Characterisation for powdered-polymer Additive Manufacturing

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MAPP Hub

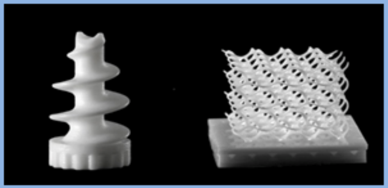
- Manufacture using Advanced Powder Processes
  - £20 million research hub, (£10 million funding from EPSRC, £7 million industrial support, over £3 million from collaborating universities)
  - Overall aim to enable Advanced Powder Processes to live up to their potential…
  - See https://mapp.ac.uk/ for details

Input

Designed for process

Process

Monitored
Dynamic control via machine learning



Output

Designed
Quality built in

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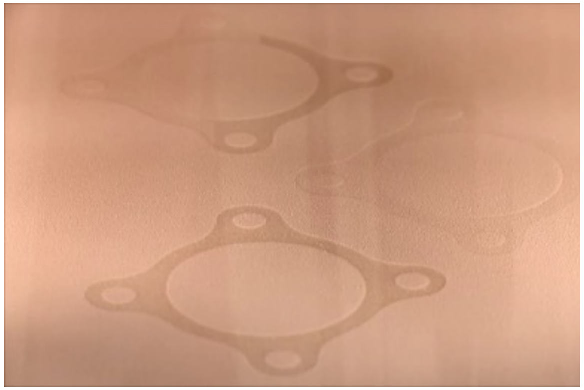
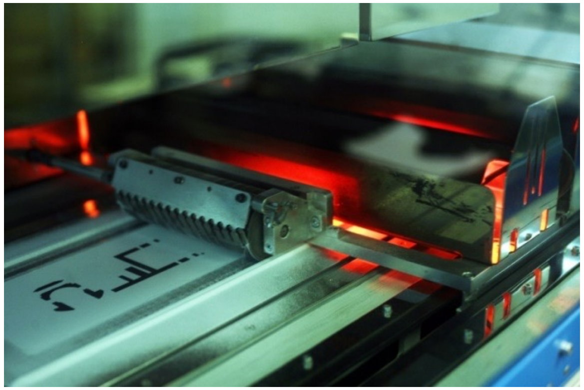
Advanced Polymer Sintering laboratory

- Major focus on powdered polymer Additive Manufacturing
  - Laser Sintering, High Speed Sintering & others
  - Process and material developments
  - Understanding of interaction between process and material



Laser Sintering
Parts built by selectively scanning and sintering cross-sections of powdered material



High Speed Sintering
Required cross-section ink-jet printed with a Radiation Absorbing Material, then sintered using an infra-red lamp

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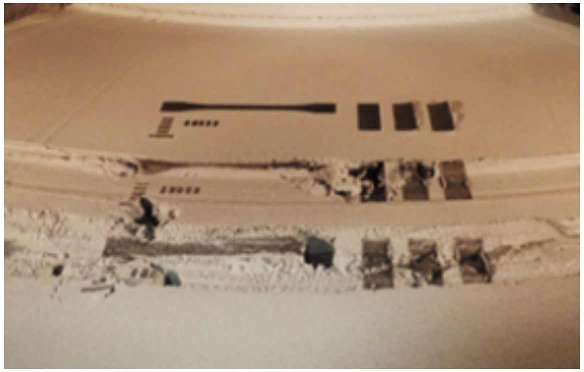
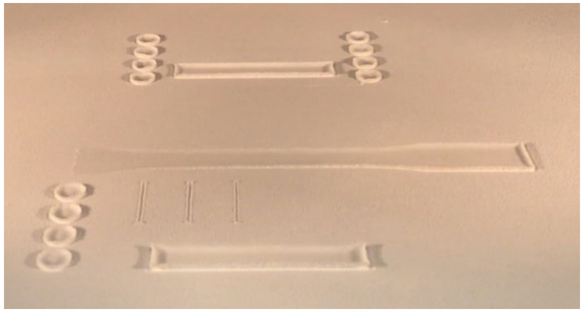
Interaction between material and process

- We want to know how our powders and processes interact, and what effect do these interactions have on the resultant parts?
  - Need to process a wider range of materials, more efficiently, and more repeatably...
  - We can't do this until we understand exactly what's going on!





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Where do characterisation techniques come in?*

*Spoiler alert… Pretty much everywhere!

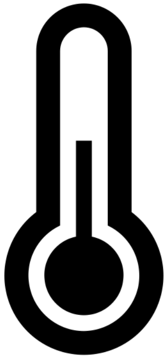
Powder deposition

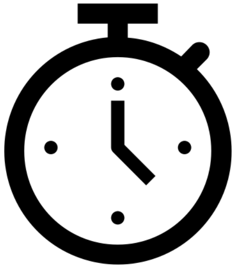
- A crucial stage… without a smooth, well-packed powder base to start with, we can end up with parts which have:
  - Low density
  - Poor accuracy/surface finish
  - Over-exposure of certain areas of parts (non-homogenous parts)

- We might want to characterise:
  - Particle size and size distribution
  - Particle shape
  - Powder flow
  - Moisture content
  - Static
  - Etc

