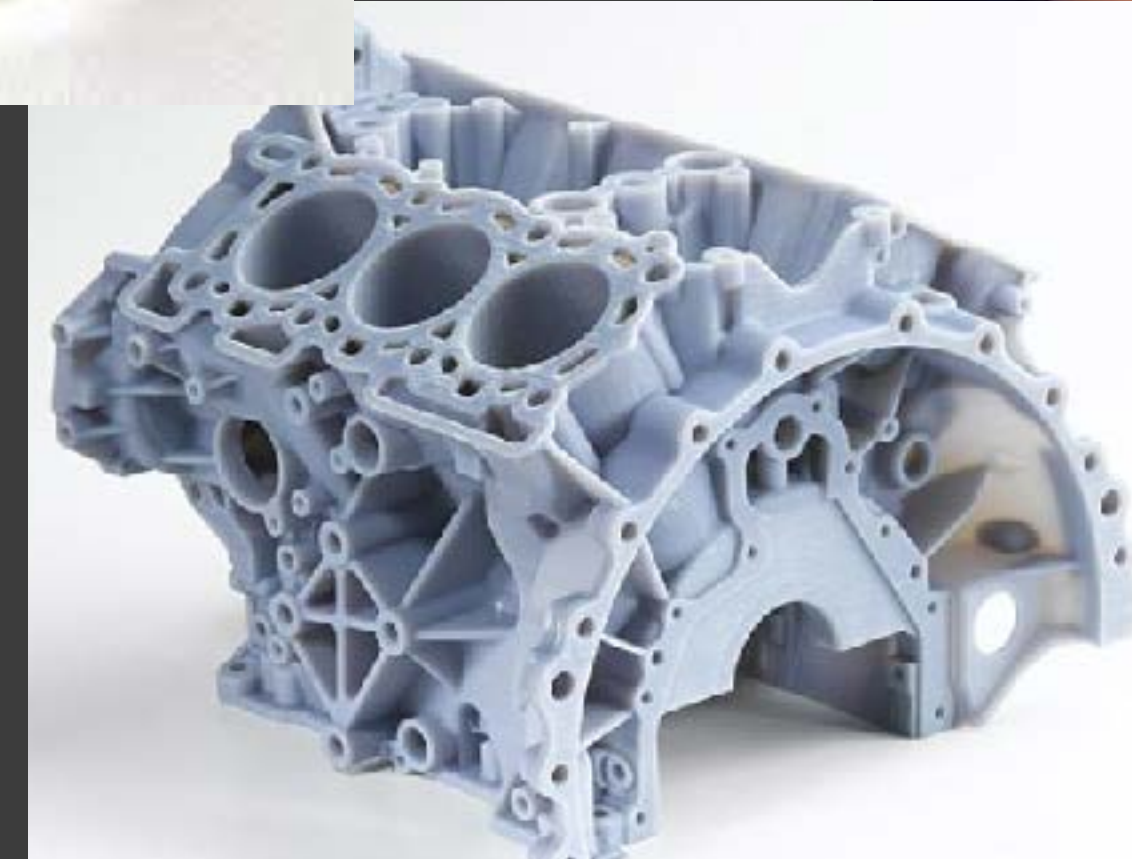
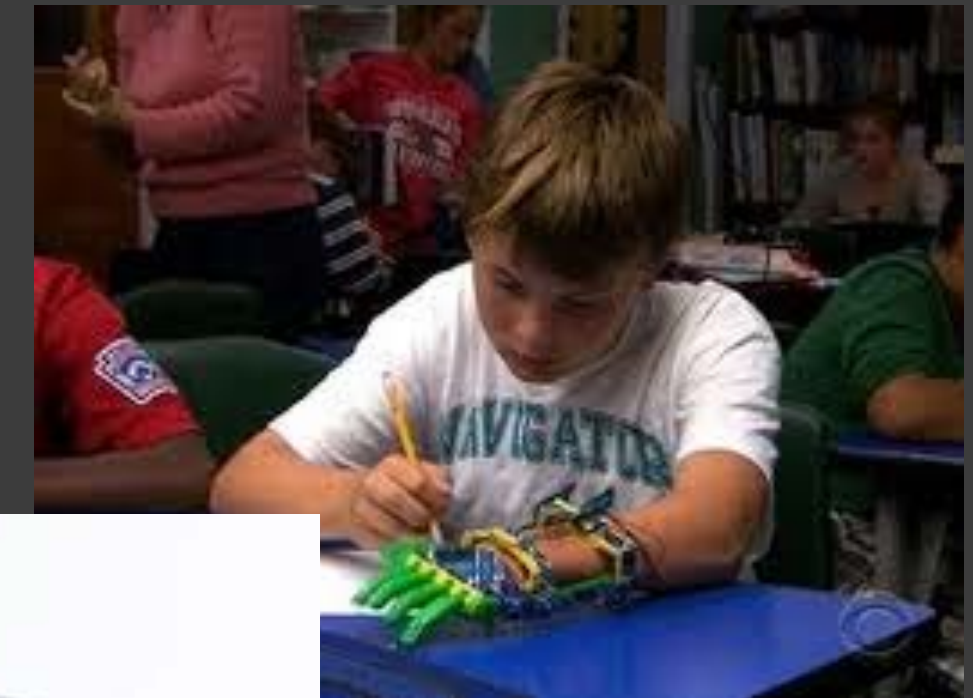
