DMSF
Non-Conventional Fabrication

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- Metal Laser Cutting
- Laser Marking and Engraving
- Ultrasonic-assisted Machining
- Desktop SLA 3d Printing
- Professional SLA 3d Printing

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Metal Laser Cutting

- Comparison of cutting processes: Wire EDM, Metal Laser Cut, Milling

	Wire EDM (Agie Charmilles CUT E 350)	Metal Laser Cut (Glorystar GS-0605P)	Milling (Mikron VCP600)
Measurement Resolution / Repeatability Accuracy	0.1μm	0.02mm	±0.001mm
Machining Accuracy	Extremely precise parts at ±0.025mm	Accuracy to ±0.025mm or better	Very good, in the range of ±0.01mm
Workpiece Dimension	820 x 680 x 250mm	630 x 530mm Mild Steel: 0.2 to 16mm Stainless Steel: 0.2 to 8mm Aluminum: 0.5 to 5mm Copper: 0.5 to 2mm Brass: 0.5 to 4mm	850 x 530mm Travel: 600 x 450 x 450mm Able to work on 3D parts
Cutting Speed	Slow	Very fast	Fair
Quality of Edge	Excellent	Very good	Excellent
Heat Affected Zone (HAZ)	Some HAZ	Some HAZ	No HAZ
Other characteristics	Limited to cutting only conductive materials.	Good for non-reflective materials and fair for reflective materials. Need different gas for cutting different materials.	Needs special fixture and tools, also requires skilled operator and usually can not work on very large parts.

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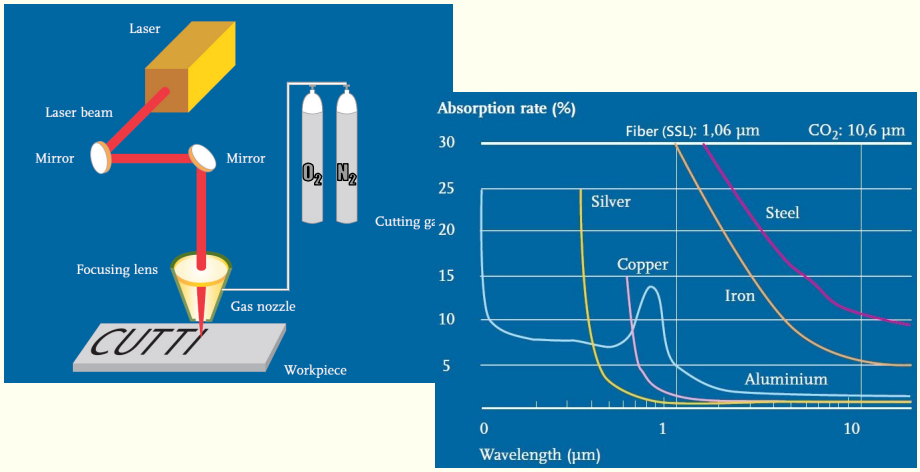
Metal Laser Cutting

- Fiber lasers vs CO_2 lasers:
  - Fiber lasers:
    - High powered solid state lasers that offer a short wavelength.
    - More readily absorbed into metals => higher cutting efficiency.
    - Optical path length never changes => no need of adaptive optics found in CO_2 lasers => less maintenance.

Metal Laser Cutting



Metal Laser Cutting

- Mild steel and low-alloy steel
  - Oxygen cutting
    - A thin oxide layer is formed on the cut surface.
      - May lead to difficulties if the cut parts are to be painted or powder coated.
    - Dross and notches will be formed on sheets with rust.
    - Painted surfaces (coated with zinc primers and iron oxide shop primers) can also cause problems.
  - Nitrogen cutting
    - Oxide-free cuts.
    - Cutting speed is reduced, especially for thick materials.
    - Can cut painted sheets.
    - Good for zinc coated / galvanized / hot dipped mild steels

Metal Laser Cutting

- Stainless steel and high-alloy steel
  - Oxygen cutting
    - Always exhibit burrs
    - Cut surfaces are discolored due to chromium and iron oxides.
      - Obstruct subsequent welding procedure.
      - Facilitate corrosion of the cut edges.
  - Nitrogen cutting
    - Oxide-free and burr-free cuts.
    - Cutting speed is reduced, especially for thick materials.
    - Kerf needs to be wider as focal point needs to be close to the back surface of the sheet.

