UK META MATERIALS NETWORK

UK Research and Innovation

EPSRC Pioneering research and skills

Adding Value in Healthcare with AM: From New Device Functions to Materials Discovery

Metamaterials for Health – Wolverhampton – 18th Sept 2024

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The BioHub BIRMINGHAM

MD-TEC
Medical Devices Testing and Evaluation Centre

HEALTHCARE TECHNOLOGIES INSTITUTE

BIRMINGHAM RESEARCH PARK

Birmingham Health Partners

Delivered by UNIVERSITY OF BIRMINGHAM

NHS University Hospitals Birmingham NHS Foundation Trust

NHS Birmingham Women's and Children's NHS Foundation Trust

BCTU
Birmingham Clinical Trials Unit

Birmingham Life Sciences Park

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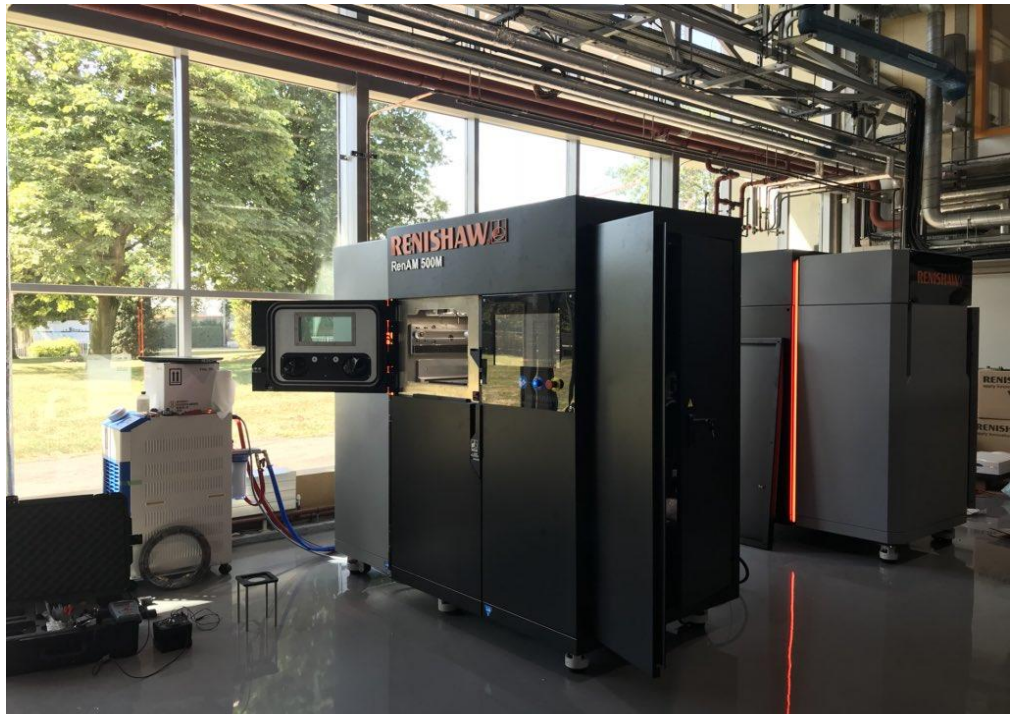
Birmingham Health Partners

HEALTHCARE TECHNOLOGIES INSTITUTE

RENISHAW apply innovation™

Bring together multidisciplinary expertise to explore the full potential of additive manufacturing in the medical devices sector



Laser Powder Bed Fusion

- RenAM 500S - Dedicated '*production style*' Ti-6Al -4V
- RenAM 500S - Reduced Build Volume for material development
- Process monitoring enabled on both

Not just a physical space…

- Strategic partnership with Renishaw PLC
- Support in research translation
- Emulate ISO 13485 Quality Management System

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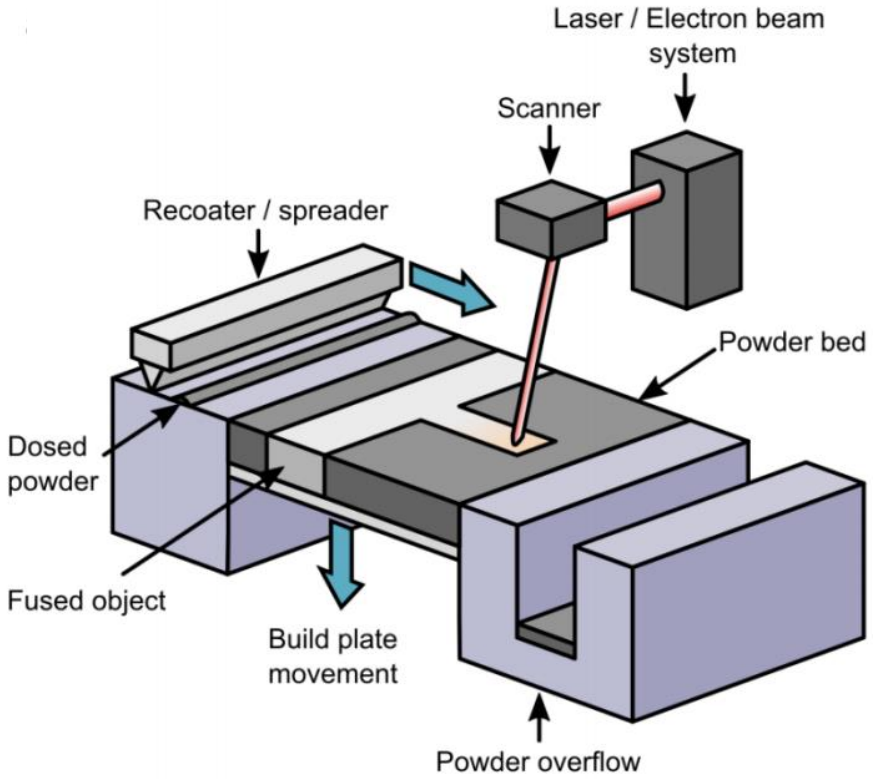
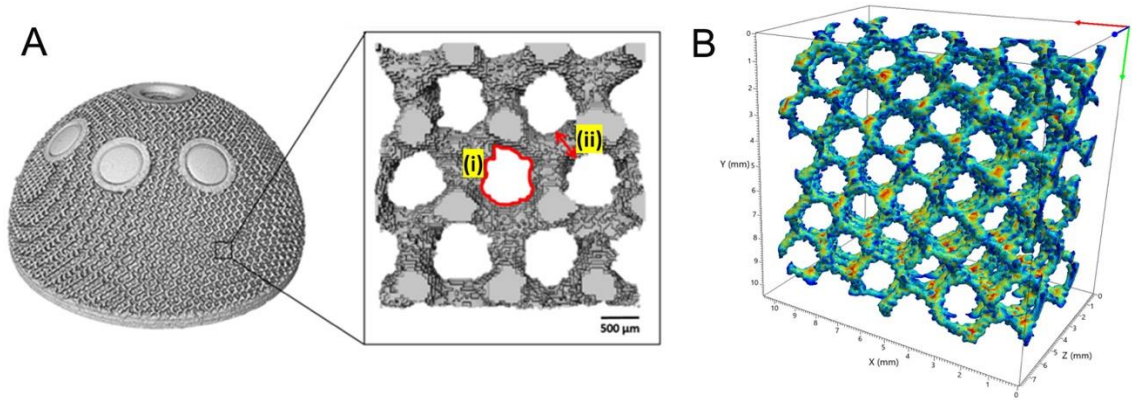
Metamaterial Structures made via Powder Bed Fusion (PBF)





Nicum, A *et al.*, EFORT Open Reviews, 2024

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Areas of Focus

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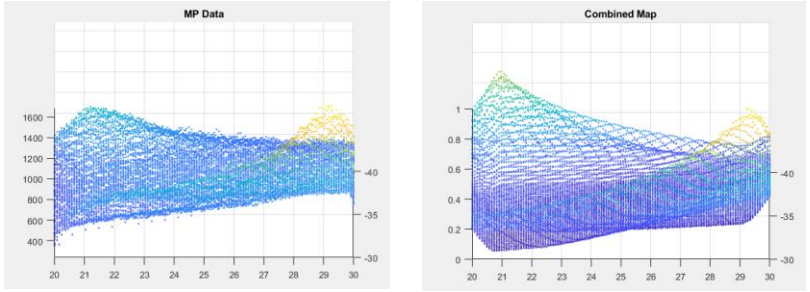
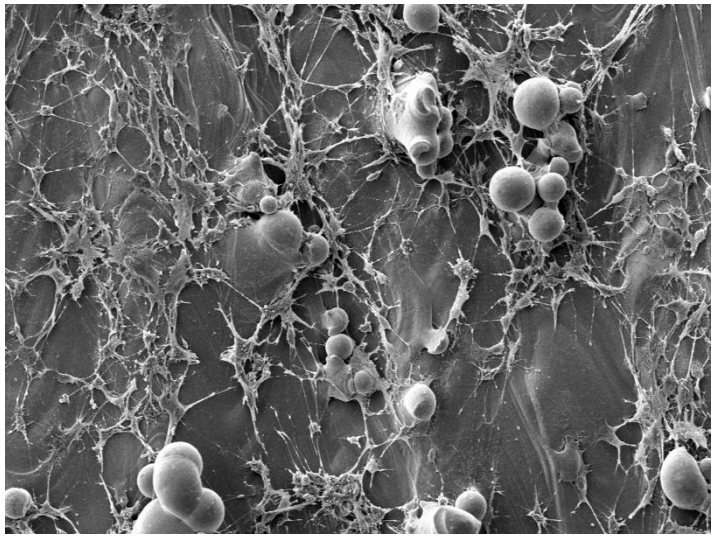
1. New Process Understanding