Parameter setting

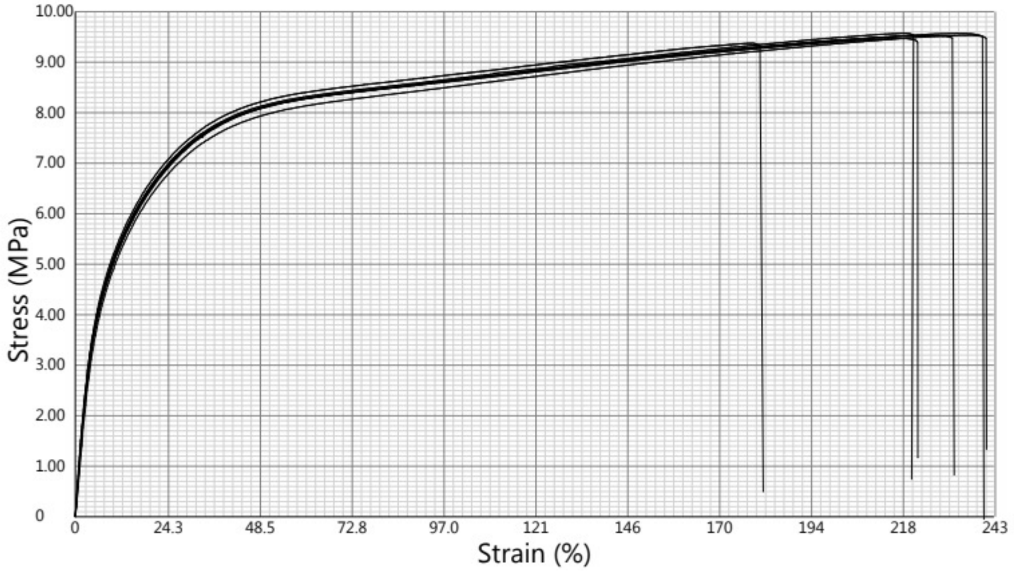
- How can we determine the ‘best’ parameters to process a given material?
  - How much energy does it take to melt the material?
  - How quickly will particles fuse together?
  - What pre-heat temperatures should we use?
  - At what point will we start to damage or degrade our material?
  - What sort of cooling regime do we need?





Analysing part structure and quality

- What's going on in our parts?* For example:
  - Mechanical properties
  - Microstructure
  - Porosity
  - Flame retardance
  - Fatigue life
  - Etc., etc.



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* (Very dependent on intended application)

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A couple of specific examples

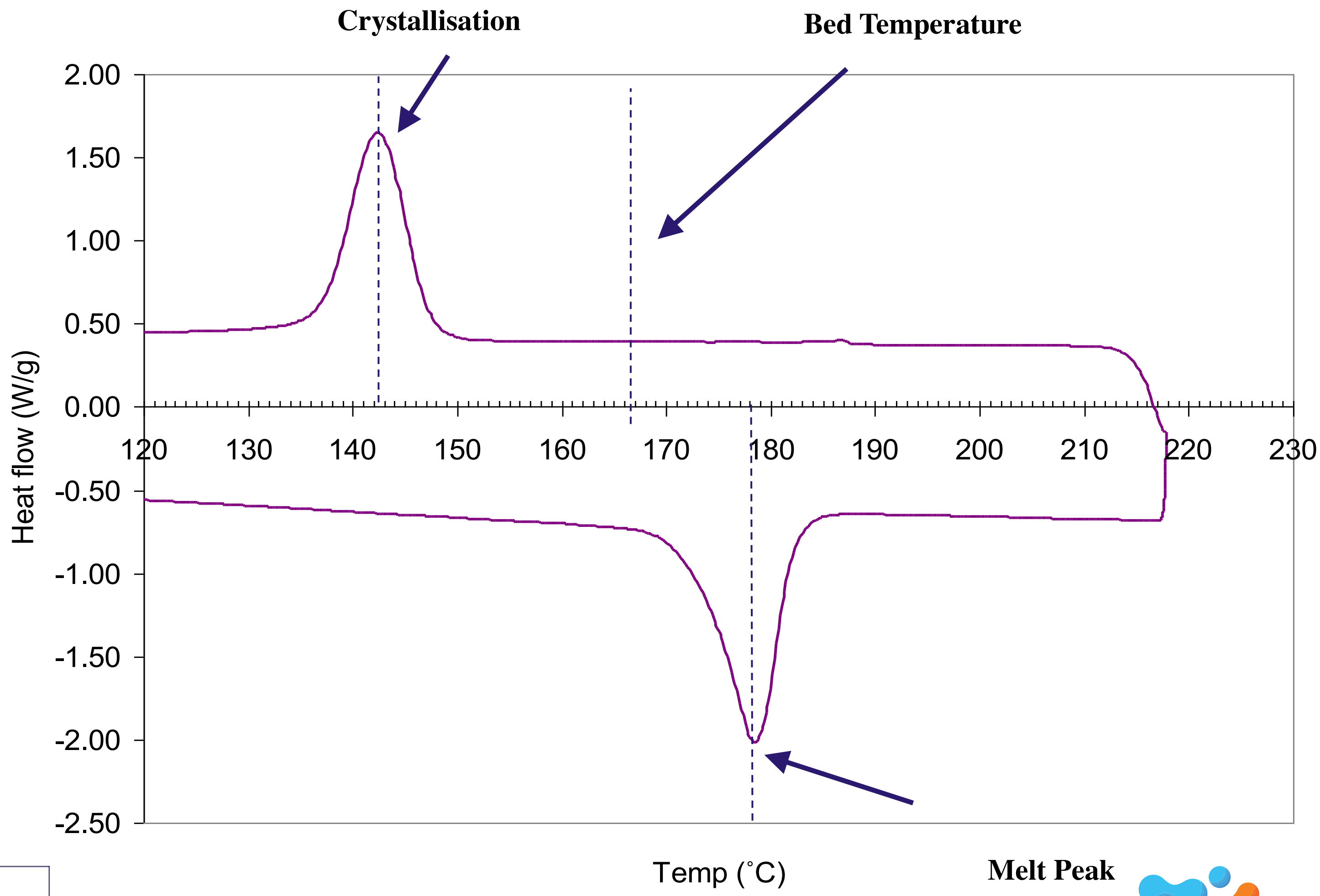
(Please ask about others if you're interested)

