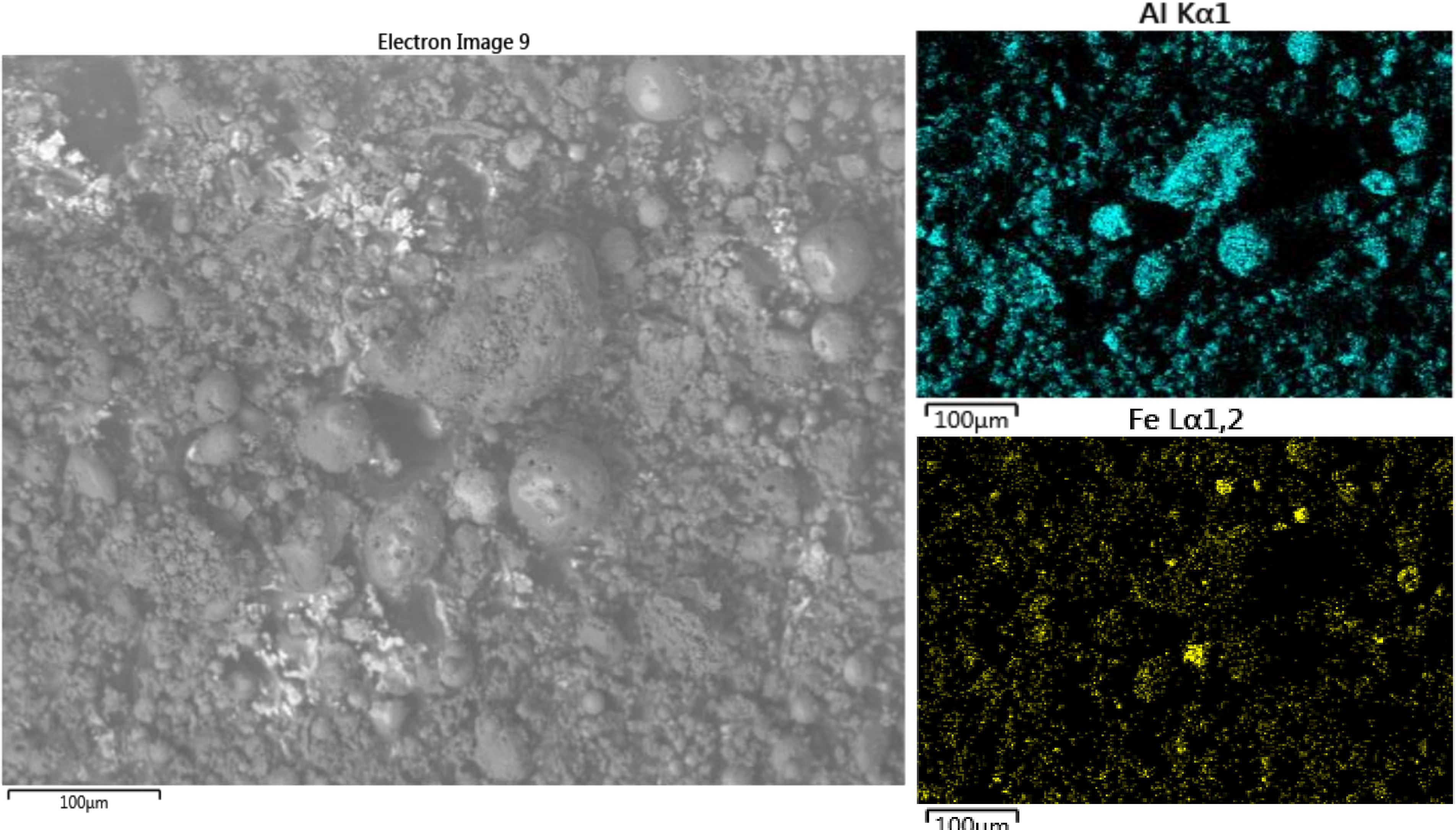