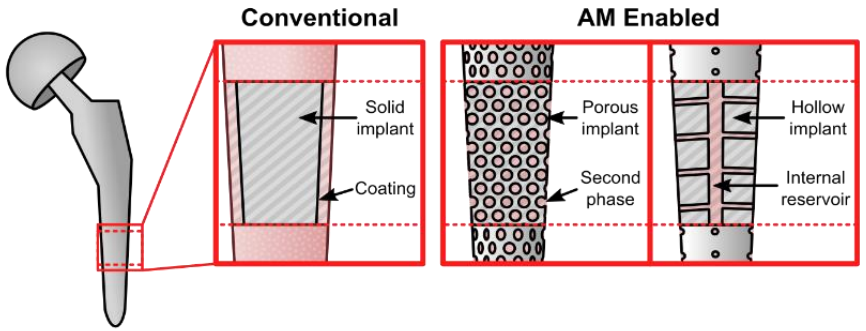
- Process monitoring
- Geometry optimisation

2. Surface Optimisation



- Characterisation
- Biological interactions

3. Adding Therapeutic Functionality



- Therapeutic loading
- Alloy development

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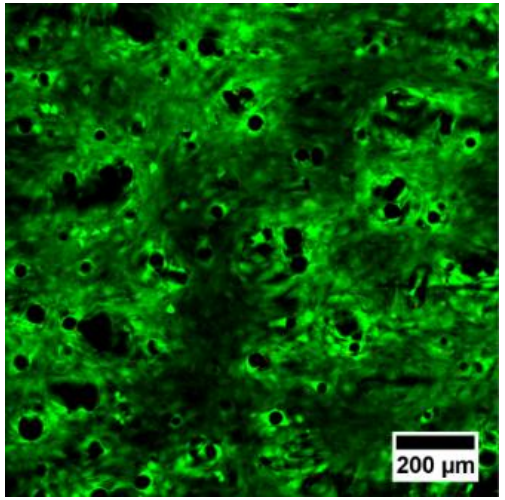
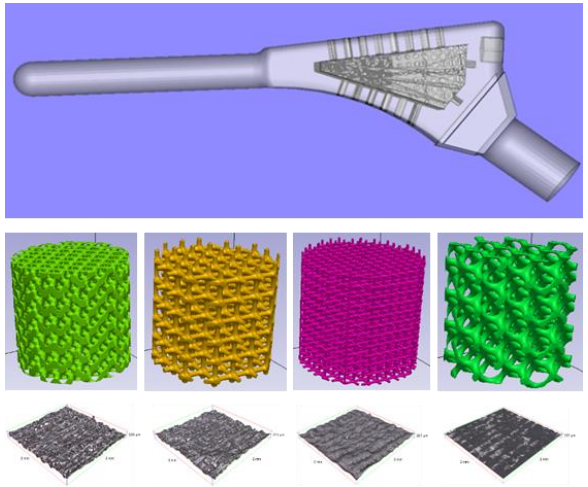
Case Studies

1. Importance of the Surface

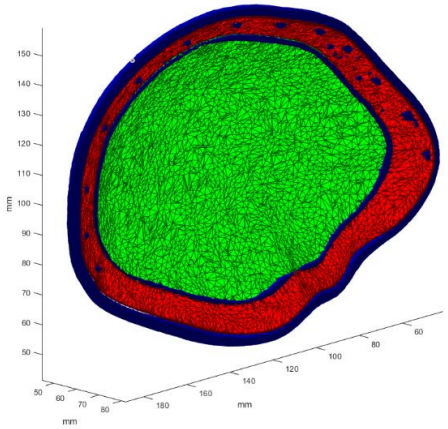


From understanding to optimising orientation and post-processing

2 & 3. Metamaterials to Add Implant Functionality

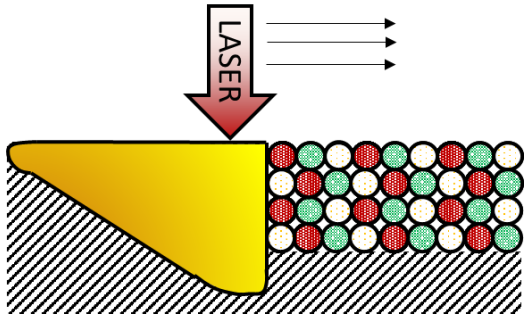


Incorporating injectable biomaterials



Facilitating post-operative imaging

4. In Situ Alloy Development



Transforming the philosophy of biomedical alloy design

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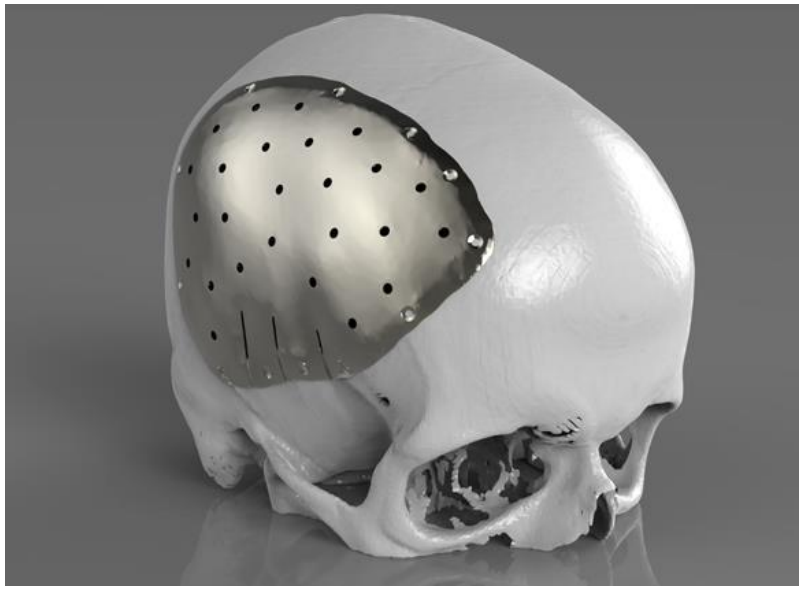
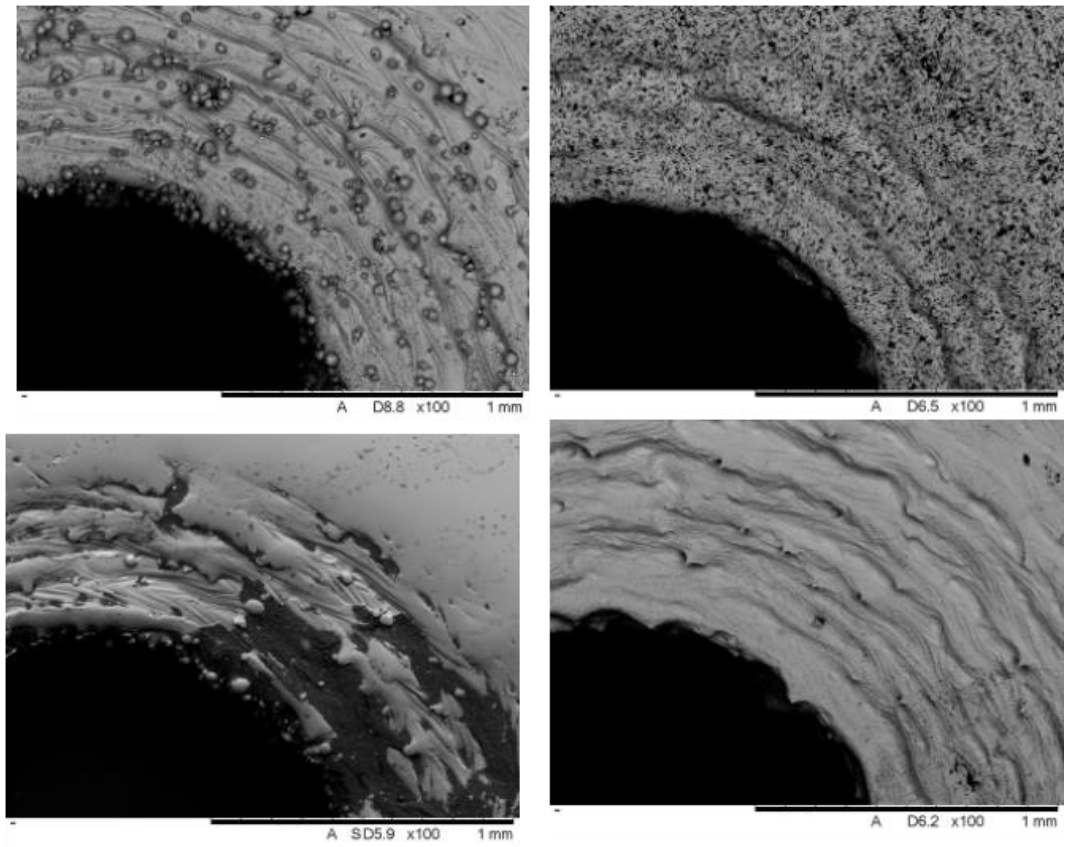
1. Importance of the Surface