Differential Scanning Calorimetry

- Thermal analysis technique
  - Measure difference in heat flow between a sample and a known reference, with respect to time and temperature
  - For example, if we heat this reference sample at a certain rate, how much energy do we need to put into our test sample to match this?

- Useful for…

Differential Scanning Calorimetry – choosing sintering parameters



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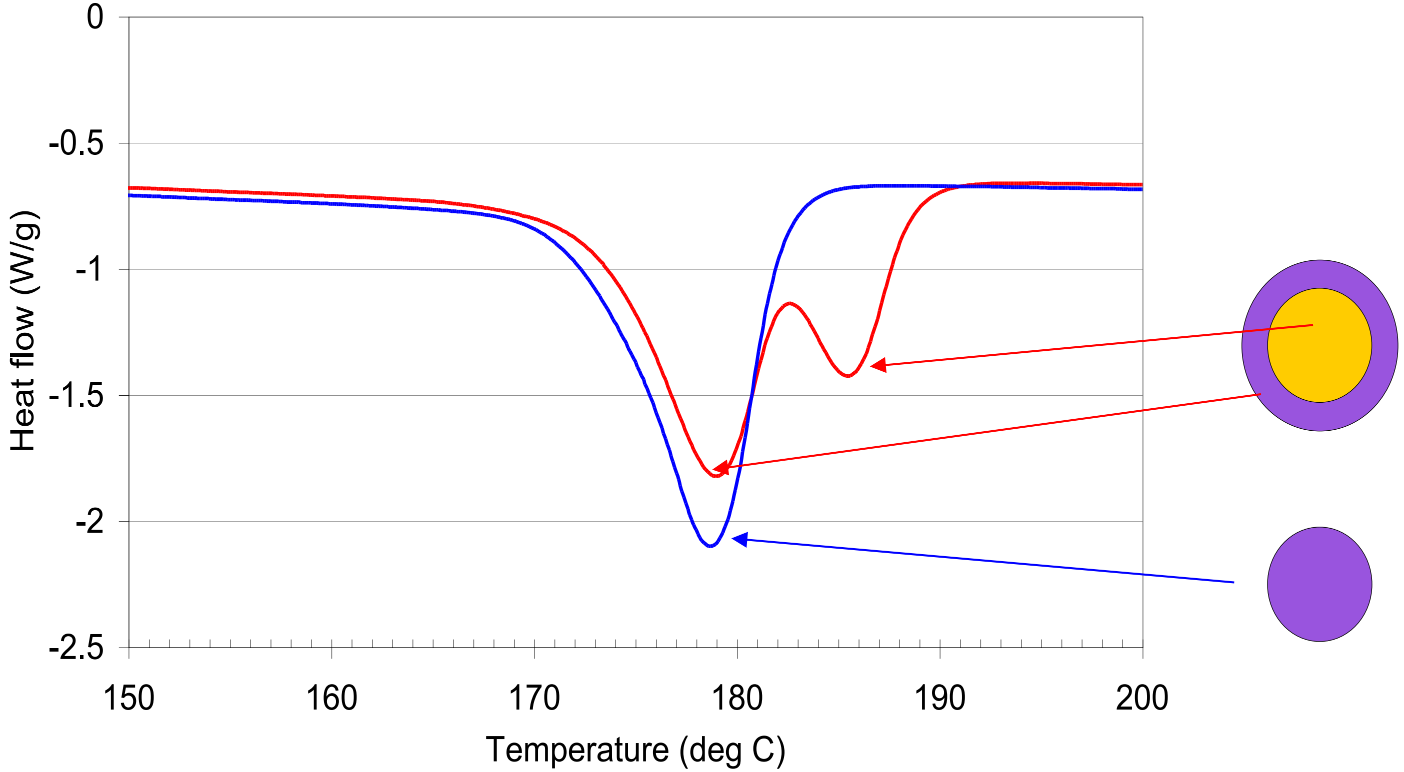
Differential Scanning Calorimetry – microstructure of parts



