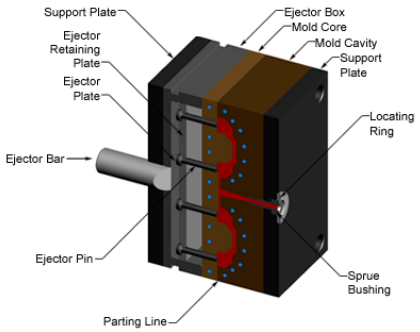
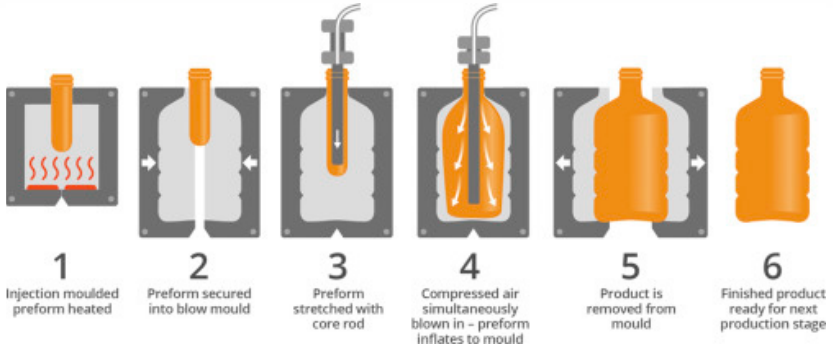
3d Printing and Polymers

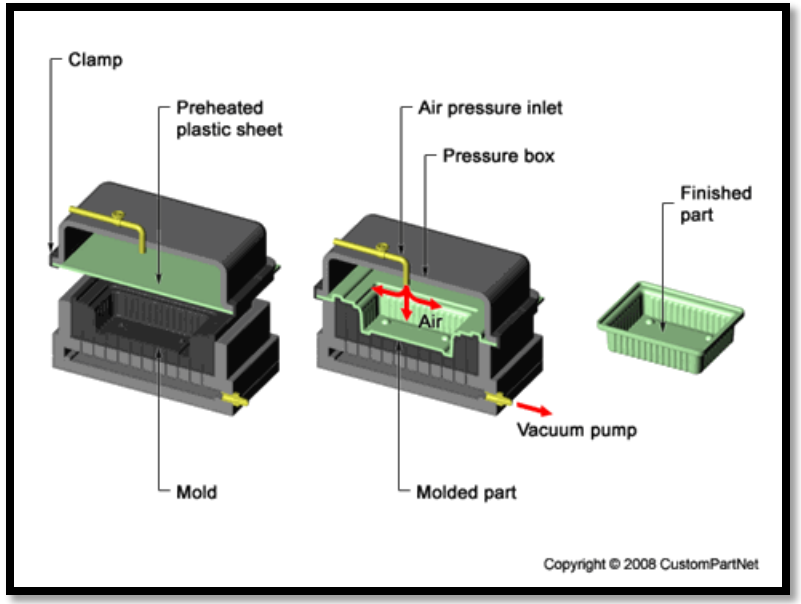
Source: Prof. Advincula, University of Tennessee, Knoxville, TN

Traditional Methods of Plastics Manufacturing

Extrusion, Injection and Blow Molding, and Thermoforming

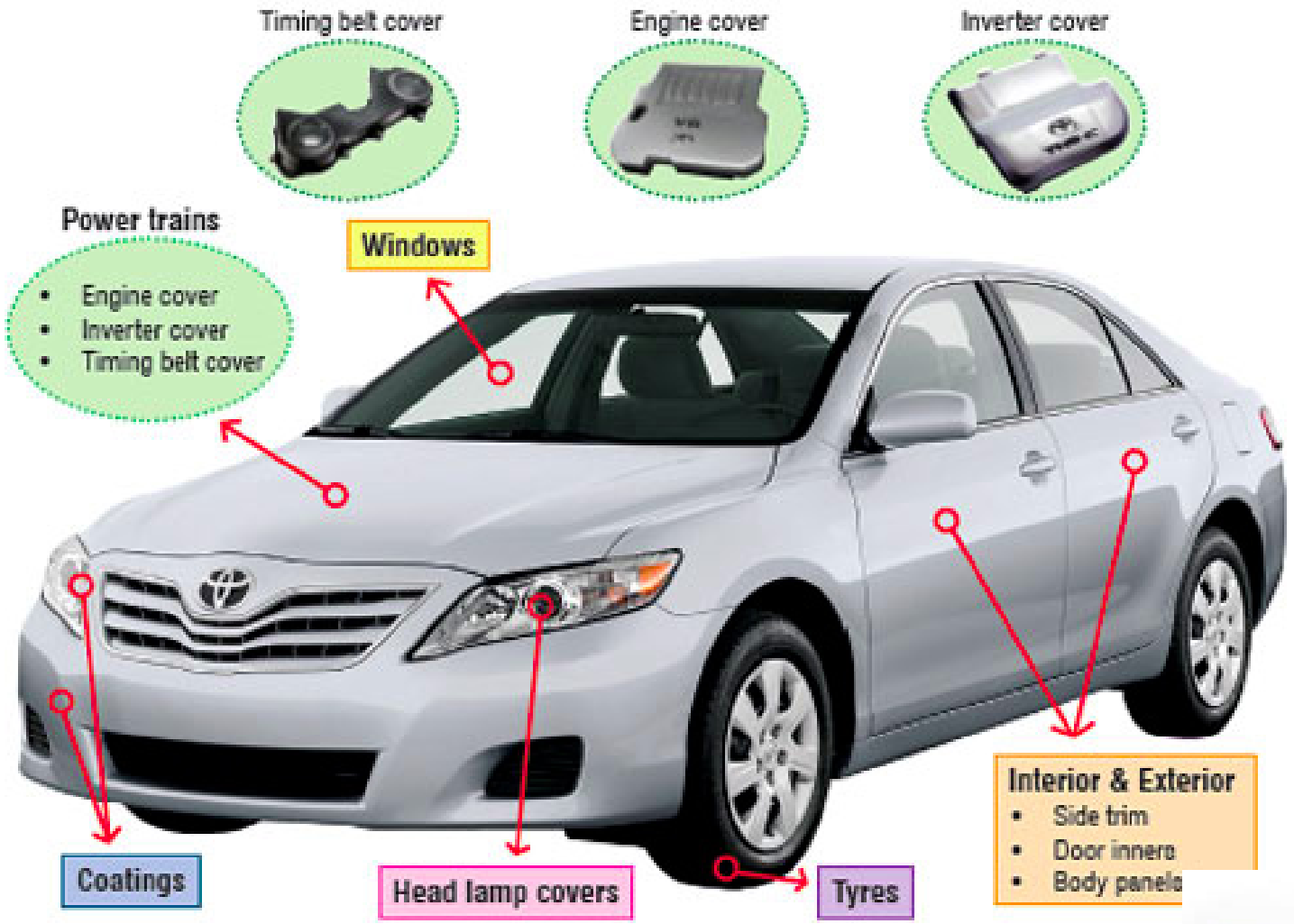






http://www.pepctplastics.com/capabilities-and-parts/process/acrylic-polishing/
http://finetrain.com/business-opportunity-injection-moulded-products/
http://www.polarttech.com/producten/solid-products/

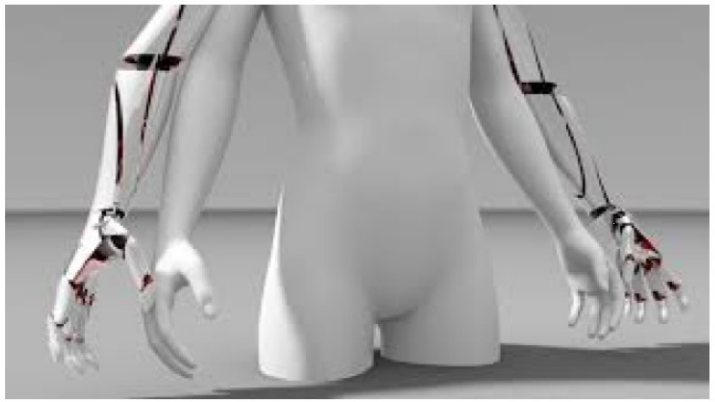
Polymer Nancomposites for Lightweighting and Strengthening