Implant Design Features





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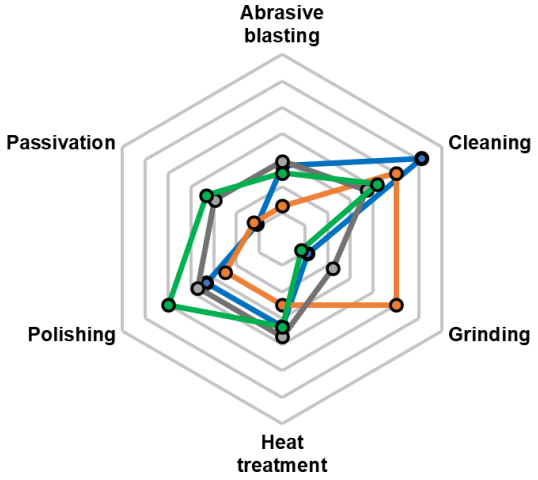
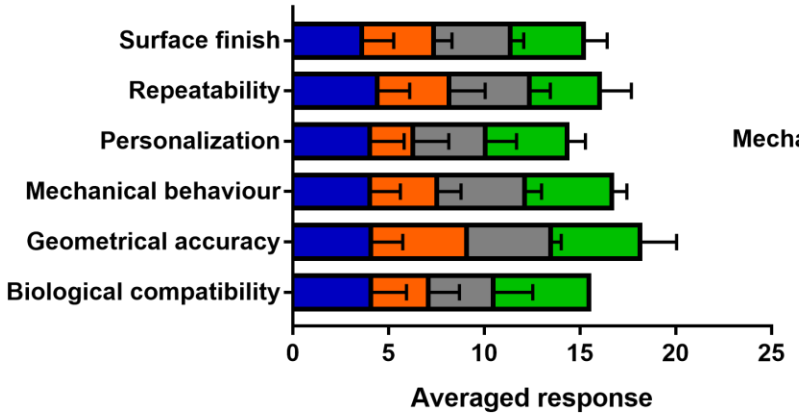
Influence of Surface Finishing

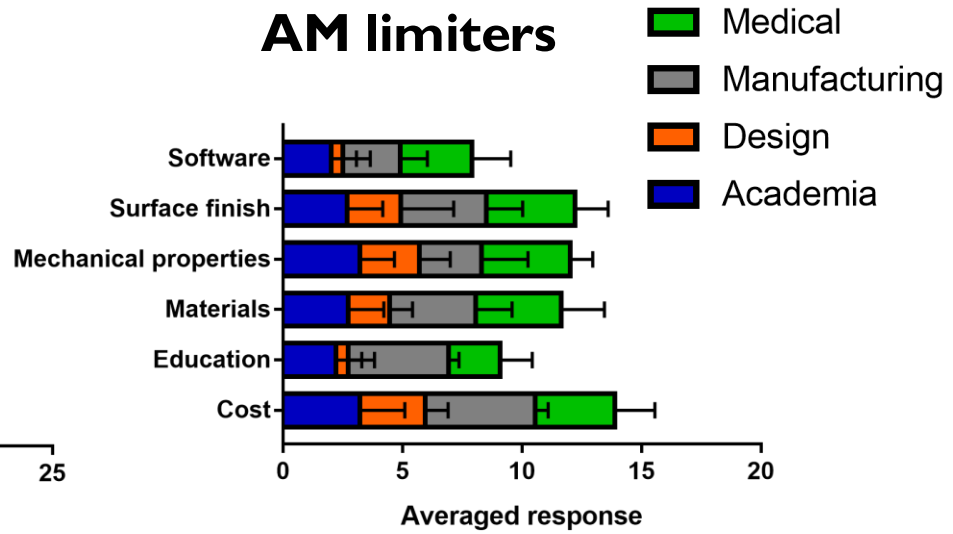
Post processing applied to AM parts



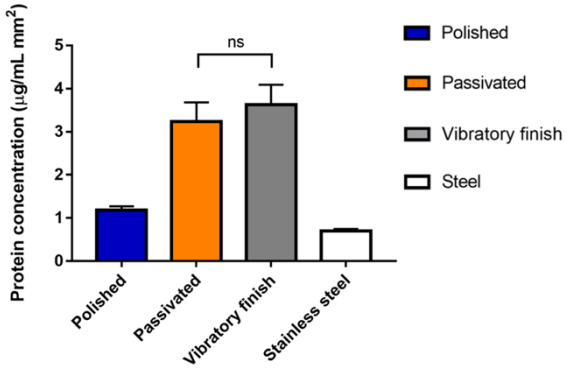
Requirements of a successful part

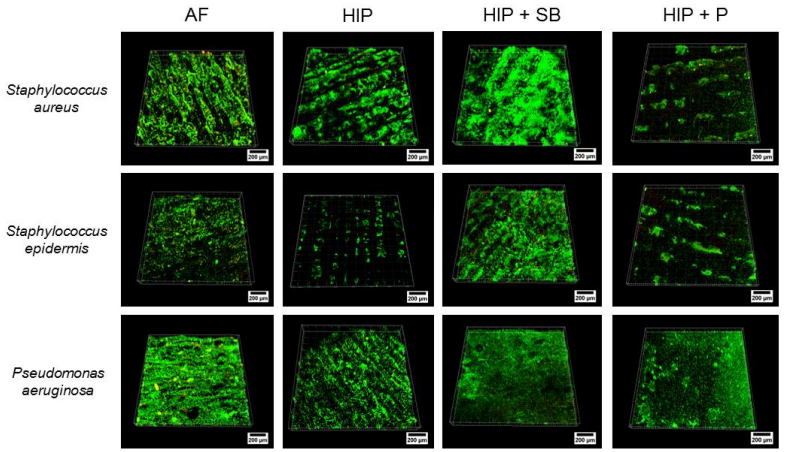


AM limiters



Biological Implications





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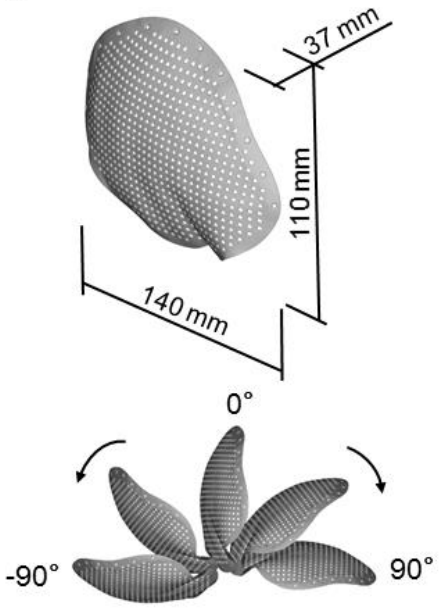
Villapun, V. M., *et al – Int J. Bioprinting 8(3), 2022*

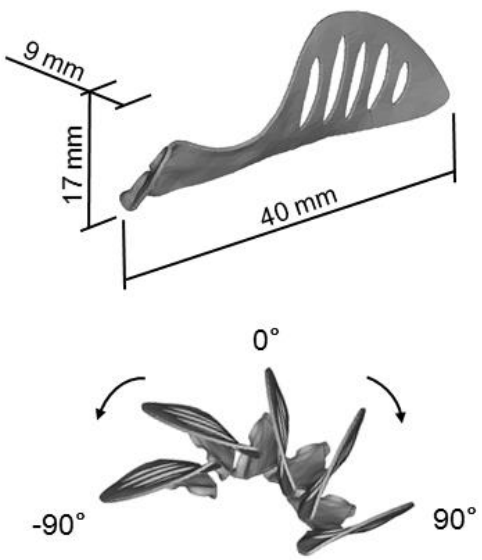
Villapun, V., *et al – ACS Biomater Sci & Eng* 10 (8), pg. 4311-4326, 2022