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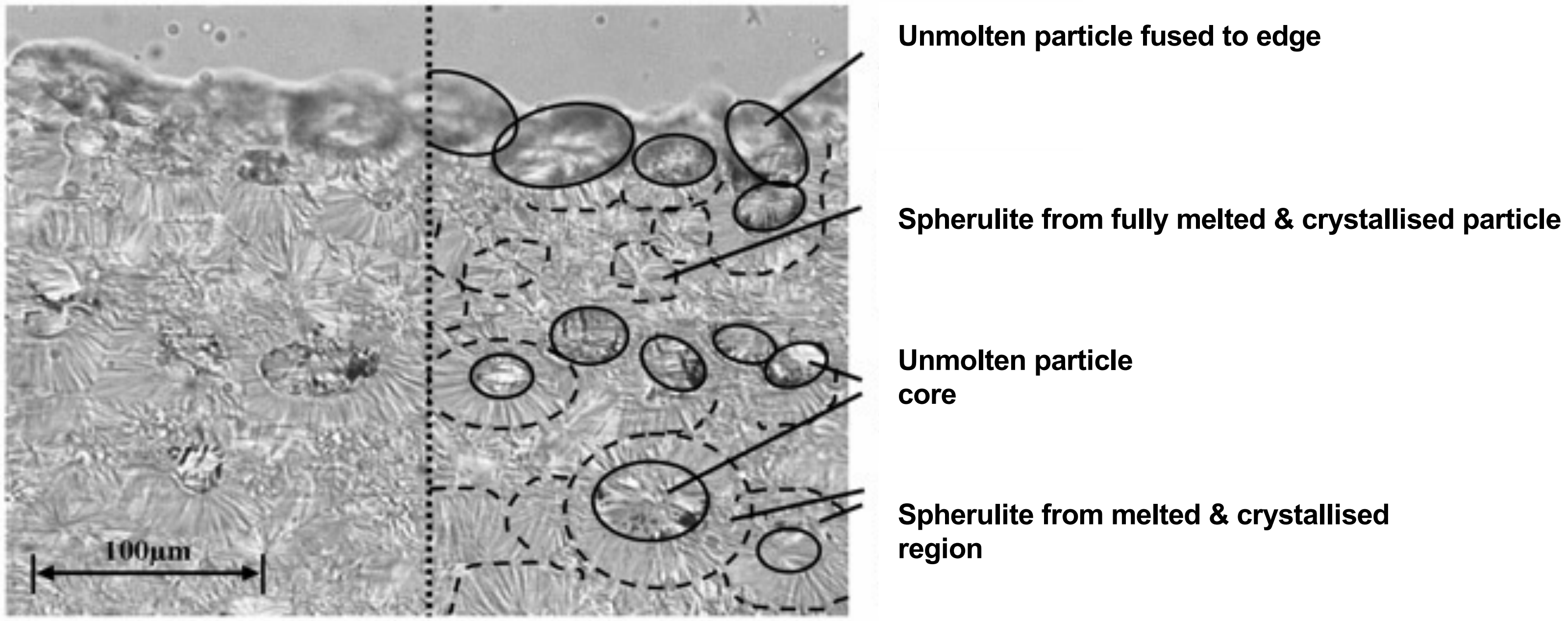
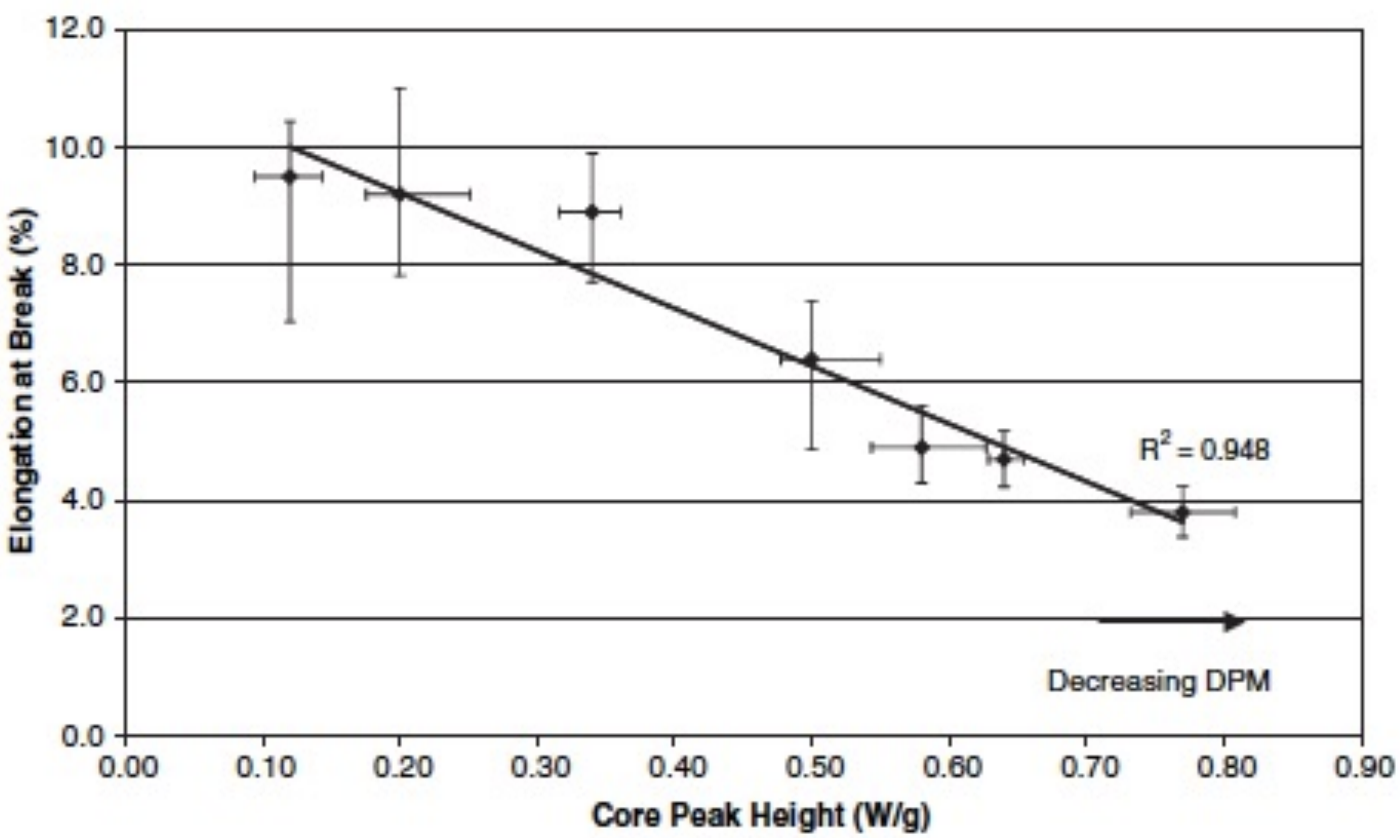
Differential Scanning Calorimetry – microstructure of parts

