

Investigation into Microstructural Damage of Brominated Nuclear Graphite

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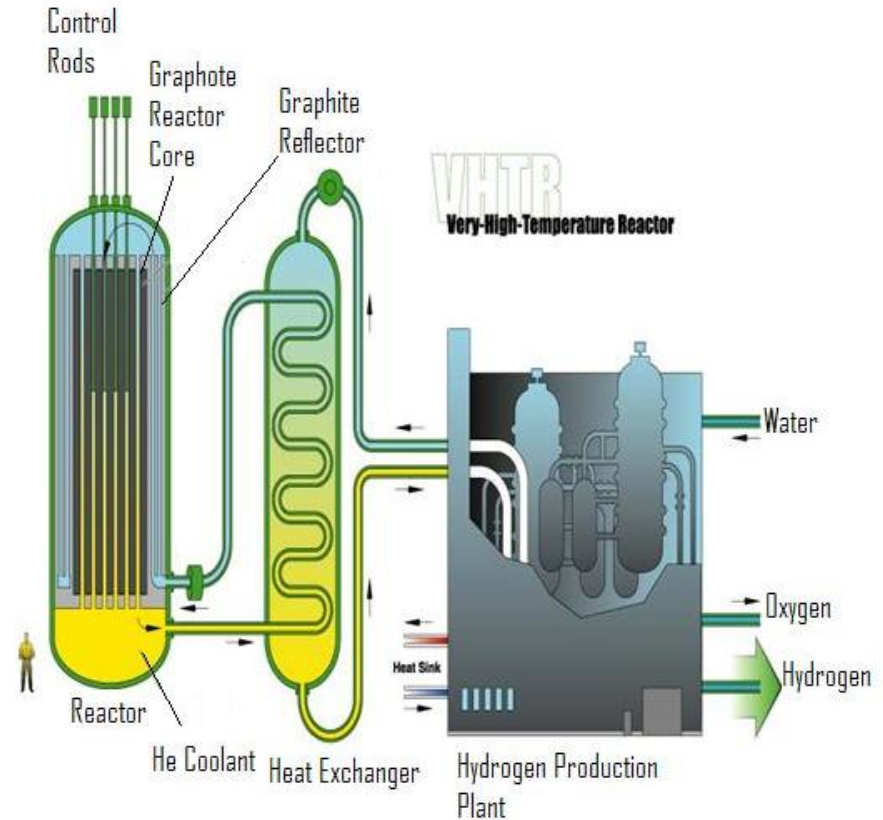
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Introduction

Work funded by KNOO
WP4, work to focus on
Gen IV issues.

Generation IV requires a
core life of 60 years.

This requires an improved
fundamental understanding
of the irradiation aging
process of graphite.



Graphite Microstructure

Graphite Microstructure

Nuclear Graphite is made up of;