Tools to Support – Printing Orientation

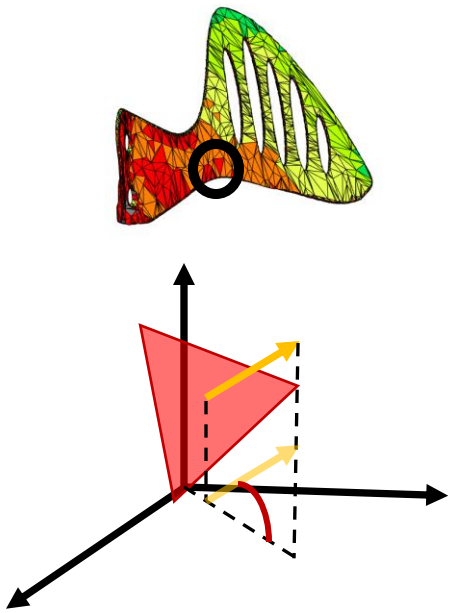
Cranioplasty

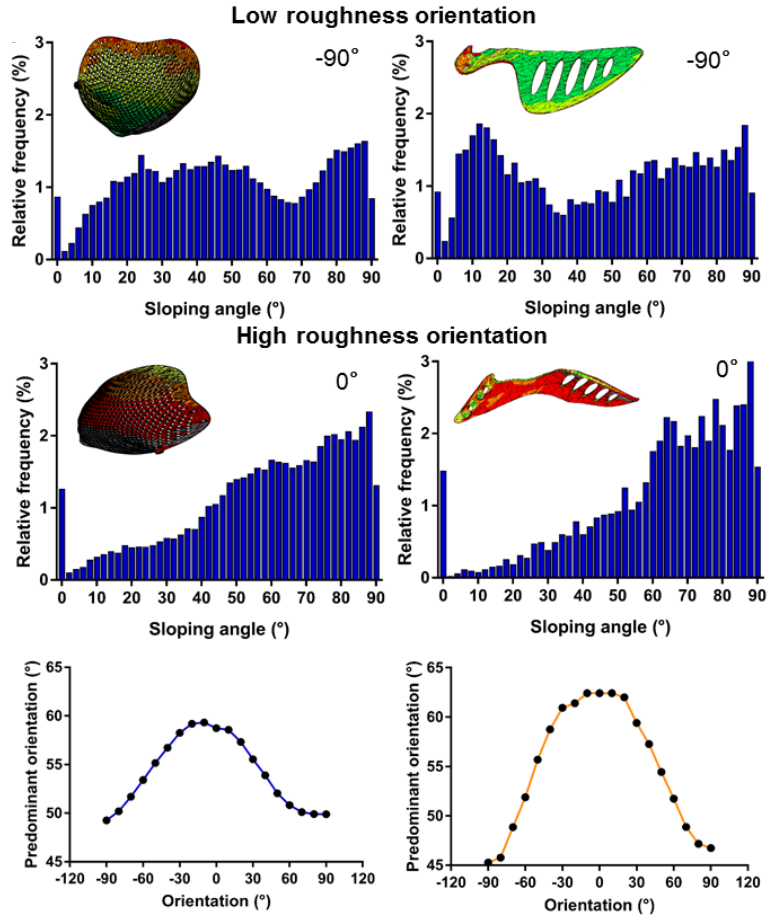


Orbital Floor



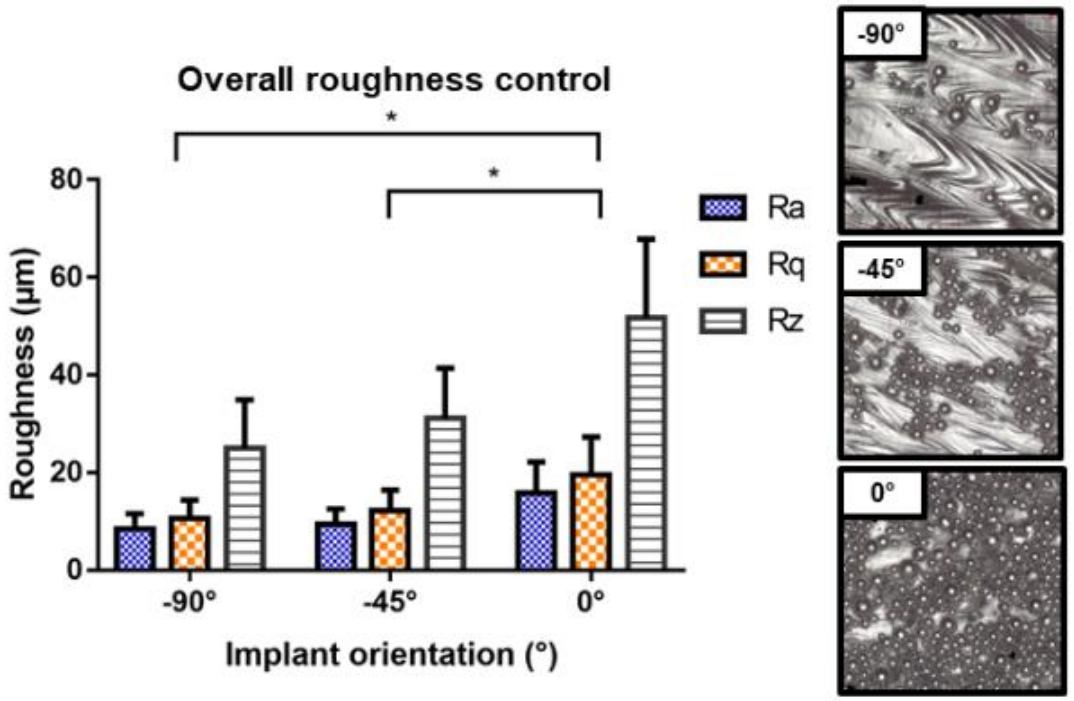
Model

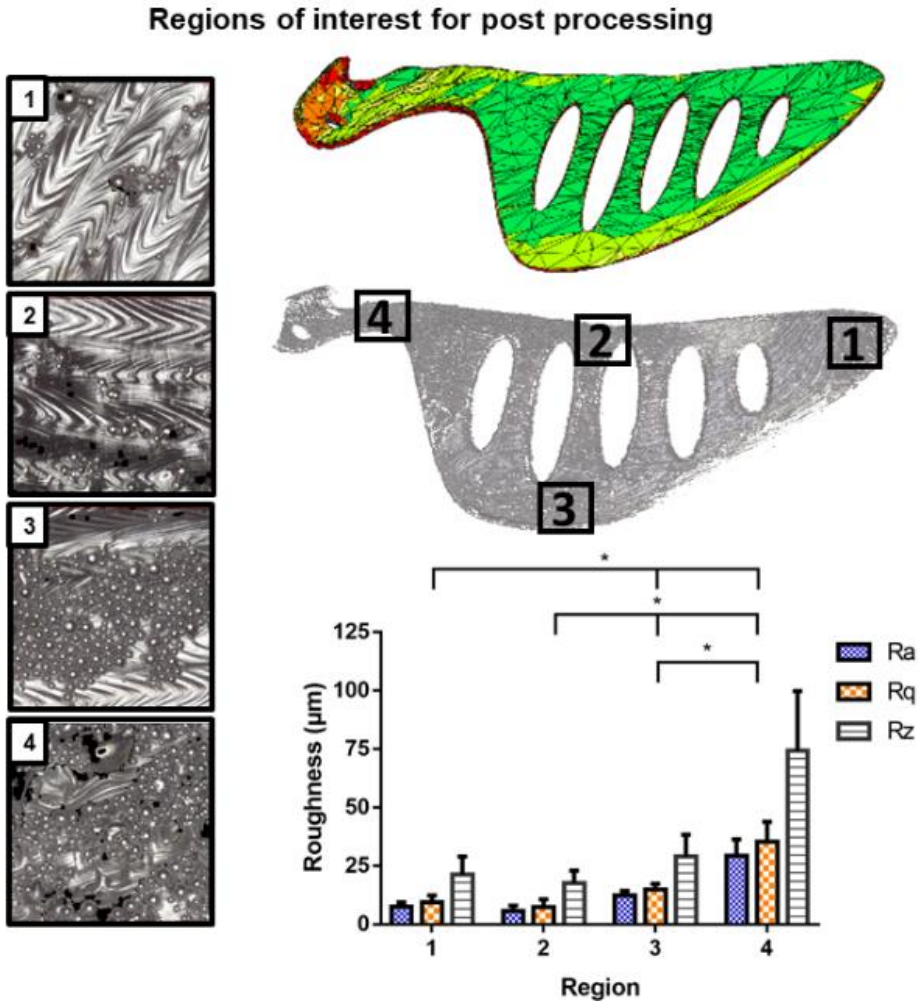




Villapun, V. M., *et al – Additive Manufacturing 36, 101528, 2020*

Tools to Support – Printing Orientation





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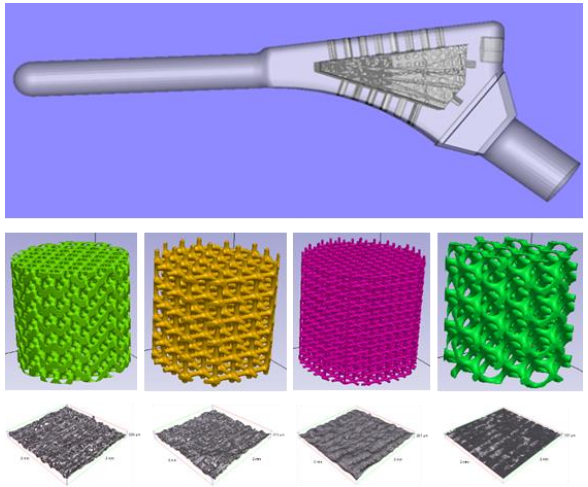
Villapun, V. M., *et al – Additive Manufacturing 36, 101528, 2020*