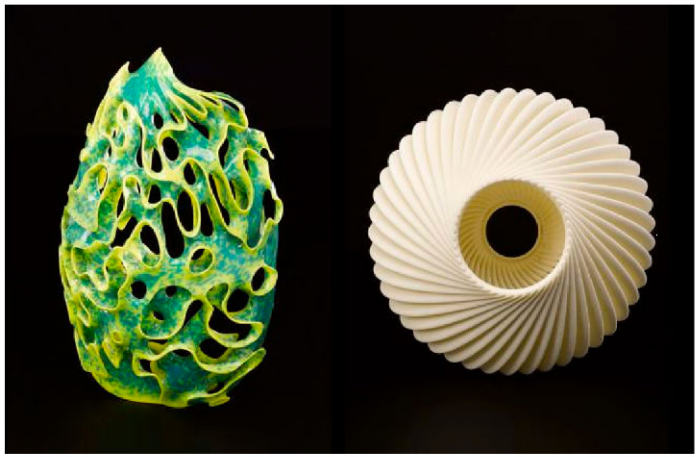


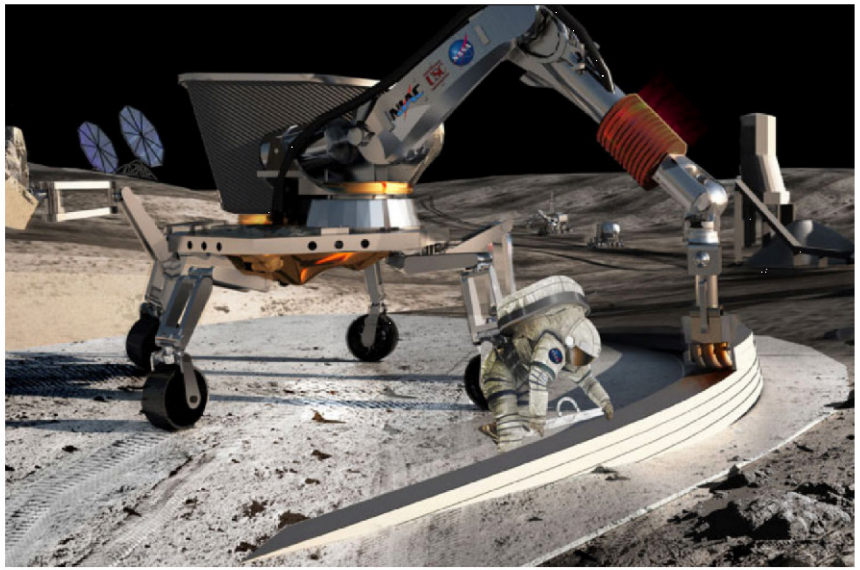
http://www.nanowerk.com/spotlight/spotid=23934.php

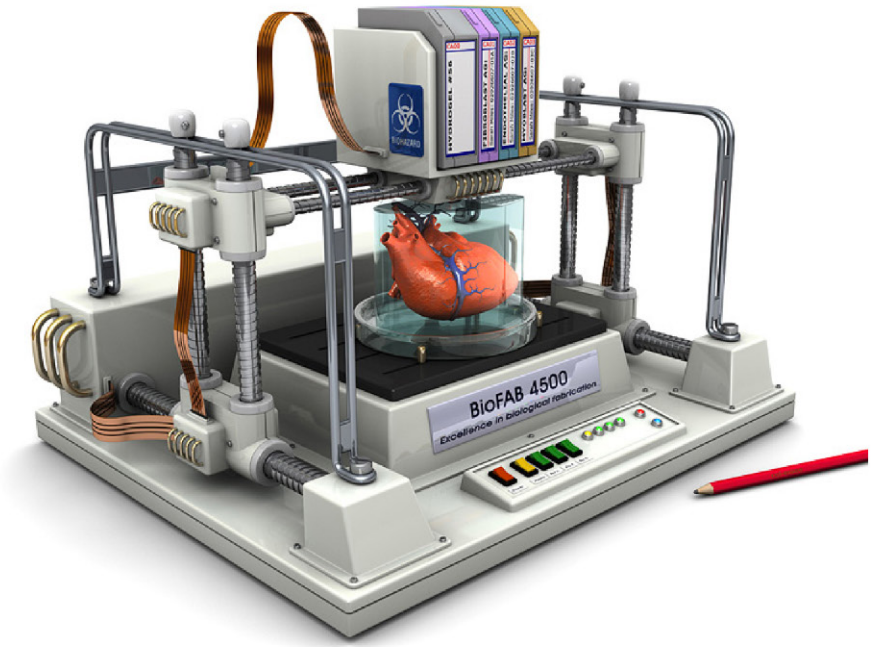
WORLD ECONOMIC FORUM

Dubai
November 2016







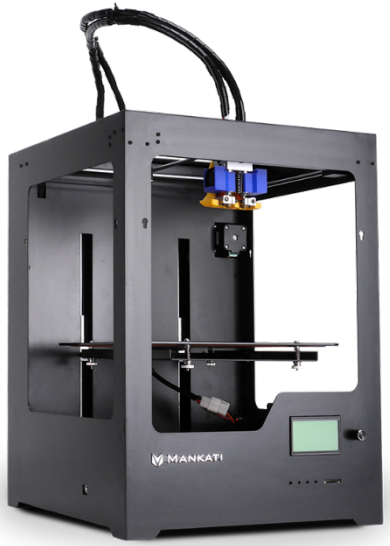


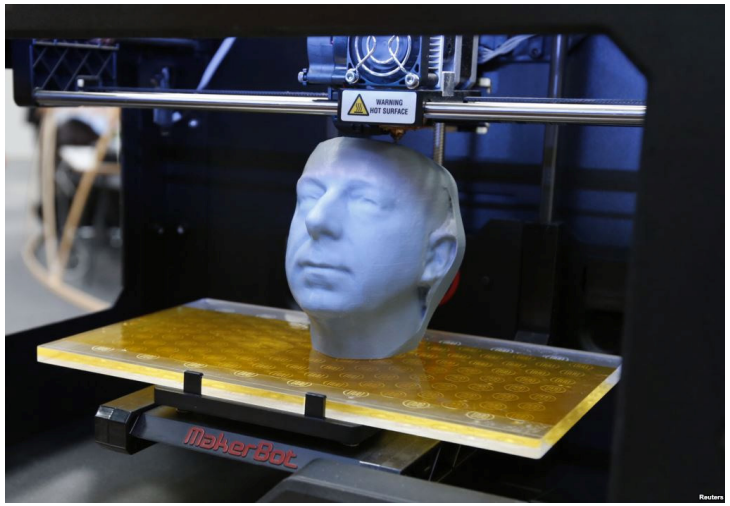
Prof. Rigoberto Advincula

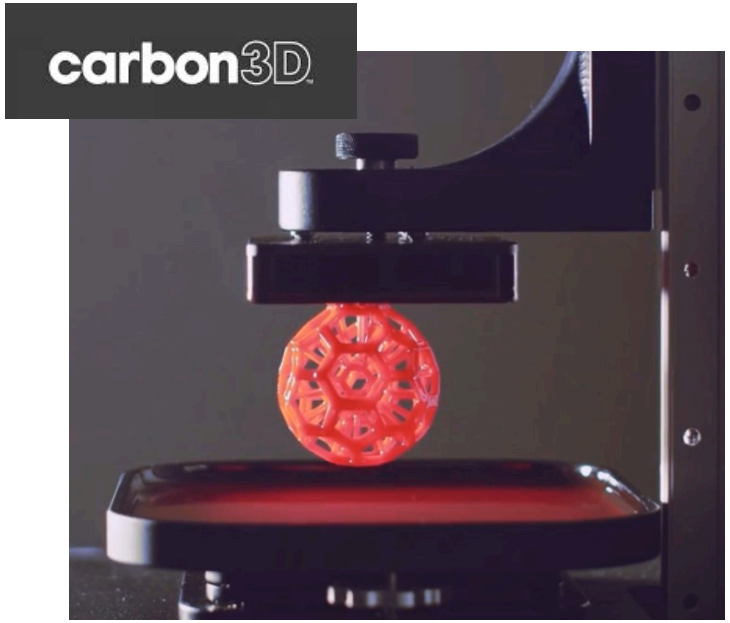
CASE SCHOOL OF ENGINEERING
CASE WESTERN RESERVE UNIVERSITY

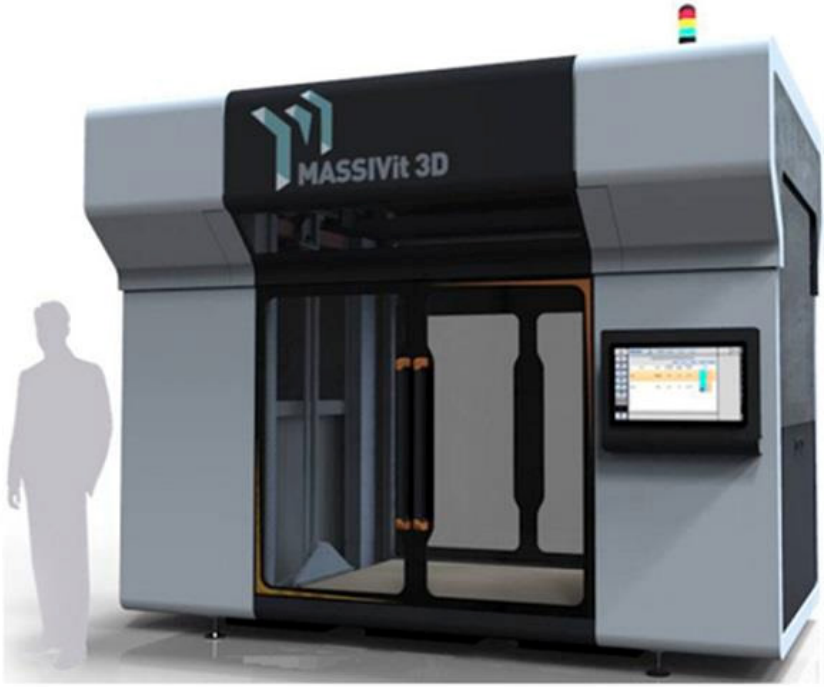
think[box]