Metal Laser Cutting

- Aluminum and aluminum alloys
  - Aluminum alloys are somewhat easier to cut then aluminum.
  - Anodized aluminum is easier to cut due to enhanced light absorption in the thick surface layer of aluminum oxide.
  - Dross-free cuts can be obtained by using high-pressure cutting with nitrogen or oxygen.
- Titanium
  - Both oxygen and nitrogen will be absorbed into the surface, where a hard and brittle layer is formed.

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Metal Laser Cutting

- Nickel alloys
  - Low-pressure oxygen-cutting
    - Cut edges exhibit dross and the cut surfaces are oxidized.
  - High-pressure nitrogen-cutting
    - Burr-free and oxide-free cuts may be achieved.
- Copper alloys
  - Copper
    - Quite a challenge due to its high reflectivity and thermal conductivity.
  - Brass
    - Easier to cut.
    - Oxide layer at cut front improves absorption of the laser beam.

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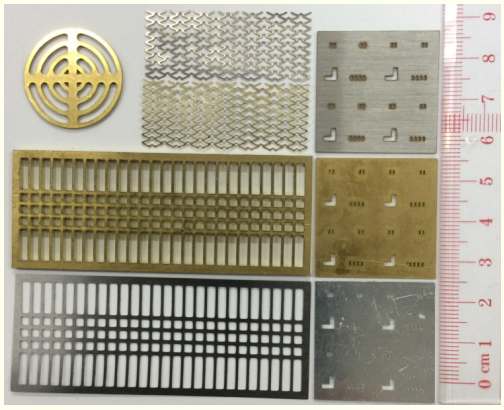
Metal Laser Cutting

- Fiber laser cutting machine of 1.5kW
  - Working area: 630 x 530 x 90 mm
  - 4th rotary axis for round pipe cutting

Mild Steel (mm)	0.2 ~ 16
Stainless Steel (mm)	0.2 ~ 8
Aluminum (mm)	0.5 ~ 5
Copper (mm)	0.5 ~ 2
Brass (mm)	0.5 ~ 4



Metal Laser Cutting

- Al plate cutting

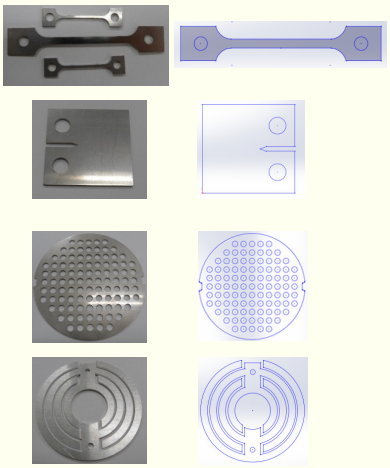
- SS pipe 4-axis cutting

Metal Laser Cutting

- Supported input file format:
  - **DXF**: Vector-based de facto industry standard from Autodesk
  - **PLT**: Vector-based plotter file format
  - **AI**: Graphics file format from Adobe, i.e. Adobe Illustrator Artwork file.

Metal Laser Cutting

- Examples
  - SMA specimens
    - Tensile specimen:
      - Materials / Thickness: 1mm
      - Production time: 45 second
    - Crack specimen:
      - Materials / Thickness: 1.5mm
      - Production time:1 min.
  - S.S. Filter specimen
    - Materials / Thickness: 1.2mm
    - Production time:8min. 30 second
  - Ti Electrode specimen
    - Materials / Thickness: 1mm
    - Production time: 2min.