Case Studies

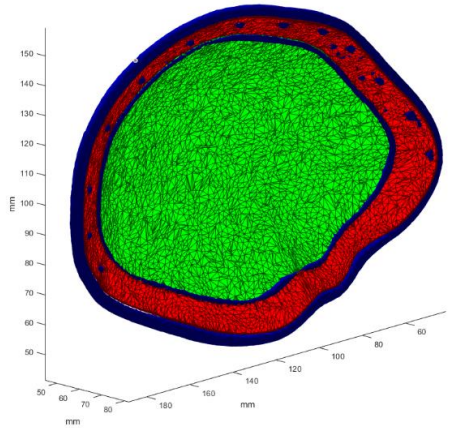
1. Importance of the Surface

From understanding to optimising orientation and post-processing

2 & 3. Metamaterials to Add Implant Functionality



Incorporating injectable biomaterials



Facilitating post-operative imaging

4. In Situ Alloy Development

Transforming the philosophy of biomedical alloy design

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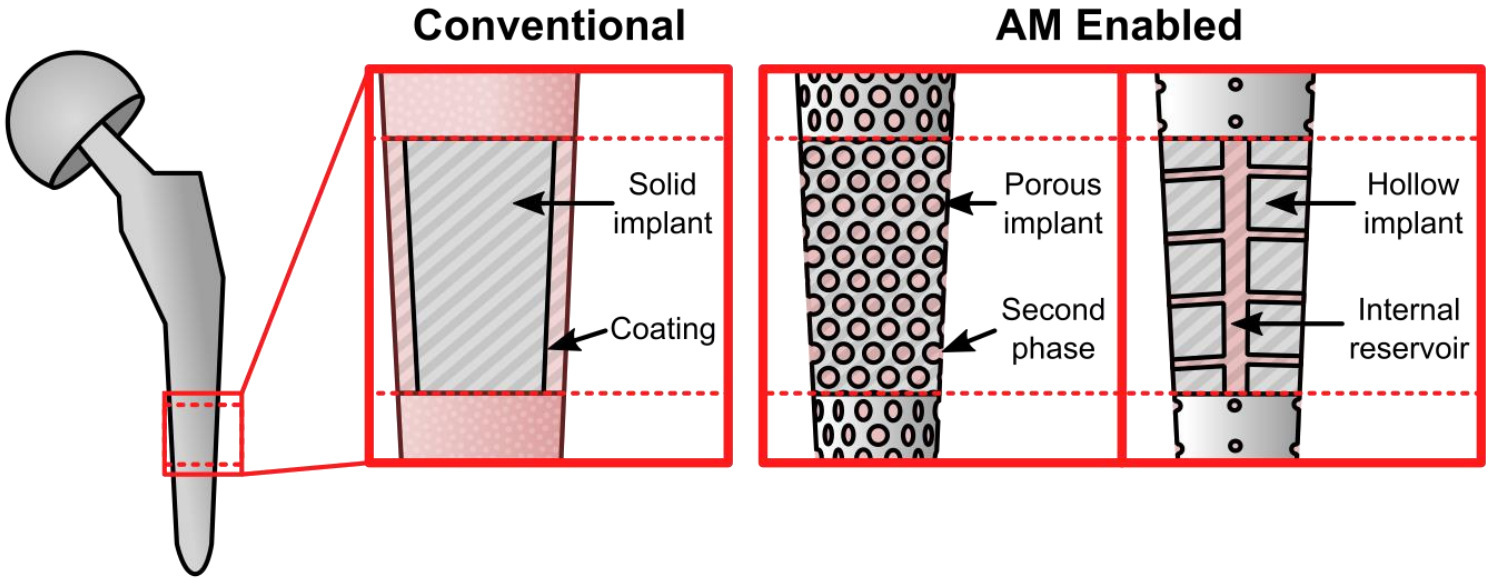
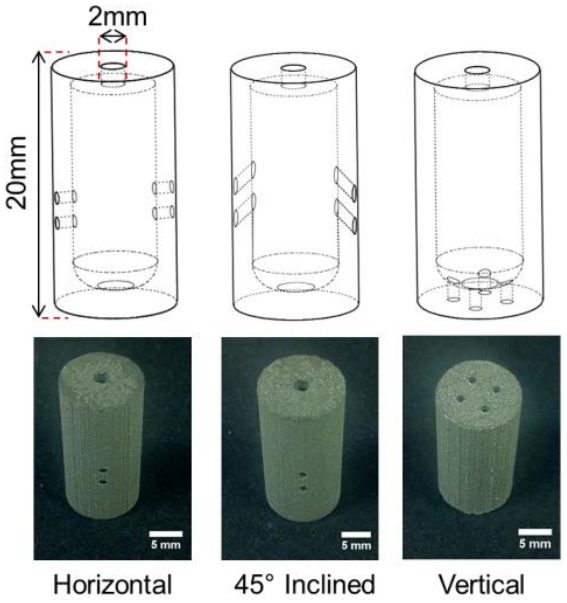
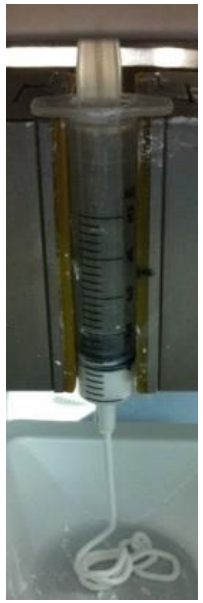
2. Metamaterial Structures as Therapeutic Reservoirs







Cox, S. C., *et al* - *Mater Sci and Eng C*, vol. 64, pp. 407-415, 2016
Hassanin, H., *et al* – Additive Manufacturing, vol. 20, pp. 144 – 155, 2018
Burton, H. , *et al* - *Mater Sci and Eng C*, 2019
Lowther, M., *et al* – *Additive Manufacturing*, 2019

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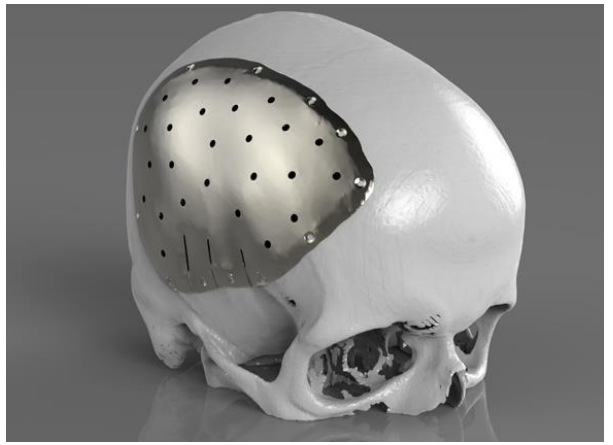
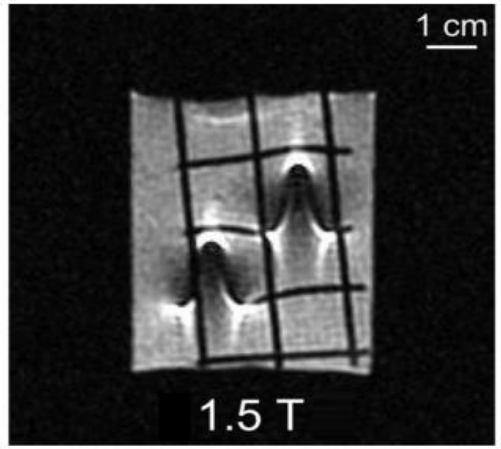
3. Metamaterials to Facilitate Post-Operative Imaging

EPSRC
Pioneering research and skills

Imaging around metal implant sites beneficial for:

- Early diagnosis of implant site infection
- Post-operative bleeding (microbleeds)
- Visualisation of surrounding anatomic structures





Use is limited by **susceptibility artefacts** even in traditionally 'non-magnetic' titanium implants due to**:**

- Weak paramagnetic properties of titanium
- Increasing field strength systems
- Gradient echo imaging sequences

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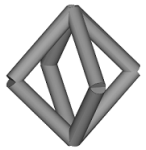
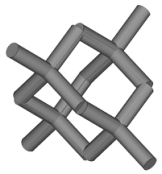
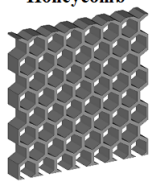
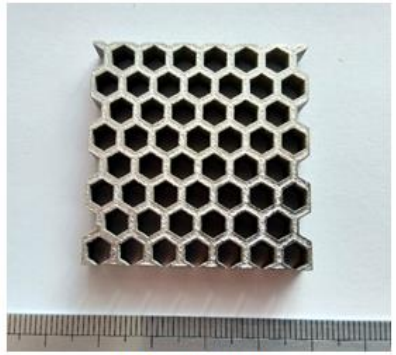
3. Metamaterials to Facilitate Post-Operative Imaging

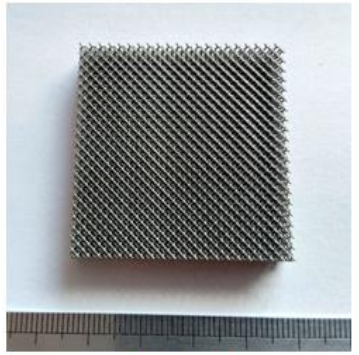
3T Siemens Prisma system (*University of Alberta*)