Proto-typing vs Production

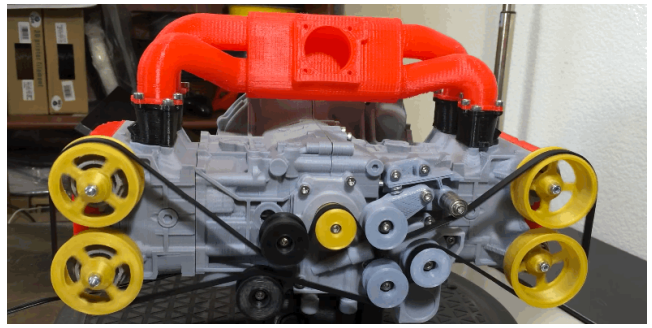




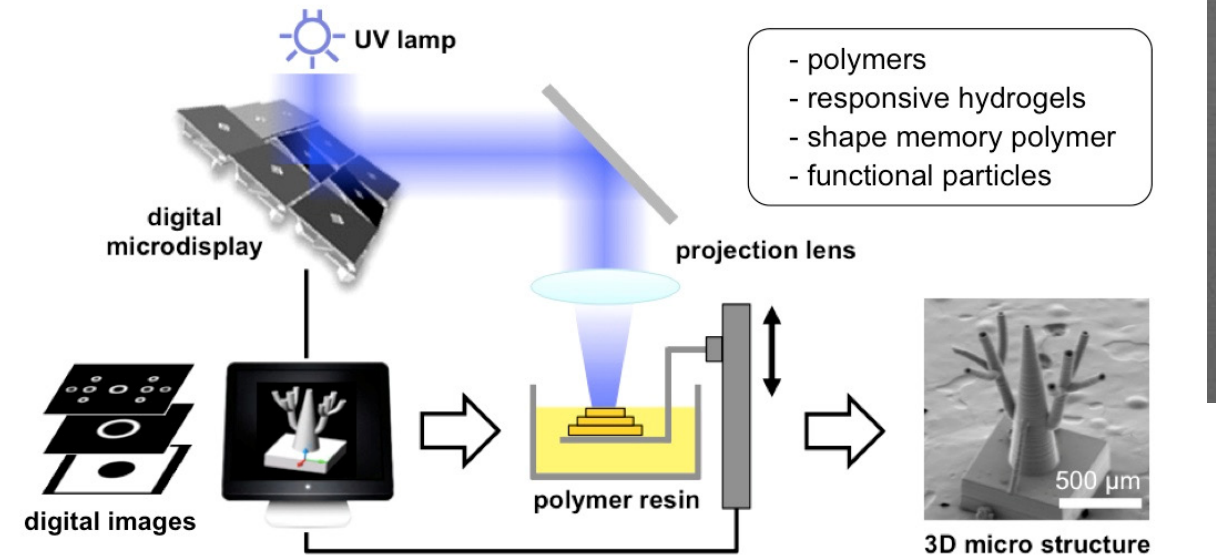




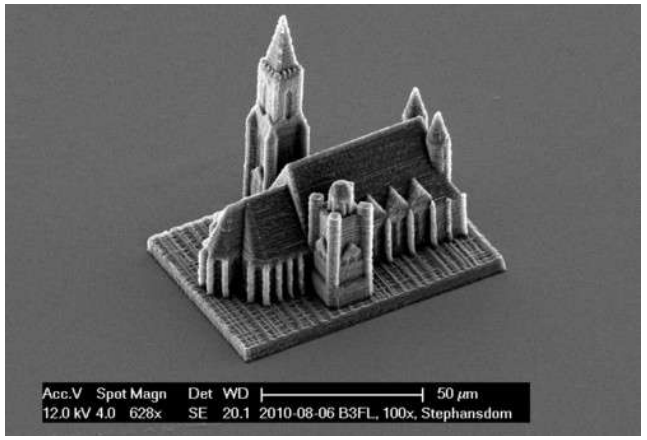
One of a kind, on demand, no transportation, no subtraction manufacturing (waste material). etc/

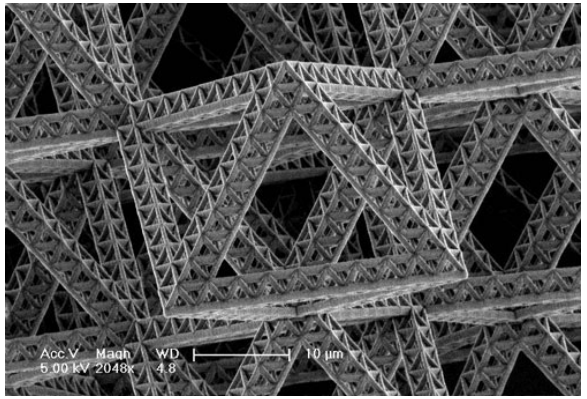


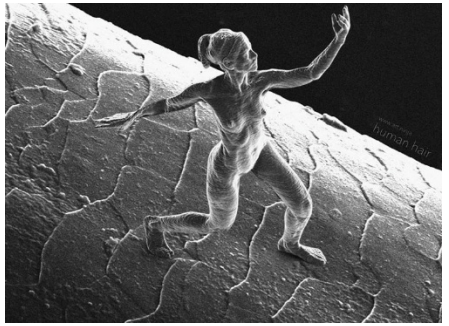
Micro- and Nano Resolution

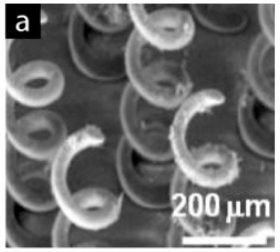


- polymers
- responsive hydrogels
- shape memory polymer
- functional particles

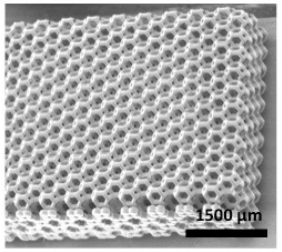




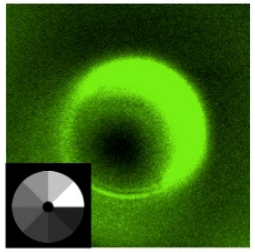




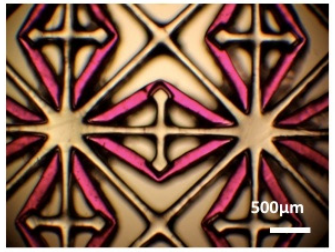
3D micro-structures



Scalable (µm to cm)