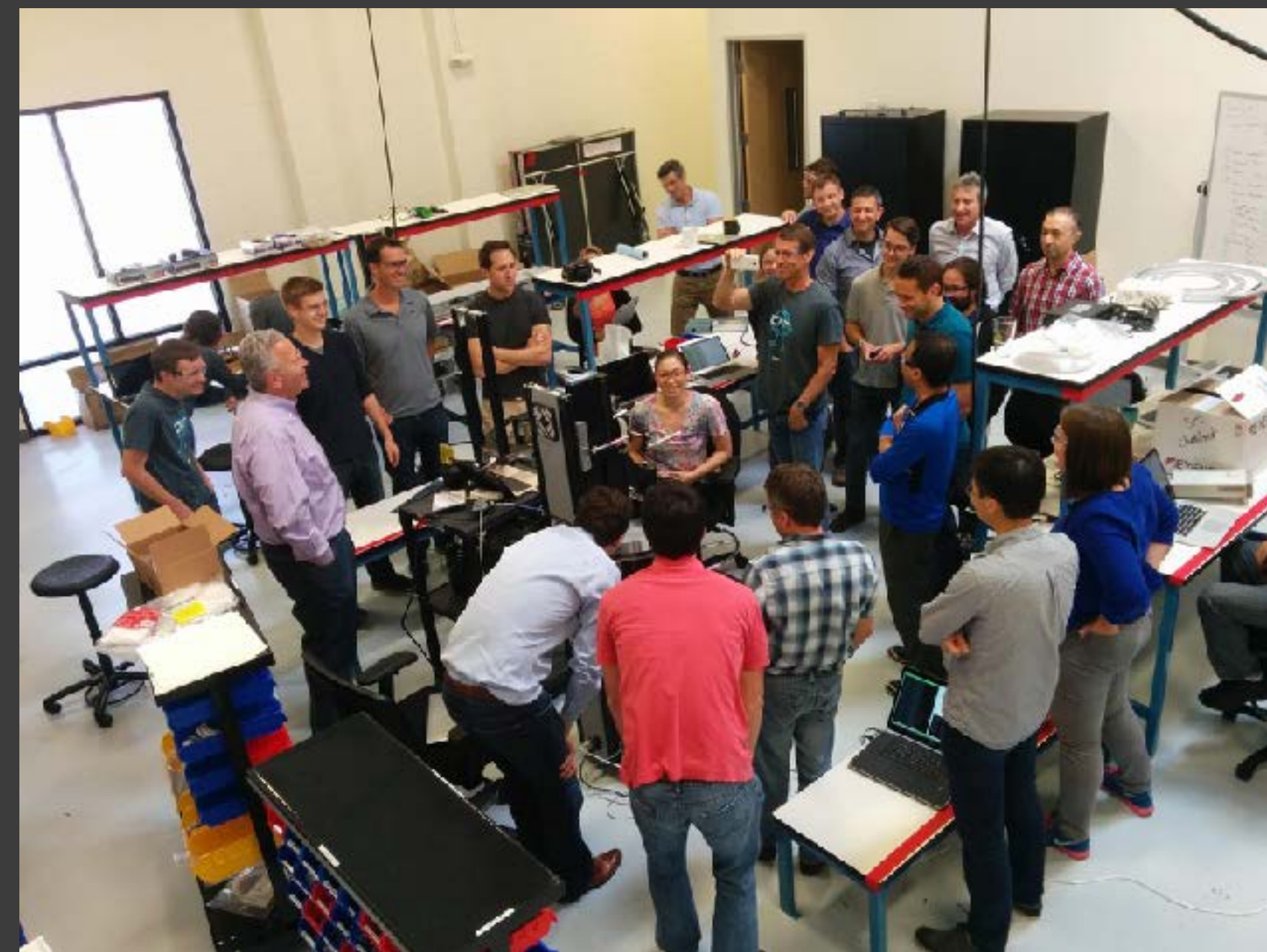
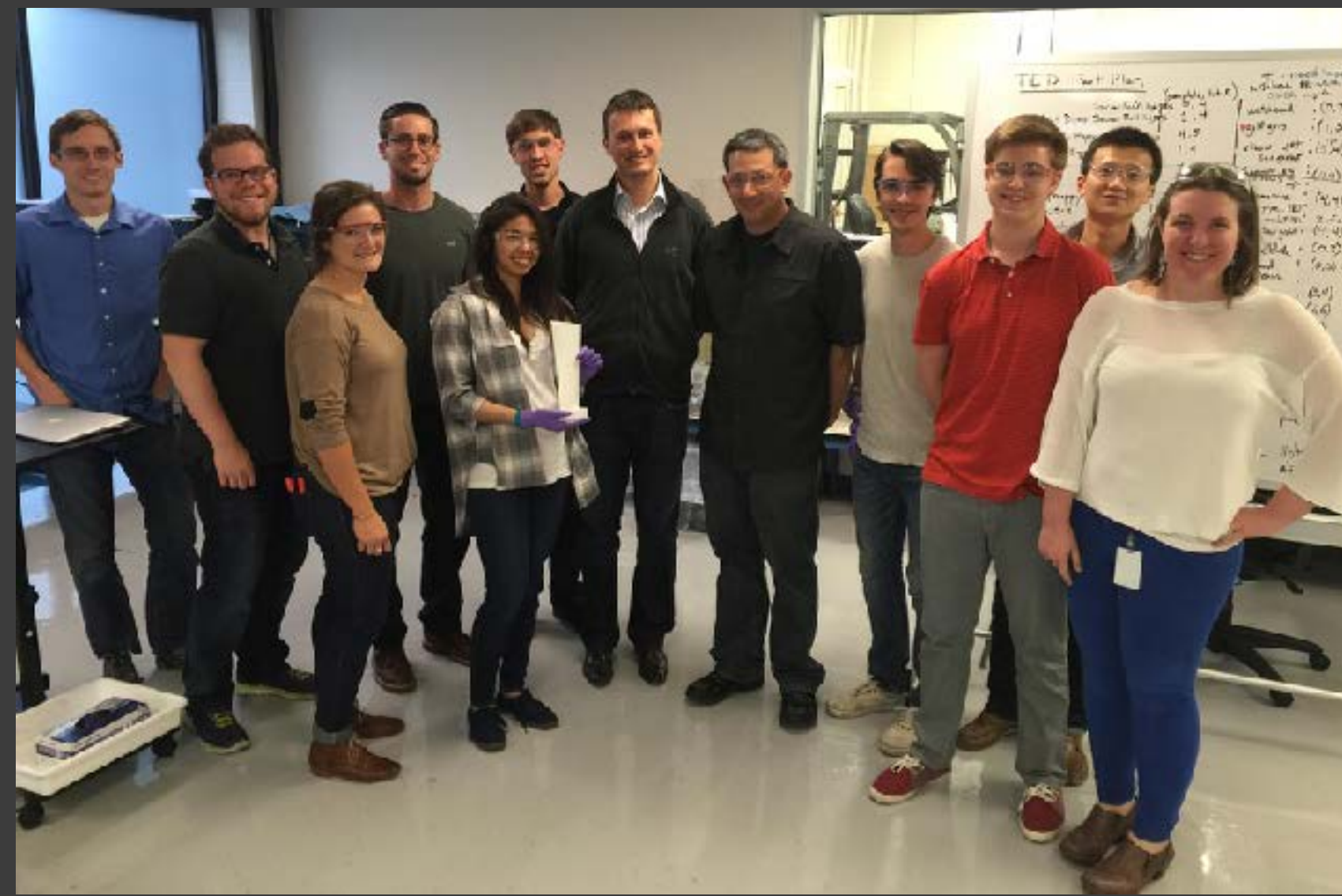