- GRE imaging sequence (T_E 1.5 ms)
- 52 coronal slices (2mm thickness)
- 0.86 x 0.86 mm in-plane pixel size
- 300s acquisition time

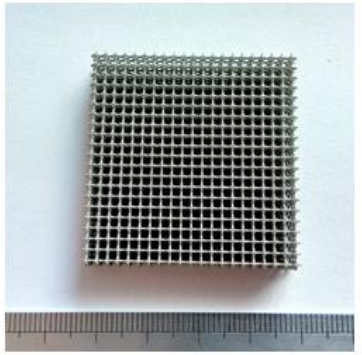
Structure	Unit Cell Size (mm)	Design Strut Dia. (μm) / Wall thickness (mm)	Relative Density (%)
Octohedral 	1	250	13.0
		350	40.8
		450	55.3
	1.5	250	5.7
		350	20.5
		450	30.8
	2	250	3.1
		350	12.7
		450	17.6
Diamond 	1	250	17.0
		350	48.5
		450	72.1
	1.5	250	7.7
		350	30.5
		450	37.7
	2	250	4.2
		350	18.0
		450	24.5
Honeycomb 	2	0.5	37.9
		1	72.1
		1.5	89.1
	4	0.5	20.3
		1	41.4
		1.5	59.2
	6	0.5	13.6
		1	29.4
		1.5	42.4
Solid	N/A	N/A	96.7*



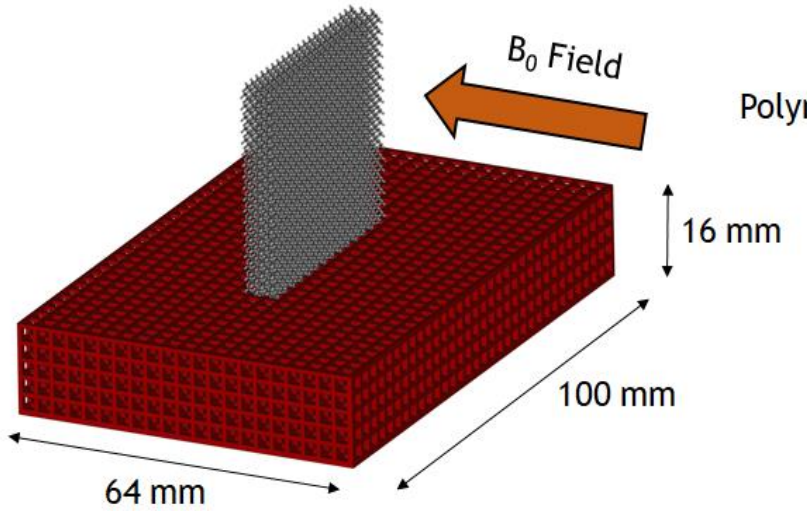
Honeycomb:
6 mm Unit Cell;
1.5 mm Wall Thickness

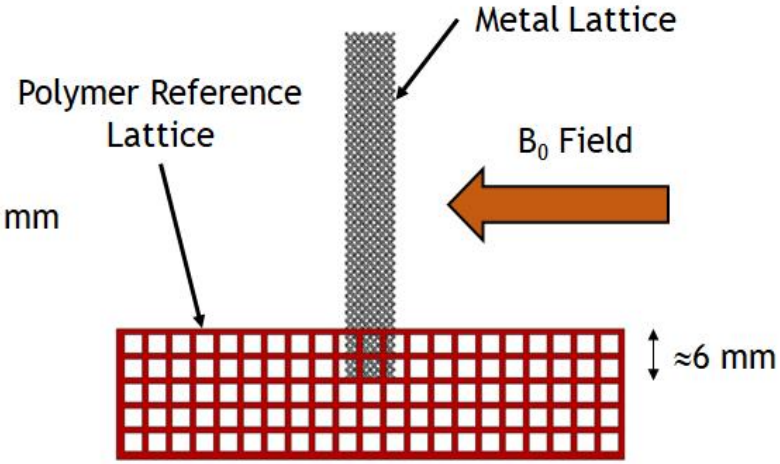


Diamond:
2 mm Unit Cell;
350 μm Strut Thickness



Octahedral:
2 mm Unit Cell;
350 μm Strut Thickness





Experimental Setup

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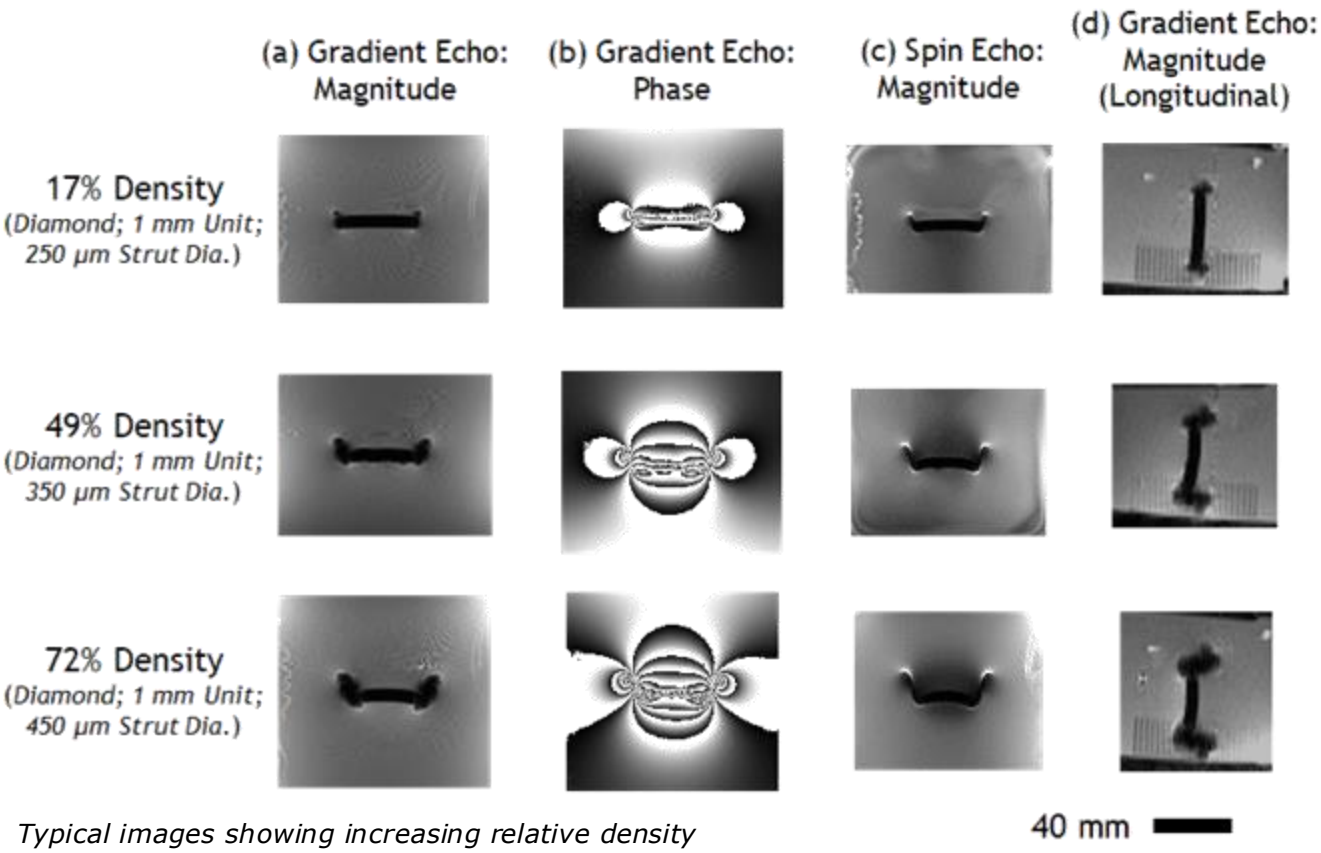
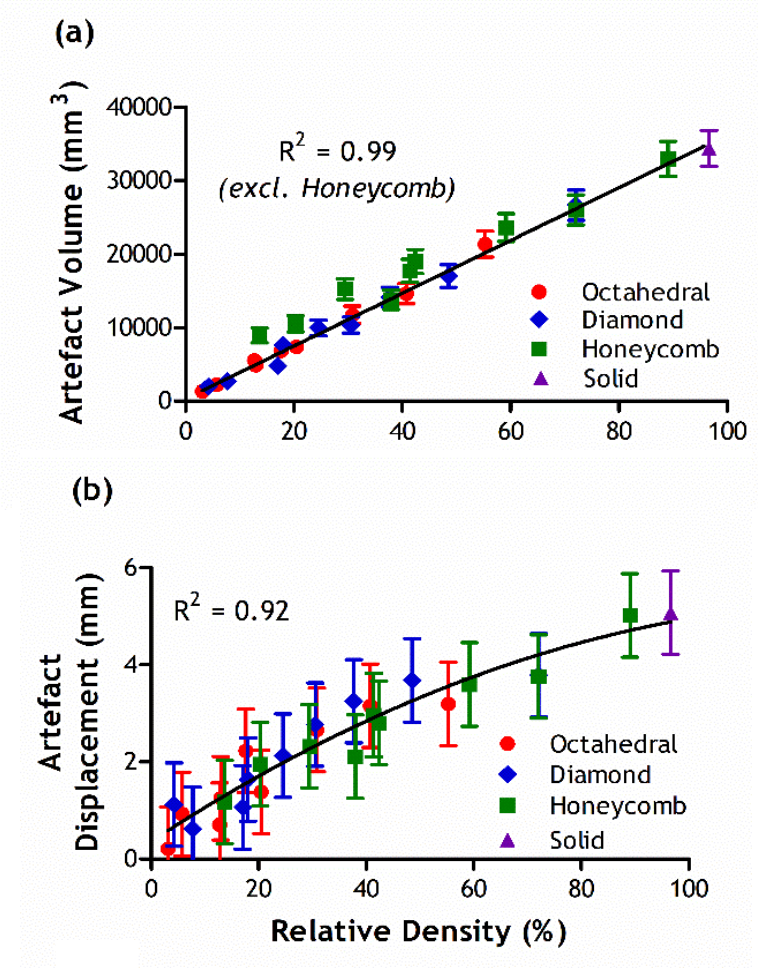
Carter, L. N., *et al – Acta Biomaterialia, 107, 338-348, 2020*