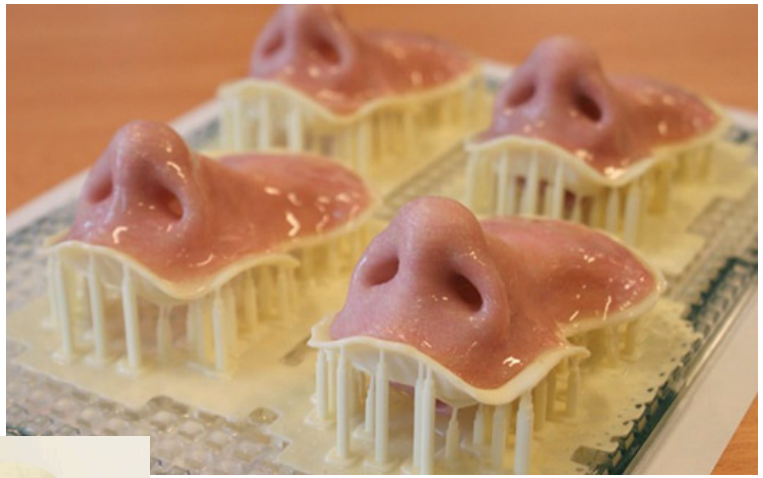


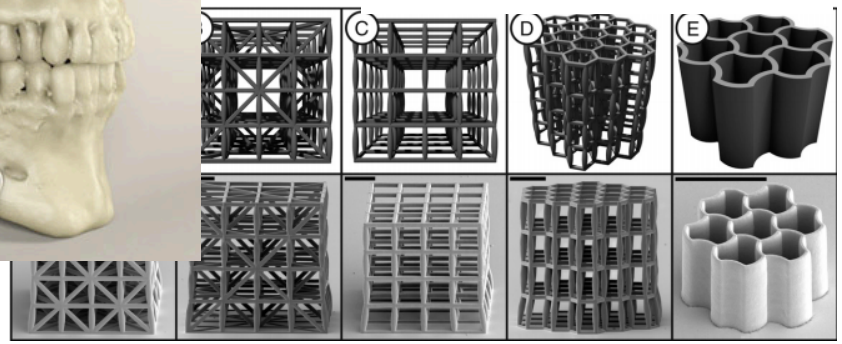
Functionally graded



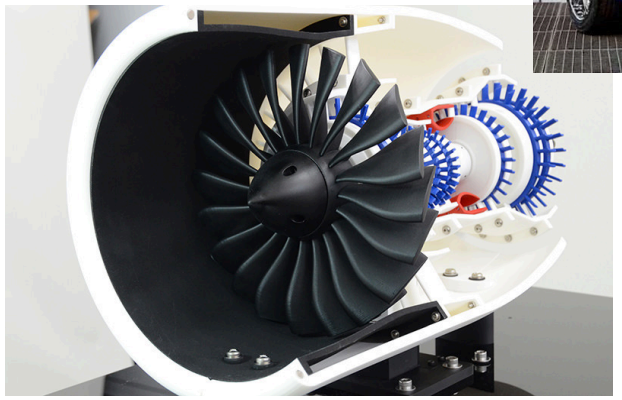
Multi-material

Biomedical Applications



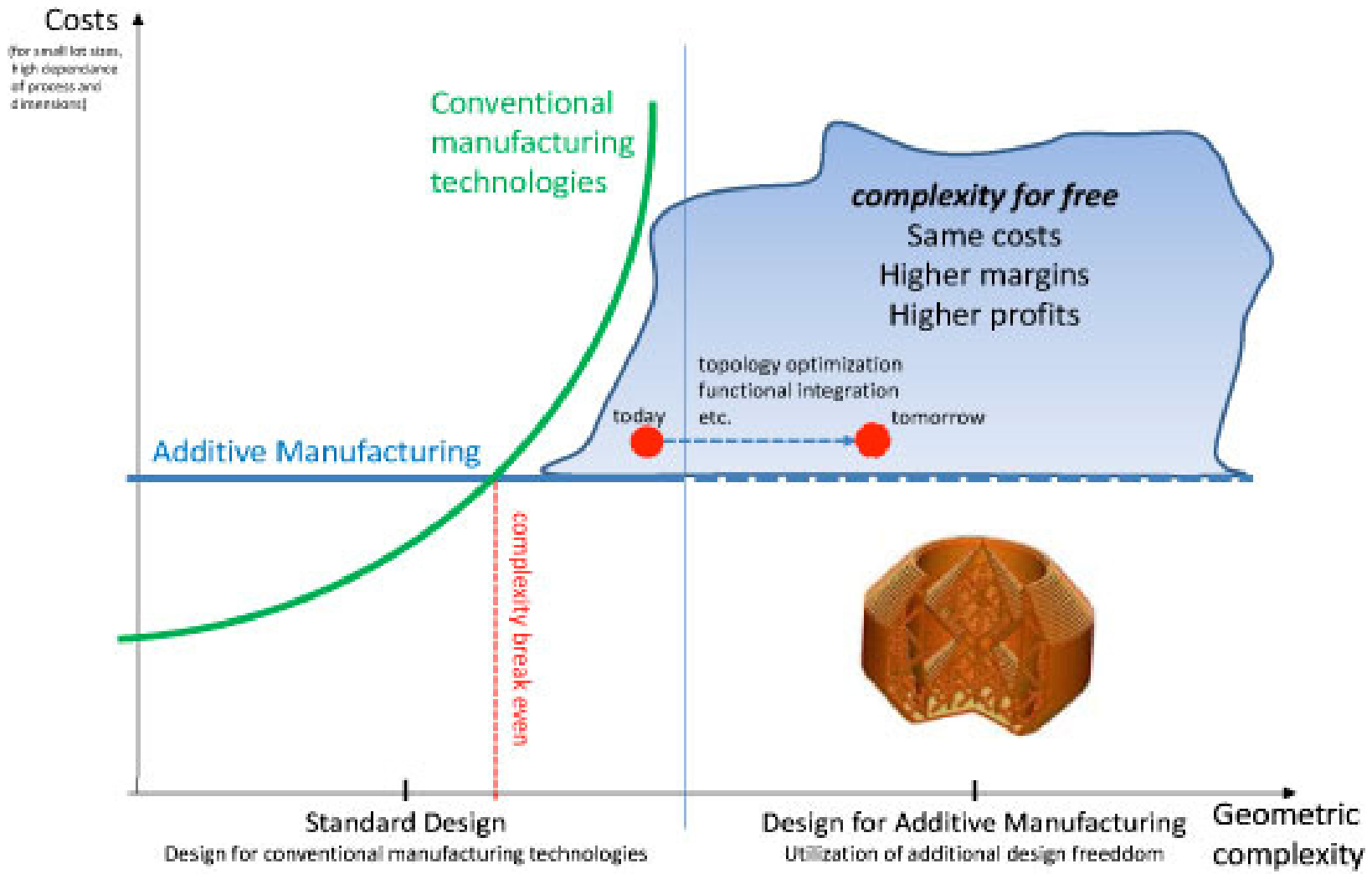


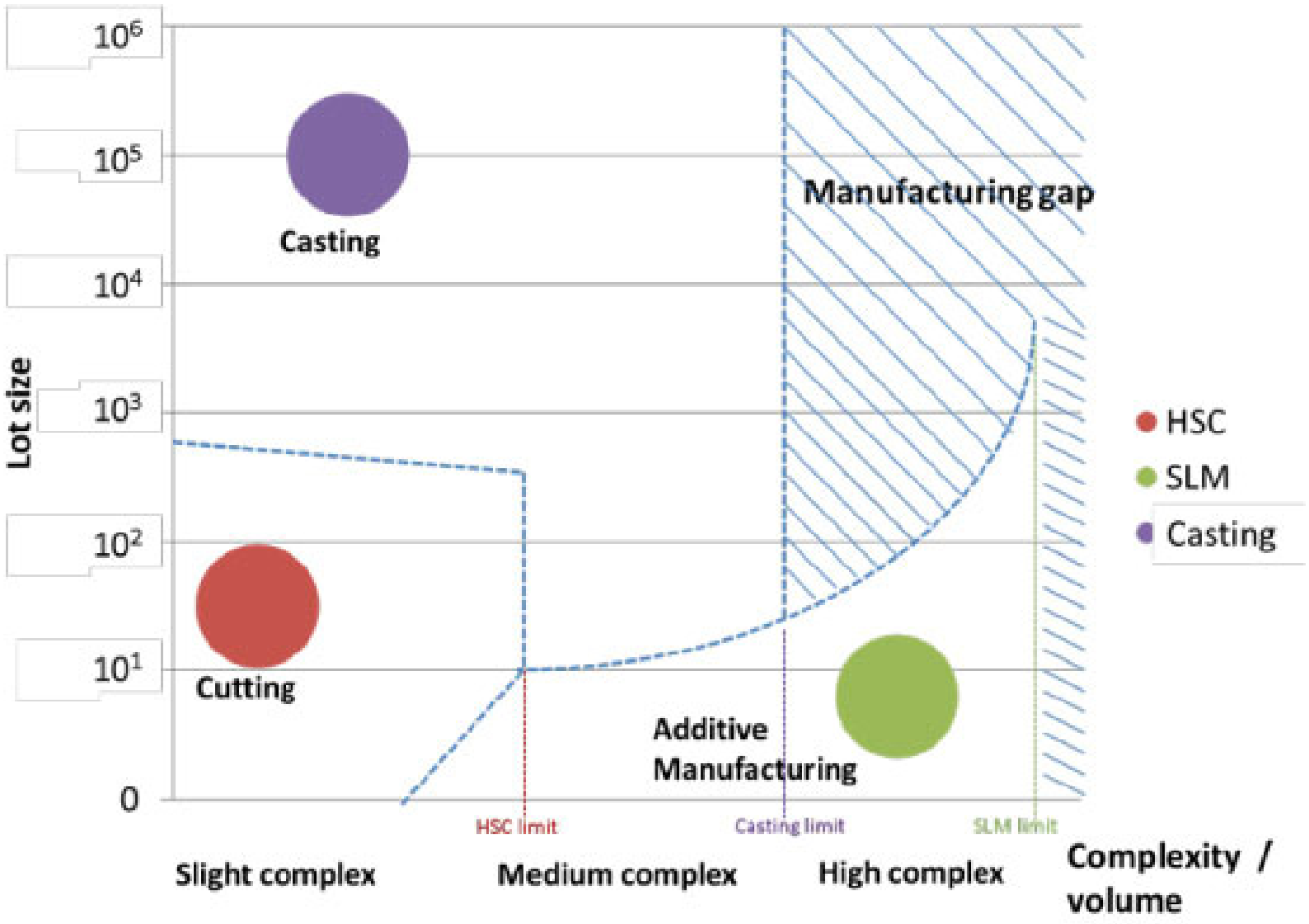
Automotive and Aerospace Applications of 3-D Printing and Additive Manufacturing



