



M.Tech Digital Manufacturing

BITS Pilani
Pilani Campus

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Guest Faculty



DMZG521- Design for Additive Manufacturing Session 7 & Lecture 13-14

Material Complexity



- Material is processed point to point in many of the AM technologies
- Achieve different material properties in different regions of the part



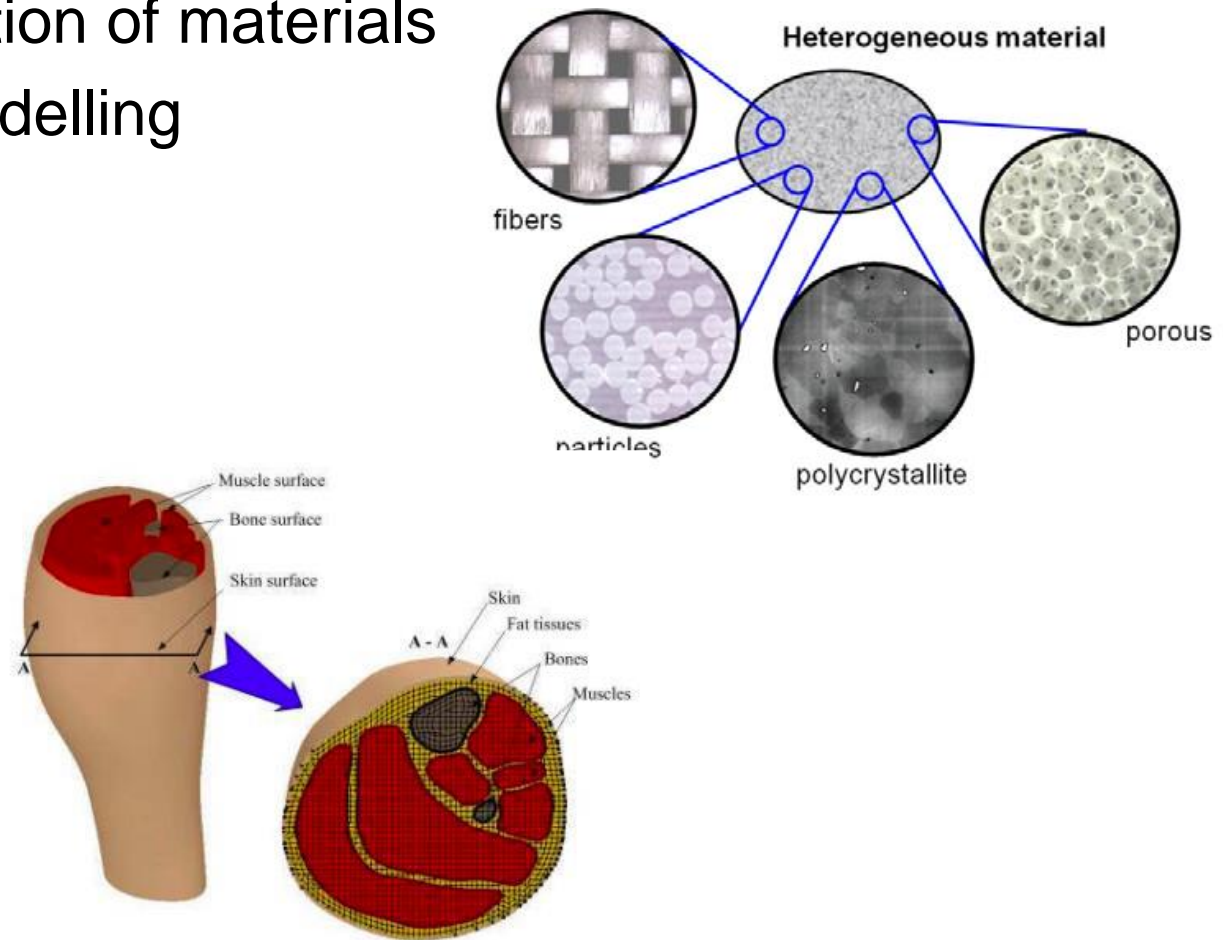
Multi-materials in AM



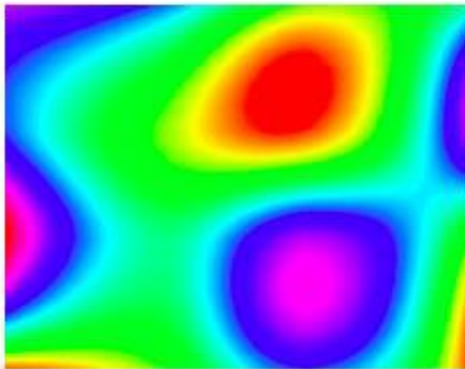
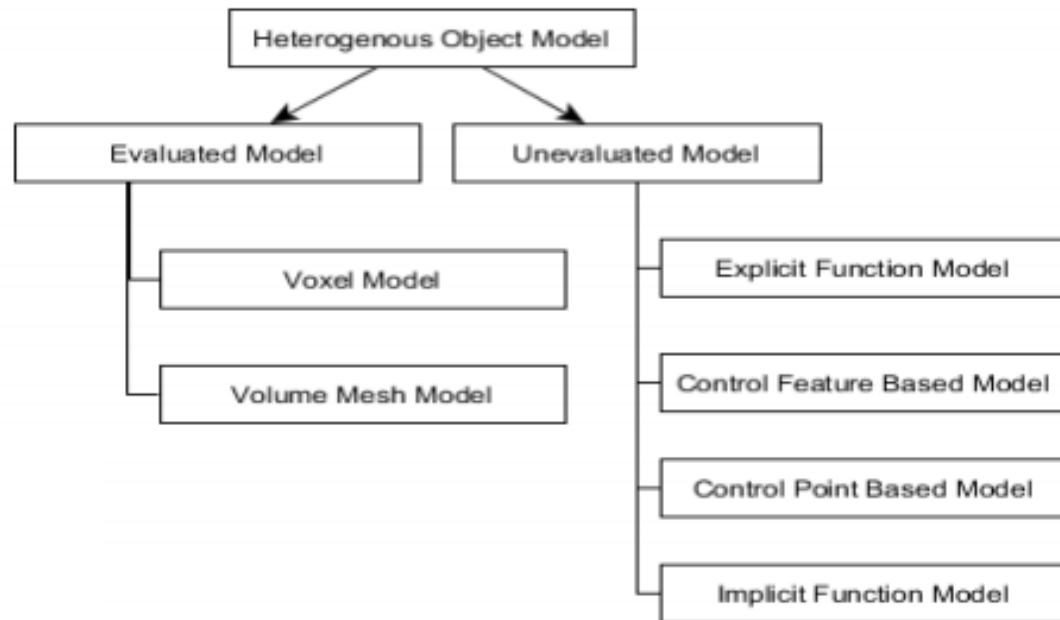
- Heterogeneous Materials or Functionally Graded Materials
- Meta materials

heterogeneous material

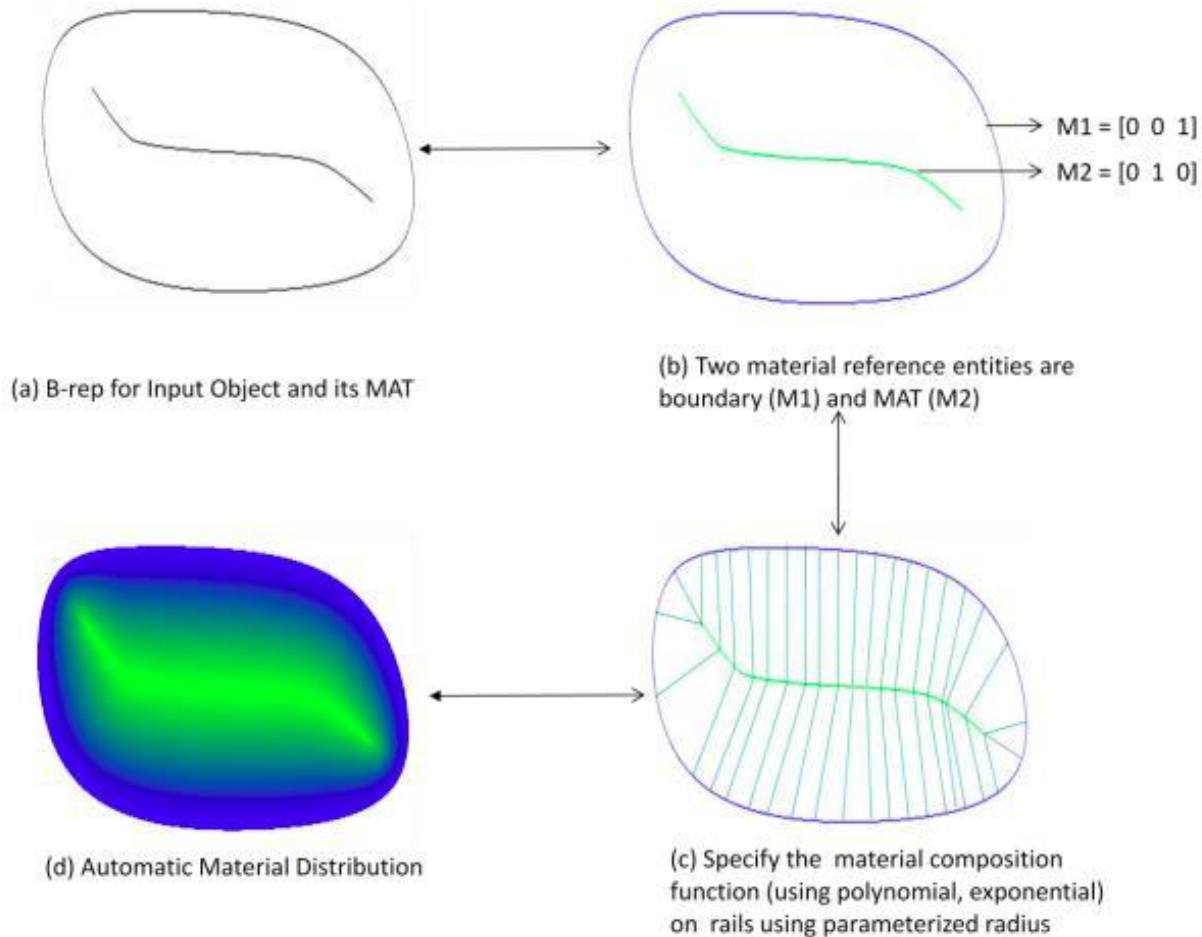
- Different composition of materials
- Heterogenous modelling