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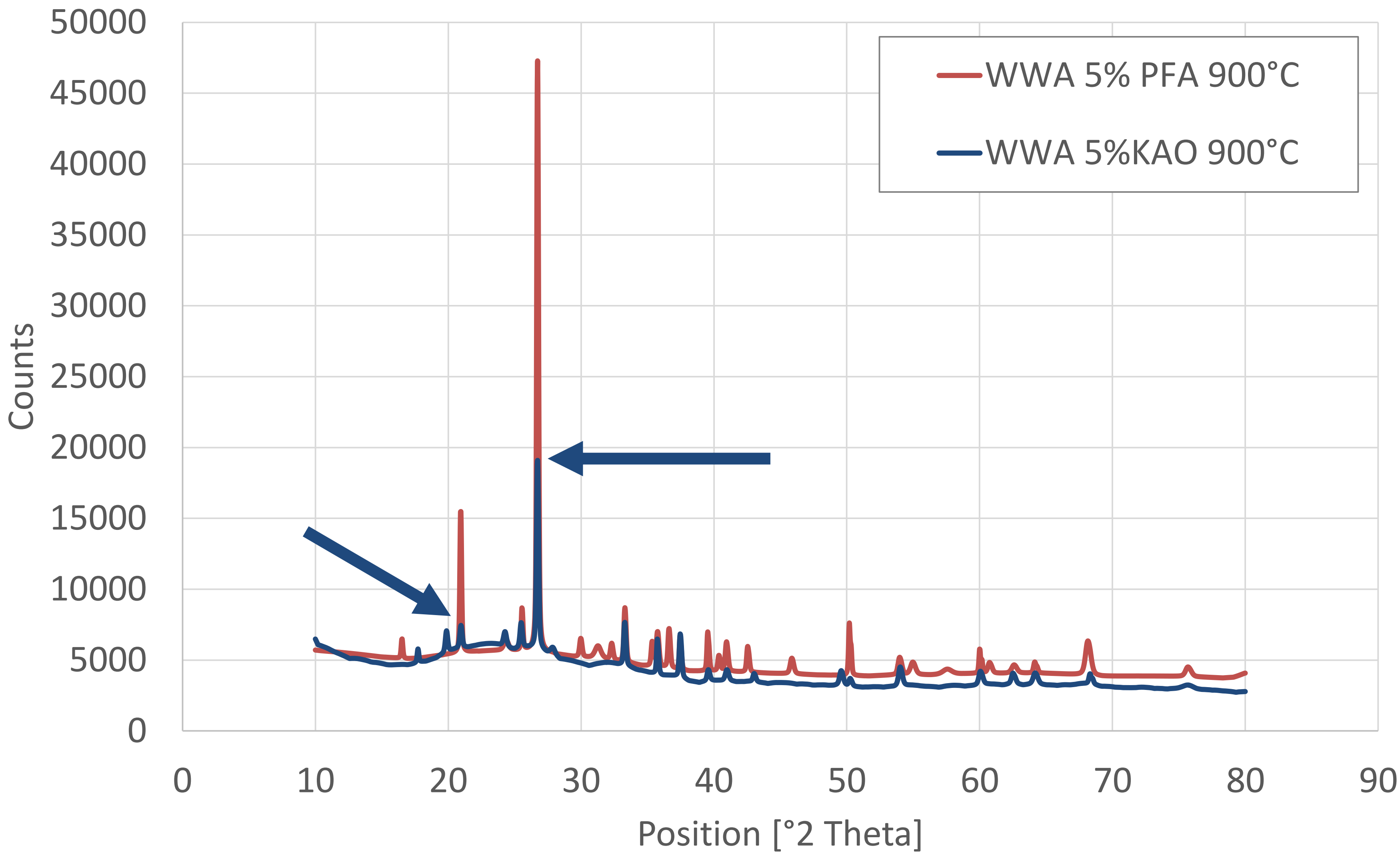