OAK RIDGE National Laboratory

http://www.gizmag.com/local-motors-strati-imts/33846/

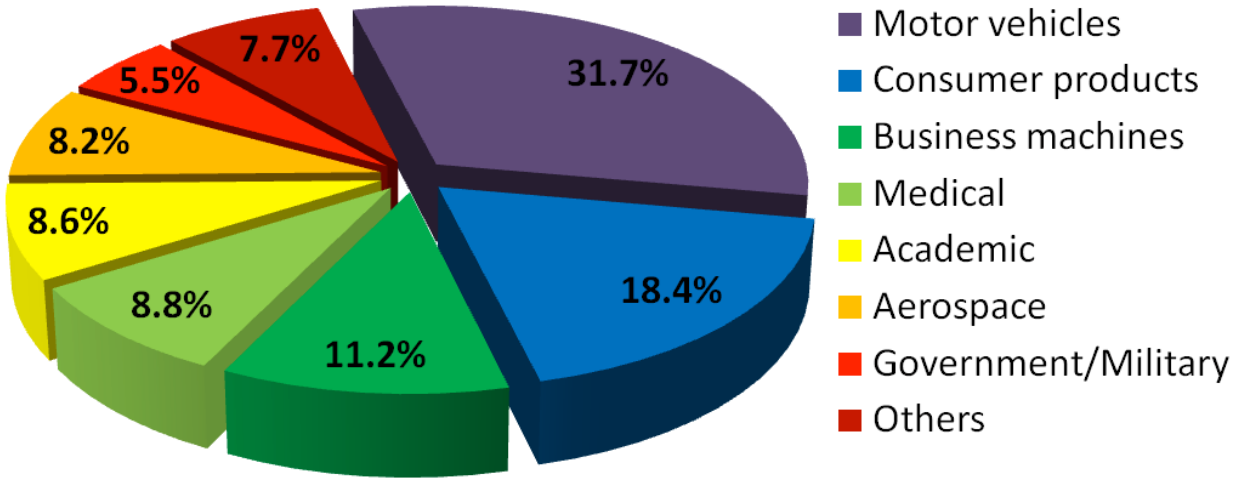

Costs
(for small lot sizes, high dependance of process and dimensions)
Conventional manufacturing technologies
complexity for free
Same costs
Higher margins
Higher profits
topology optimization
functional integration
etc.
today
tomorrow
Additive Manufacturing
complexity break even
Standard Design
Design for conventional manufacturing technologies
Design for Additive Manufacturing
Utilization of additional design freeddom
Geometric complexity

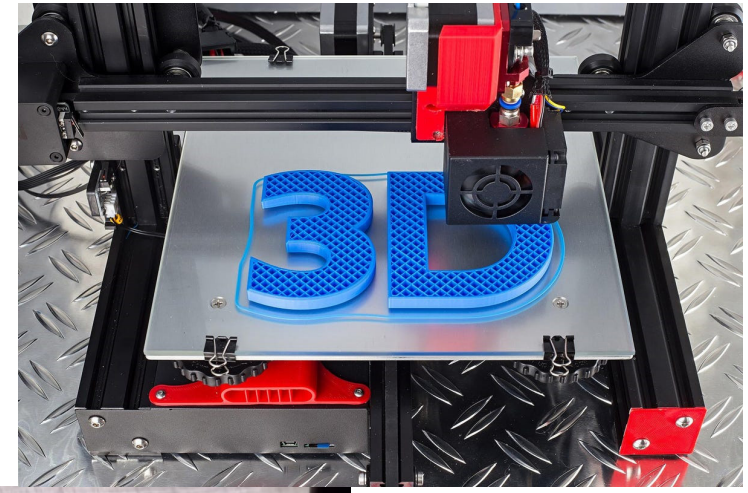

10^6
10^5
10^4
10^3
10^2
10^1
0
Lot size
Casting
Manufacturing gap
Cutting
Additive
Manufacturing
HSC limit
Casting limit
SLM limit
Slight complex
Medium complex
High complex
Complexity / volume
HSC
SLM
Casting

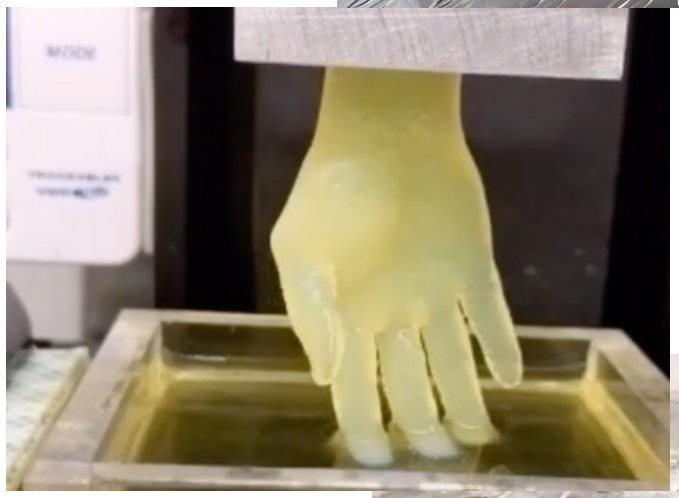
Alternative Names	Additive Technologies
3D Printing (3DP)–Global	Direct metal laser sintering (DMLS)
3D Rapid Manufacturing–Global (historic)	Selective laser melting (SLM)
3D Direct Digital Manufacturing (DDM)–USA	Electron beam melting (EBM)
Freeform Fabrication (FFF)–USA	Fused deposition modeling (FDM)
Solid Freeform Fabrication (SFF)–USA	Stereolithography (SLA)
Generative Manufacturing–Germany	Selective laser sintering (SLS)
eManufacturing–Germany	Laminated object manufacturing (LOM)
Constructive Manufacturing–Germany	Powder bed and inkjet head 3D printing
3D Additive Layer Manufacturing (ALM)–EADS	Plaster-based 3D printing (PP)

Biggest Advantage yet:

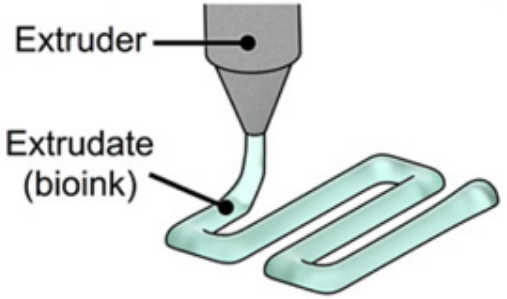
On-demand and limited production of high performance and unique design, complicated geometries, using high performance materials!