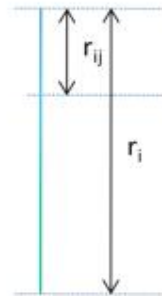
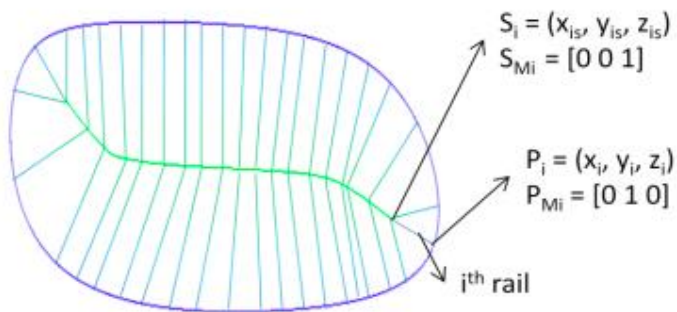
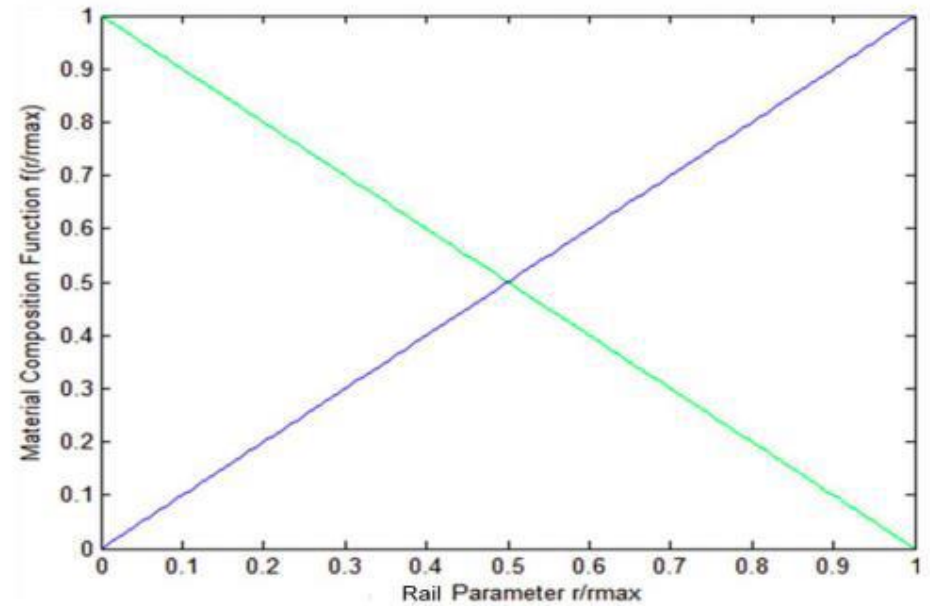
Heterogenous modelling