Laser Marking and Engraving

- Laser is used to alter the materials properties locally, which produces text / shapes.
- Similar to high-resolution point matrix printing.
  - Laser head moves from side to side.
  - Engraving dots form lines.
  - Those lines form images or letters.

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Laser Marking and Engraving

- Laser Marking Machine
  - 10W fiber laser
  - Max. size is 110mm X 110mm

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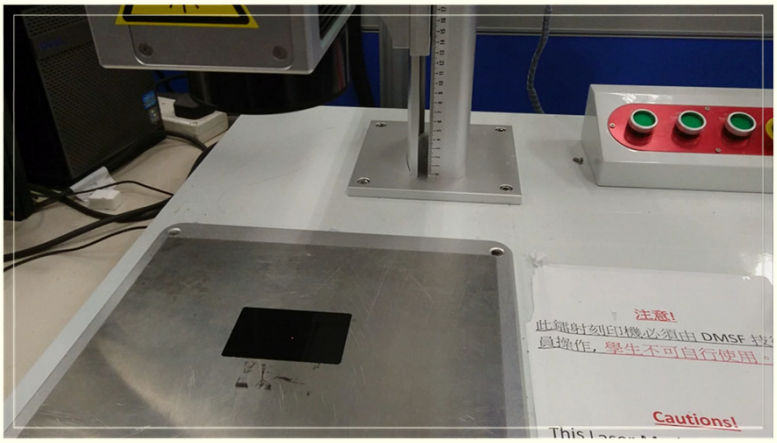
Laser Marking and Engraving



Laser Marking and Engraving

- Sample of laser marking on SS block and thin Al sheet.

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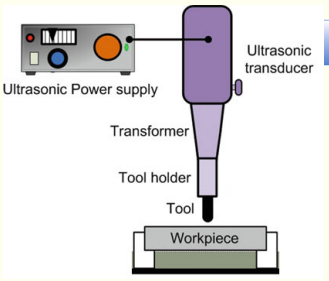
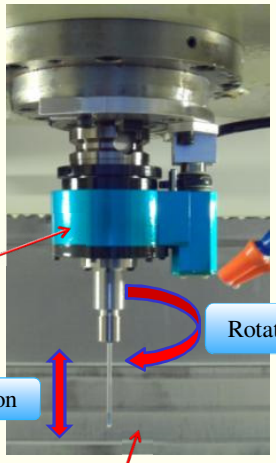
Ultrasonic-Assisted Machining

- Ultrasonic tool holder - Acrow
  - Fast, small and deep hole machining
  - Length / Diameter > 10
  - Hard or ultra-hard material cutting
  - Glass, Ceramics, Vulcanization silicon, etc.
  - Stainless steel, Tungsten steel, Molybdenum, etc.





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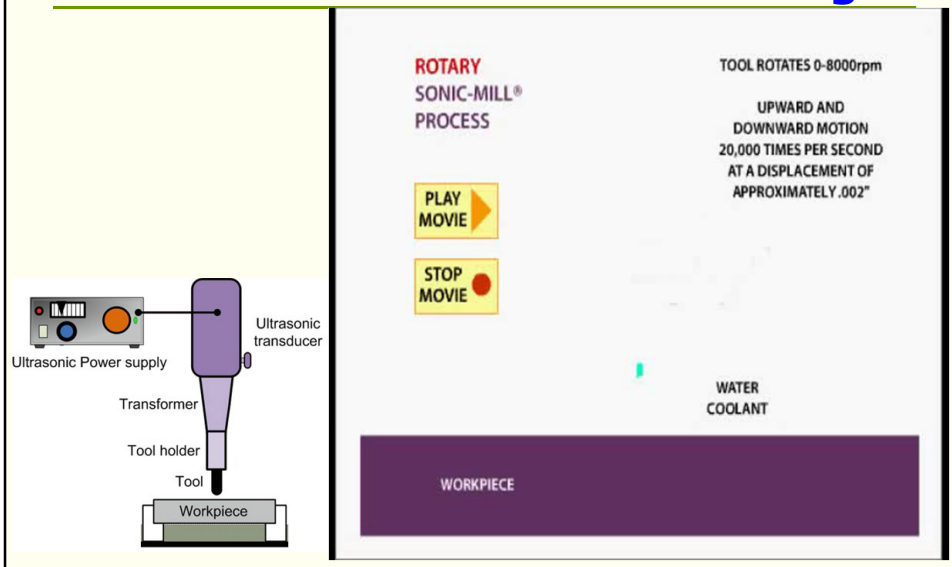
Ultrasonic-Assisted Machining