- What this shows us…
  - Parts are often comprised of regions with varying proportions of melting.



Zarringhalam, H., Hopkinson, N., Kamperman, N.F., de Vlieger, J.J., 2006, Effects of processing on microstructure and properties of SLS Nylon 12, Materials Science and Engineering A, Vol. 435-436, pp 172-180, ISSN 0921-5093

Differential Scanning Calorimetry – microstructure of parts



Majewski C, Zarringhalam H & Hopkinson N (2008) Effect of the degree of particle melt on mechanical properties in selective laser-sintered Nylon-12 parts.

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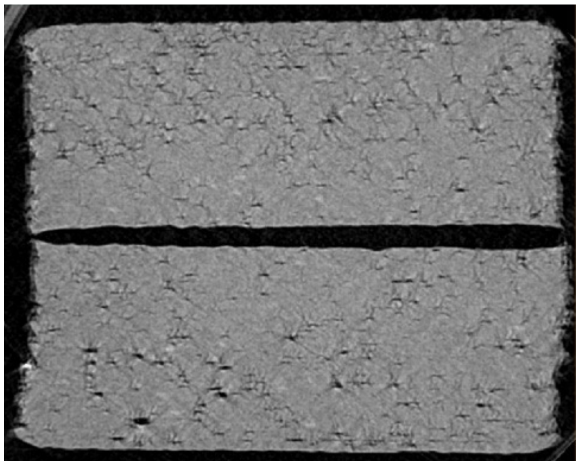
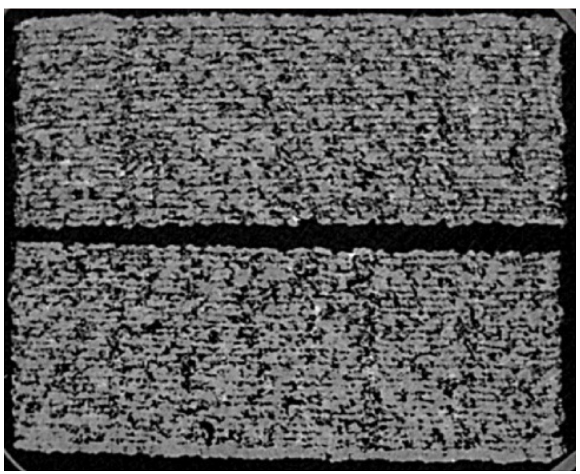
X-ray computer micro-tomography (Micro-CT)

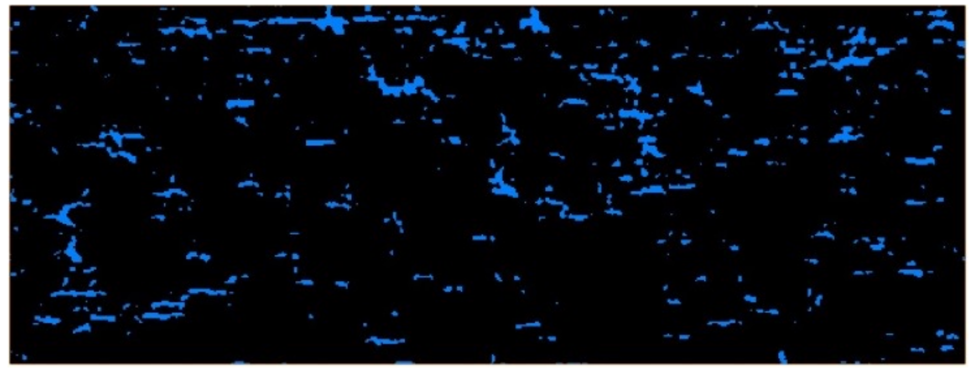
- A non-destructive 3D imaging technique
  - Can help in analysing the internal and external geometry of complex components