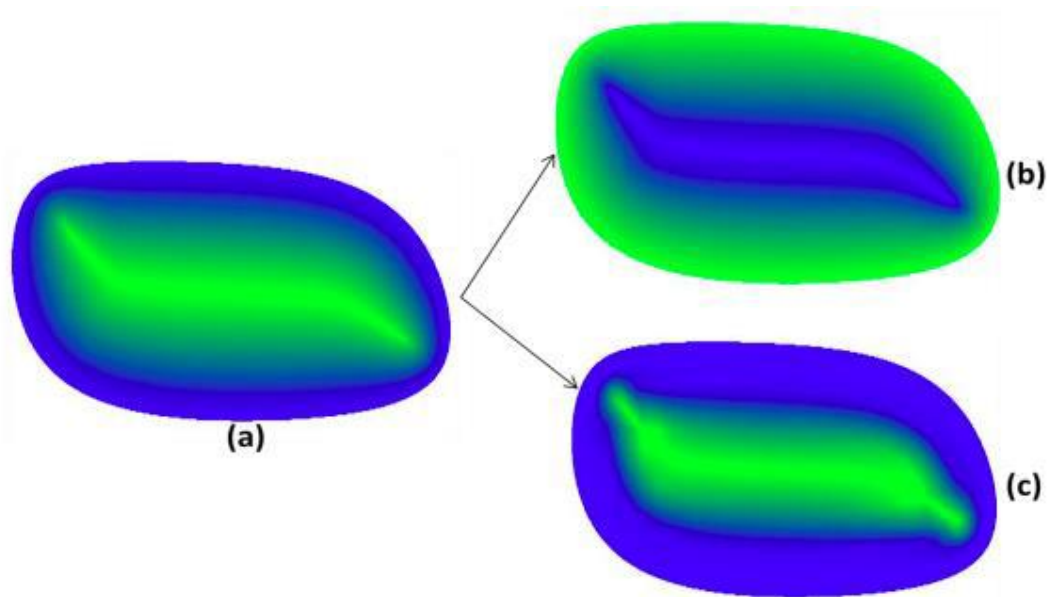
Medial Axis Transform



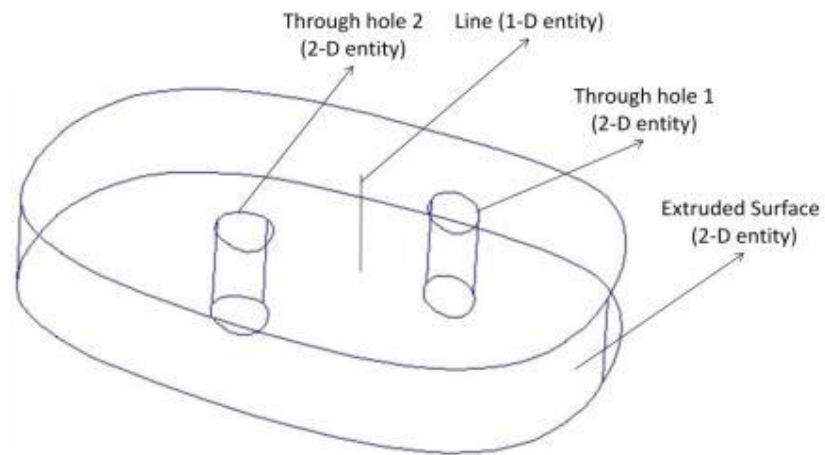
Rail Parameter



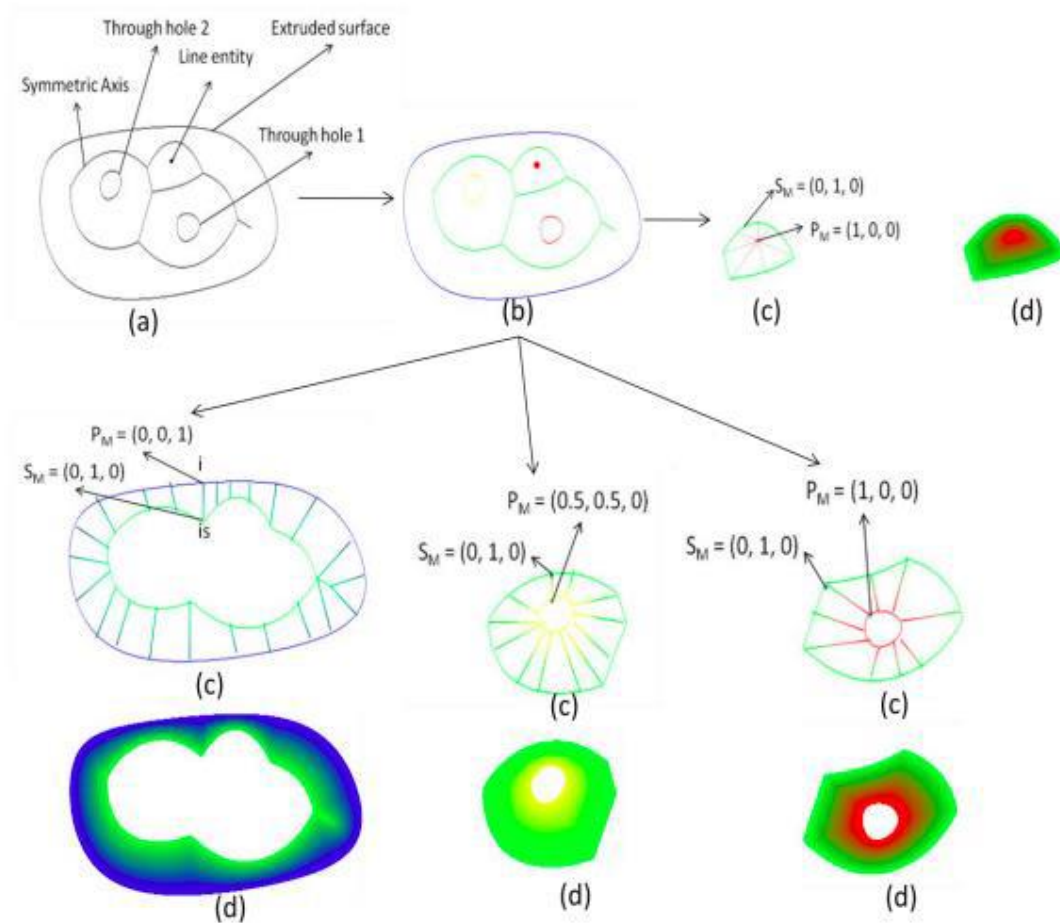
Variation of property



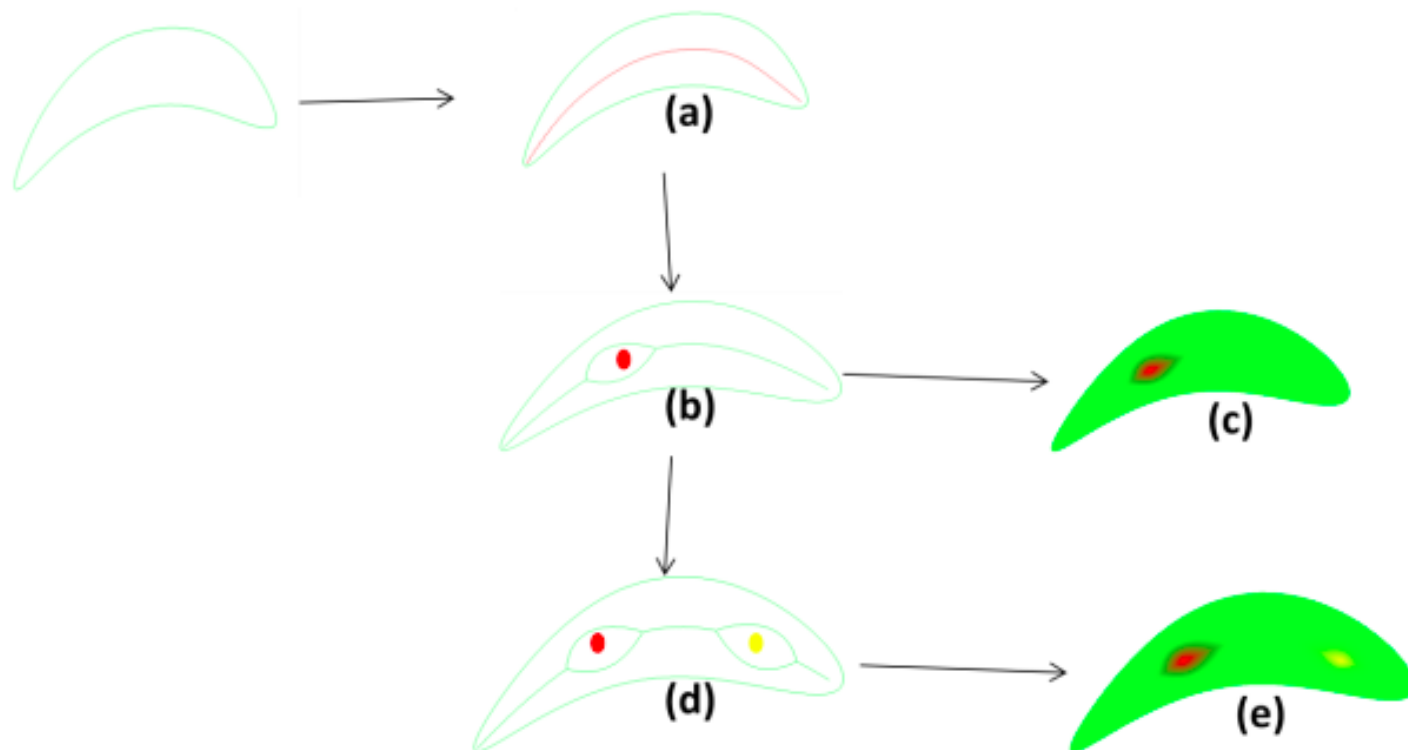
Case study



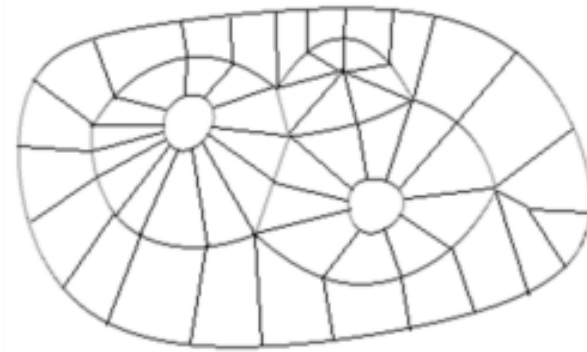
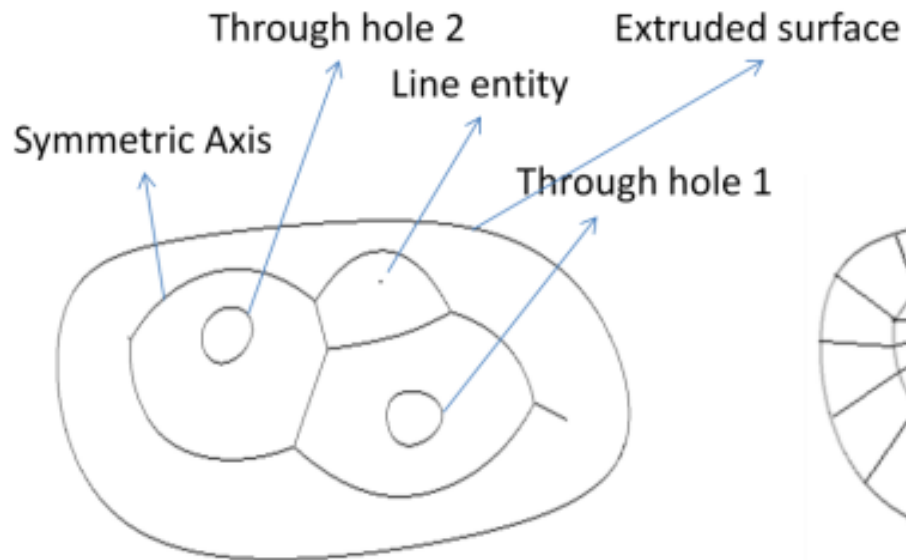
Case study



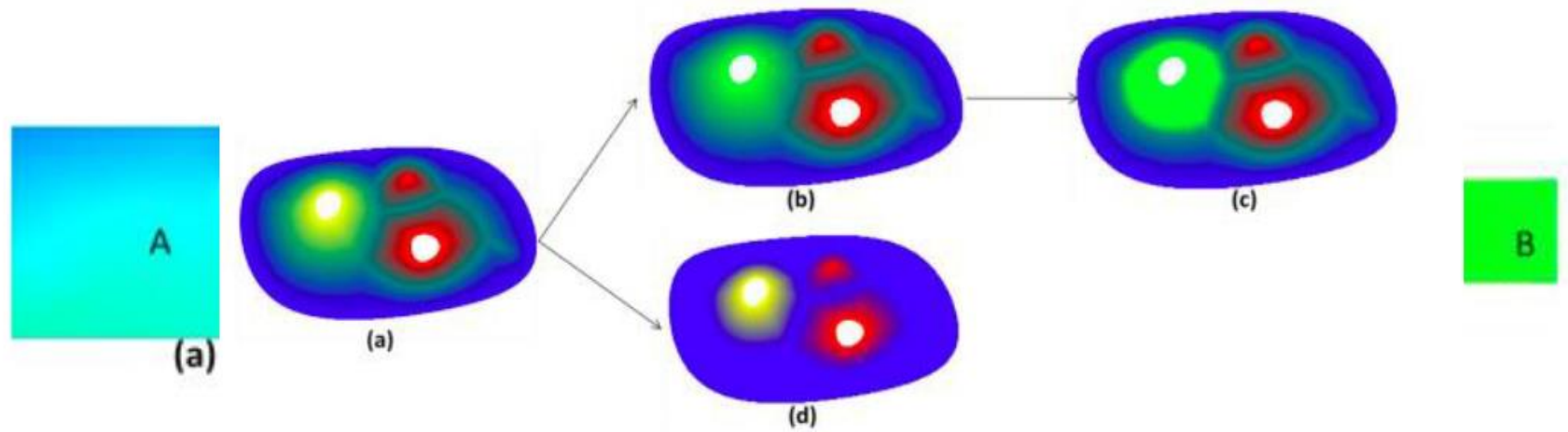
Example



Using Voronoi Polygon



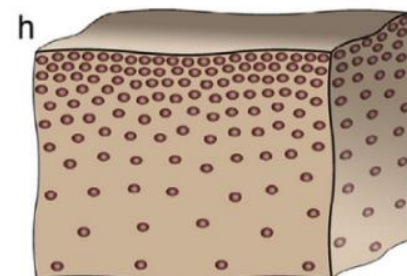
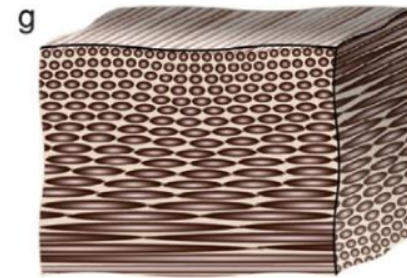
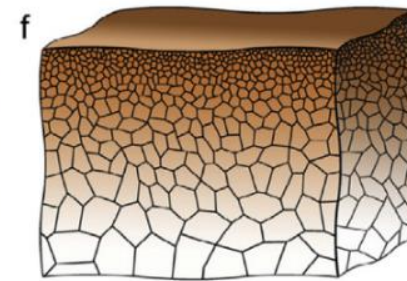
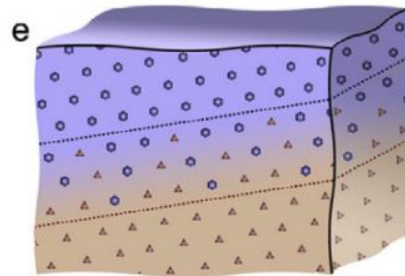
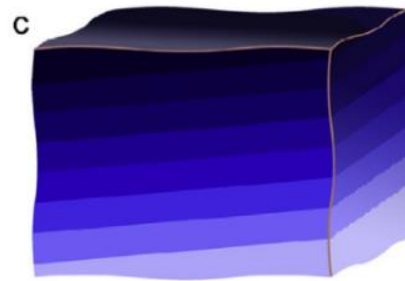
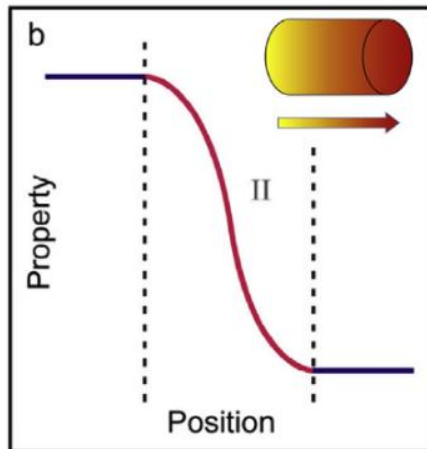
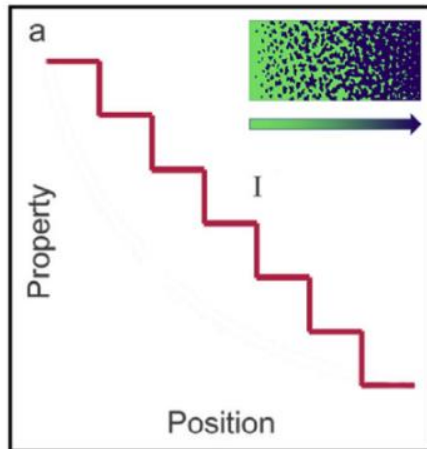
Different Material Distribution



Functionally Graded Materials



- Characterized by the variation in composition and structure gradually over volume, resulting in corresponding changes in the properties of the material
- The materials can be designed for specific function and applications



Manufacturing of FGM

- Chemical vapour deposition
- Physical vapour deposition
- Thermal spray
- Surface reaction process
- Centrifugal casting
- Electrode deposition
- Ion beam assisted deposition
- Plasma spraying

AM methods



- Laser based process
- Stereolithography process
- Material Jetting process
- Fused deposition modelling

Challenges in heterogeneous modelling



- CAD capability
- STL file doesn't contain the material information

Multi-Material Additive Manufacturing (MMAM)



- The emerging Multiple Material Additive Manufacturing (MMAM) technology can enhance the performance of AM parts by adding more complexity and functionality.
- Design Freedom
- Design protection
- Increased Functionality
- Elimination of assembly
- Efficient Manufacturing systems

Multi-Material Additive Manufacturing (MMAM)