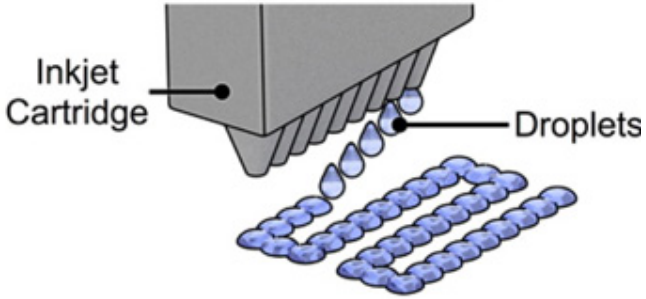




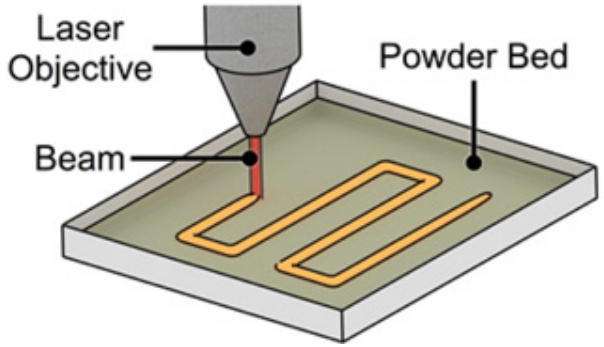
Extrusion Printing



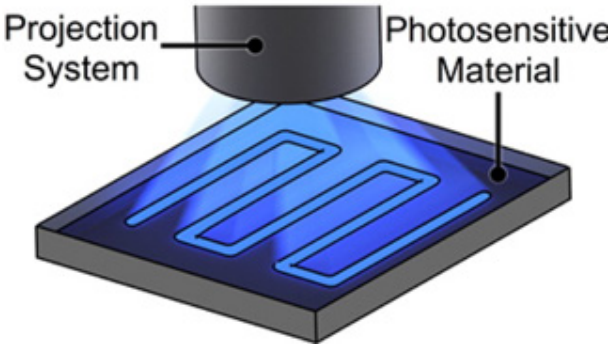
Inkjet Printing



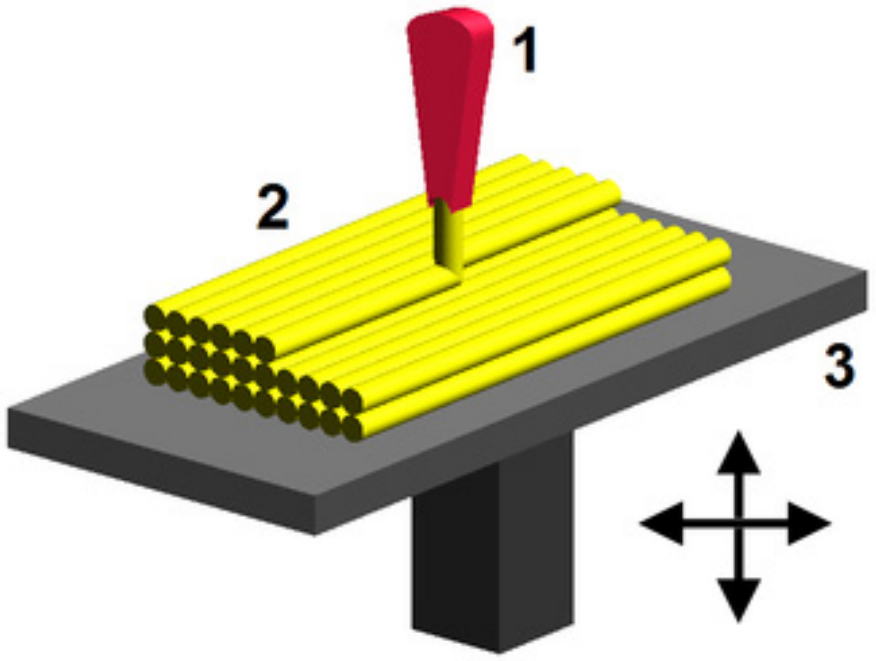
Selective Laser Sintering



Projection Stereolithography



FDM: Fused Deposition Modeling



FUSED DEPOSITION MODELING: In FDM - materials are extruded which harden immediately to form layers.

A thermoplastic **filament** that is wound on a coil is unreeled to supply material to a heated extrusion nozzle head – that turns the flow on and off.

Stepper or servo motors move the extrusion head and adjust the flow - horizontal and vertical directions with a microcontroller using a computer-aided manufacturing (CAM) software.

Typical Polymers - Acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polylactic acid (PLA), high density polyethylene (HDPE), PC/ABS, and polyphenylsulfone (PPSU).

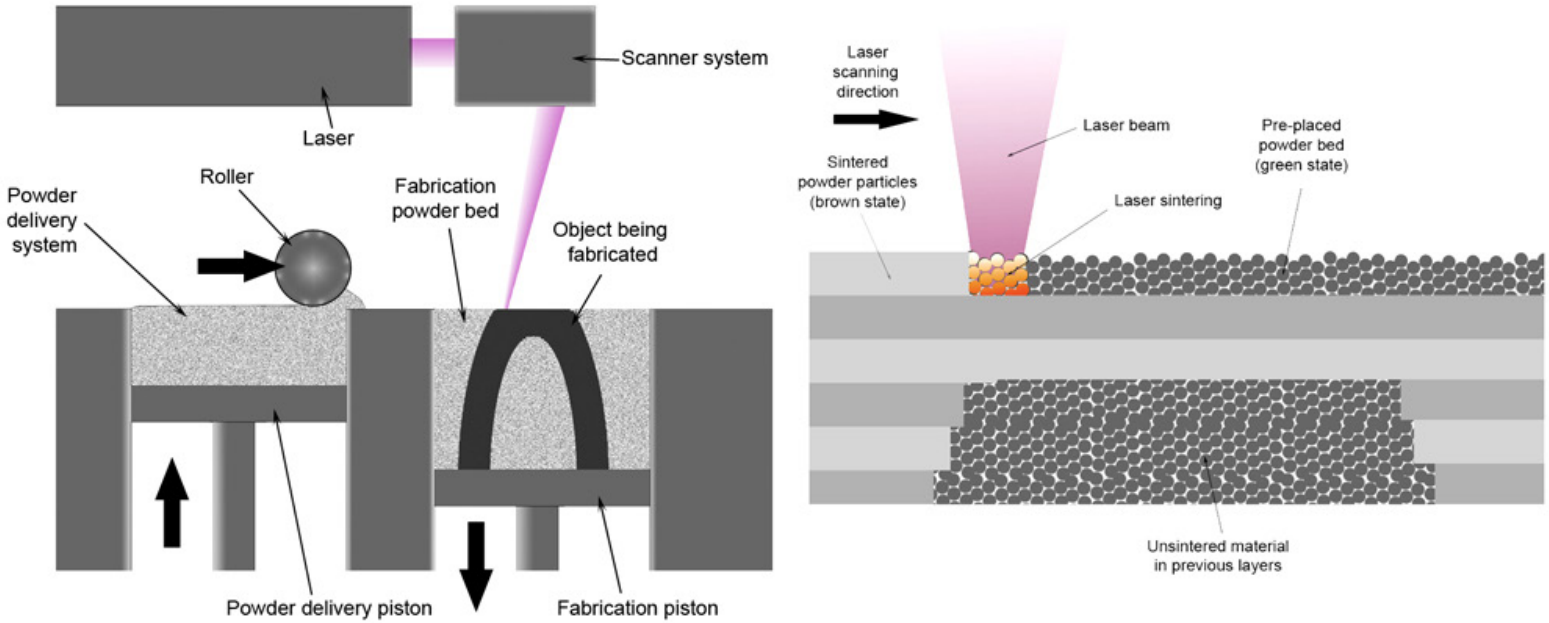
VERY IMPORTANT: Understand the Failure Mechanisms?

COMPOSITES? NANOCOMPOSITES? BLENDS? COPOLYMERS? METALS?

THERMOPLASTICS

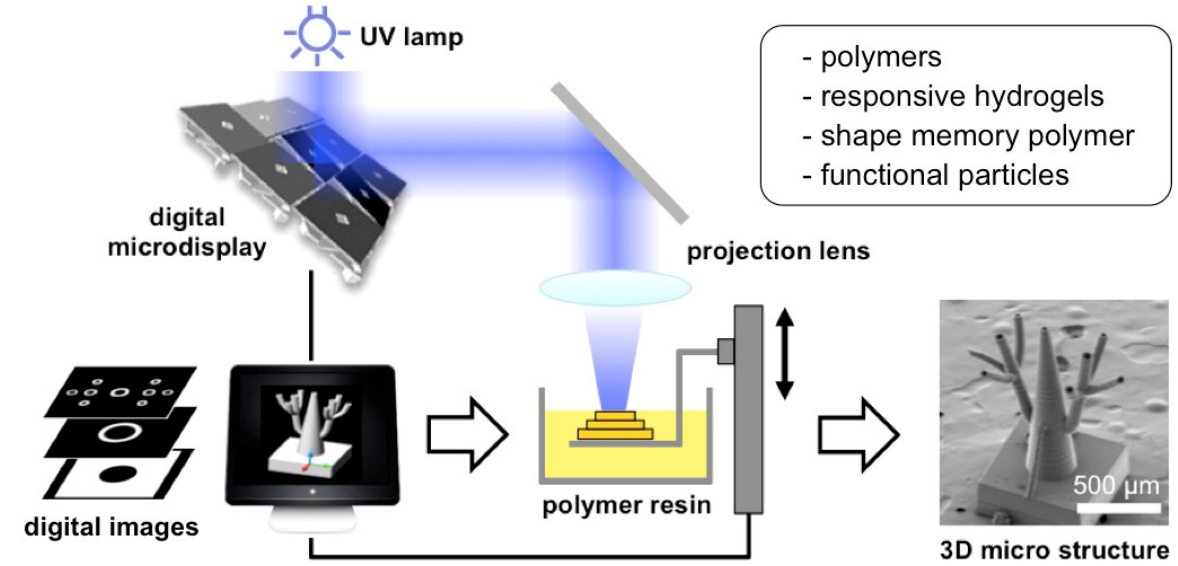
SLS: Sintering and Materials

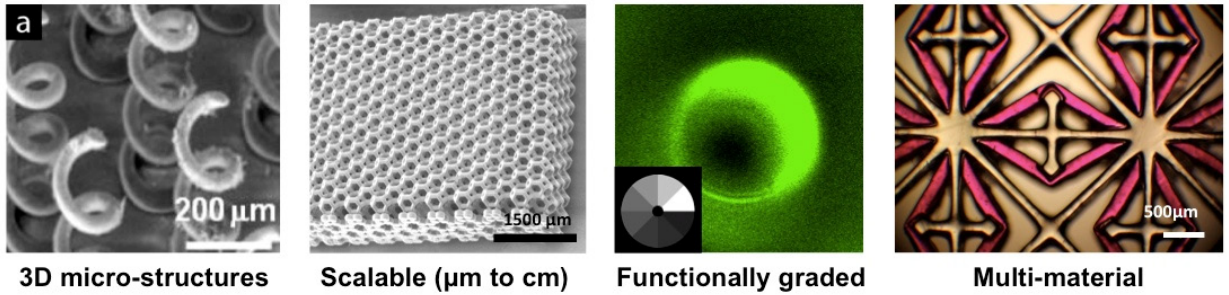
- Another 3D printing approach is the selective fusing of materials in a granular bed. The technique fuses parts of the layer, and then moves the working area downwards, adding another layer of granules and repeating the process until the piece has built up. A laser is typically used to sinter the media into a solid. Examples include selective laser sintering (**SLS**), with both metals and polymers (e.g. PA, PA-GF, Rigid GF, PEEK, PS, Alumide, Carbonmide, elastomers), and direct metal laser sintering (DMLS).