Ultrasonic-Assisted Machining

- Examples
  - Stainless steel SUS 316 drilling, hole dia = 1mm, depth = 10mm

  - Glass drilling, 0.7mm thick, hole dia = 0.25mm
  - Glass milling, diamond grinder of dia = 3mm

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Ultrasonic-Assisted Machining

- Examples
  - Stainless steel SUS 316 drilling, hole dia = 1mm, depth = 10mm

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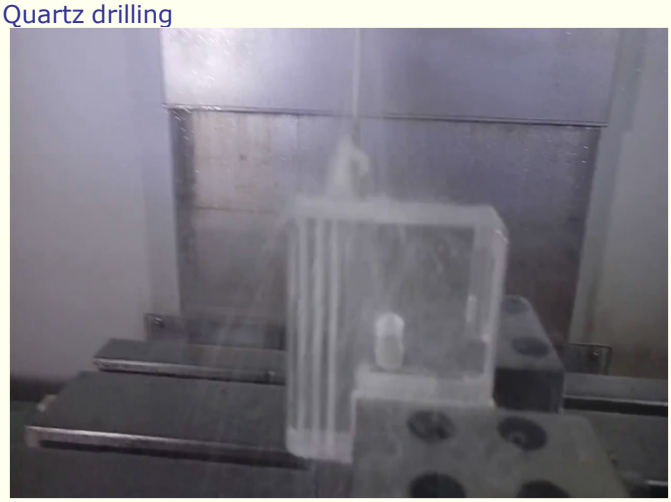
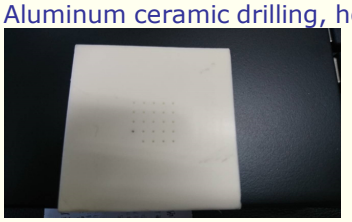
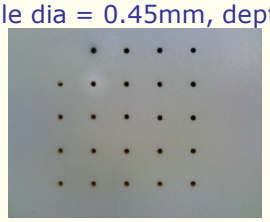
Ultrasonic-Assisted Machining