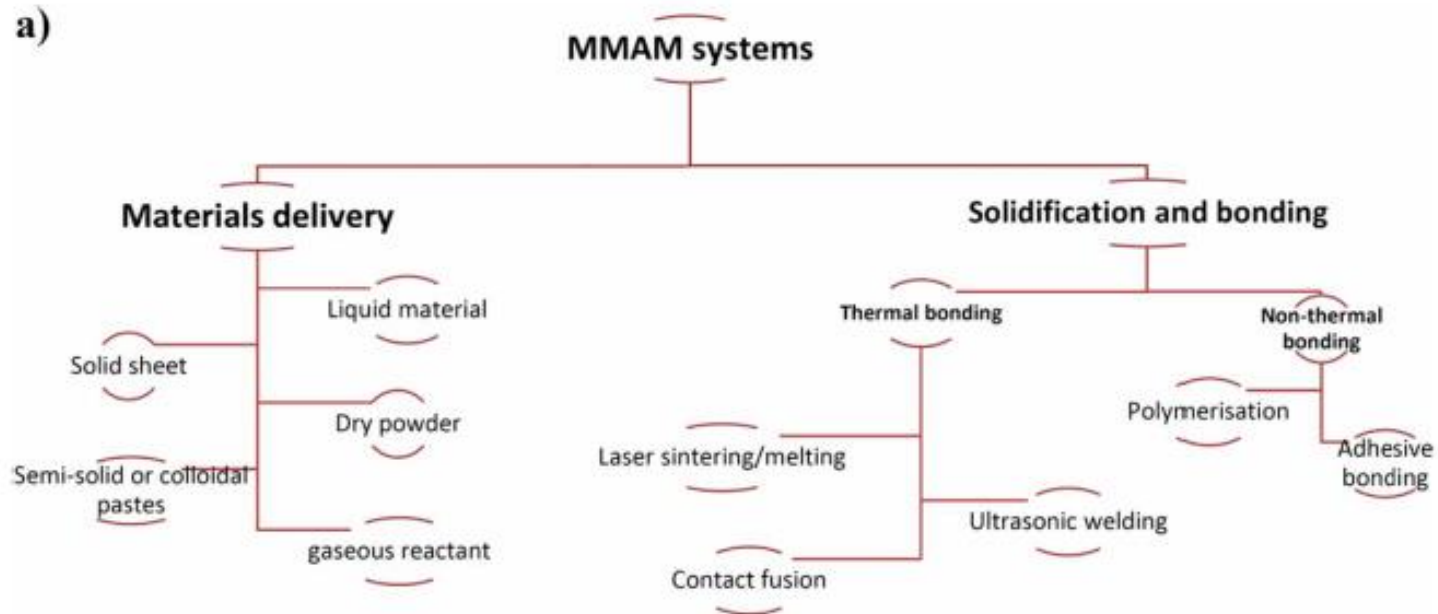


1. Discrete Multiple materials
2. Composite materials
3. Porous materials

Material Types

1. Dry powder (SLS, LENS, SLM, 3DP)
2. Semi-solid or colloidal paste (FDM)
3. Liquid material (VP, MJ)
4. Gaseous reactant (CVD)

MMAM Systems



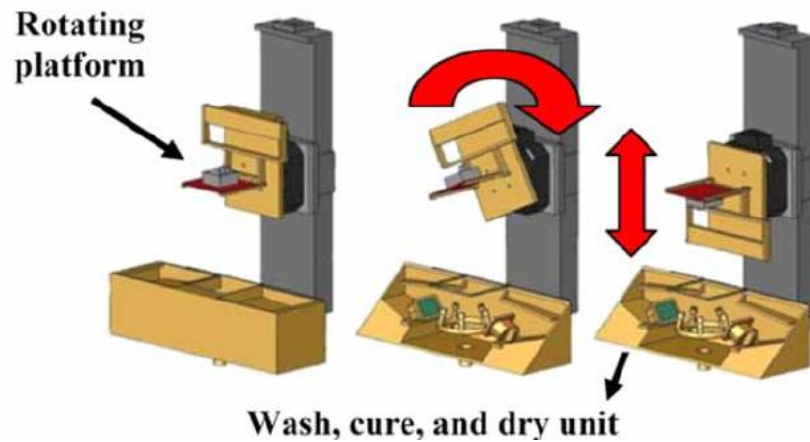
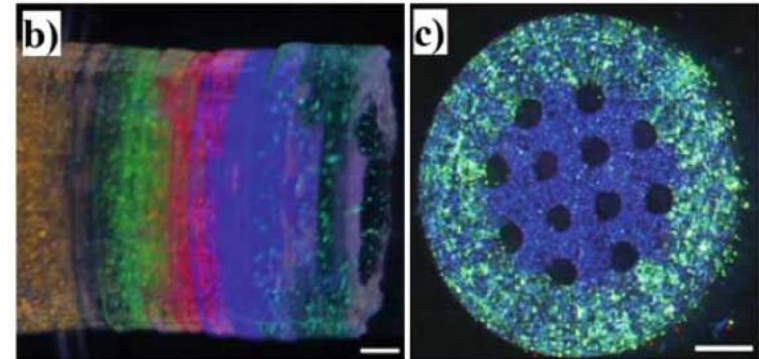
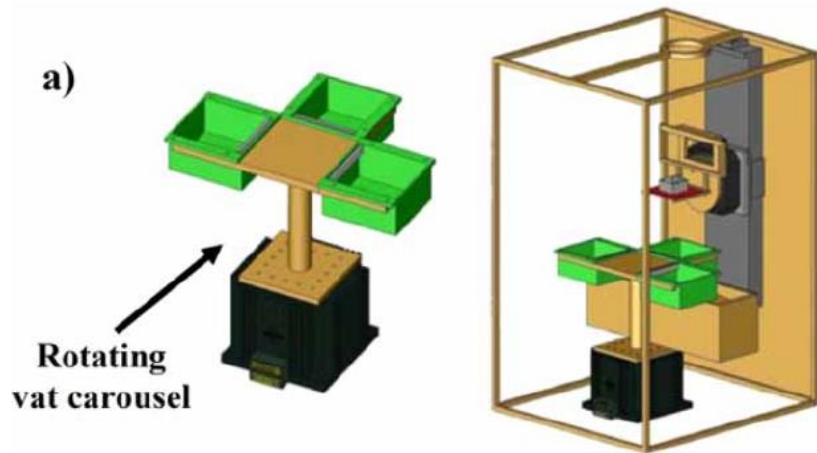
9. a) MMAM main subsystems and b) different kinds of multiple-materials parts.

Suitable AM processes

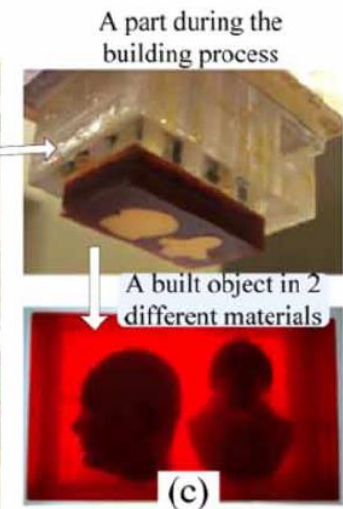
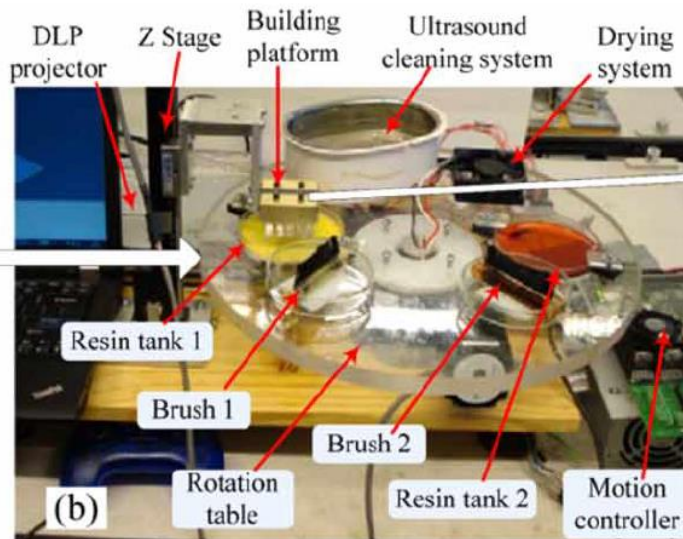
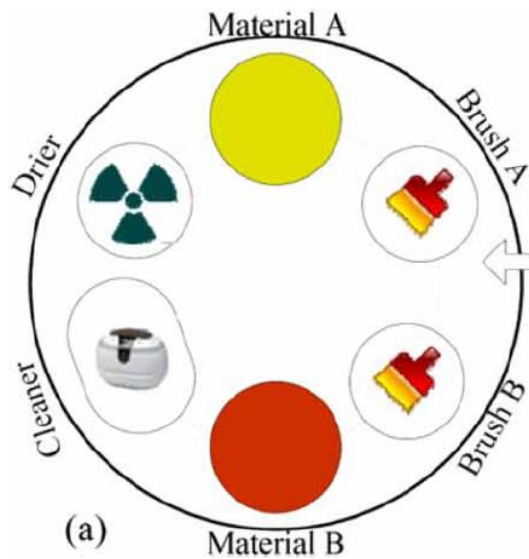


1. Vat Photopolymerization
2. Material Jetting
3. **Binder Jetting**
4. Extrusion based system
5. Powder Bed Fusion Process
6. Sheet Lamination
7. Hybrid and Direct writing Process