Filler Particles

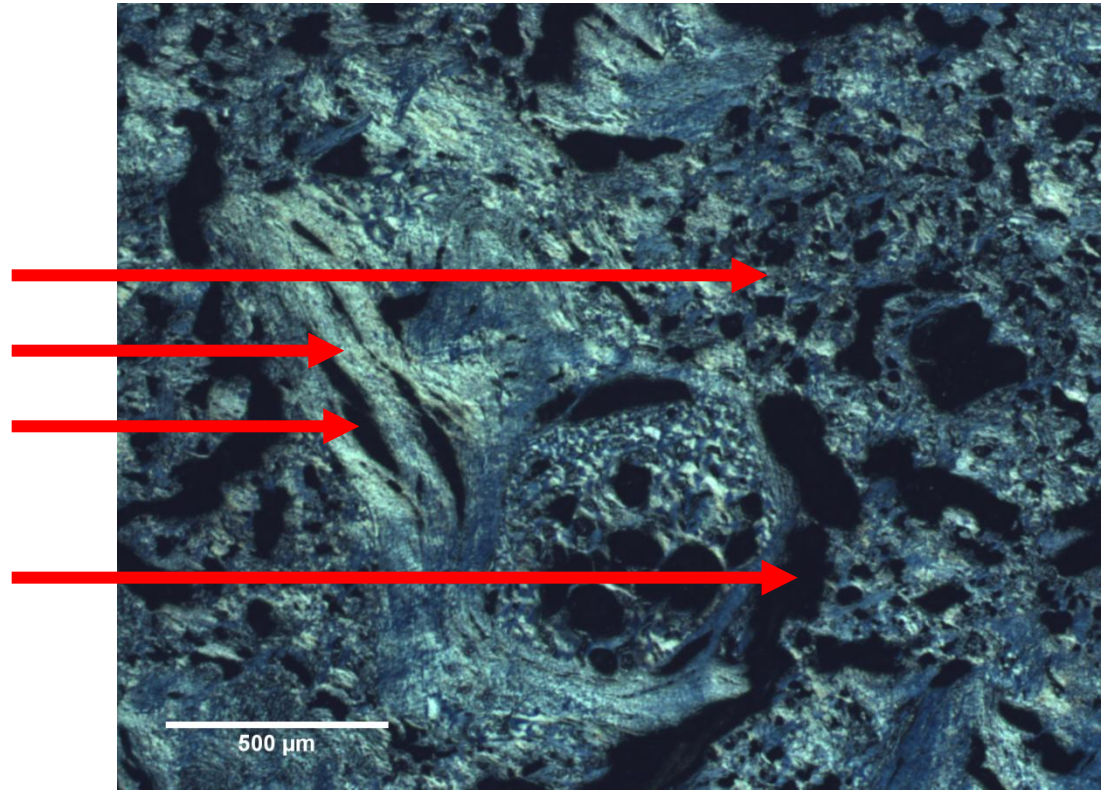
- petroleum or natural cokes

Binder Matrix

- Flour
- Binder pitch

Porosity

- Calcination cracks
- Gas evolution pores

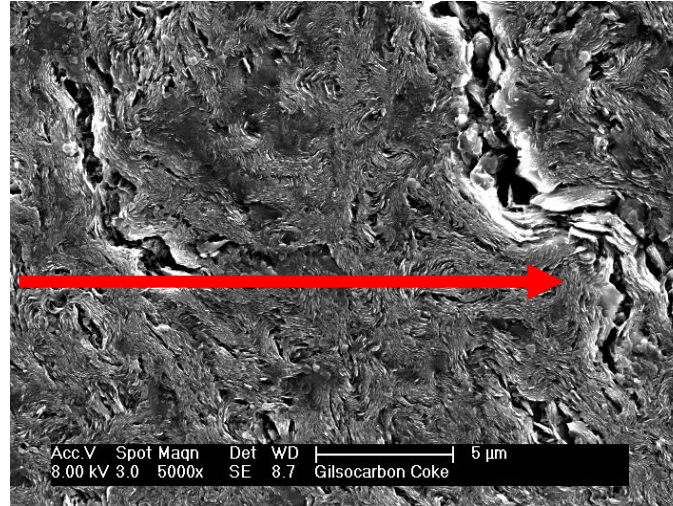


Bulk Structure (polarised optical image)

Graphite Microstructure

Crystallite Arrangement

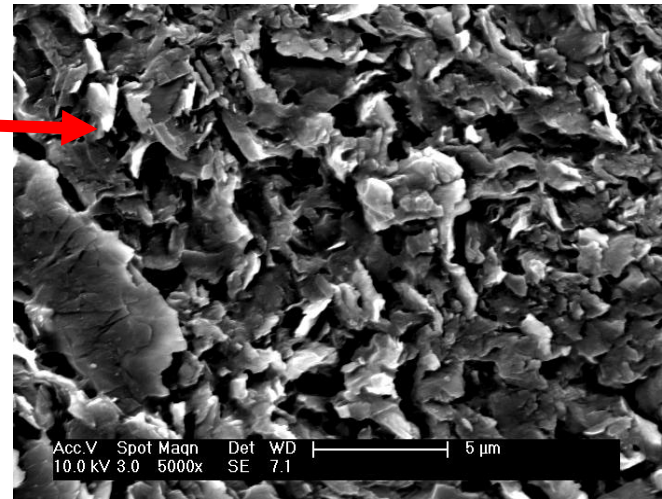
Filler particle made up of aligned crystallites



Filler Particle

(Image Will Bodel)

Binder matrix made up of disordered crystallites



Binder Matrix (graphitised)

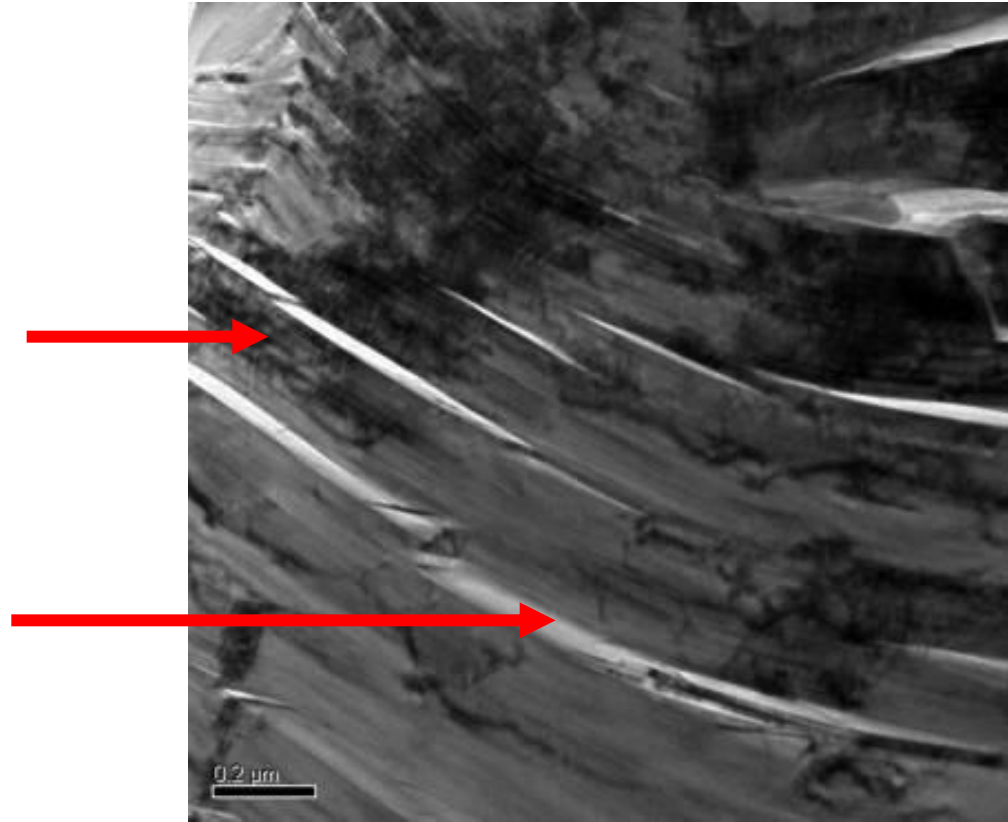
(Image Abbie Jones)

Graphite Microstructure

Crystallite Structure.