The Transformative Potential for 3D Printing

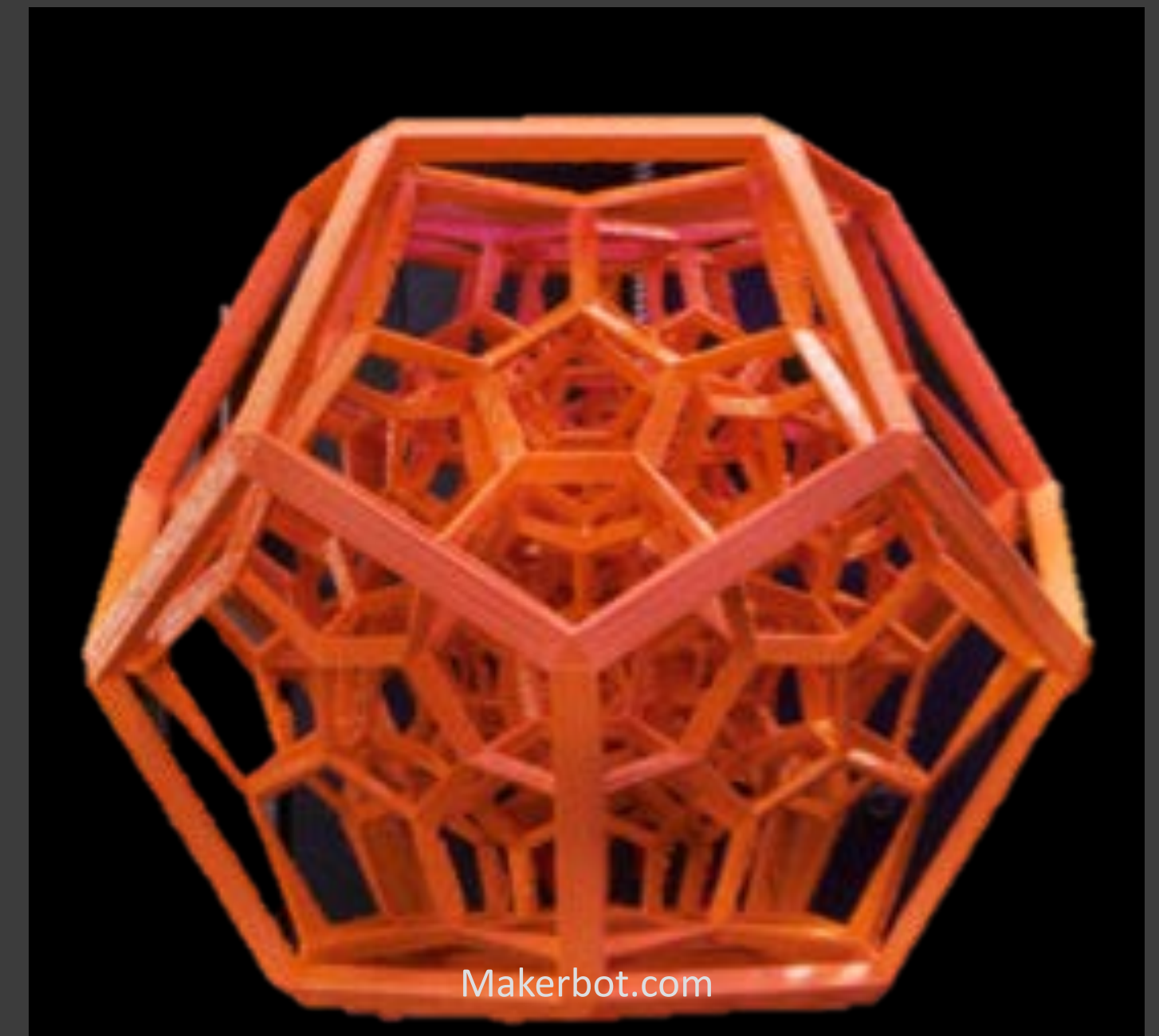




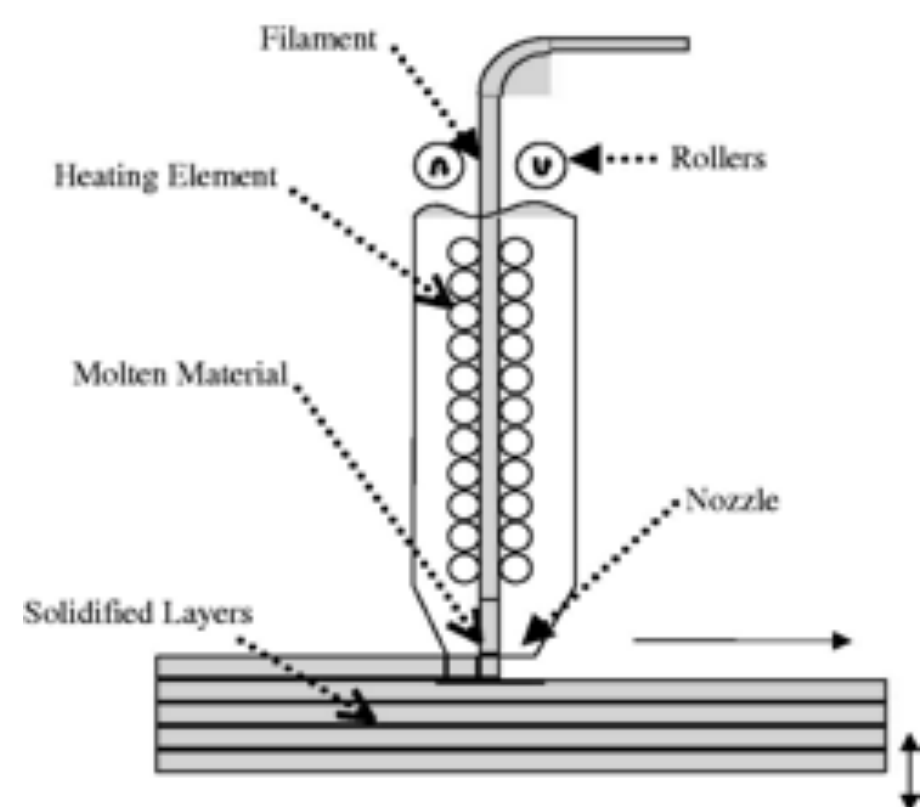
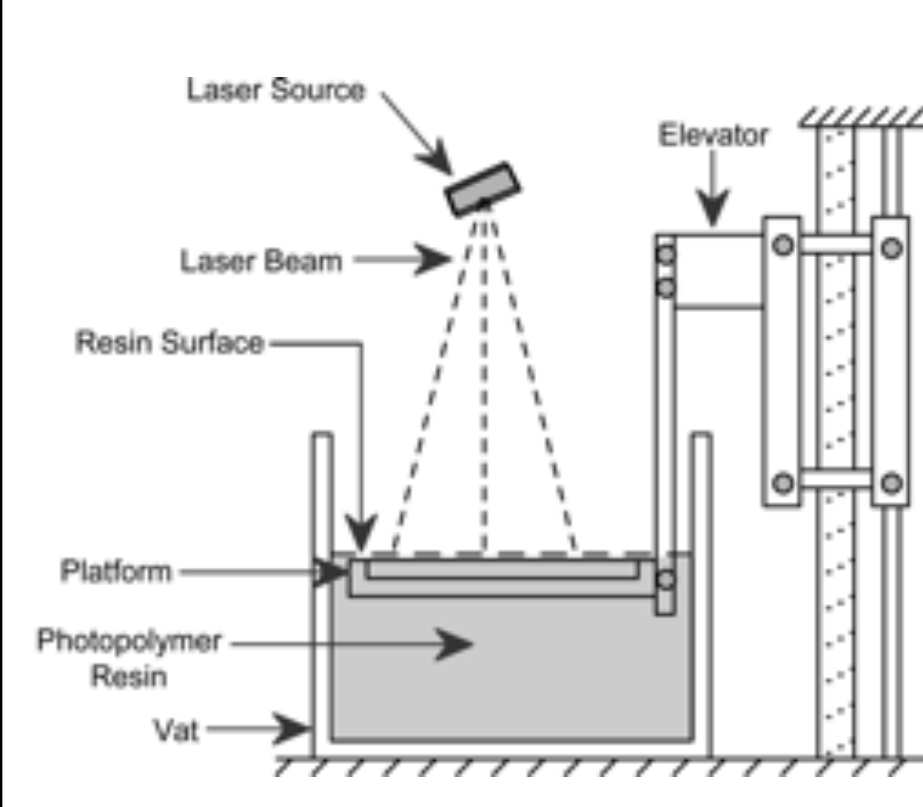
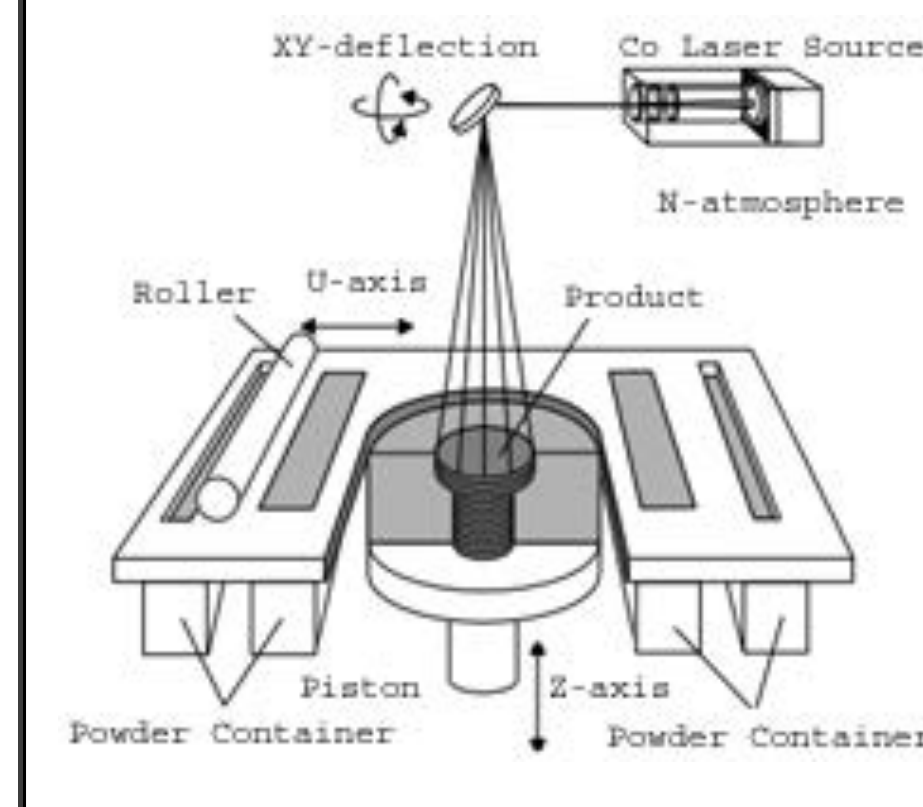
Why 3D printing?

(a digital printing technology)

- Complexity is free
- Unlimited design space
- Zero lead time
- Precise replication from scanner
- Compact, portable manufacturing
- Zero skill manufacturing
- Empowering to everyone...



Polymer-Based 3D Printing Processes

	Fused Deposition Modeling (FDM) & Inkjet	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Layout	 <p>Material melted in nozzle or sprayed</p>	 <p>Resin in vat</p>	 <p>Powder in bed & heating source(e.g. laser)</p>
Layer Creation	Continuous extrusion or ink jet	Liquid layer deposition	Layer of powder
Phase Change	Solidification by cooling or UV cure	Photopolymerization	Laser melting & Resolidification by cooling
Materials	Polymers / Colloids Wax Metals with binder Ceramics with binder	Photopolymers	Polymers Glass Metals Sand Ceramics