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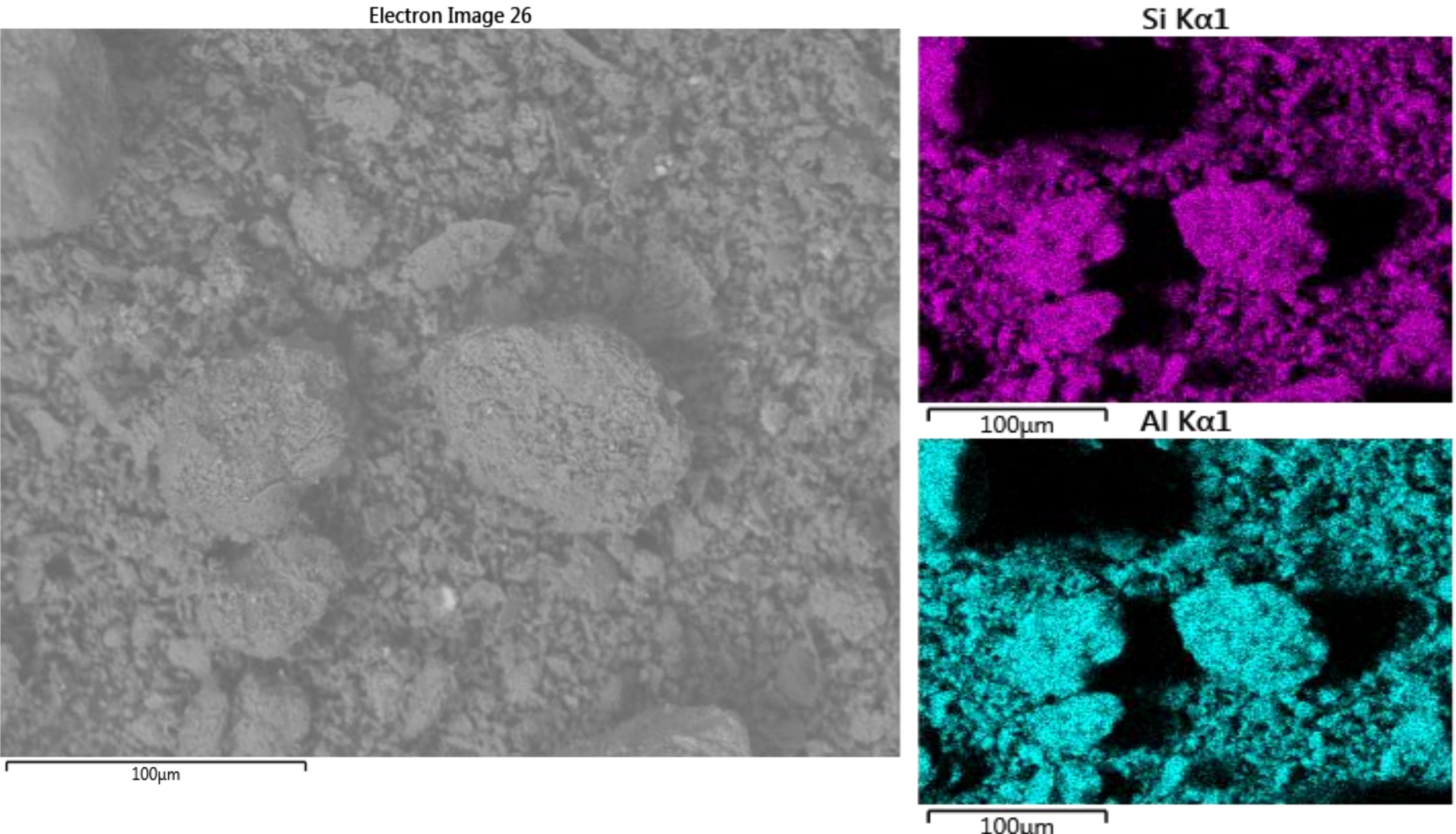

# Further Testing

- High temperature viscometry – to determine viscosity temperature relationship for OCA-5% KAO

- Pilot-scale testing – to determine how effectively lab scale tests reflect boiler operation

# Summary

- PFA and Kaolin mechanisms are different, despite similar composition
- Kaolin is extremely effective at reducing KCl release – much less effective for other K species
- Coal PFA improves OCA behaviour to lesser extent
- Induces sintering in WWA, although lower concentrations may improve results

# Acknowledgements

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- Sibelco, for the supply of kaolin HPC used in this study.