Crystal

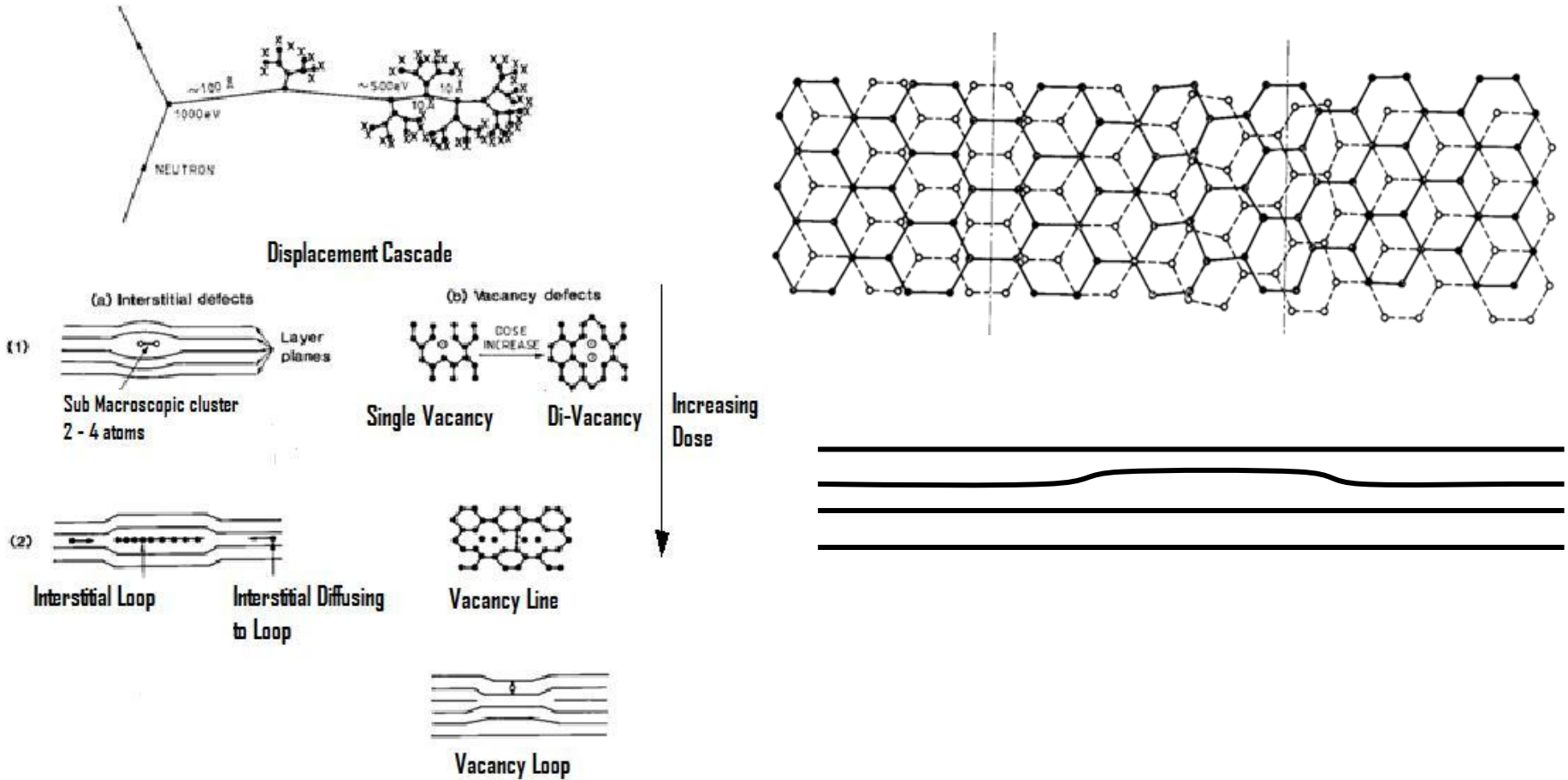
Mrozowski cracks



Crystallite Structure (Image Abbie Jones)