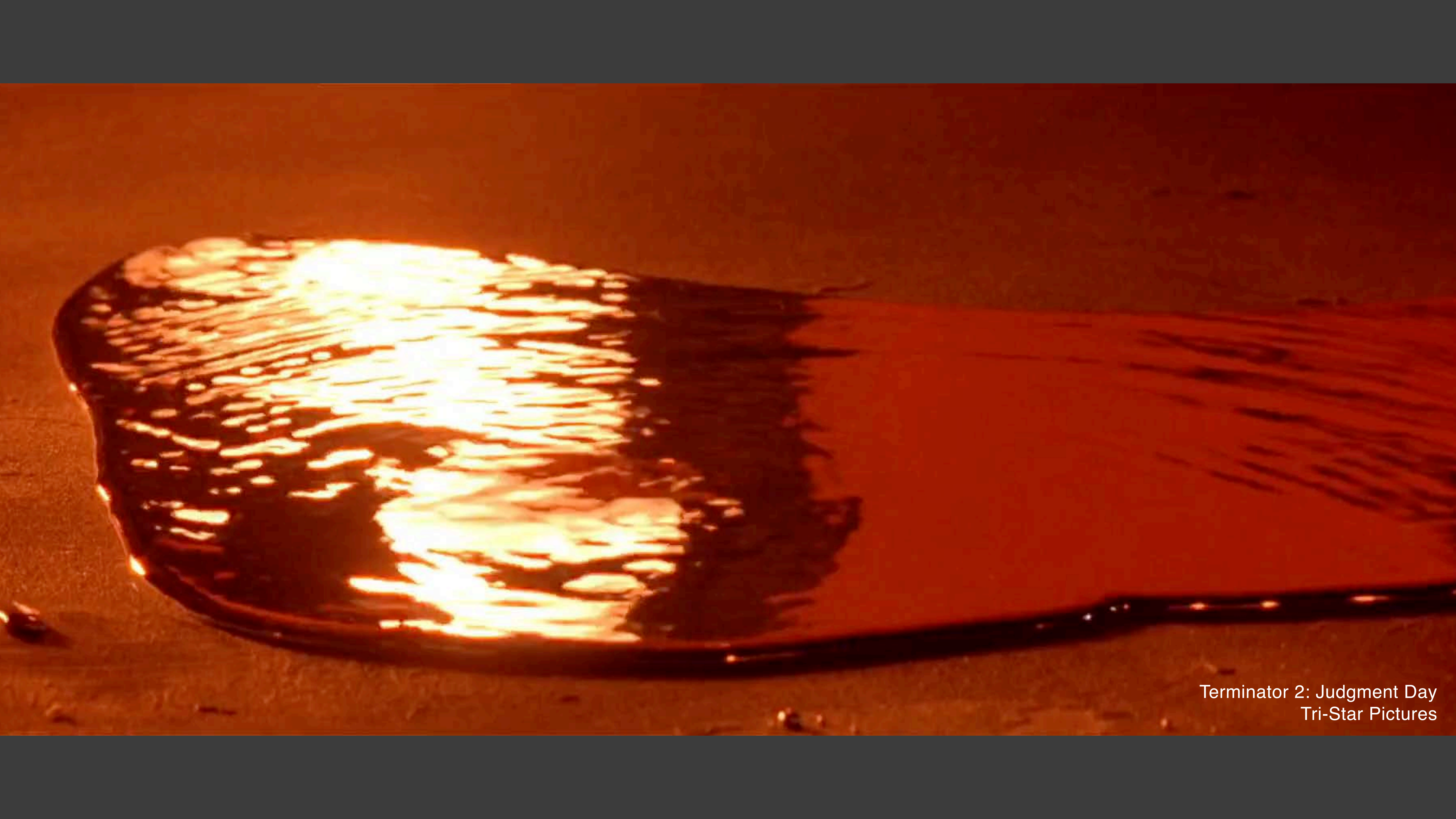
2D PRINTING

OVER AND OVER

3D Prints **Take Forever**

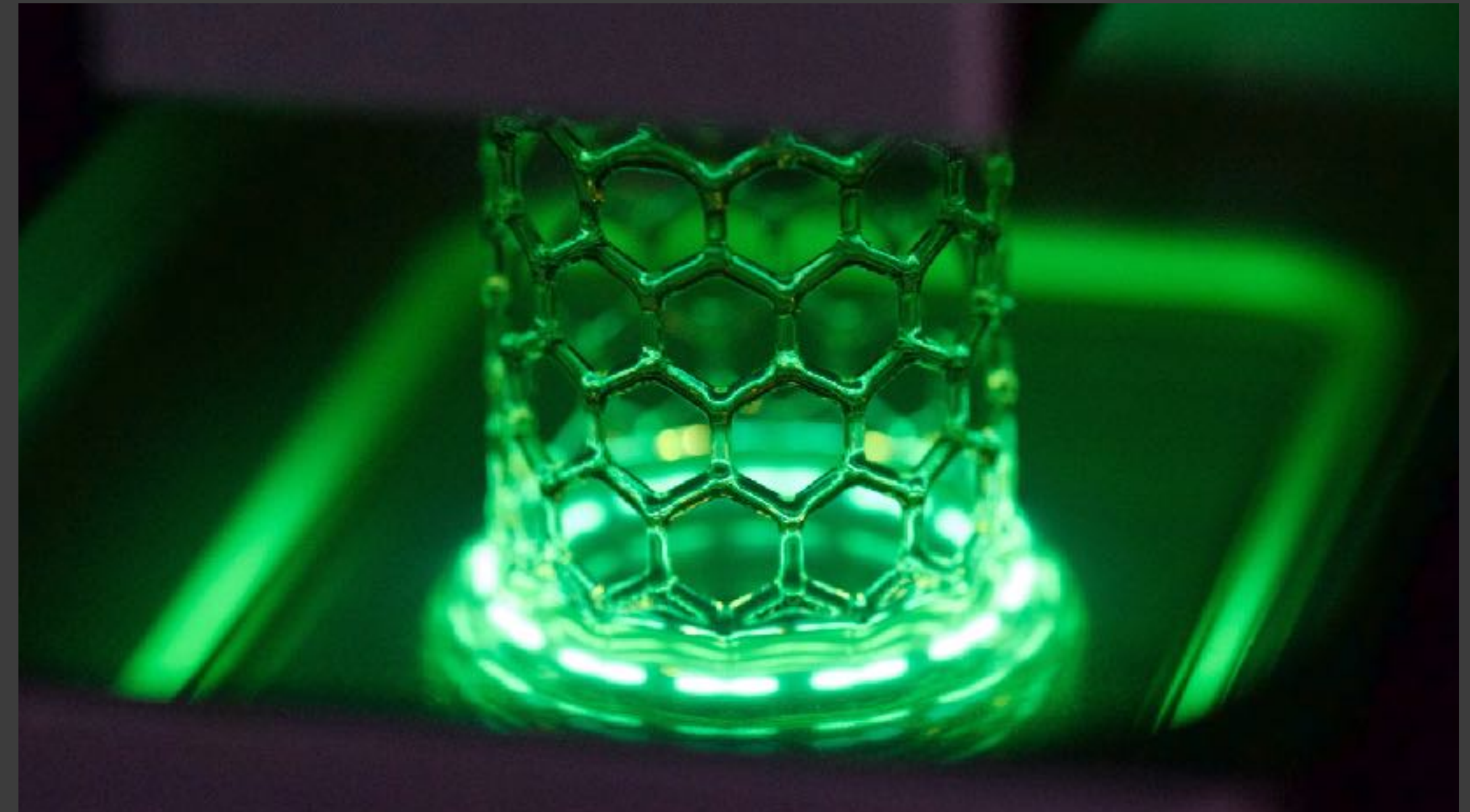
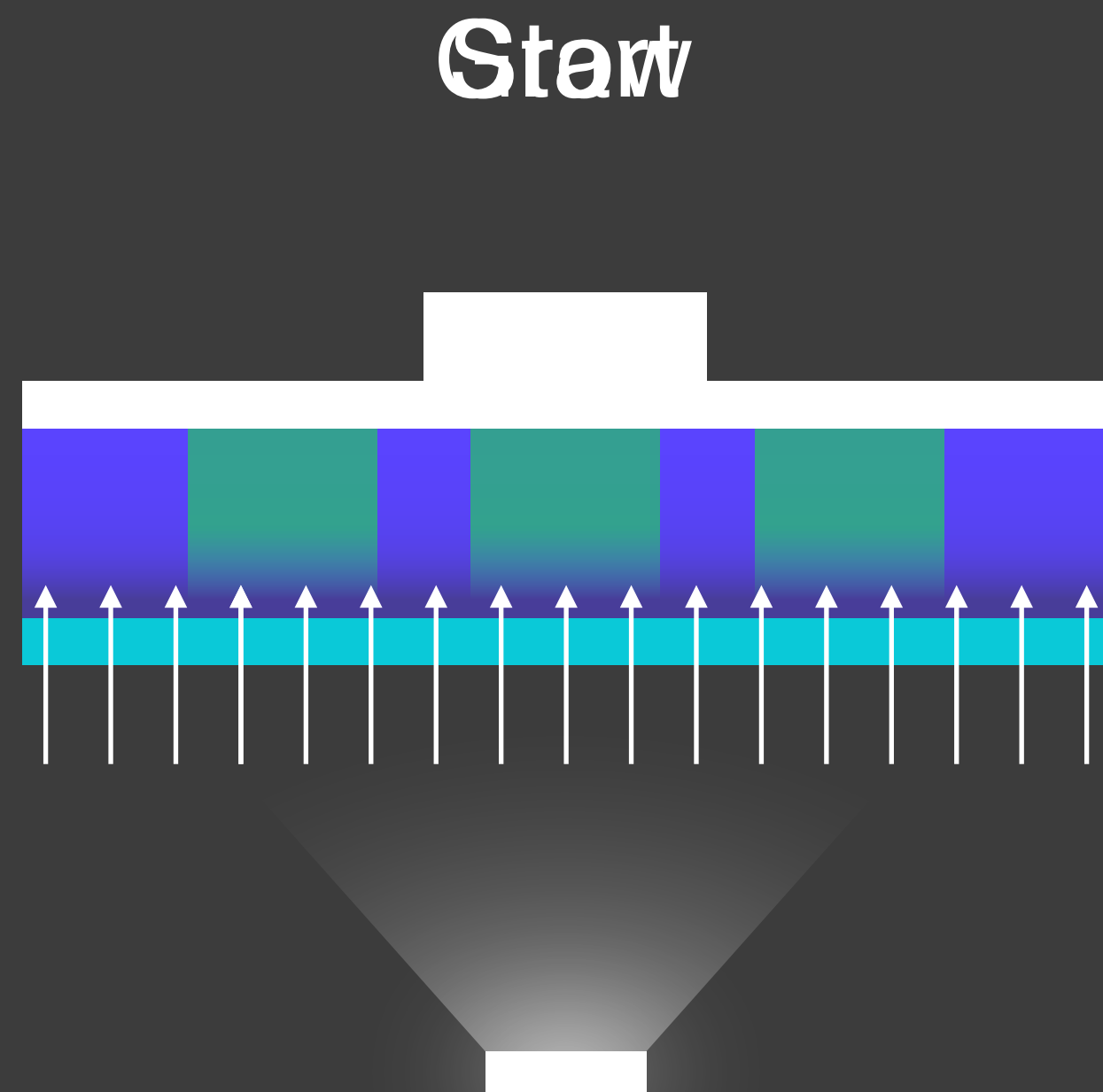
Printed Parts are **Mechanically Weak**