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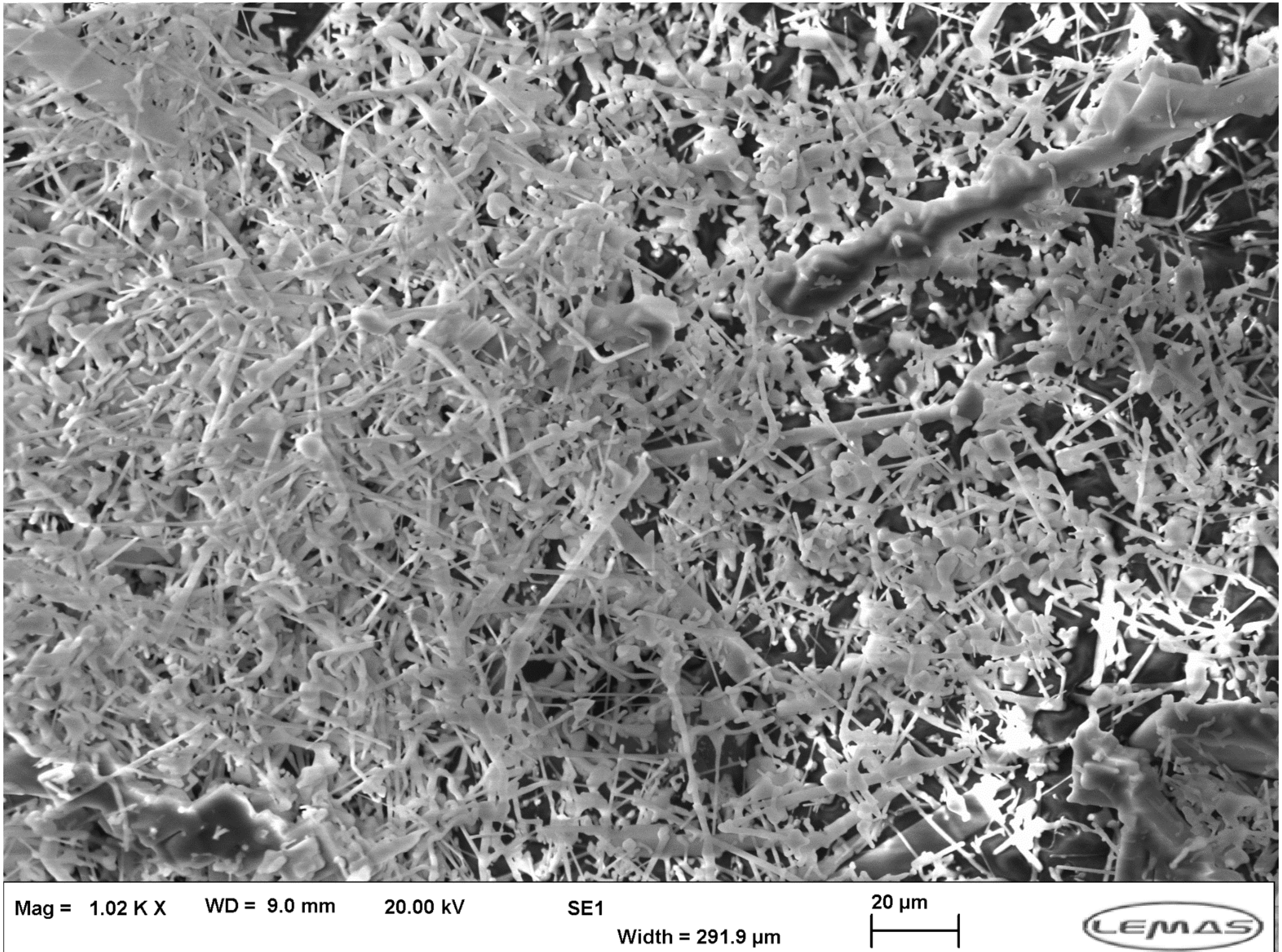
# Additional Results