- Examples
  - Quartz drilling

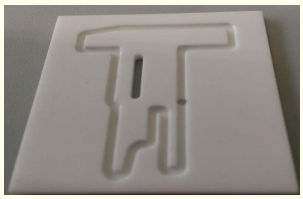


Ultrasonic-Assisted Machining

- Examples
  - Aluminum ceramic drilling, hole dia = 0.45mm, depth = 10mm

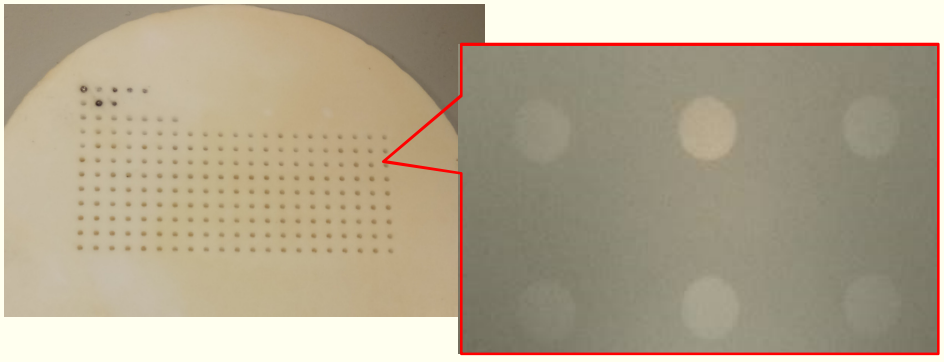



  - Aluminum ceramic milling, diamond grinder of dia = 2mm

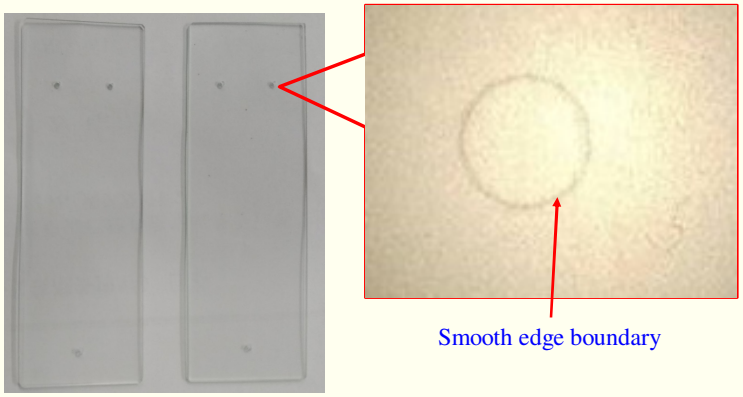
Ultrasonic-Assisted Machining

- Examples
  - Alumina, Small hole drilling / milling (blind hole)
    - Hole diameter = 1.2mm; depth = 1.4mm
    - # of holes to be drilled per workpiece = 400



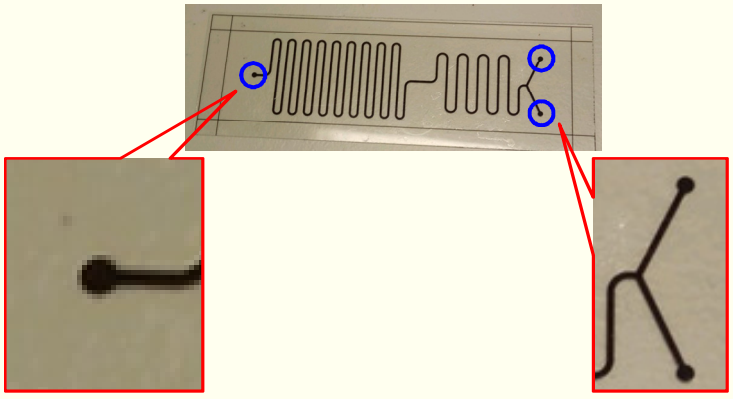
Ultrasonic-Assisted Machining

- Examples
  - Glass, Small hole drilling (thru' hole)
    - Hole diameter = 0.6mm; Glass plate thickness = 1mm
    - # of holes to be drilled per workpiece = 4



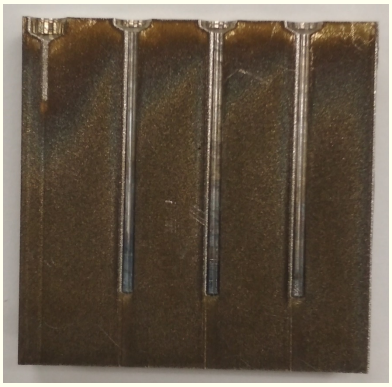
Ultrasonic-Assisted Machining

- Examples
  - Glass channel, Small hole drilling (thru' hole)
    - Hole diameter = 1.0mm; depth = 1mm
    - # of holes to be drilled per workpiece = 3