Material Choices are **Far Too Limited**



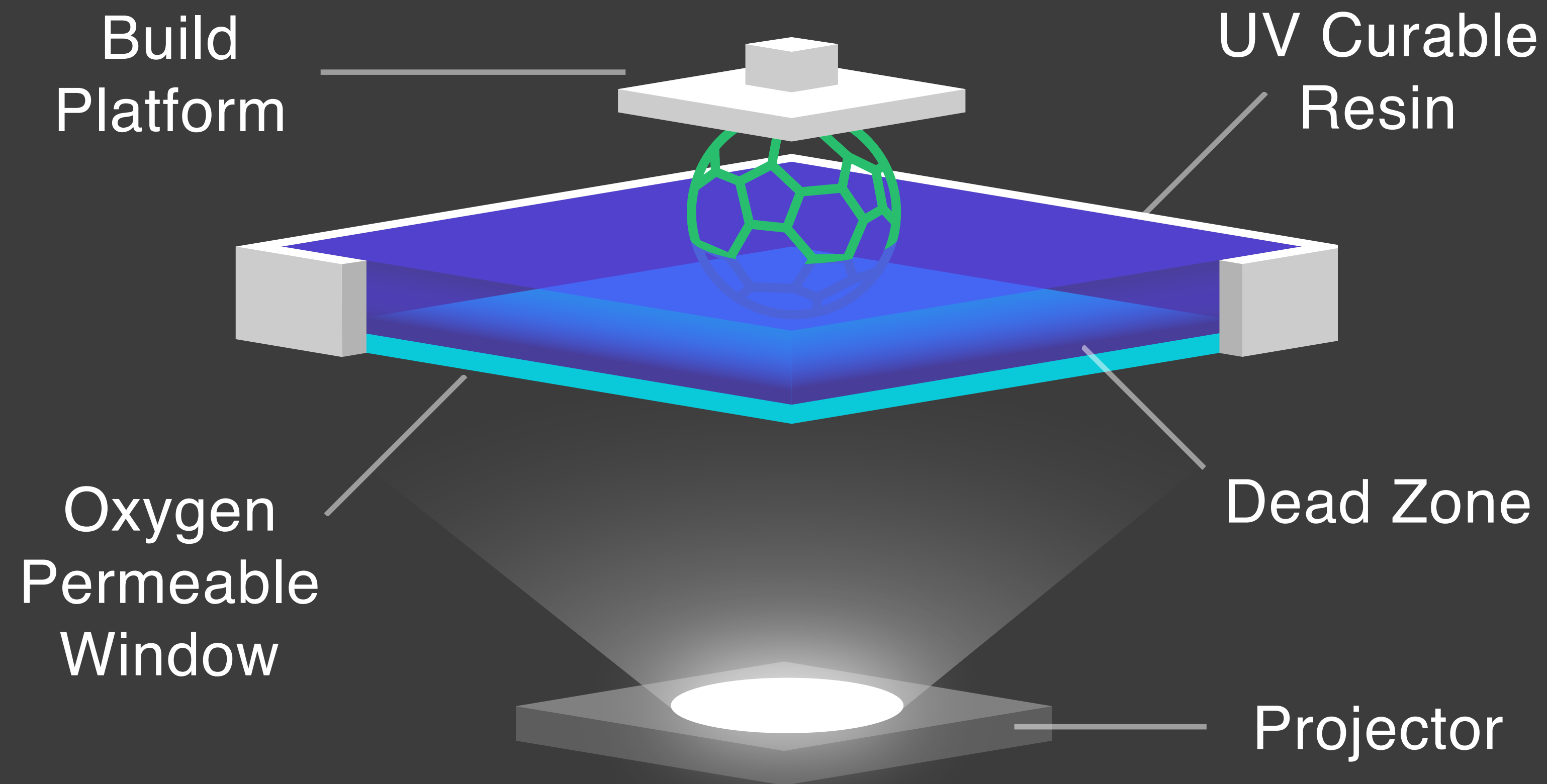
Terminator 2: Judgment Day
Tri-Star Pictures

Could 3D Printing Be Continuous?