Damage mechanism

Fast Neutron Irradiation



Interstitial Layers

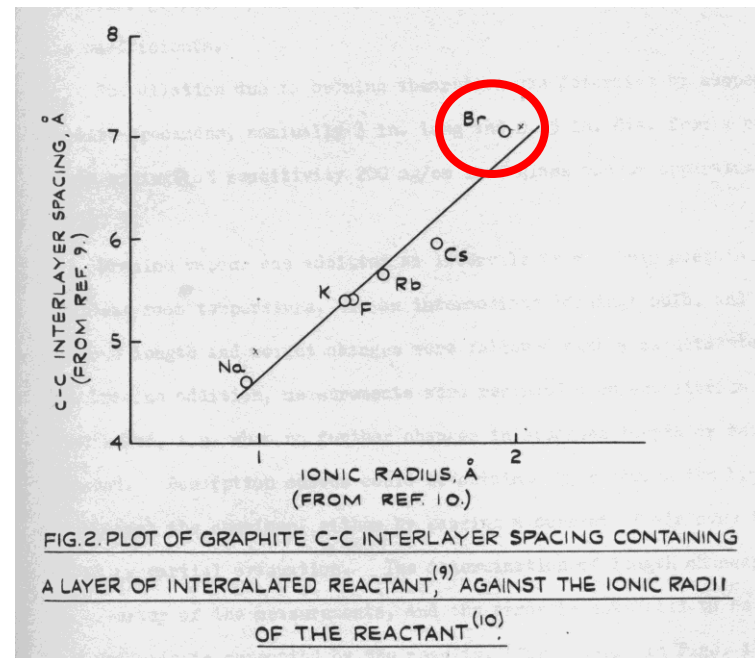
OR

Ruck Tuck & Buckle

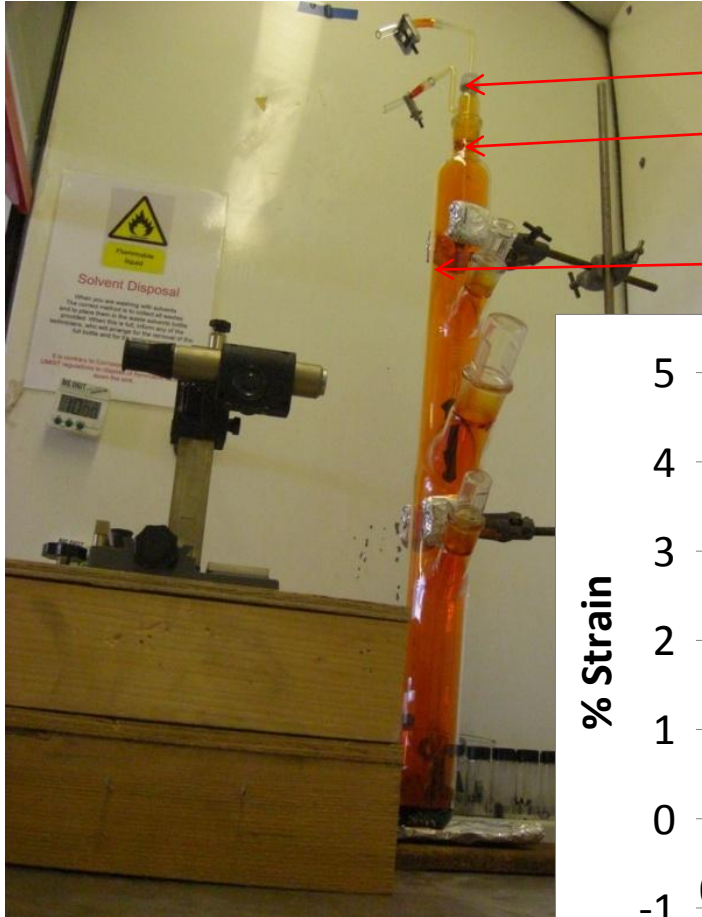
Bromination Experiments

Brockelhurst has shown that crystal strains of a similar magnitude to those produced through fast neutron irradiation can be induced through intercalation of foreign atoms to the graphite crystal structure.

Bromine was settled upon as the most suitable intercalate as it produces similar interlayer spacing to that produced by interstitial atoms.