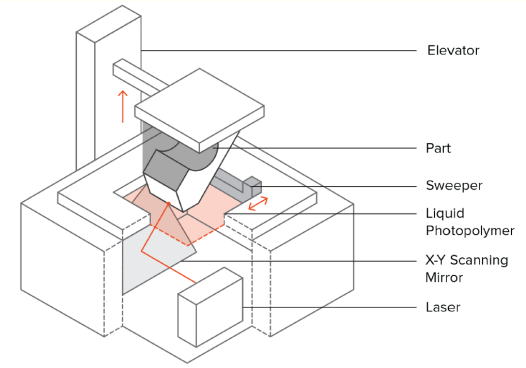
Ultrasonic-Assisted Machining

- Examples
  - Stainless steel, Small hole drilling (blind hole)
    - Hole diameter = 0.2mm and 0.9mm
    - Depth = 5mm and 20mm
  - SMA Shape Memory Alloy, Small hole drilling (thru' hole)
    - Hole diameter = 0.075m
    - Thickness = 2mm



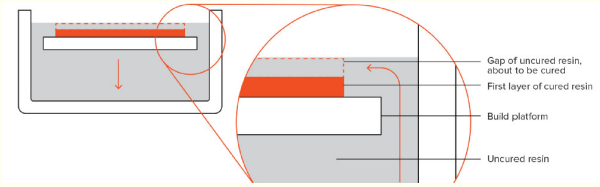
SLA 3d Printing Desktop & Professional

- SLA 3D printing
  - Selectively curing a polymer resin layer-by-layer using an UV laser beam.
  - Photosensitive thermoset polymers.
  - Most effective 3D printing technology for very high accuracy and/or smooth surface.

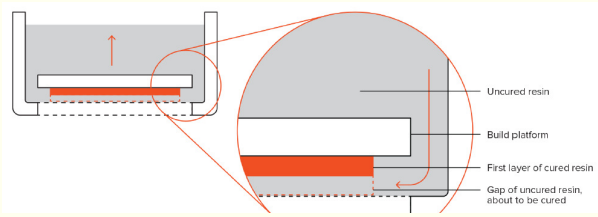


SLA 3d Printing Desktop & Professional

- SLA 3D printing
  - Top-down mode



  - Bottom-up mode



SLA 3d Printing Desktop & Professional

- SLA 3D printing – Top-down vs Bottom-up

	Bottom-up (Desktop) SLA	Top-down (Industrial) SLA
Advatages	+ Lower cost + Widely available	+ Very large build size + Faster build times
Disadvantages	– Small build size – Smaller material range – Requires more post-processing, due to extensive use of support	– Higher cost – Require specialist operator – Changing material involves emptying the whole tank

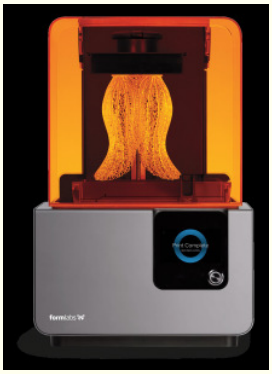
SLA 3d Printing Desktop & Professional

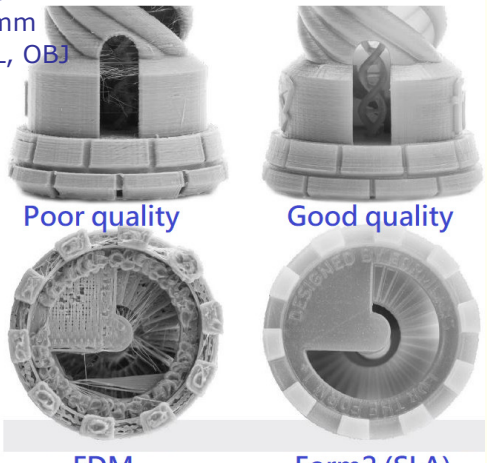
- SLA 3D printing – Top-down vs Bottom-up