- Useful for…

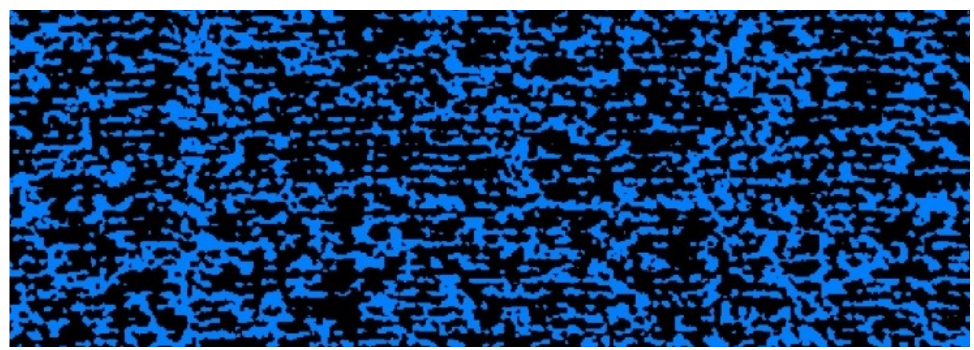
Micro-CT – understanding porosity





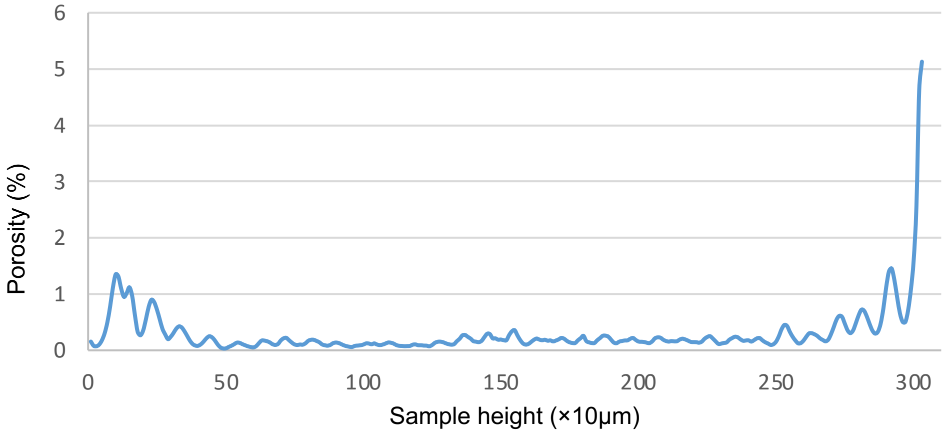


High energy - **Porosity: 6.79% (vol)**

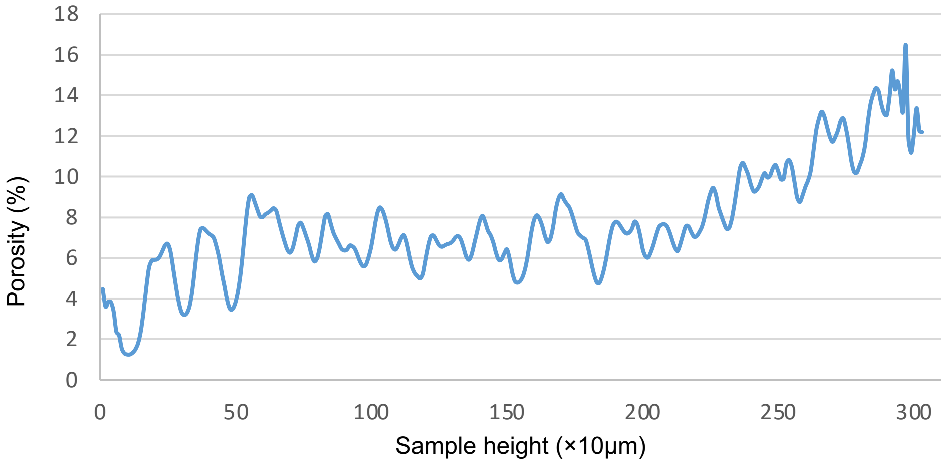


Low energy - **Porosity: 32.08% (vol)**

Micro-CT – understanding porosity



Higher energy - Porosity: 0.58% (vol)



Lower energy - Porosity: 7.36% (vol)