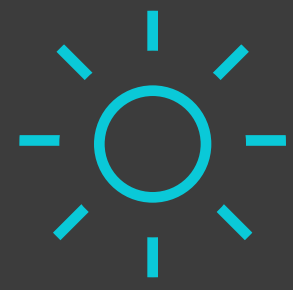


- Go from mm/hr to hundreds of mm/hr
- No layering
- Delicate and new materials

Continuous Liquid Interface Production



Science 2015, 347, 1349-1352



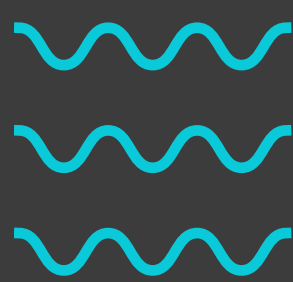
Light



Oxygen



3D Model

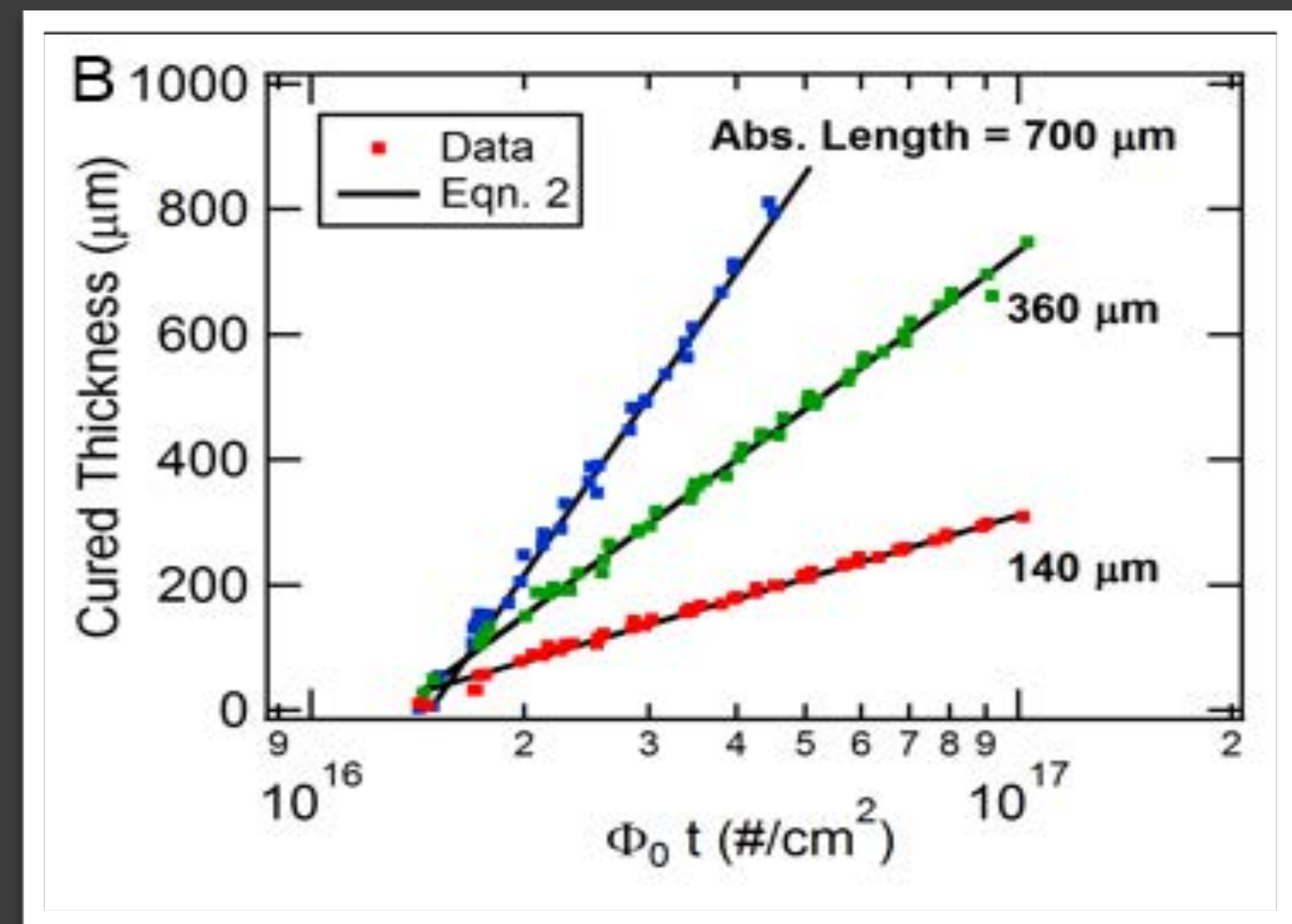
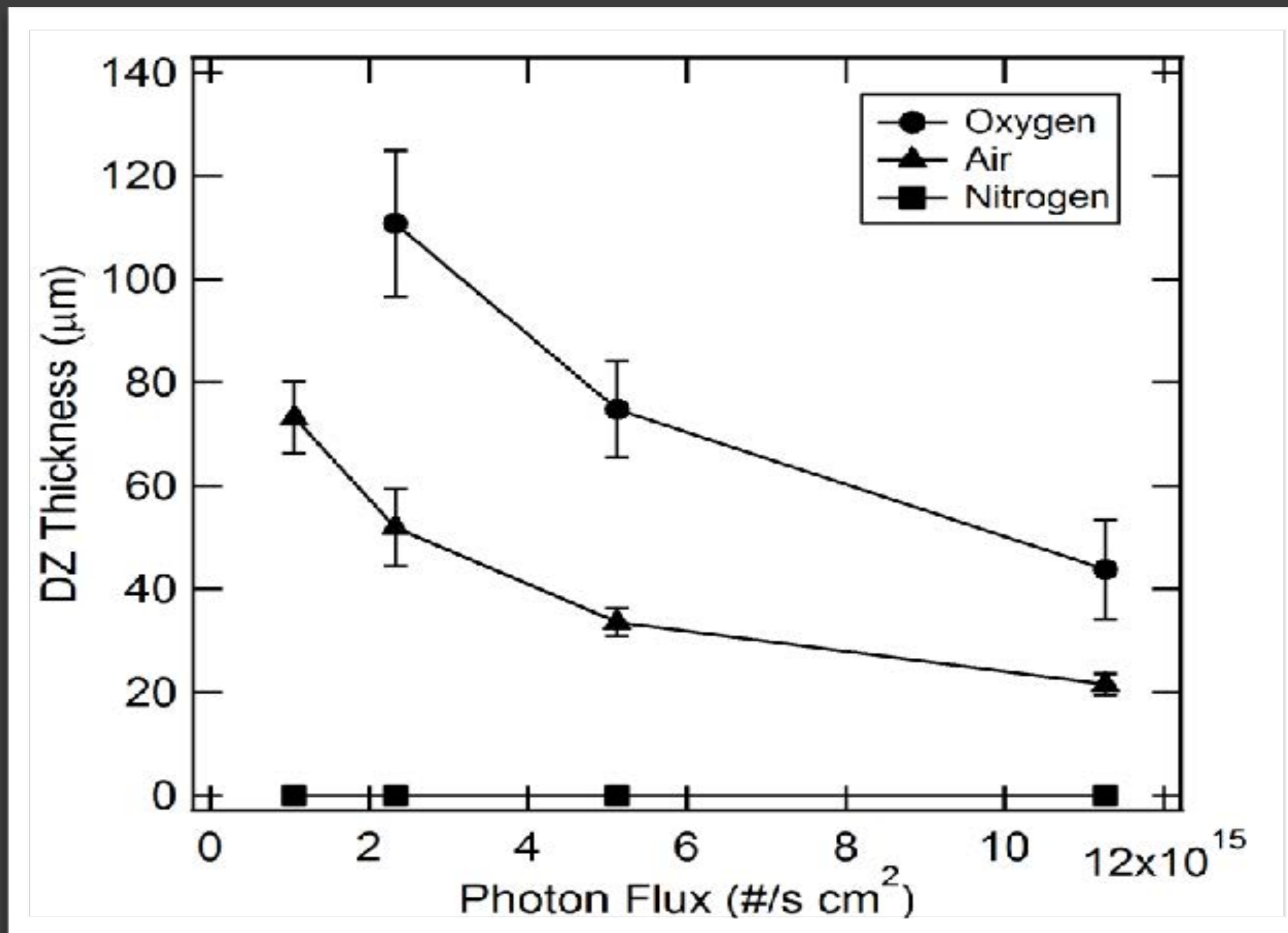
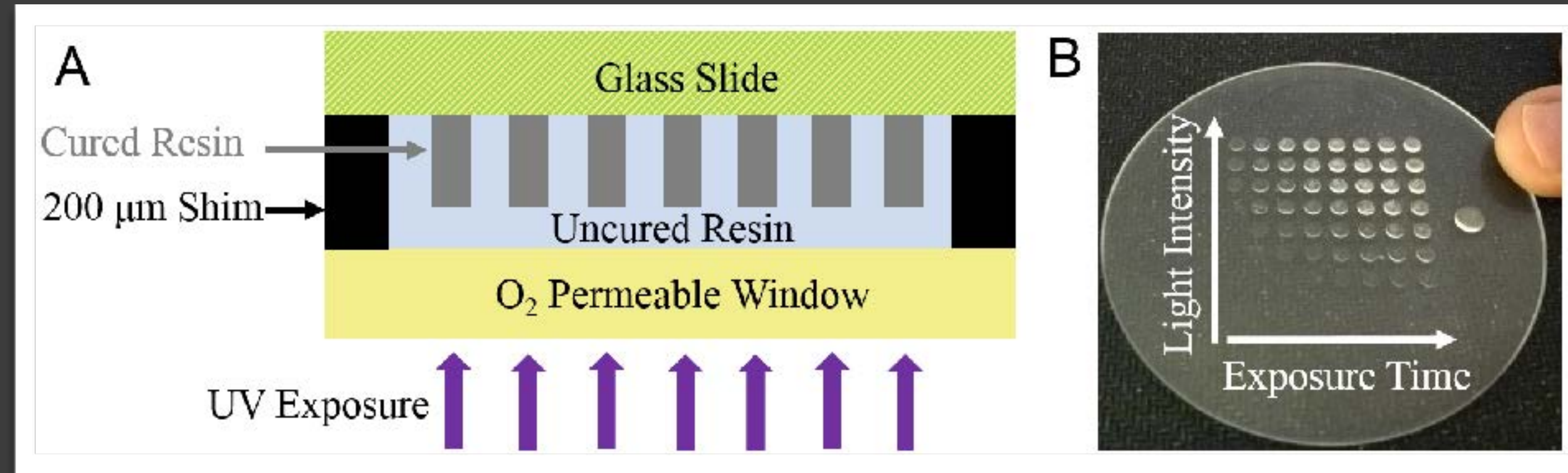