3. Metamaterials to Facilitate Post-Operative Imaging



Typical images showing increasing relative density

Artefact Severity



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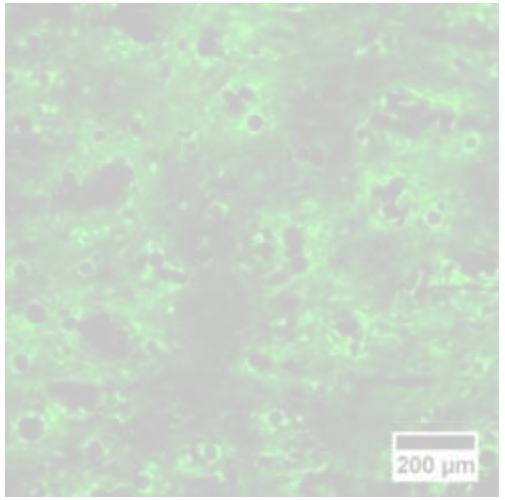


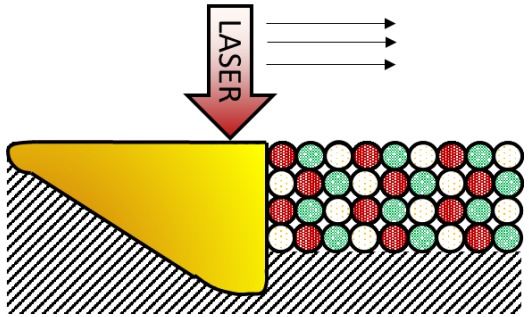
From understanding to optimising orientation and post-processing

2 & 3. Metamaterials to Add Implant Functionality

Incorporating injectable biomaterials

Facilitating post-operative imaging

4. In Situ Alloy Development



Transforming the philosophy of biomedical alloy design

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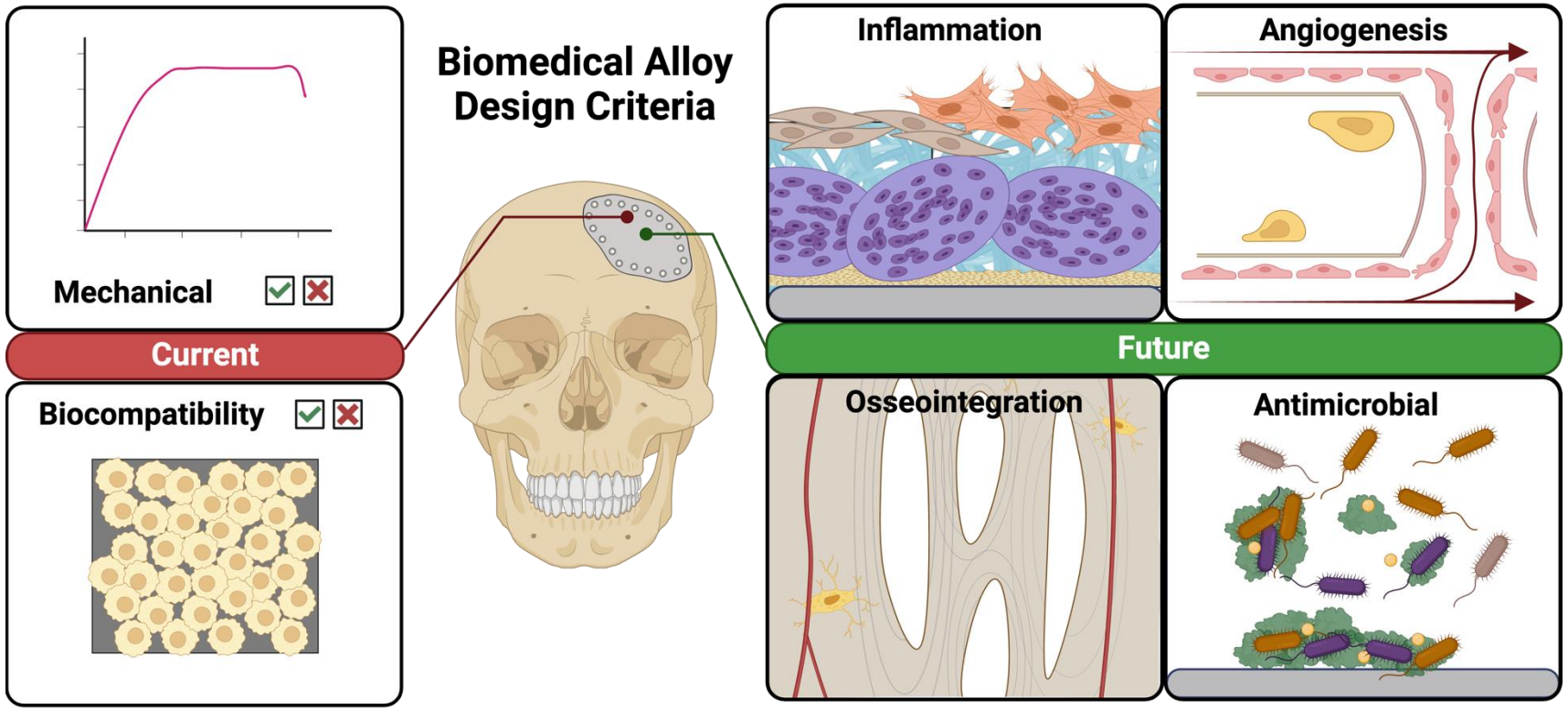
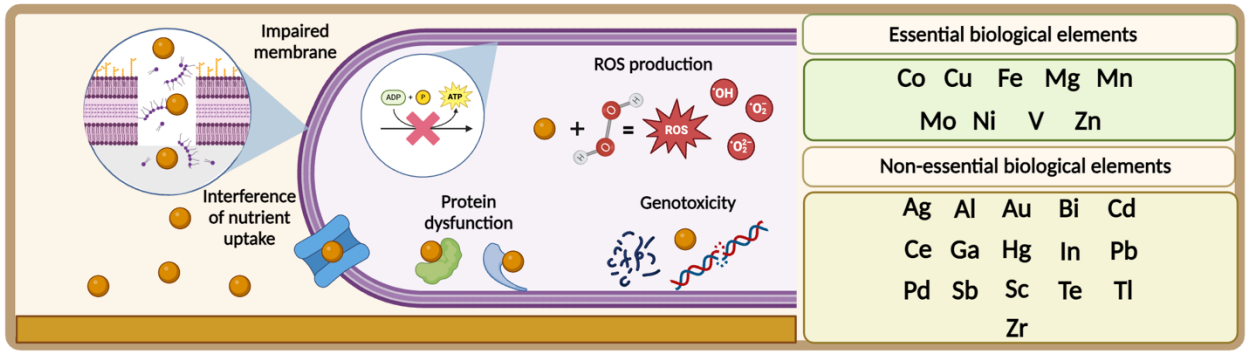
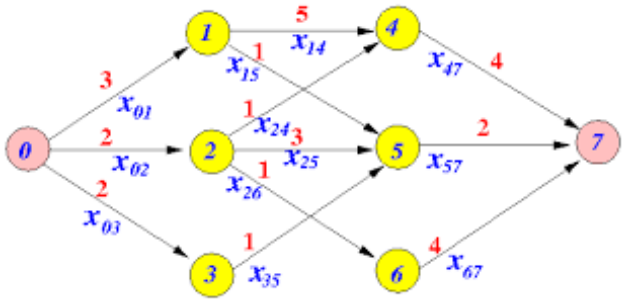
4. In Situ Alloy Development – Transforming Mindset