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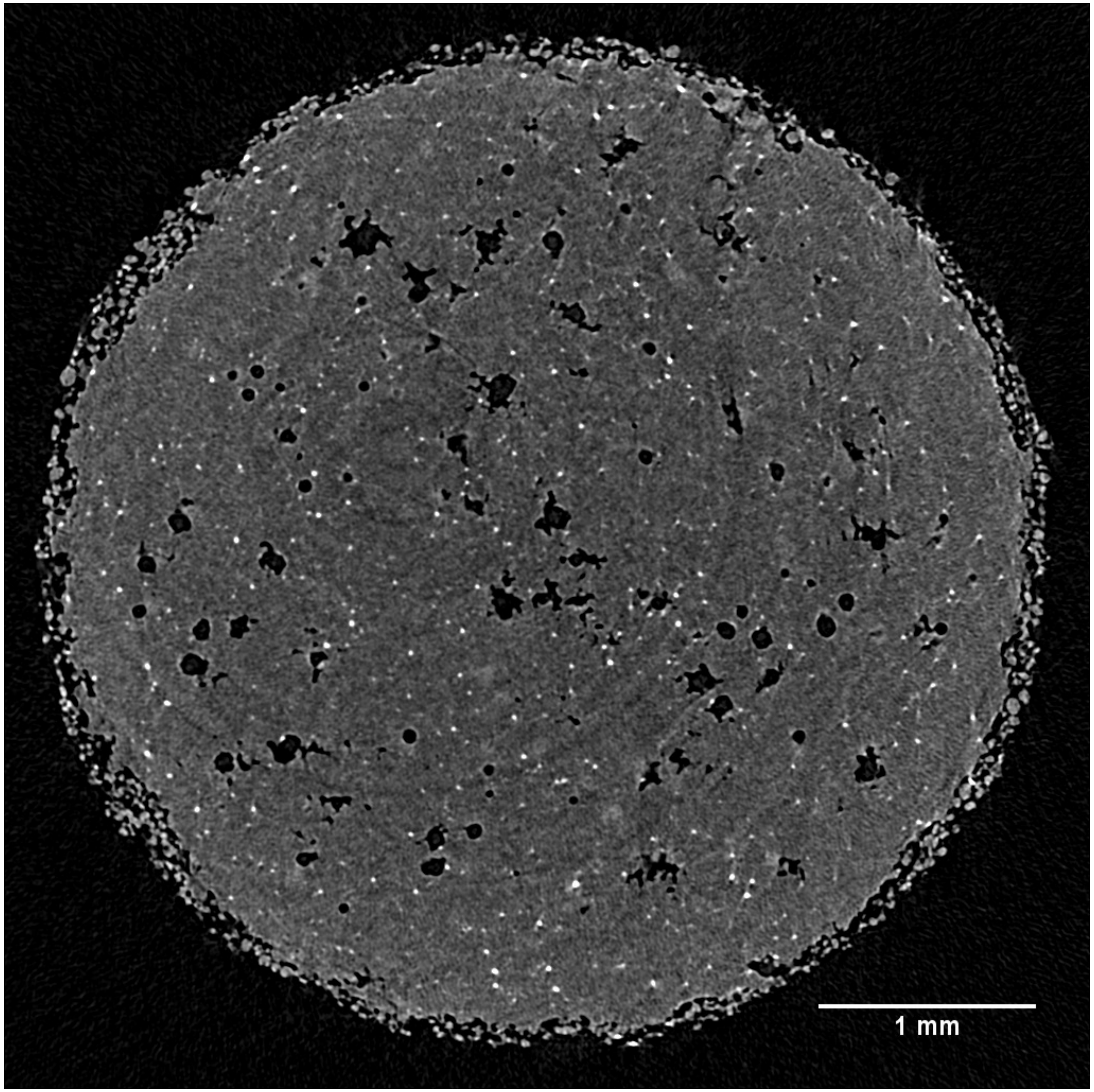
Micro-CT – homogeneity