On the left, a part oriented for a top-down SLA printer (minimizing support). On the right, a part oriented for a bottom-up SLA printer (minimizing cross-sectional area)

Desktop SLA 3d Printing

- Desktop SLA 3D printer – Form 2
  - Build volume 145 x 145 x 175 mm
  - Layer Thickness 0.025 - 0.1 mm
  - File Formats for Printing: STL, OBJ
  - Professional print quality





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Desktop SLA 3d Printing

- New desktop SLA 3D printer – Form 2
  - Supported materials – Standard & Functional

		Standard			
		Clear	White	Grey	Black
Supported Layer Thickness	0.2	✓			
	0.1	✓	✓	✓	✓
	0.05	✓	✓	✓	✓
	0.025			✓	✓
Applications		• Transparent polish • Internal Channels • Working with light	• Neutral Tone • Slightly Opaque • Base for Painting	• Neutral Tone • Slightly Opaque • Smooth surface • Great for photography	• Highly pigmented • Most opaque • Small details • Delicate features

		Functional			
		Tough	Castable	Flexible	High-Temp
Supported Layer Thickness	0.2				
	0.1	✓	✓	✓	✓
	0.05	✓	✓	✓	✓
	0.025		✓		
Applications		• Impact Resistant • Cyclic stress/strain • Machining • Snap-fit	• Designed for Investment Casting • Burns out cleanly • Requires post-cure	• Impact Resistant • Compression • Ergonomic, soft-touch grips	• HDT of 289 °C @ 0.45 MPa • Mold prototyping • Heat resistant fixtures • Hot air & fluid flow • Environmental testing

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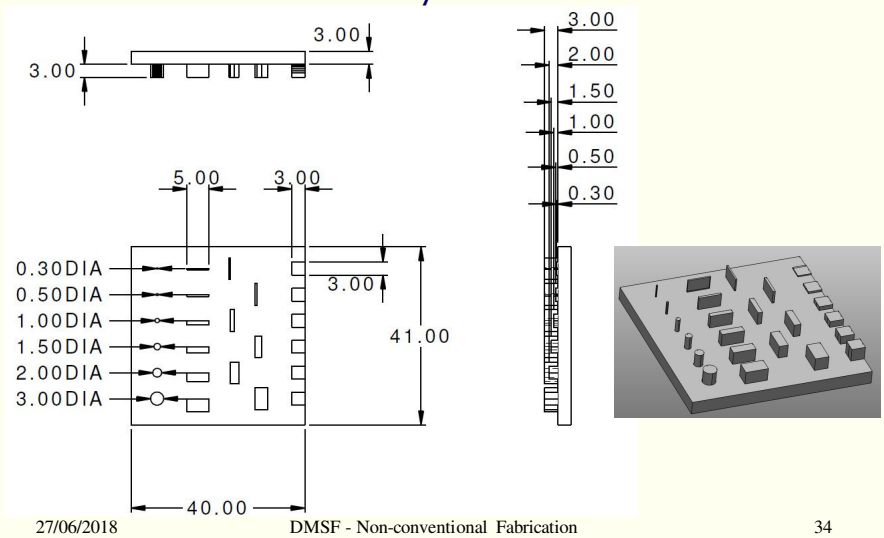
Desktop SLA 3d Printing

- Benchmark for accuracy and smallest feature



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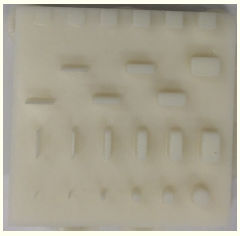
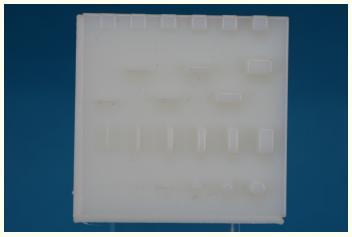
Desktop SLA 3d Printing