VAT Photopolymerization



Multiple materials DMD²-based SL system

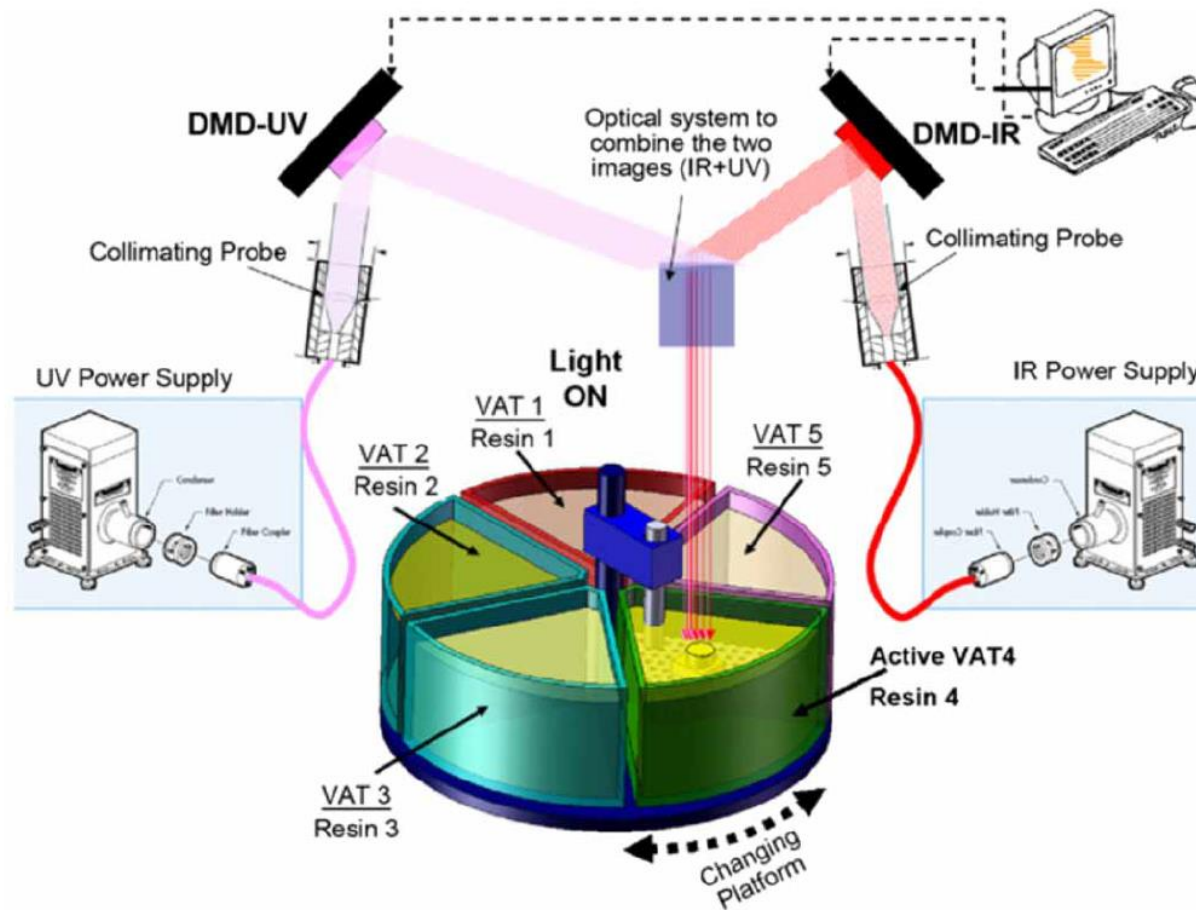


micro stereo-thermal-lithographic process

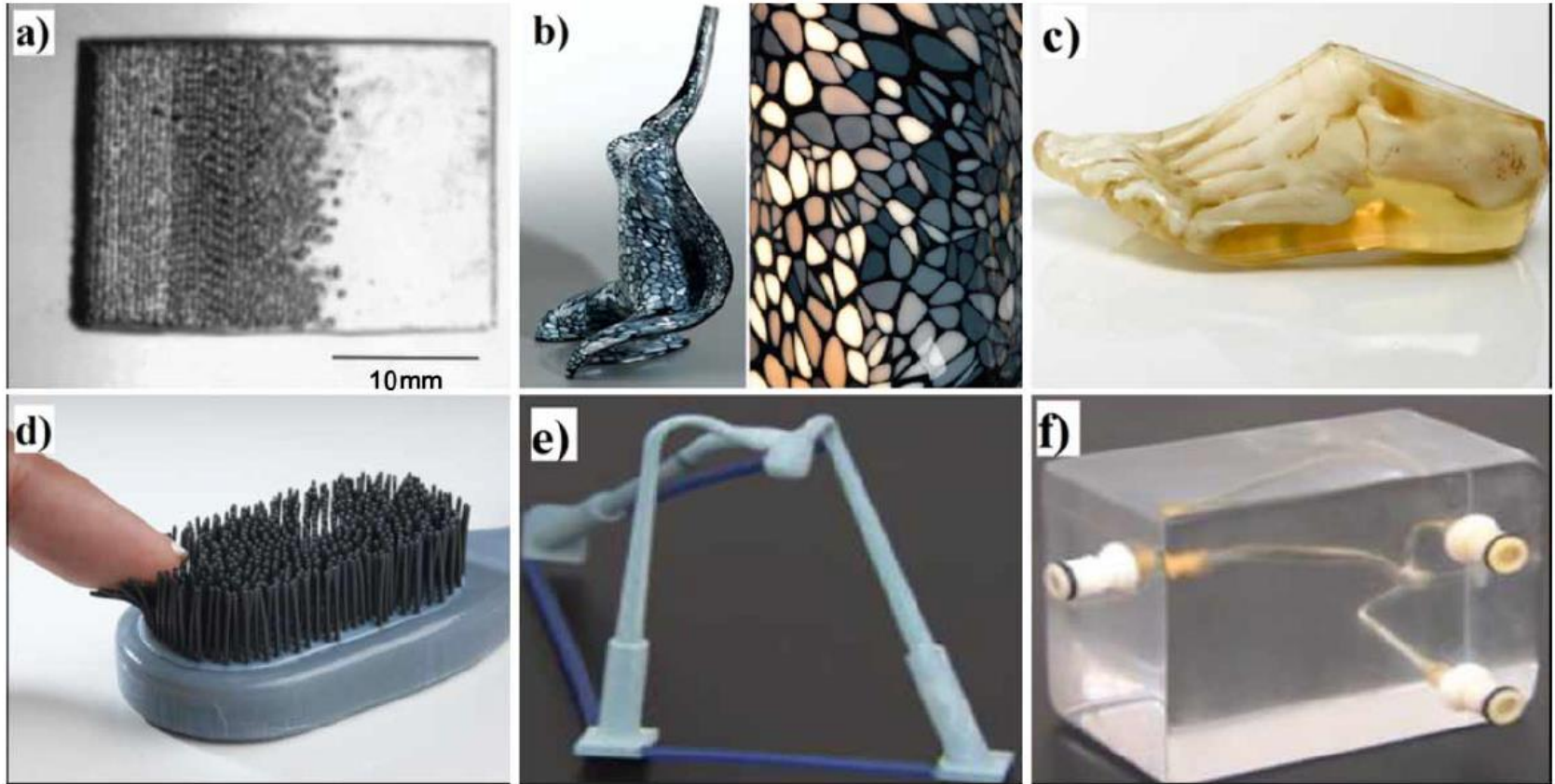
innovate

achieve

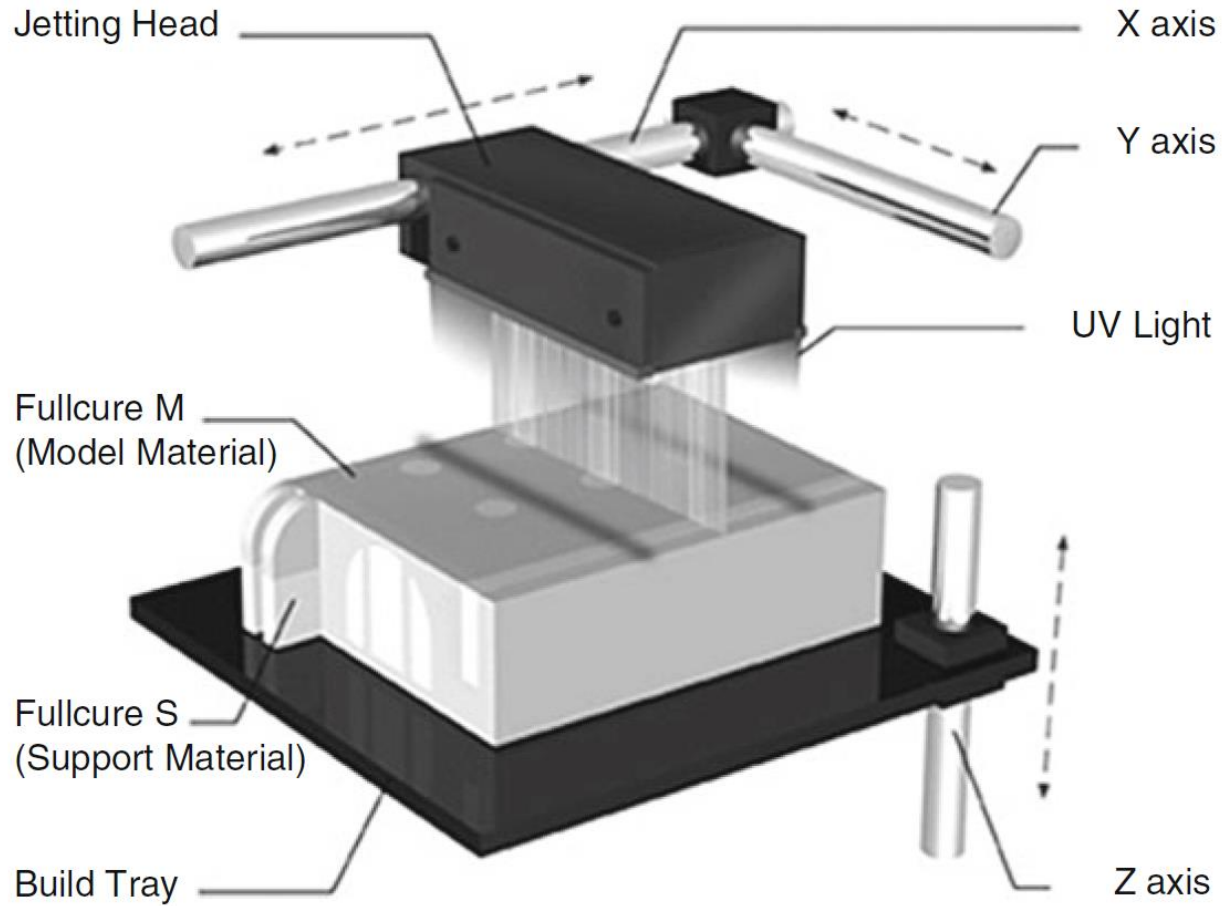
lead