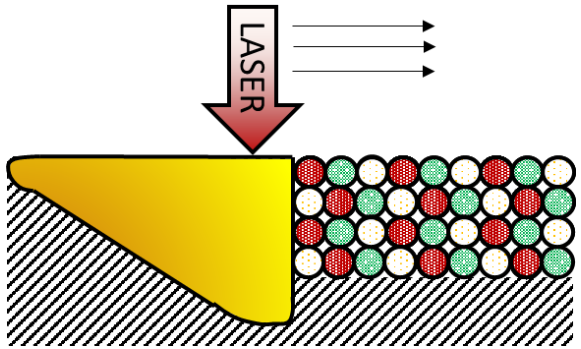
Transforming the Whole Process…



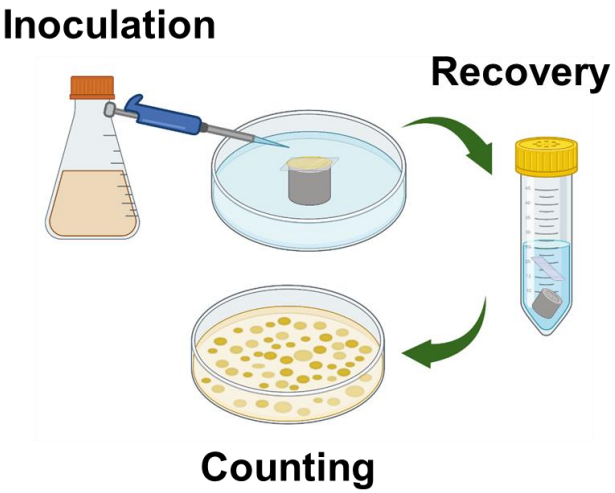
Targeted Biological Criteria



Alloy screening

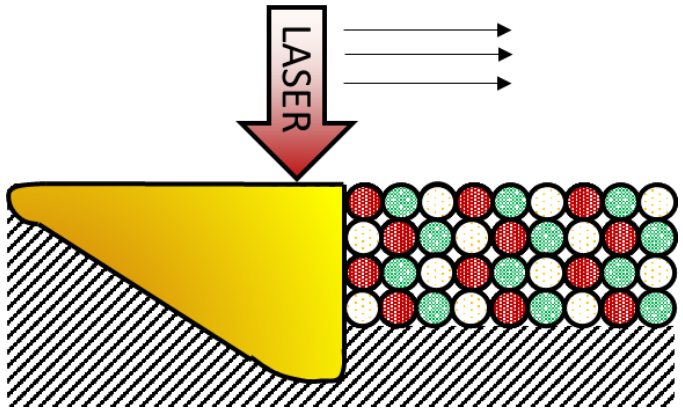


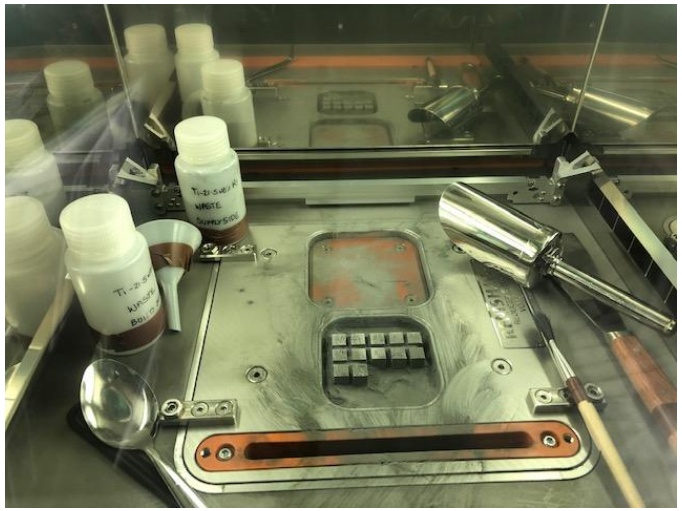
Manufacture
E.g. Ti-Mo, Ti-Cu



Validation

Blended Powder PBF-LB





RenAM 500S with RBV insert following BP-LBPF

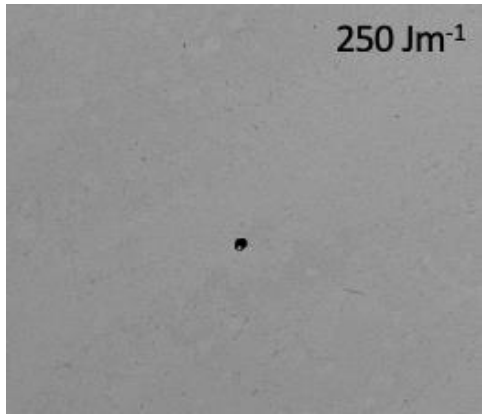
- Small (~150µm) molten pool provides good mixing, and limits macro-segregation
- Single step production of high-density specimens
- Process parameters can be used to control elemental segregation (*see Ti-Cu and Ti-Mo micrographs*)

X Requires liquid-range overlap

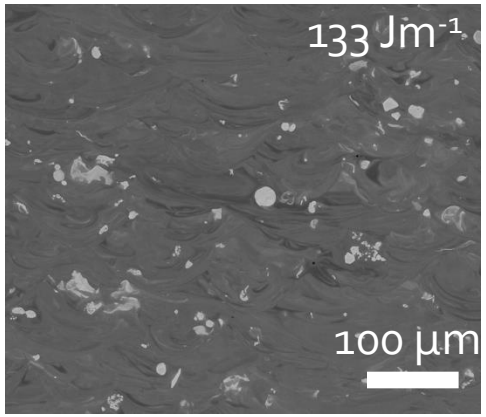
X Dissimilar laser absorptivity may lead to pore defects

X Typically requires an initial study to determine process window

X Dissimilar powders can lead to poor spreading during the process



Ti-1 1.5Cu (as built)

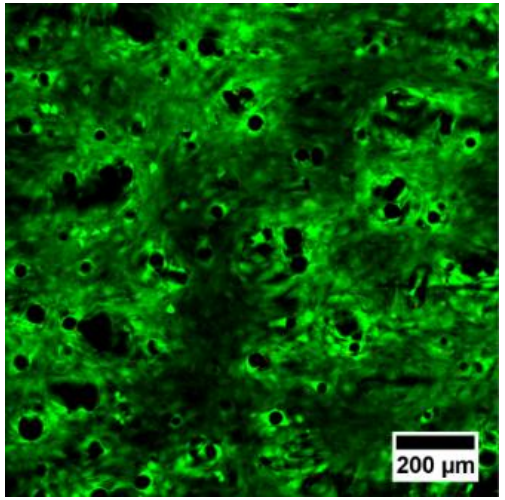


Ti-2 1.5Mo (as built)

Ti-2 1.5Mo LPBF specimens on build substrate

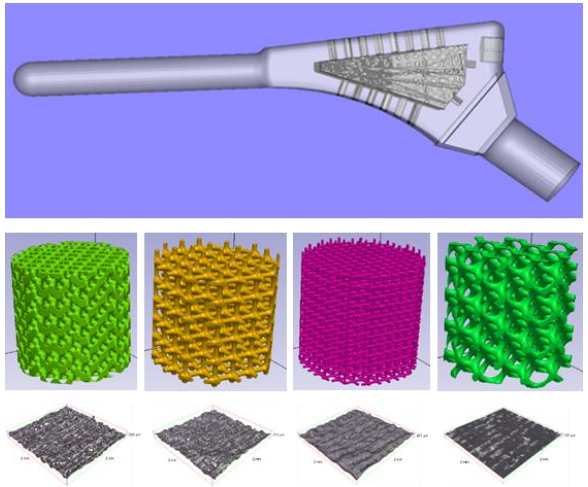
Case Studies

1. Importance of the Surface

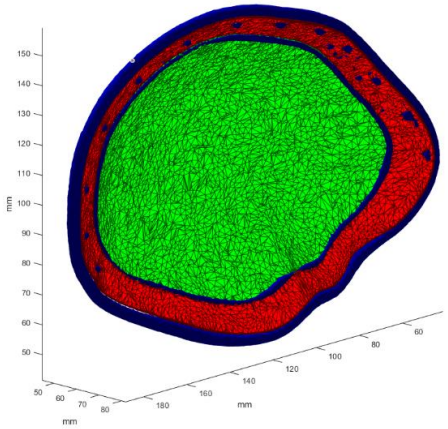


From understanding to optimising orientation and post-processing

2 & 3. Metamaterials to Add Functionality

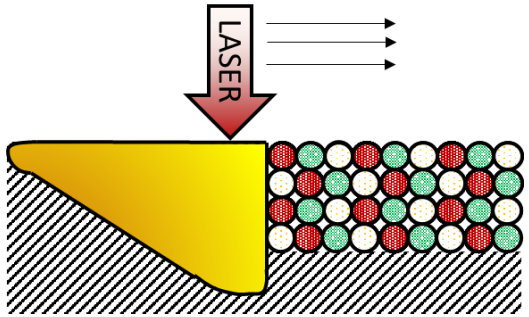


Incorporating injectable biomaterials



Facilitating post-operative imaging

4. In Situ Alloy Development



Transforming the philosophy of biomedical alloy design

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Submission Deadline: 14 November, 2024

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