Material



00:00:00

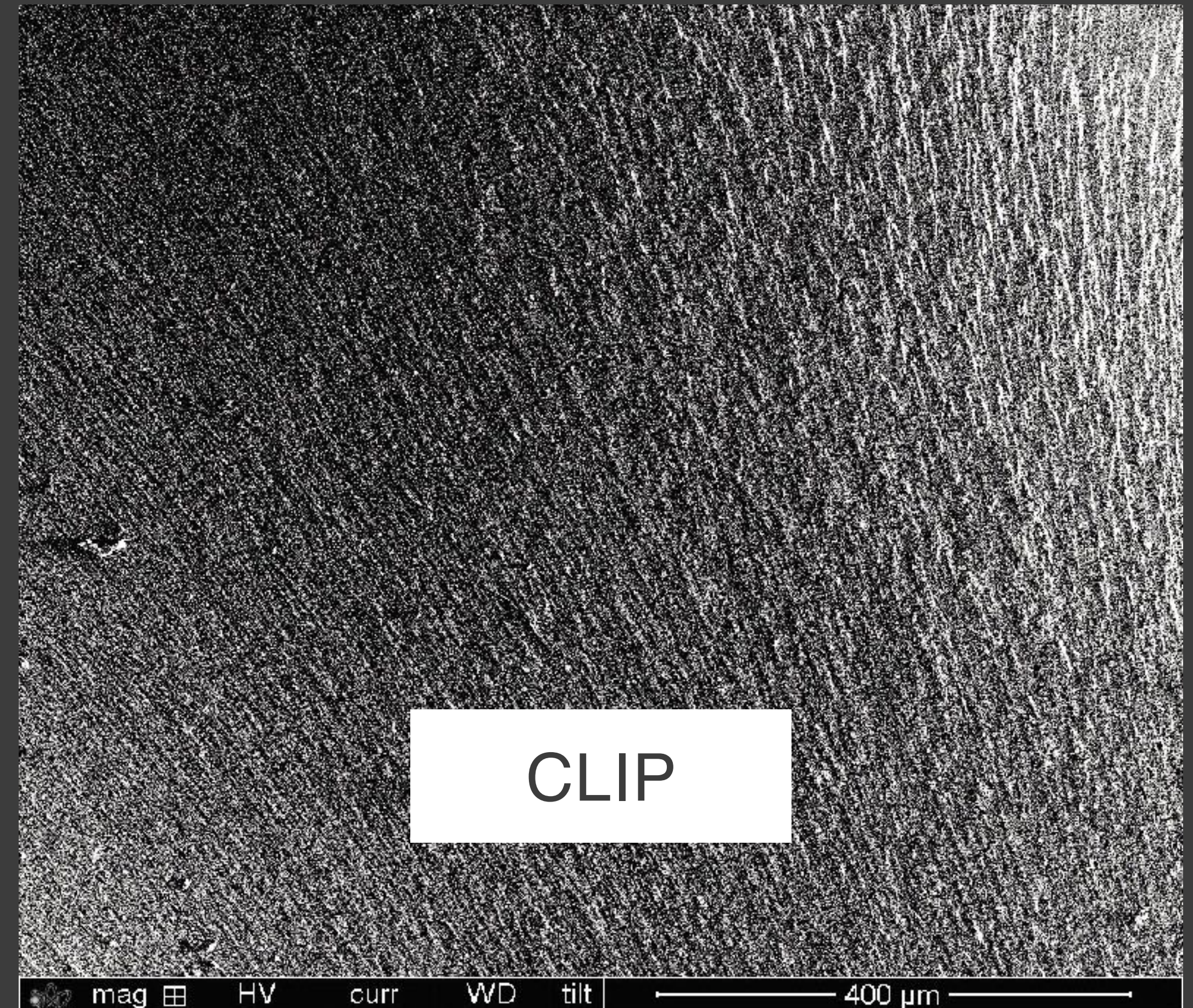
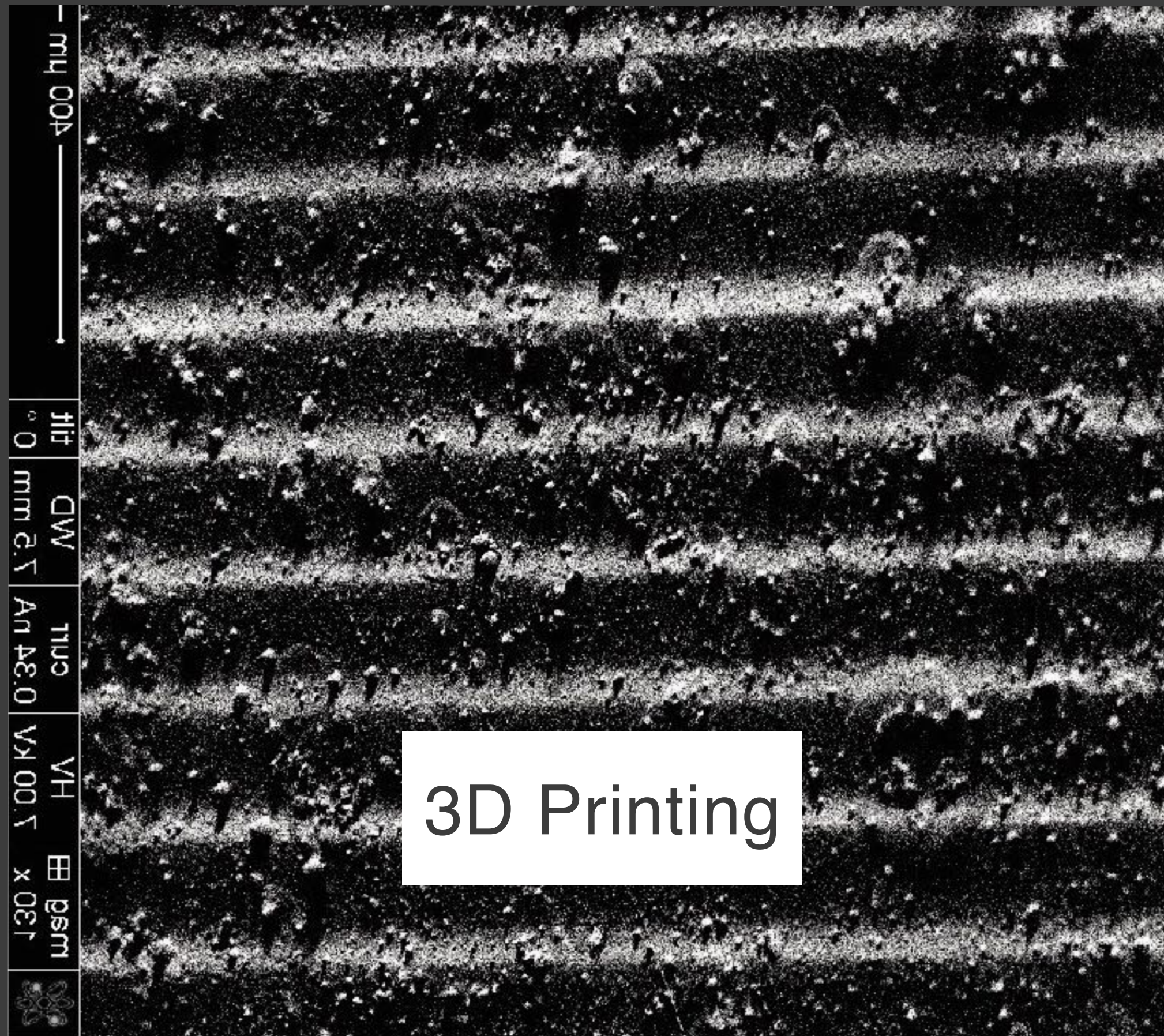
Continuous Liquid Interface Production