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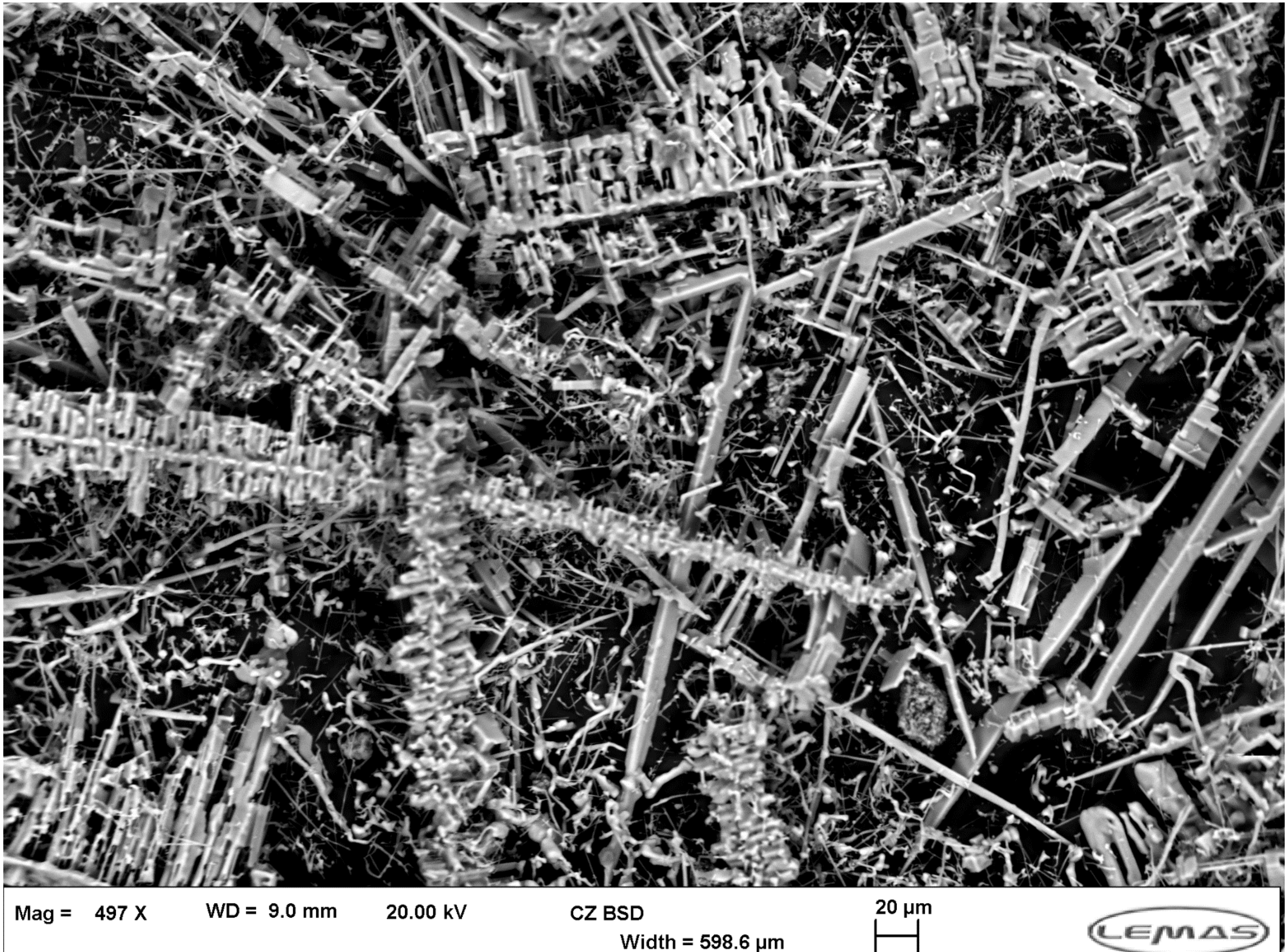

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