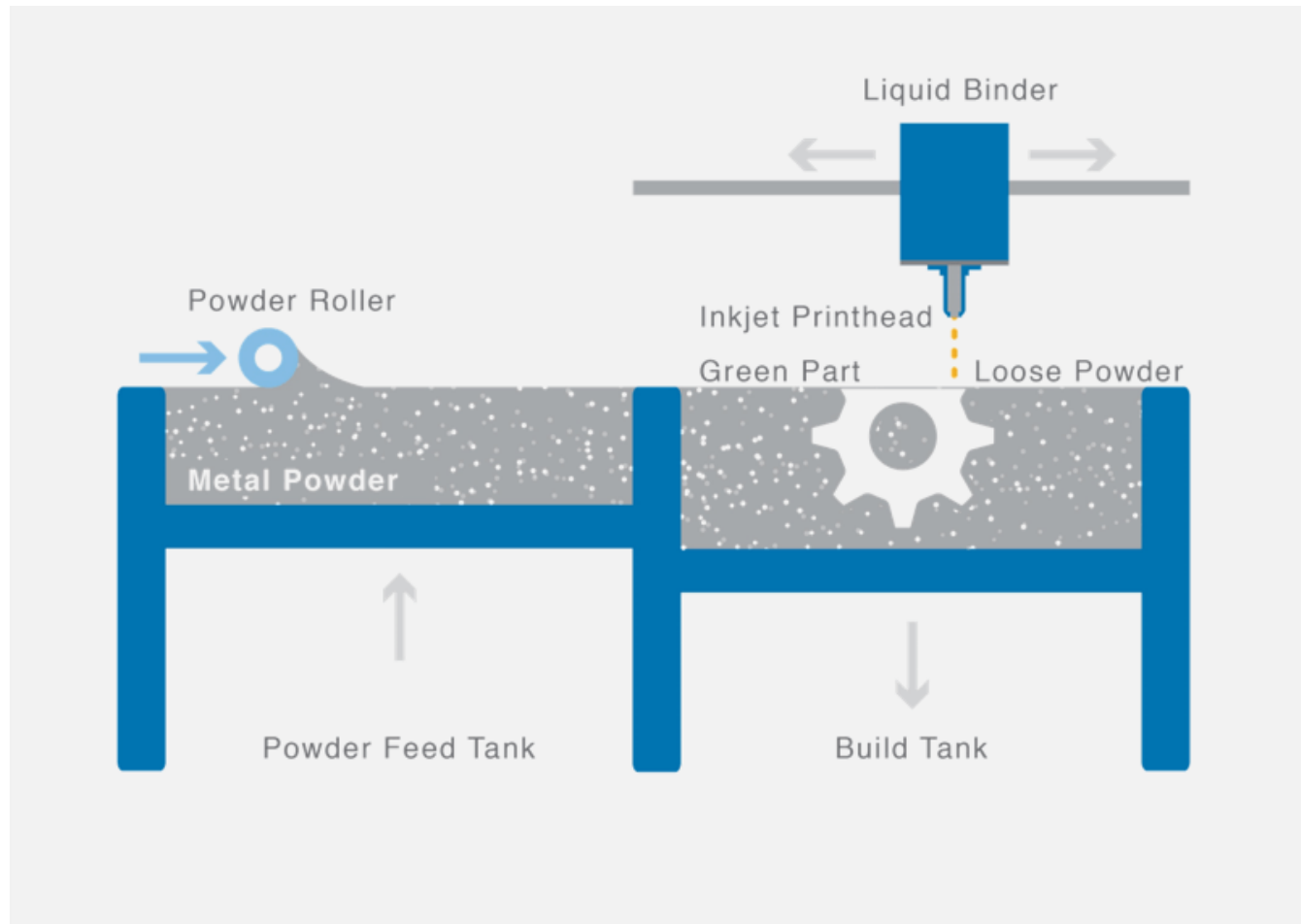
Material Jetting



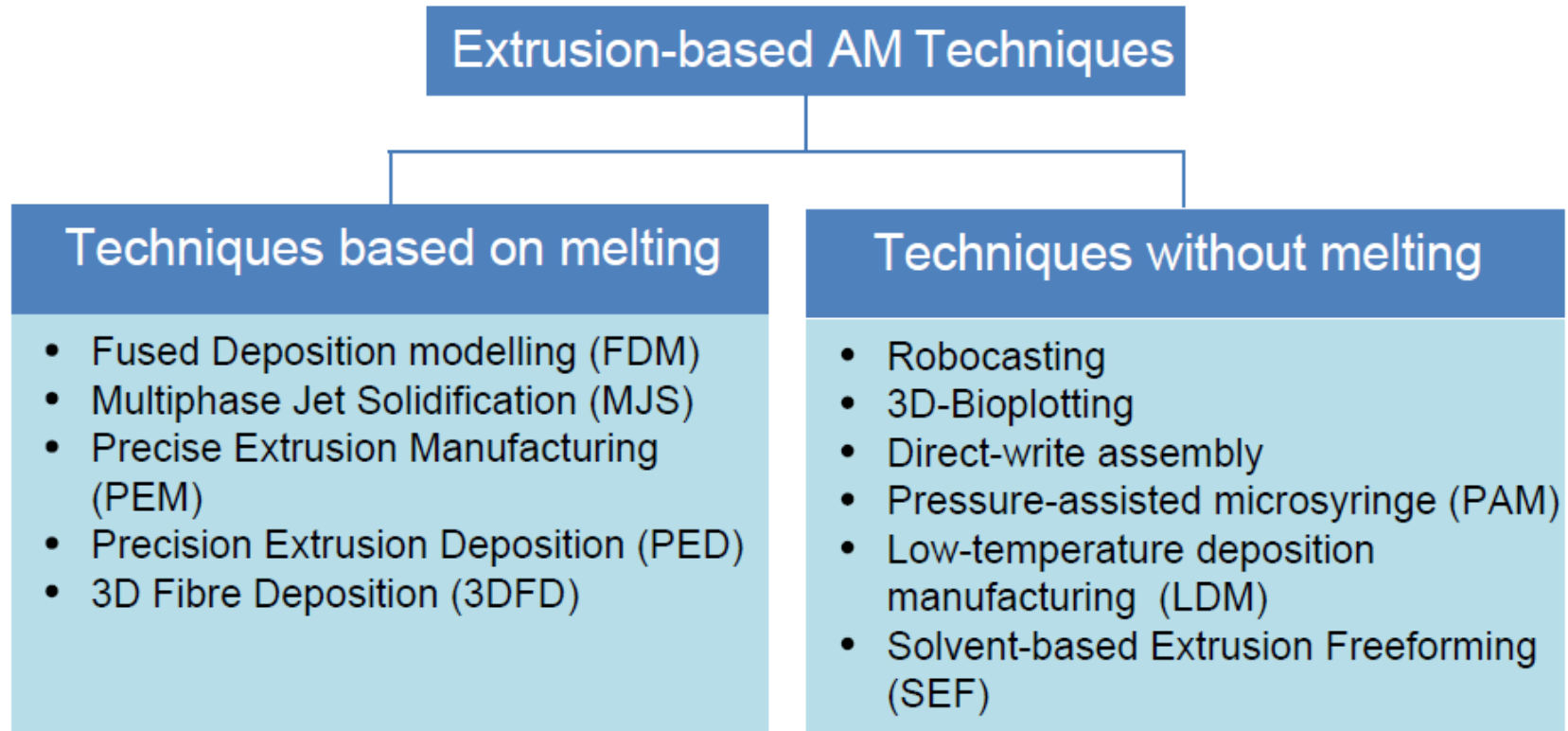
Polyjet Process



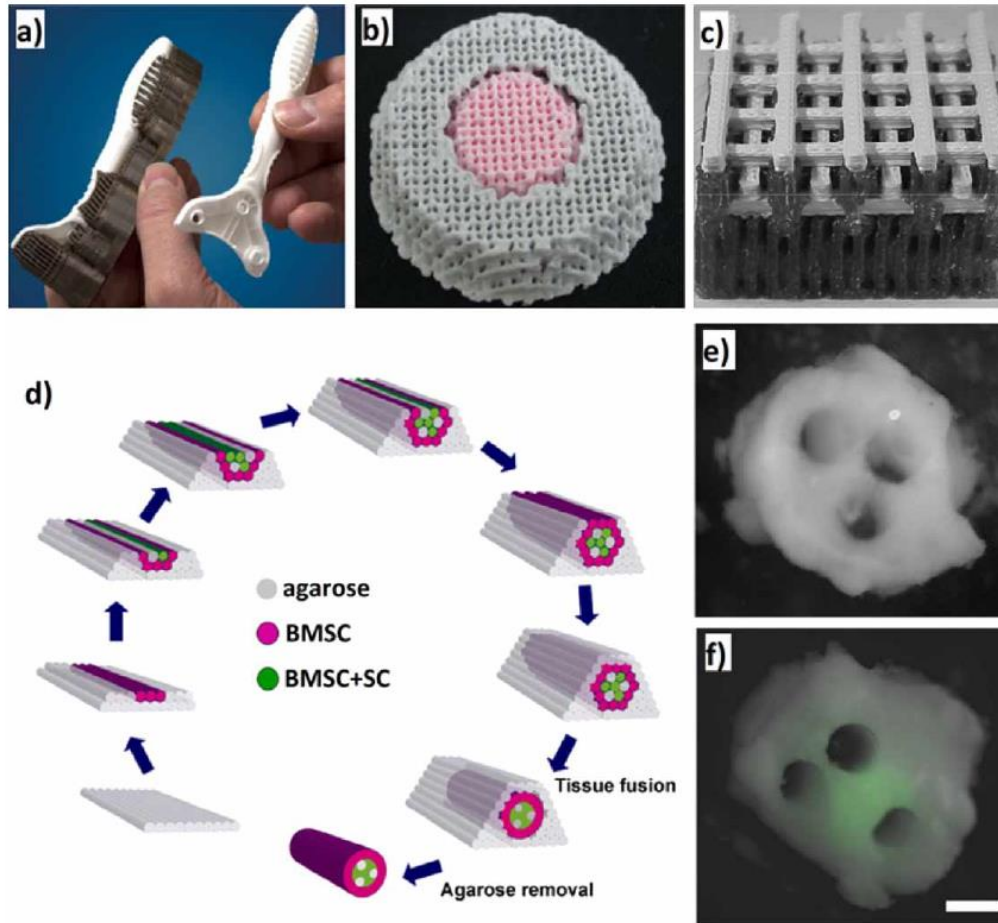
Binder Jetting



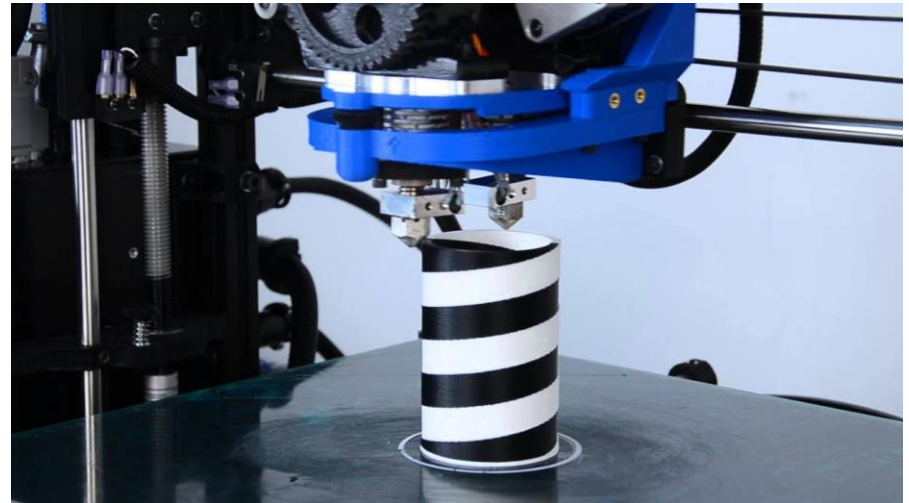
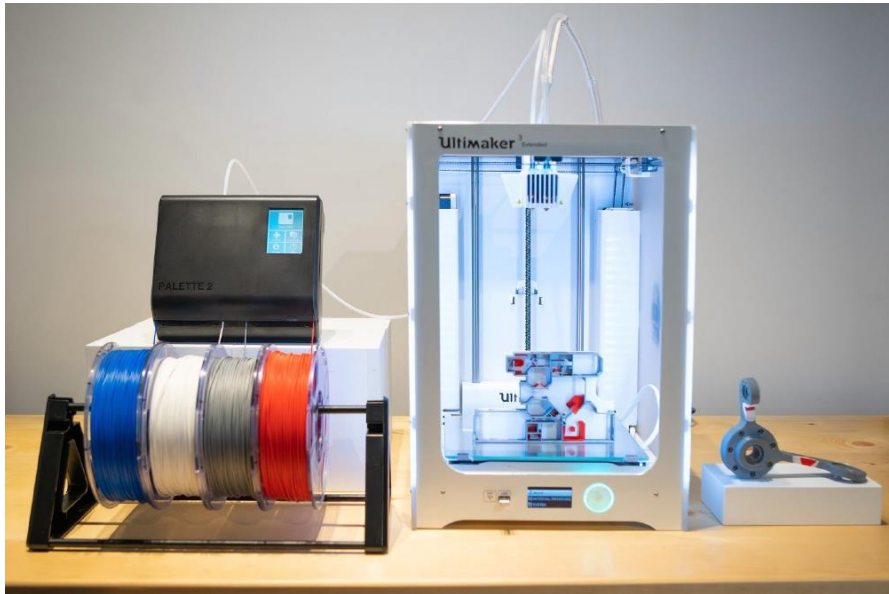
Extrusion Based System