Brocklehurst's Experiment



Experimental Rig

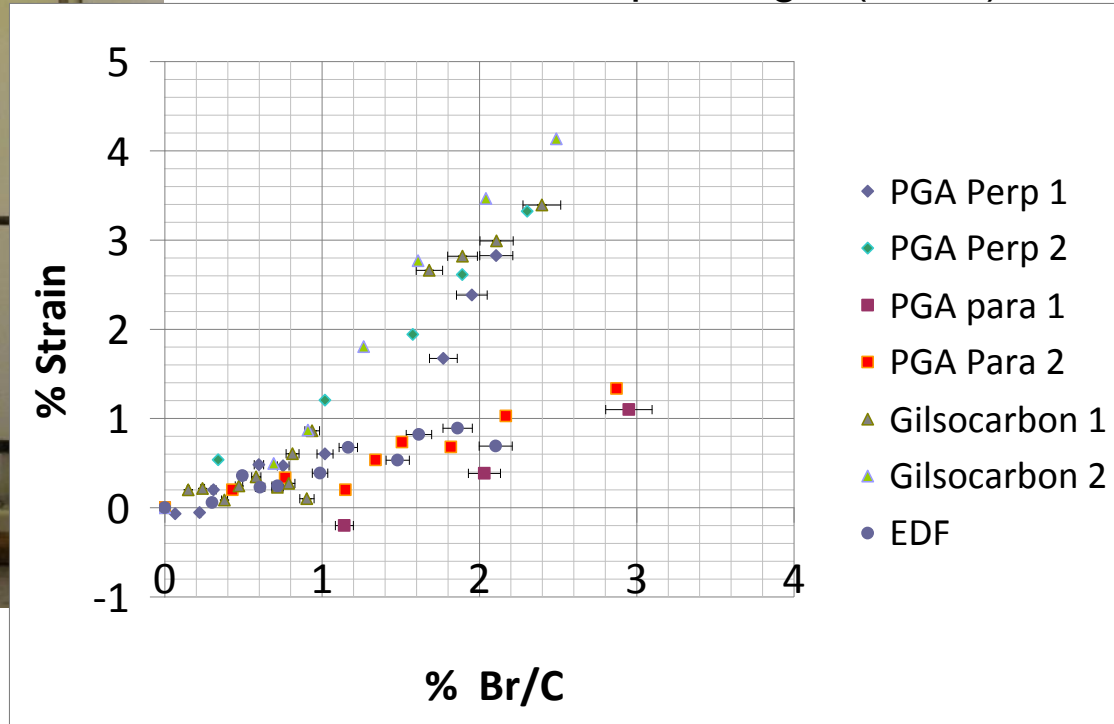
Bromine Atmosphere

75mm x 10Ømm Graphite Sample

Travelling Microscope Measure:

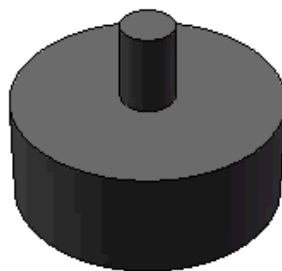
Δ spring length (mass)

Δ sample length (strain)



Strain due to Bromination

Experimental Rig



Graphite Sample: Area of interest $\text{\O}1\text{mm} \times 1.5\text{mm}$

PTFE: Reference point for position and density

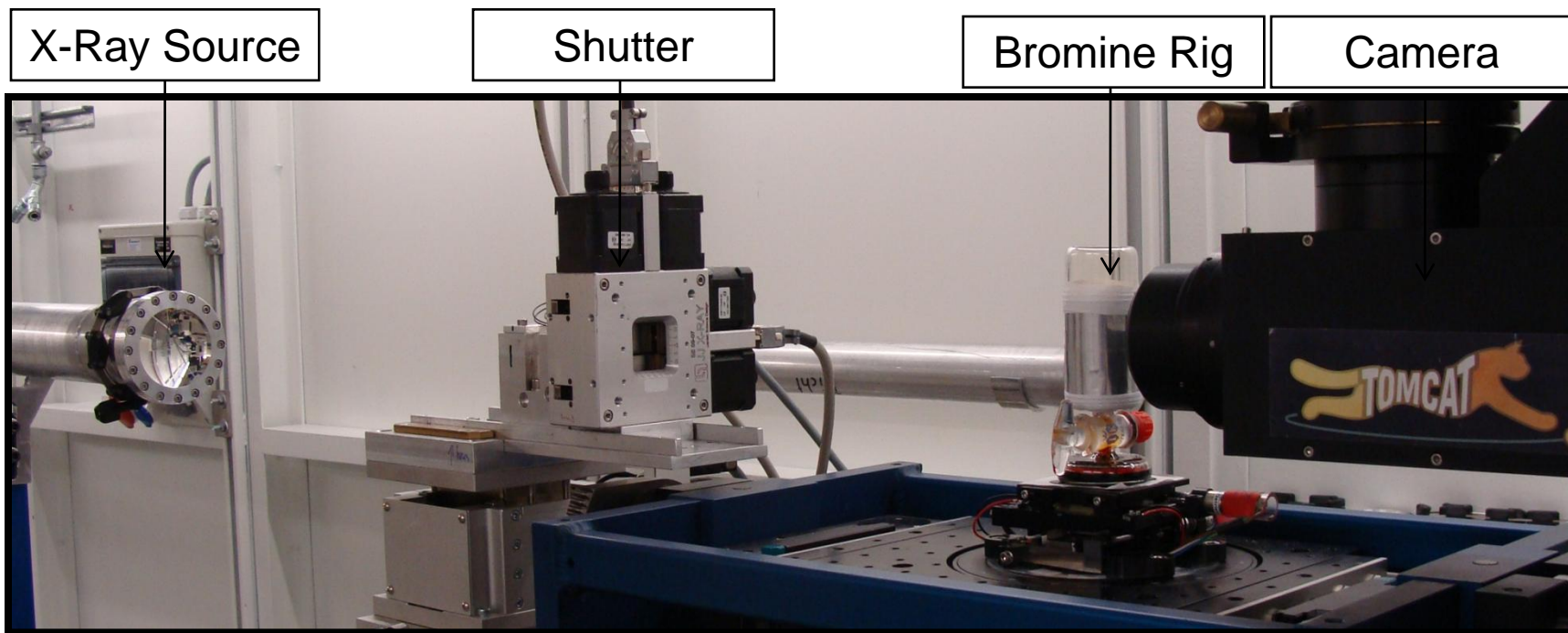
3 samples in rig to maximise usage of beam time

Case: PTFE coated Aluminium

Bromine Container: Custom glassware (must be less than 50mm)