LITHOGRAPHY: SLA AND RESOLUTION

- **Mask-image-projection-based stereolithography**
- **Photopolymerization**
- In this technique a 3D digital model is sliced by a set of horizontal planes. Each slice is converted into a two-dimensional mask image. The mask image is then projected onto a photocurable liquid resin surface and light is projected onto the resin to cure it in the shape of the layer.

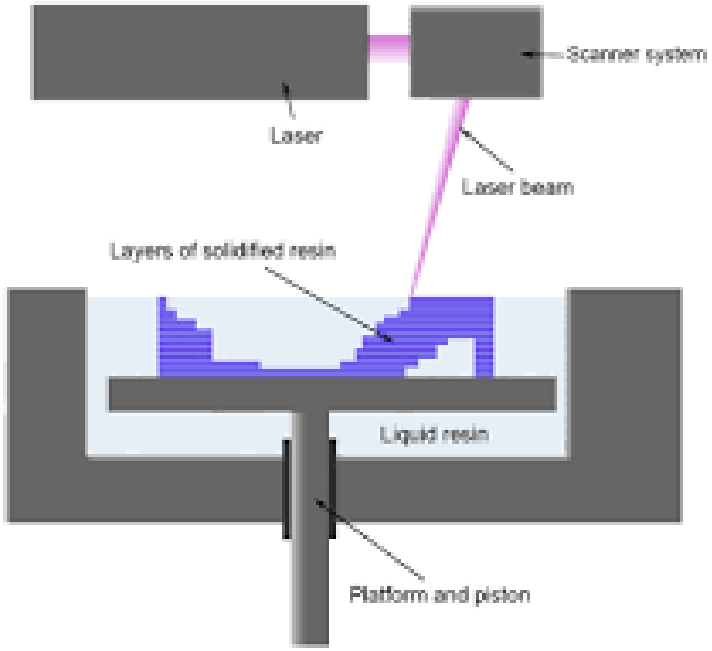


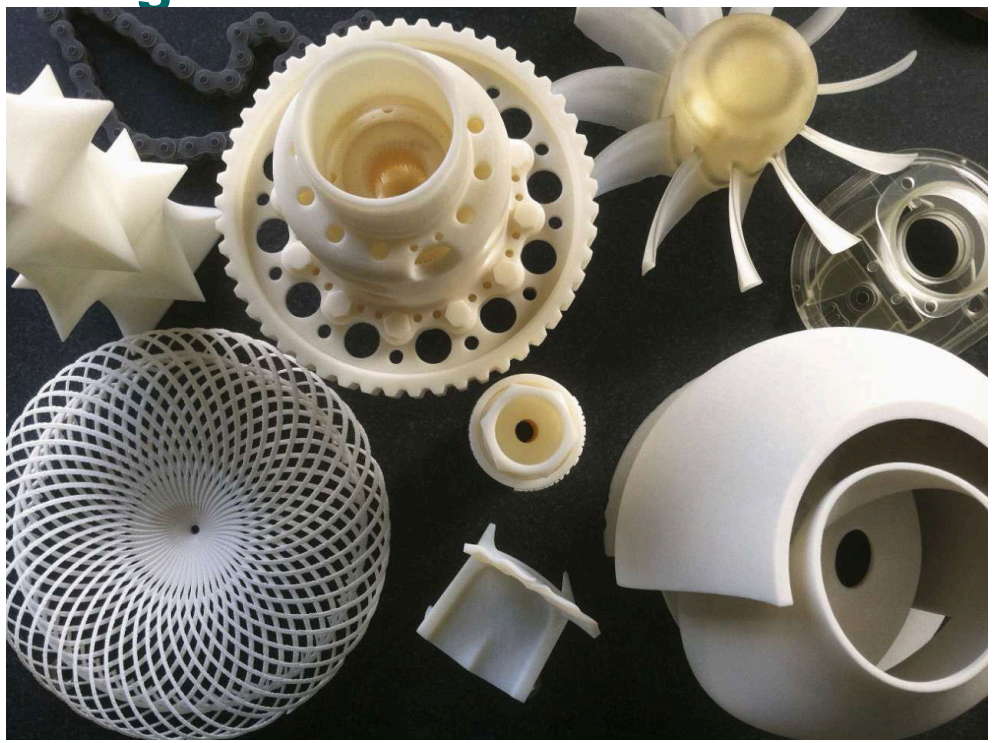


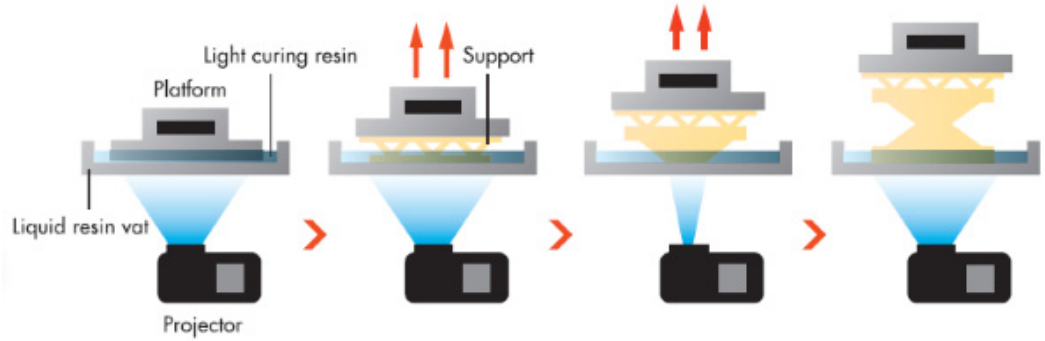
3D micro-structures | Scalable (µm to cm) | Functionally graded | Multi-material

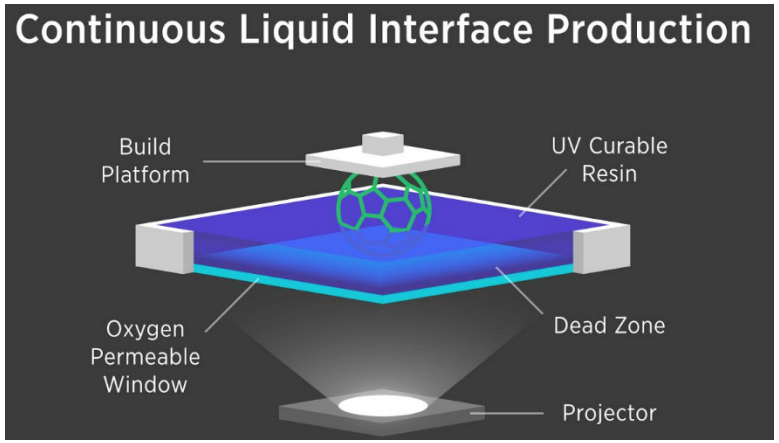
.