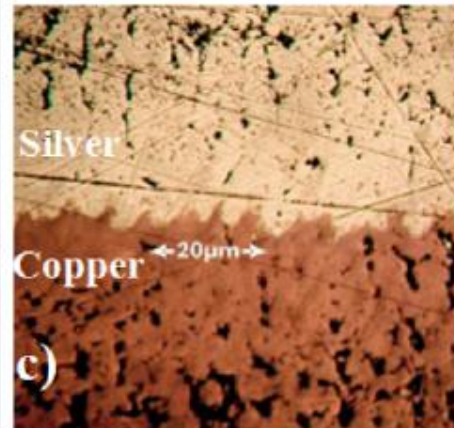
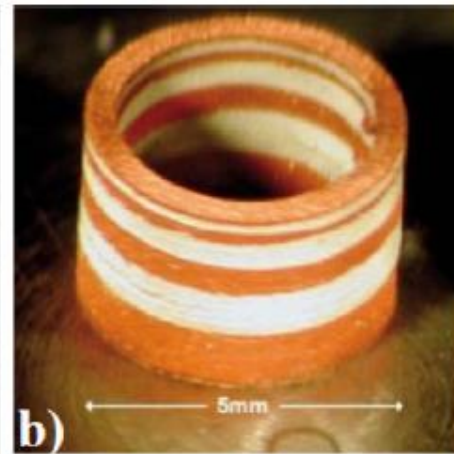
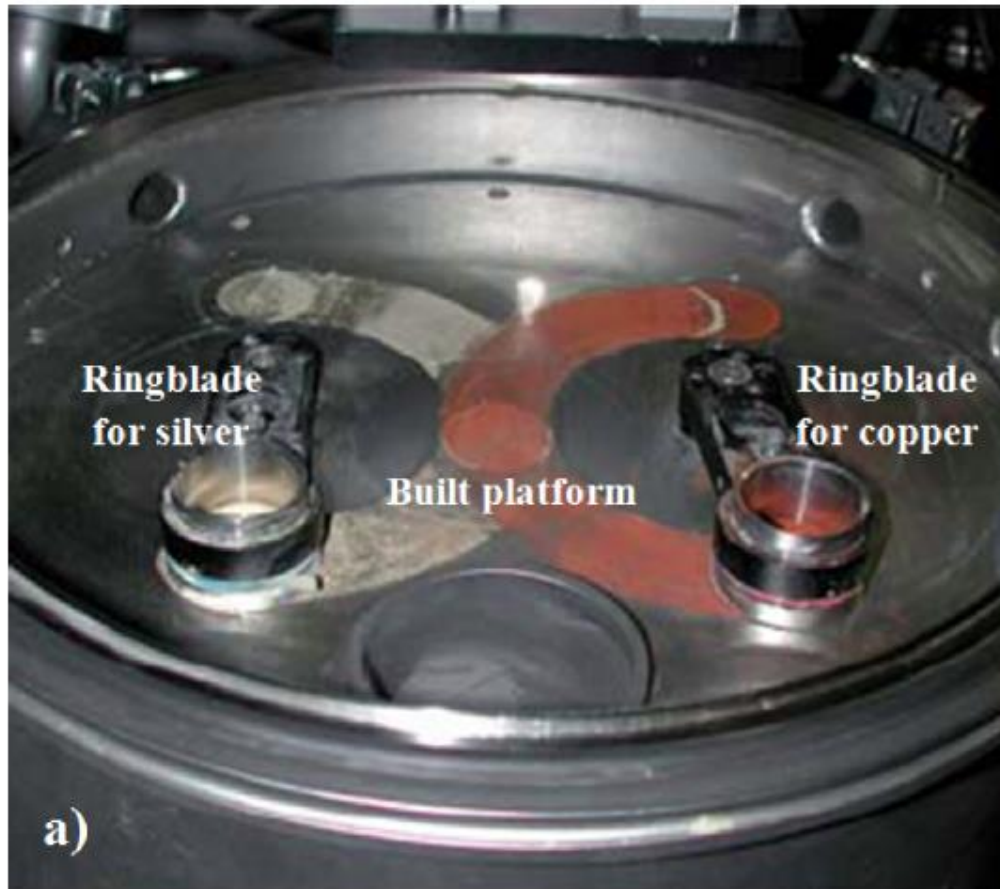
Example part in FDM



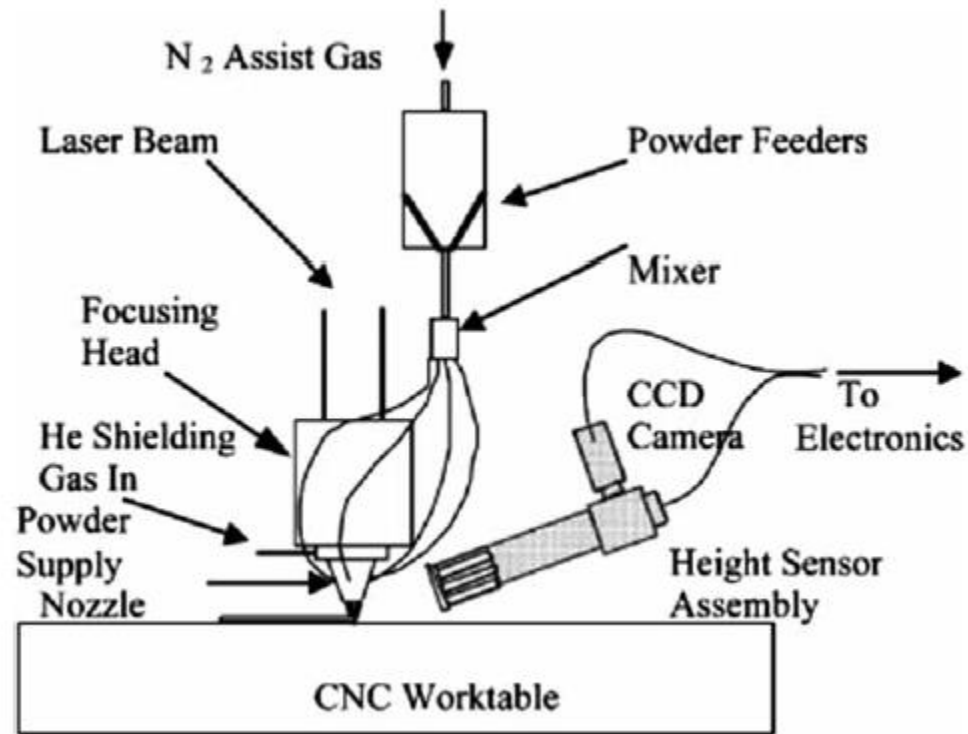
Dual Extruder Printers



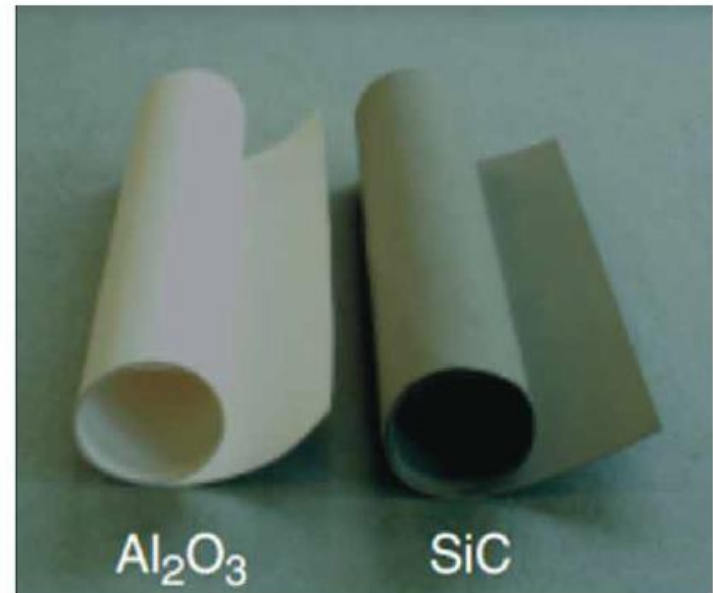
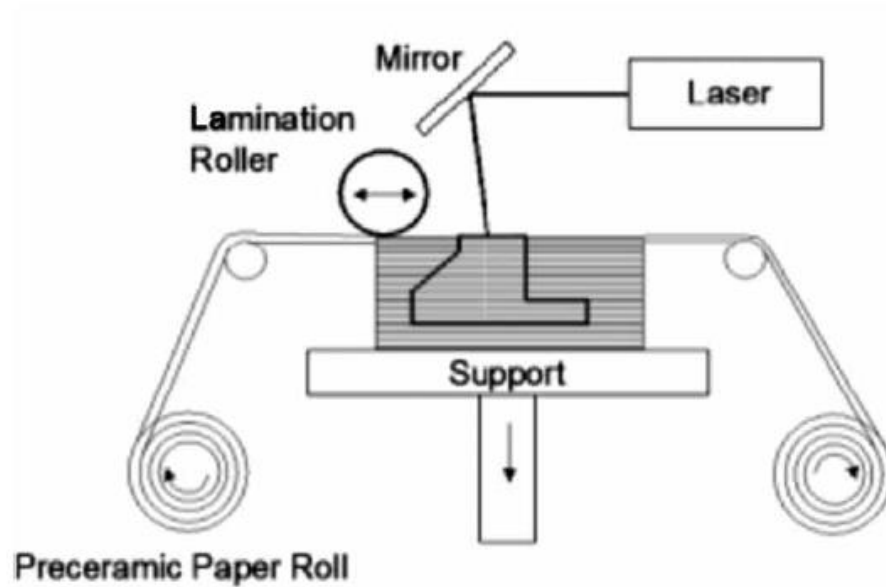
Powder Bed Fusion Process



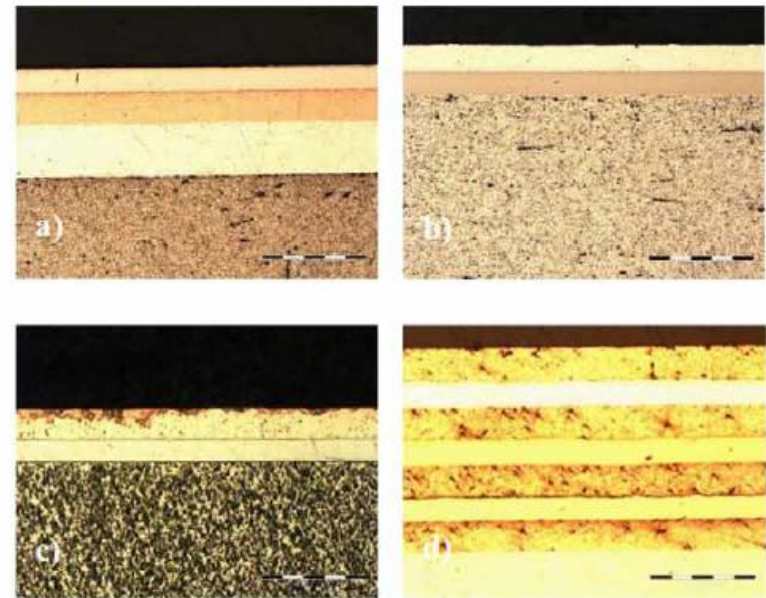
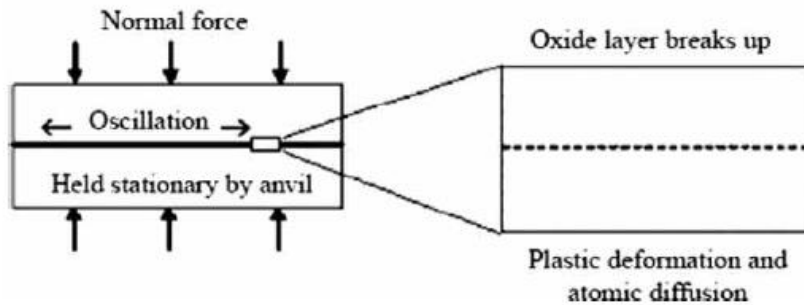
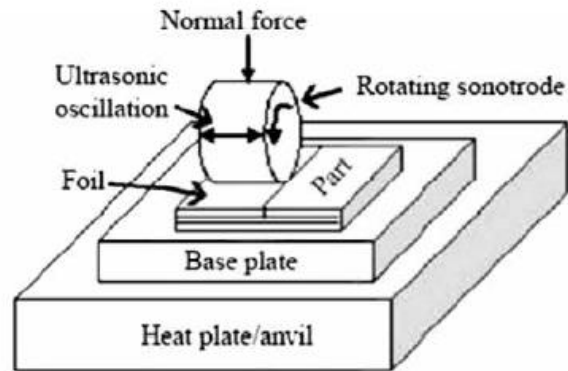
Directed Energy Deposition