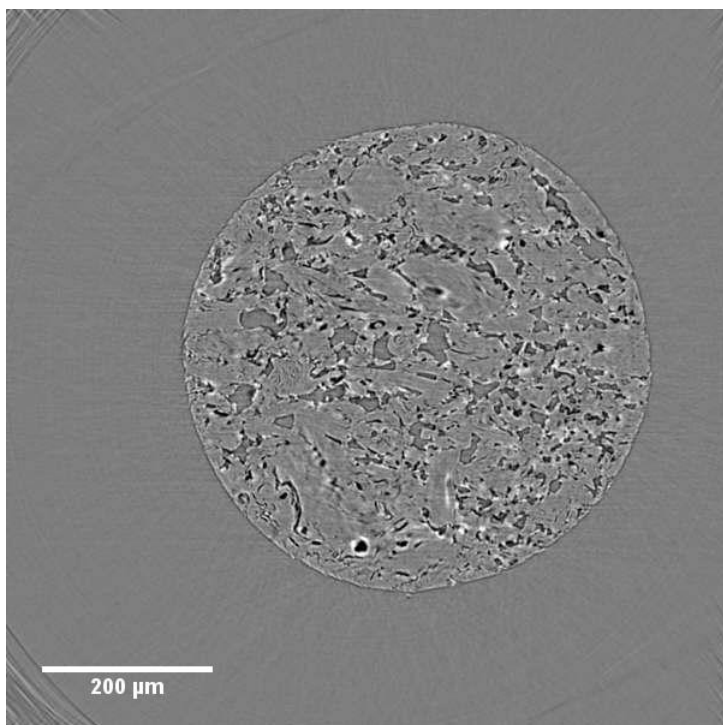
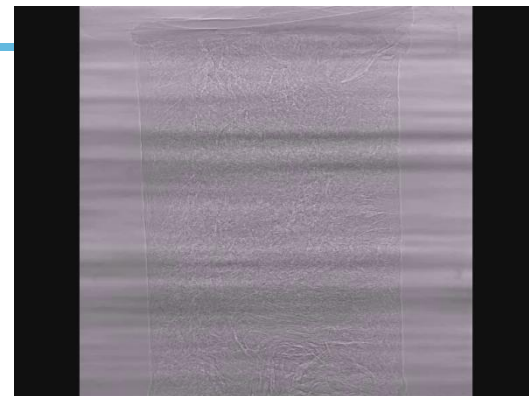
B40 Stopper

Experimental Setup

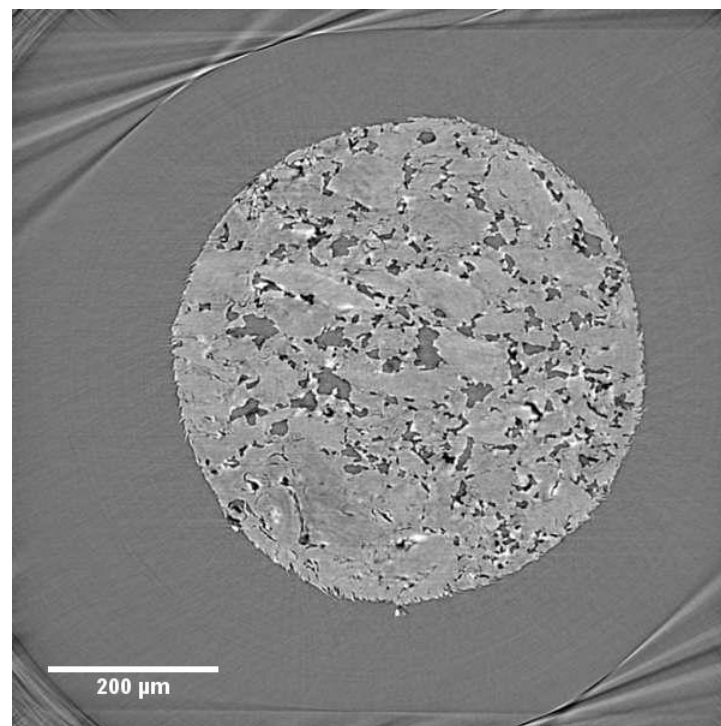


Beam Energy:	28KeV	(high)
Projections:	1501	(reduces noise)
CCD exposure time:	160ms	(fast)
Binning:	2 x 2	(reduces image resolution)