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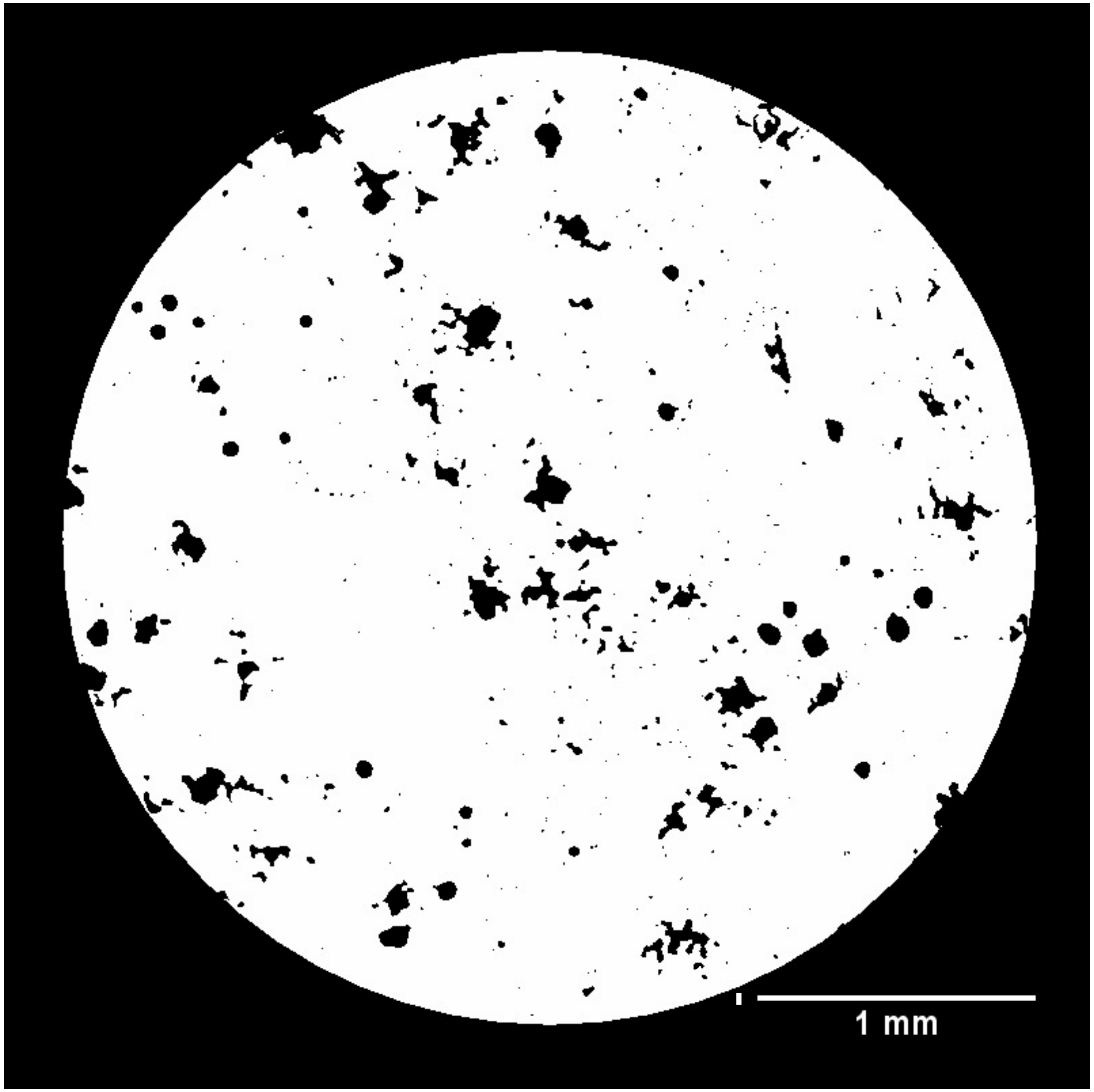
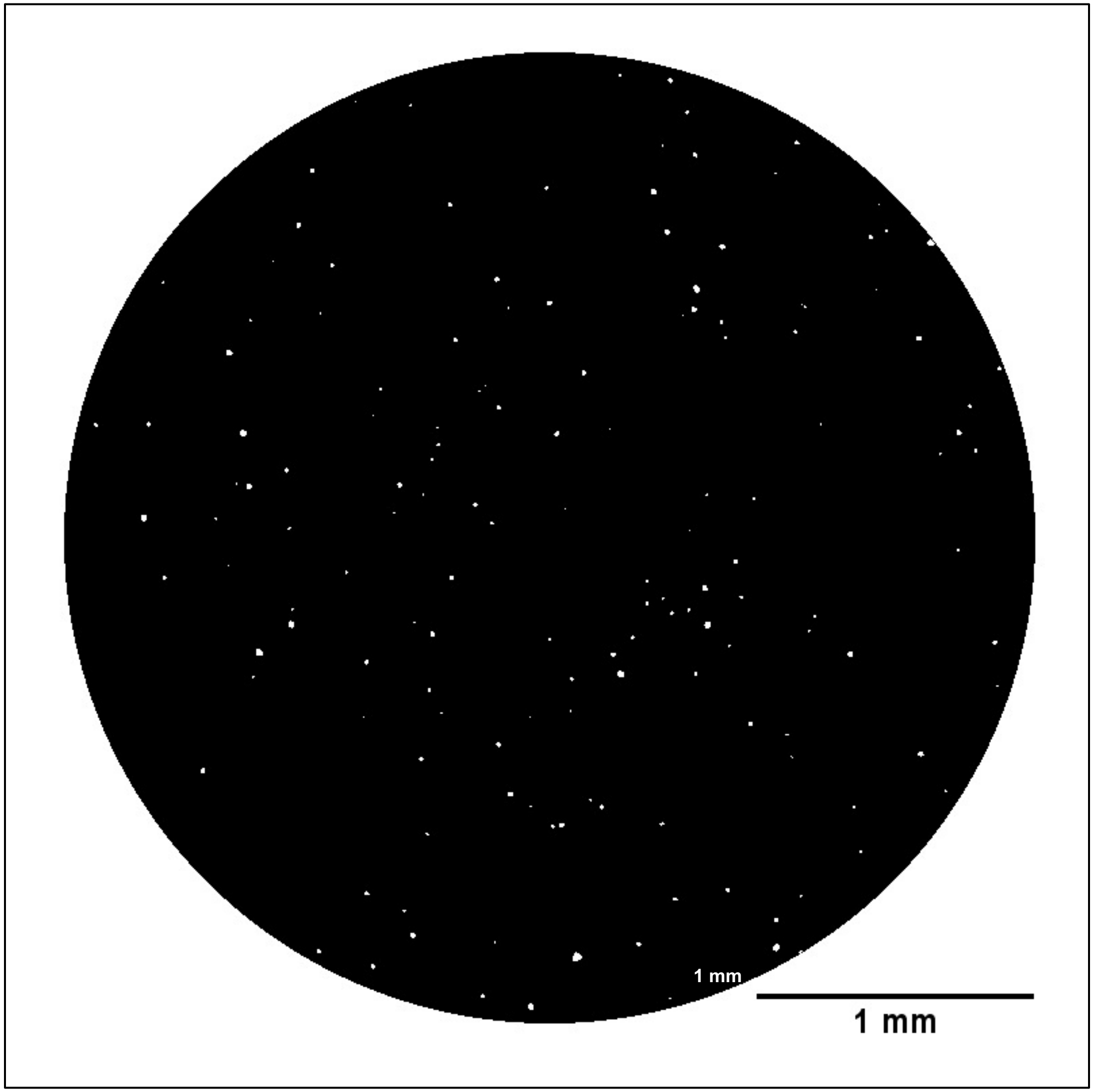
Micro-CT – homogeneity



Micro-CT – homogeneity



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Any Questions?

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