Sheet Lamination



Ultrasonic Consolidation

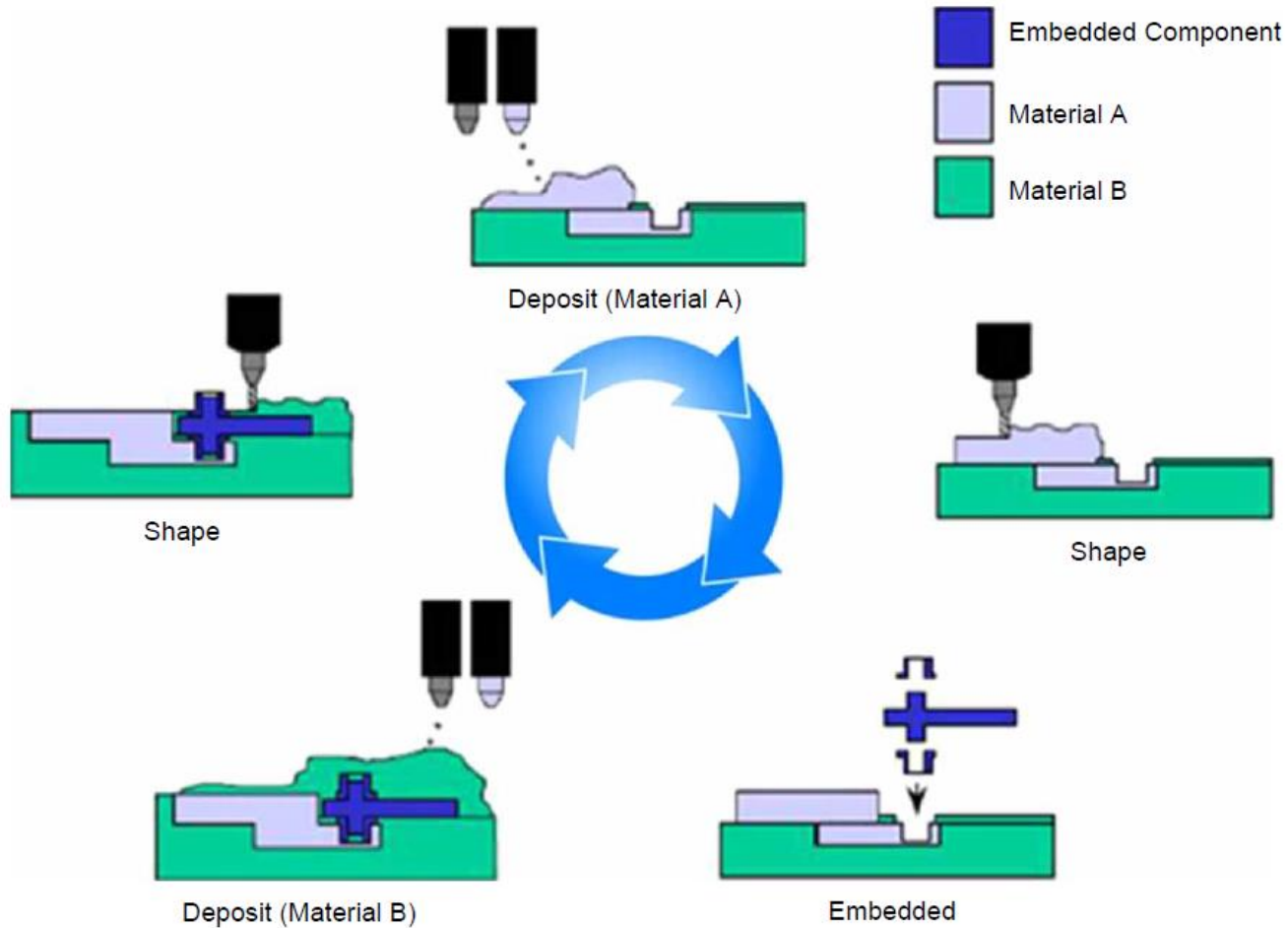


Shape Deposition Manufacturing

innovate

achieve

lead



Challenges



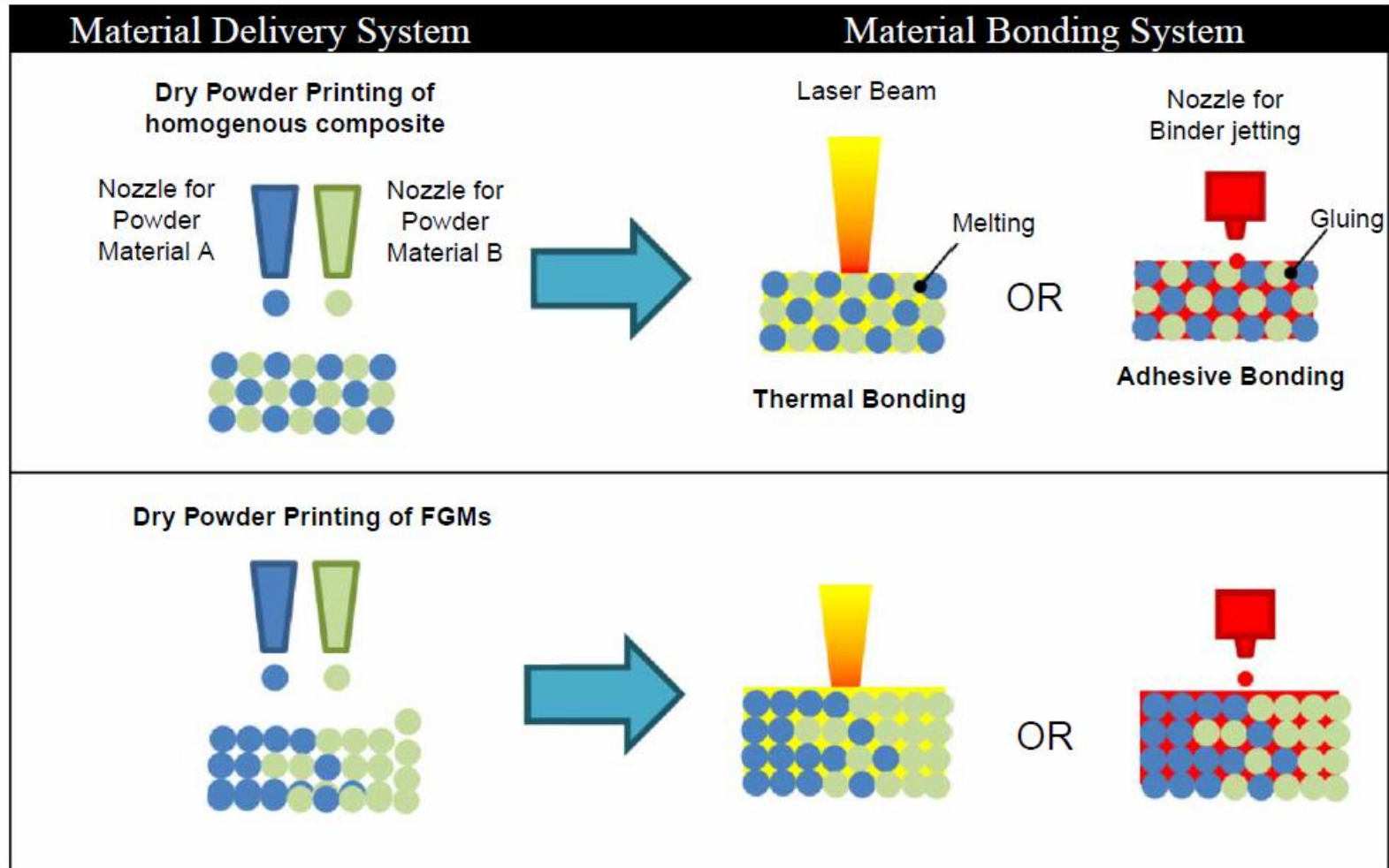
- Contamination
- Bonding
- Data Processing
- Process Interruption
- Hybrid and multi axis system
- Material development

Bonding Between Layers

Two types of bonding

- Thermal bonding (sintering/melting, ultrasonic welding or contact fusion)
- Non-thermal bonding (polymerisation or adhesive bonding)

Challenges in Powder based process



Application of Multi-materials



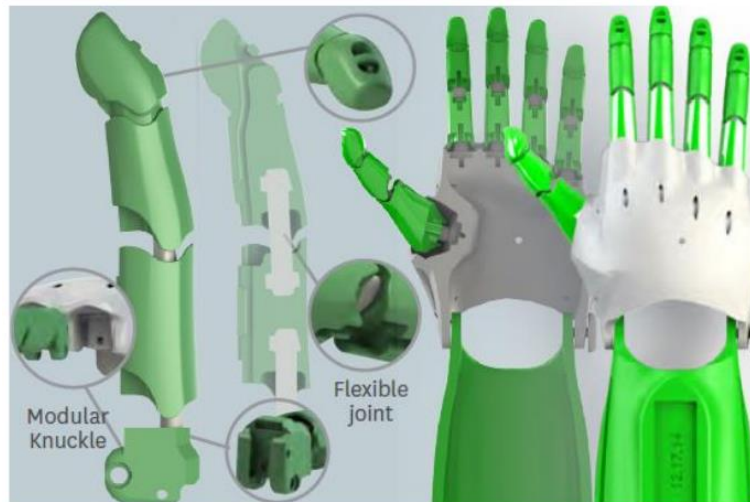
3D printed tooth brush
using polyjet printer



3D printed phone case
using Ultimaker 3.0
printer



3D printing of flexible
soles and breathable
elastics



Hybrid MMAM



Technology	Material	Institution
SLA + DW	Photopolymer, silver-based ink	University of Texas, USA
FDM + DW	Thermoplastic, silver-based ink	Stratasys and Optimec Inc., USA
UC + DW	Polymer, silver-based ink	Utah State University and University of Texas and Sandia National Laboratories, USA
FDM + UC	Thermoplastic, silver-based ink	Utah State University, USA
FDM + Robocasting	Thermoplastic, low-melting-point alloys and a variety of gels and slurries	Cornell University, USA
DW + Electrophoretic Deposition	Aluminium, copper oxide	Lawrence Livermore National Laboratory, USA



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End of session 7