Results

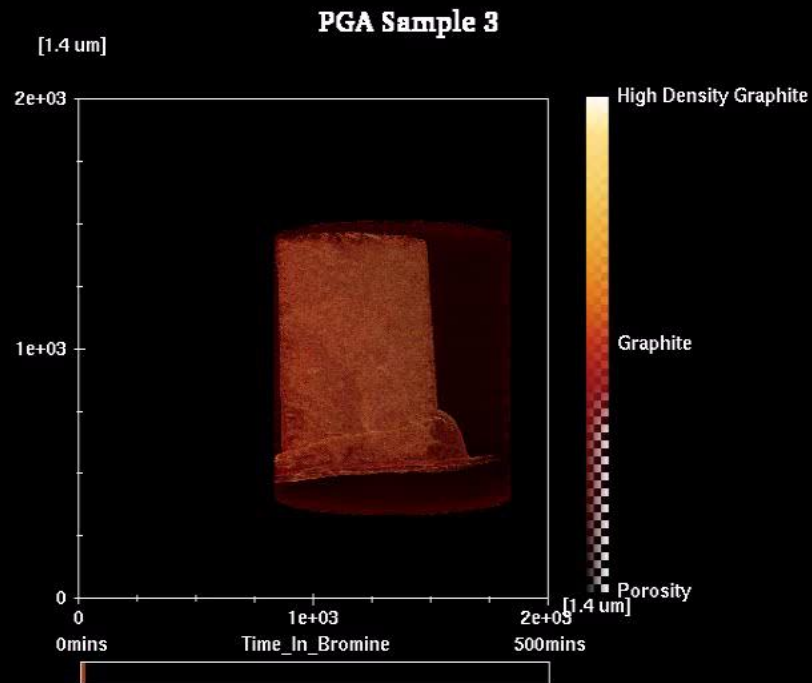
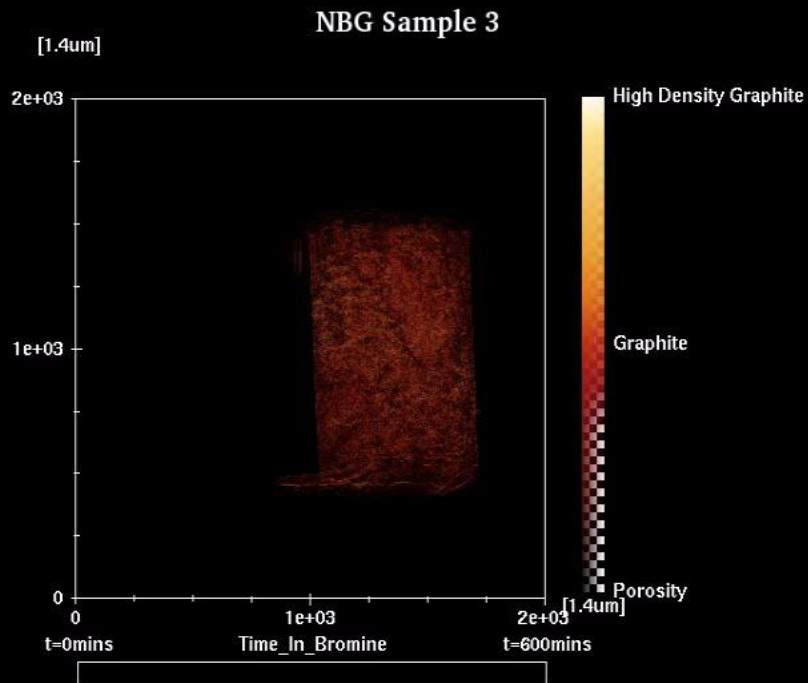


PGA slice $t=0$



PGA slice $t=500$

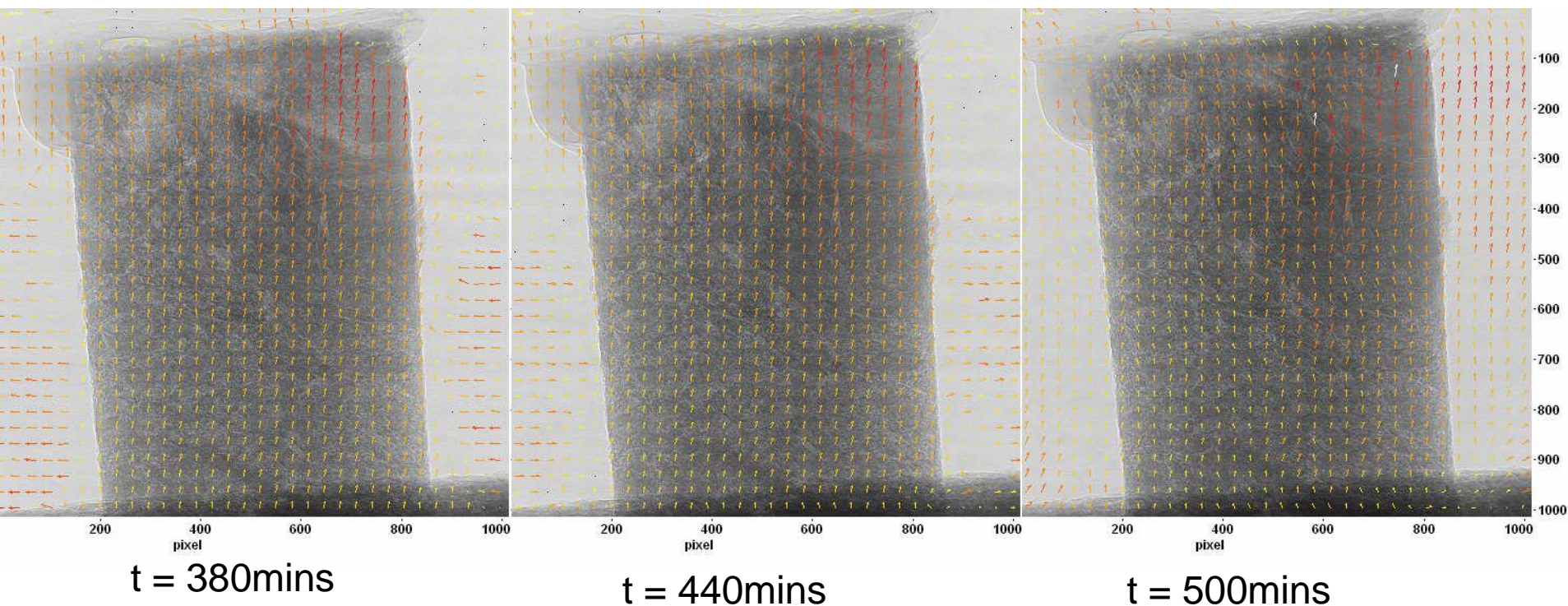
Visualisation of Bromination



PGA has a larger increase in density for two reasons;