- Benchmark for accuracy and smallest feature
  - Form2 vs Connex 350

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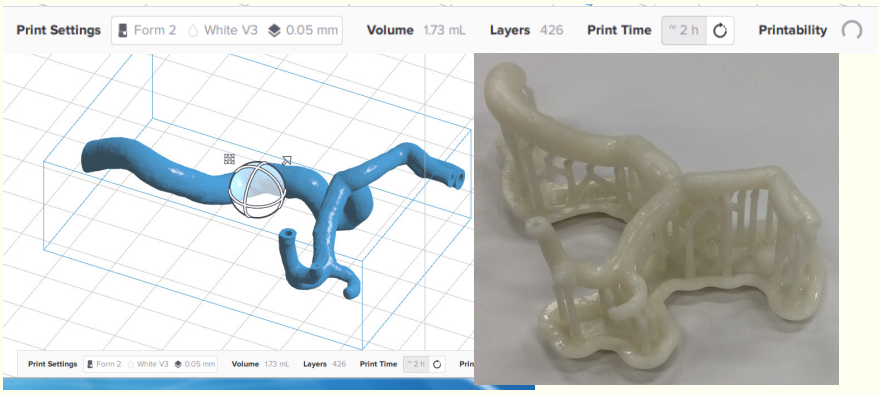
Desktop SLA 3d Printing

- Examples
  - Blood vessel
    - Materials – Standard White
    - Minimum feature size = 0.5mm



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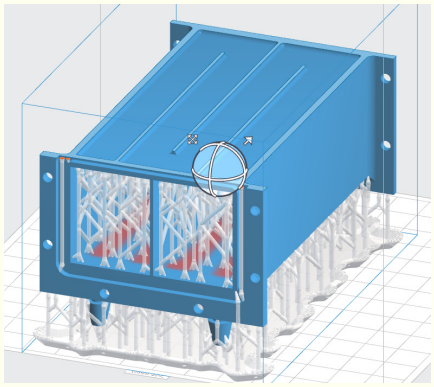
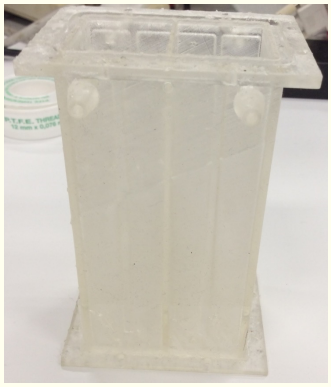
Desktop SLA 3d Printing

- Water channel model
  - Materials – Standard Clear
  - Channel size = 2.5mm
  - Internal water circulation

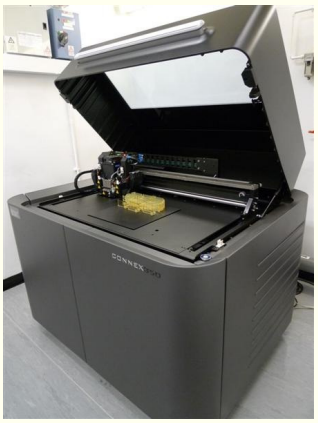


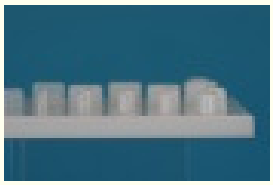


DESIGN & MANUFACTURING SERVICES FACILITY

Professional SLA 3d Printing

- Professional SLA 3D printer – Connex 350
  - Build volume 342 x 342 x 200 mm
  - Layer Thickness 0.016 - 0.03 mm
  - File Formats for Printing: STL
  - Able to print feature of 0.3 mm





Professional SLA 3d Printing

- Examples
  - Thin model with digital mixing material property
    - Digital mixing materials to produce variation in tensile strength, etc.
      - Vero White: Tensile strength = 50-65 MPa
      - Tango Black: Tensile strength = 1.8-2.4 Mpa
    - Total thickness = 1mm