SLA vs DLP and 3D Printing

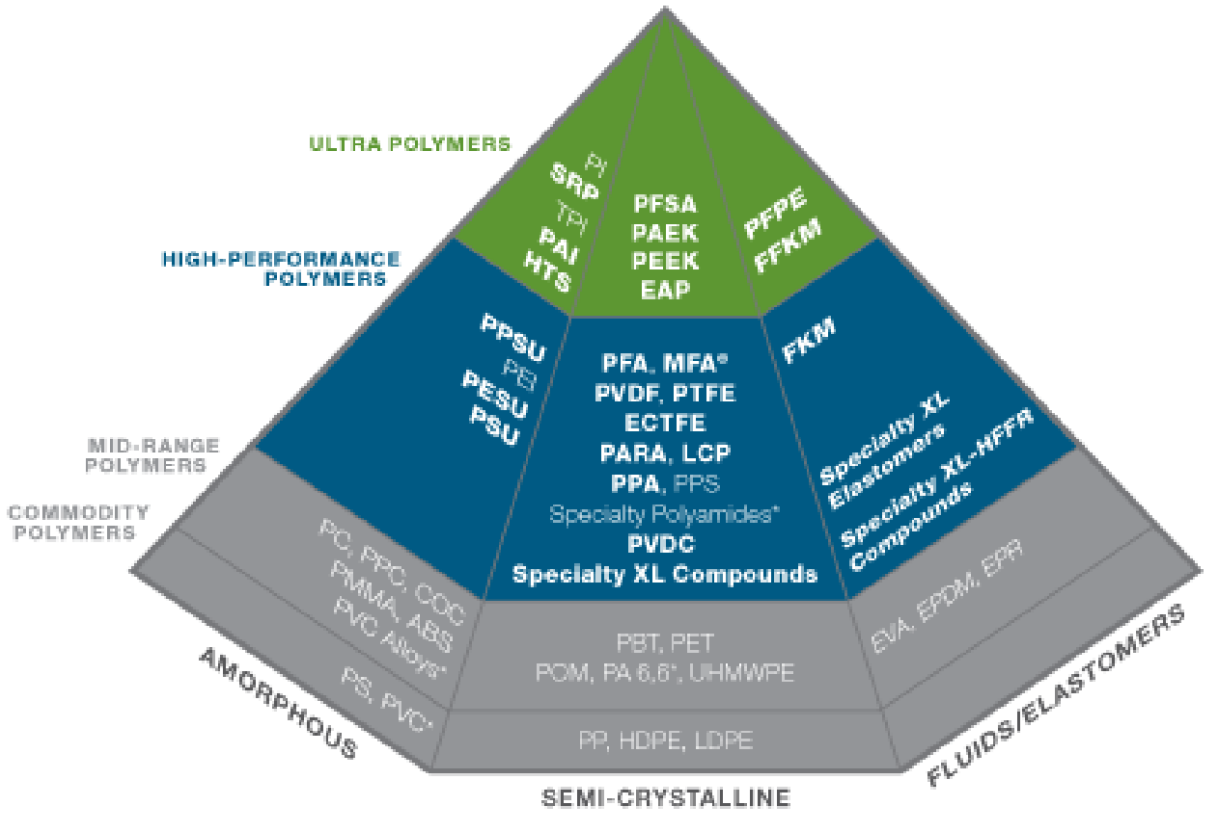




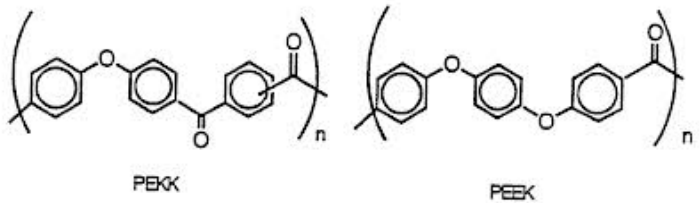




Polymers and *High Performance Materials*

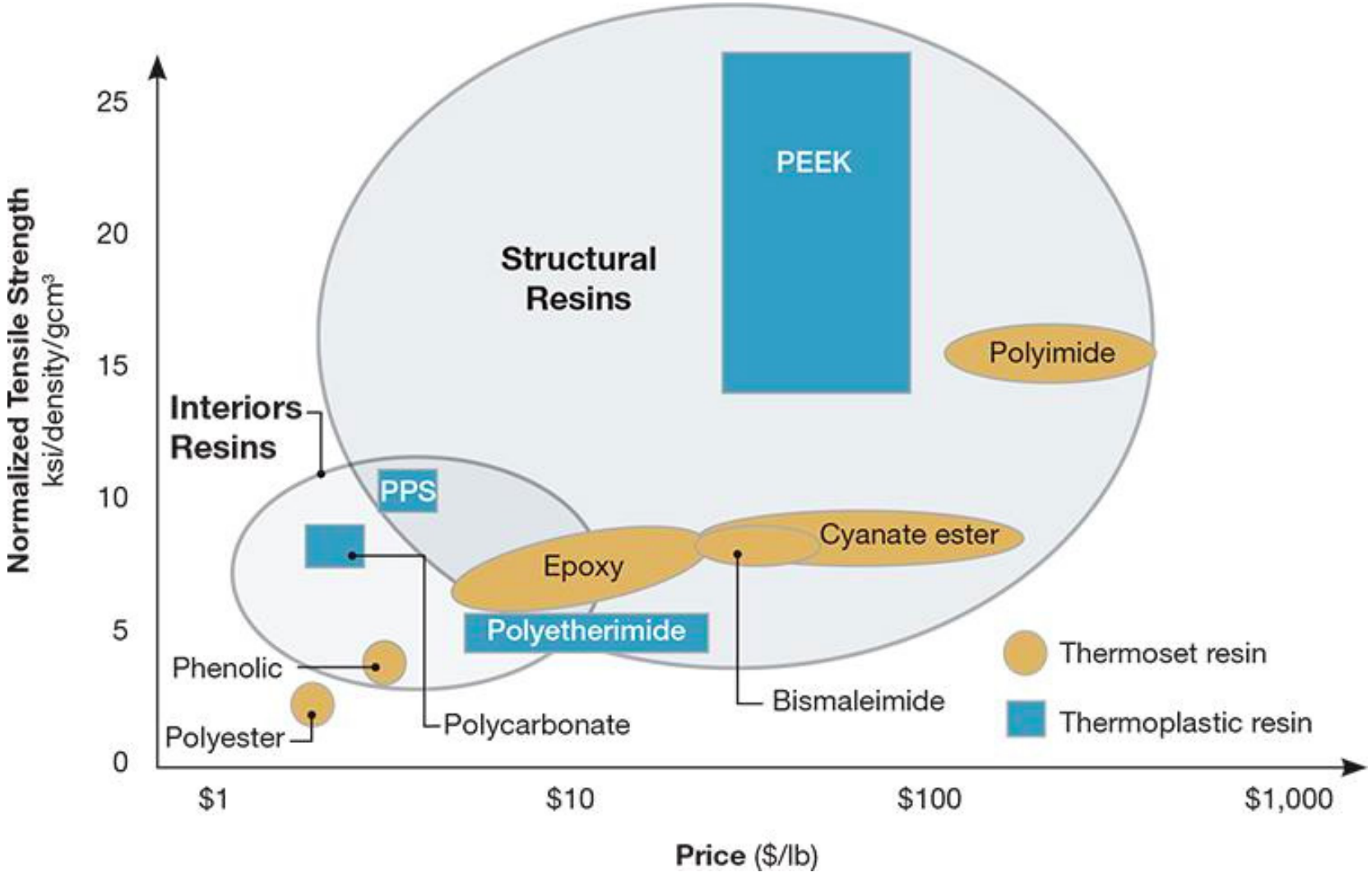


Polymer Abbreviations	
PI	polyimide
PEEK	polyetheretherketone
PEI	polyetherimide
PA	polyamide (nylon)
LCP	liquid crystal polymer
PES	polyethersulfone
PPA	polyphthalamide
PC	polycarbonate
ABS	acrylonitrile-butadiene styrene terpolymer
PBTP	polybutylene terephthalate
PMMA	polymethylmethacrylate (acrylic)
POM	polyoxymethylene (acetal)
(E)PS	expandable polystyrene
PP	polypropylene
LLDPE	linear low density polyethylene
LDPE	low density polyethylene
HDPE	high density polyethylene
PVC	polyvinyl chloride
HIPS	high impact polystyrene



http://www.imt.kit.edu/english/243.php

Polymer Choices

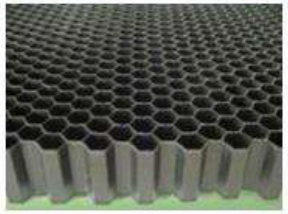


http://www.compositesworld.com/articles/the-outlook-for-thermoplastics-in-aerospace-composites-2014-2023

Possible Industrial Applications

Aerospace
- Repair and overhaul
- Aero-engine component
- Feature addition to the existing parts






Reinforcement

Automotive
- Rapid manufacturing
- Rapid prototyping
- Repair & modification
- Cladding of valves and shafts



Heat Exchanger

Car engine air intake

Car dashboard

Marine, Oil & Gas
- Free forming
- Conformal channel
- Reduce No. of parts, processes, and weight


Diesel pump

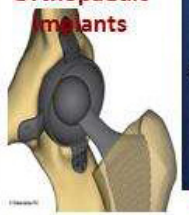
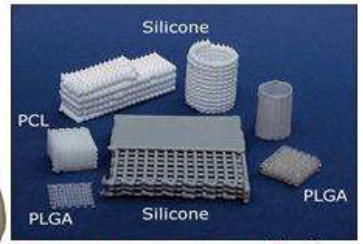
PE-industry
- Complex tooling
- Tool & die repair & modification


Complex cooling systems

Injection mould

Bimetallic tools

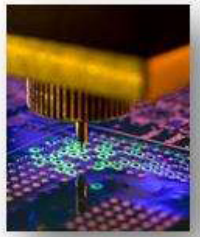
Medical
- Medical devices
- Medical implants


Orthopaedic implants



Tissue engineering scaffolds



Consumer
- Furniture
- Fashion apparel,
- Phone accessories
- Jewellery
- Lighting

Electronics:
- Thin Film Transistors
- Micro-optics / display
- Interconnects
- Clean energy




Building Construction
- Building models
- Township planning