- 1.) PGA has a larger surface area due to a higher percentage of open porosity
- 2.) PGA has larger regions of aligned crystalites which allows the bromine to travel in to the graphite quicker

Analysis by Image Correlation



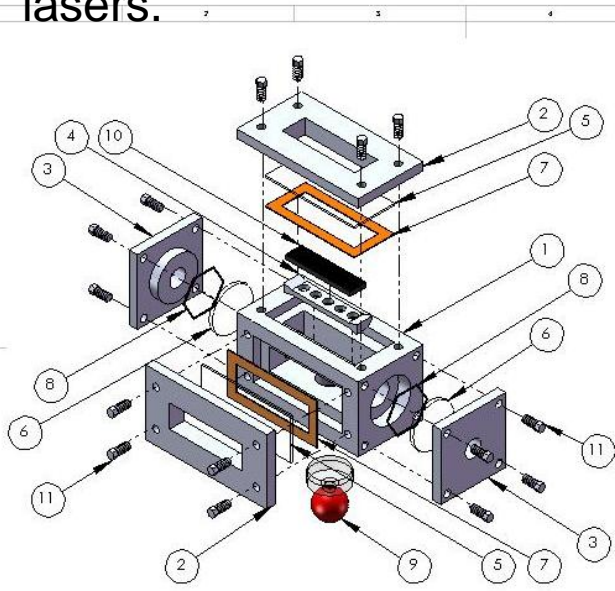
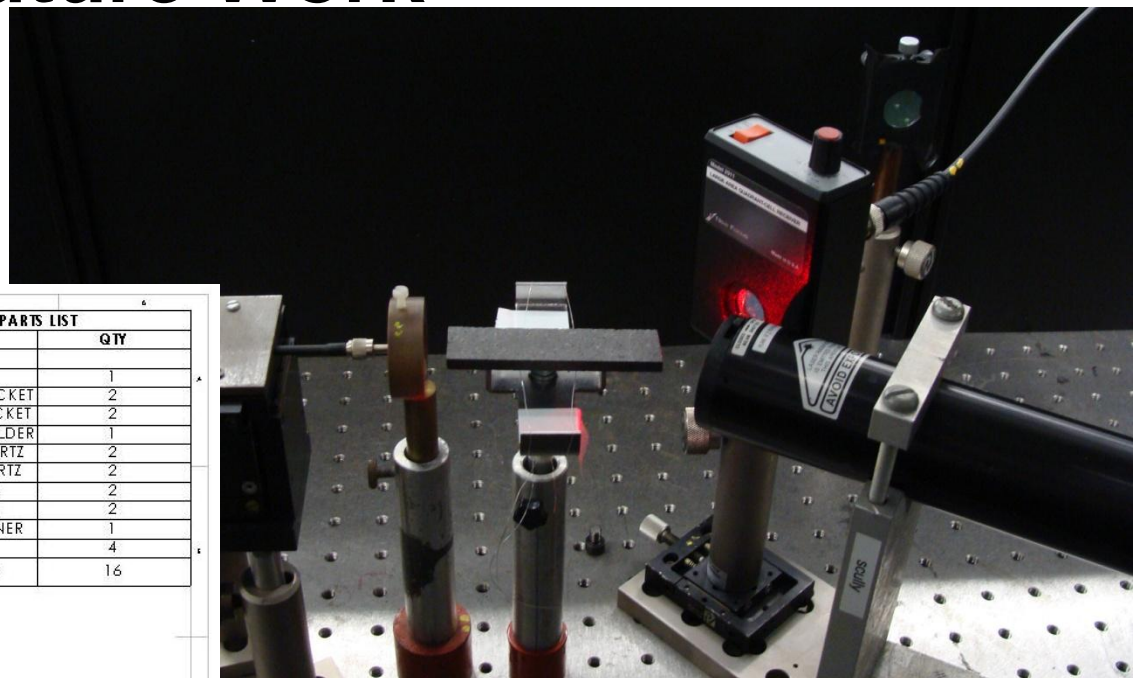
As the bromine is absorbed, the strain is increased.
Regions of aligned crystalites experience high strain rates

Conclusion

- We have successfully built a rig which has given an insight into microstructural damage due to bromination.
- The development of internal strains is influenced by the microstructure;
 - The size and layout of the open porosity
 - The degree of alignment of the crystallites
- Initial analysis using Digital Image Correlation indicates that higher levels of strain are experienced in the filler particles

Future Work

Initial Stages of an experimental rig designed to measure the change in Young's Modulus of Brominated Graphite using lasers.



PARTS LIST	
PART	QTY
P1 BASE	1
P2 LARGE BRACKET	2
P3 SMALL BRACKET	2
P4 SAMPLE HOLDER	1
P5 LARGE QUARTZ	2
P6 SMALL QUARTZ	2
P7 LARGE SEAL	2
P8 SMALL SEAL	2
P9 BR CONTAINER	1
P10 SAMPLE	4
P11 M8 SCREW	16

EXPLODED DIAGRAM PHASE 1 OF YOUNG'S BR RIG
SCALE 1 : 3
LEWIS LUYKEN 62603 (15 JULY '09)



Thank You

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University of Manchester

University of Manchester

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