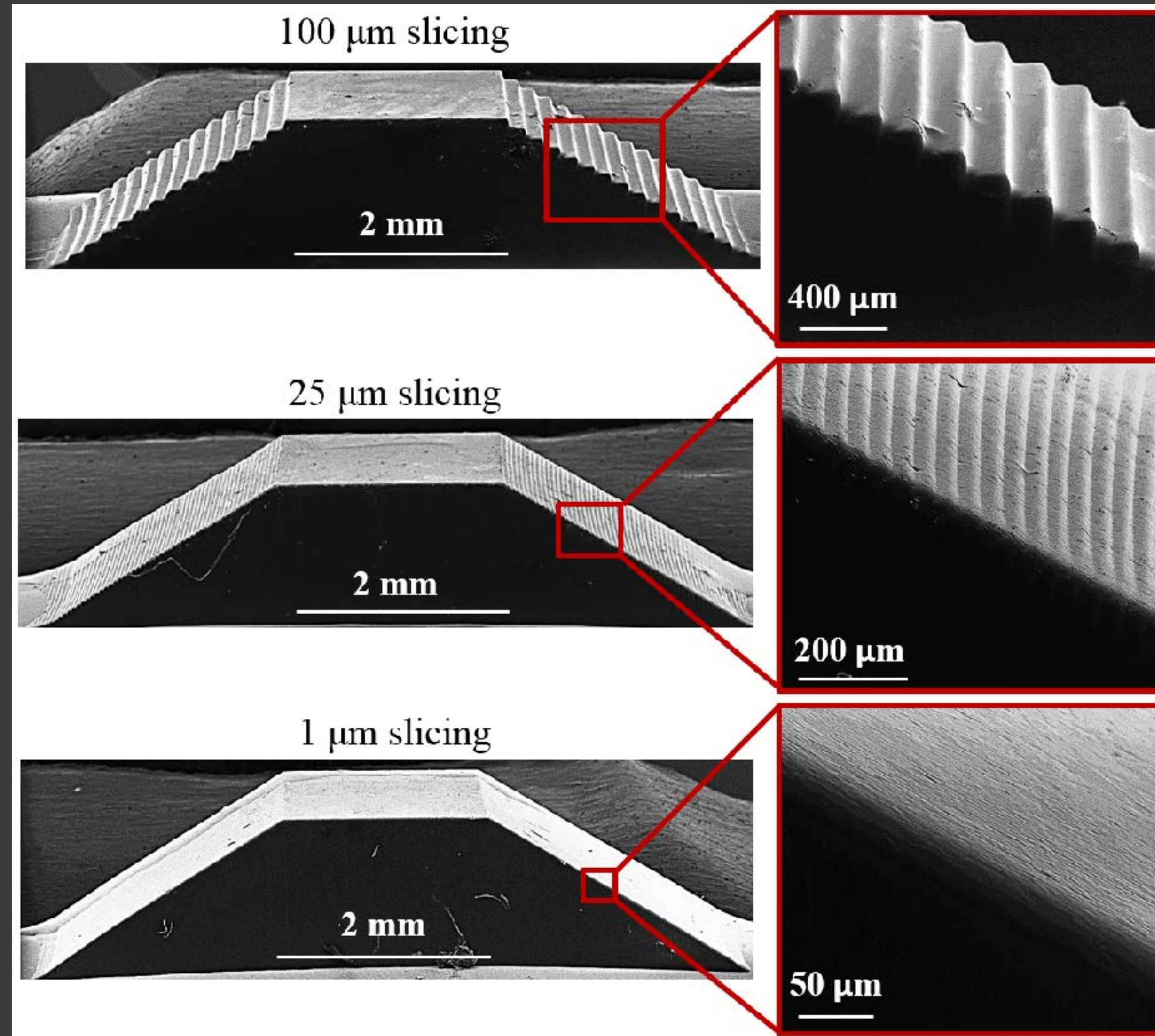
25-1000X

FASTER

Smooth Surface Finish

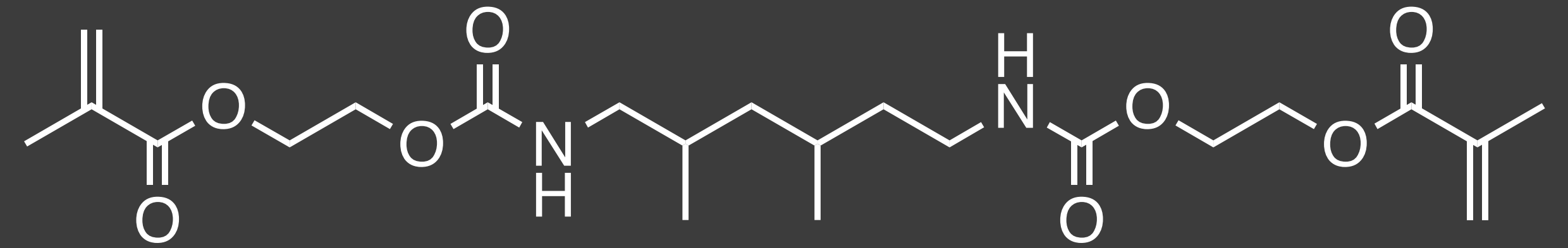


Manufactured Part Quality



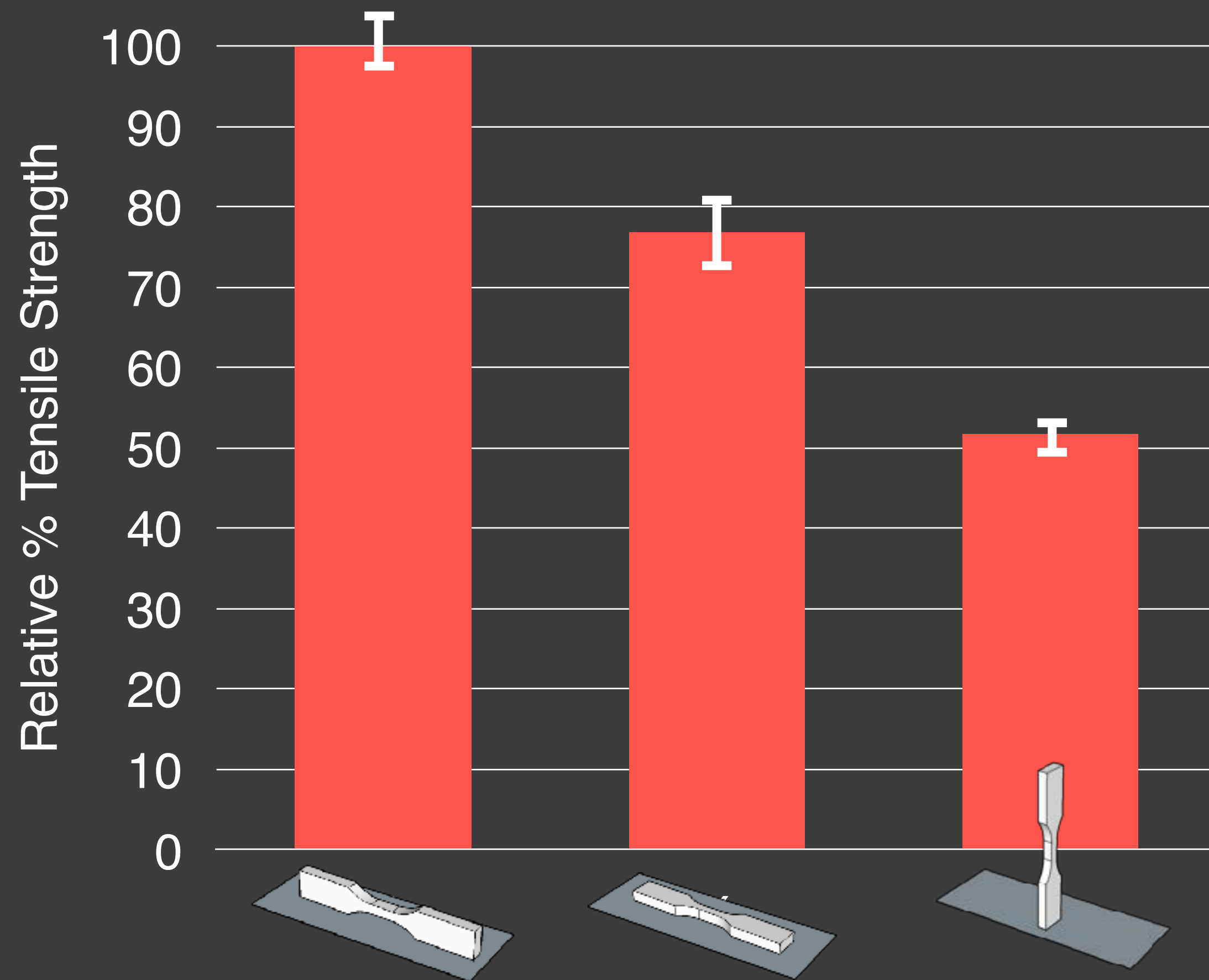
Urethane Acrylate Prototyping Resins

	Tunable Range
Tensile Strength	20 - 55 MPa
Modulus	1000 - 2000 MPa
Elongation	1 - 25 %
Impact Strength	< 26 J/m
Viscosity	500 - 2500 cP
Flexural Strength	10 - 75 MPa
Flexural Modulus	350 - 2000 MPa
Heat Deflection Temperature	50 - 75 °C

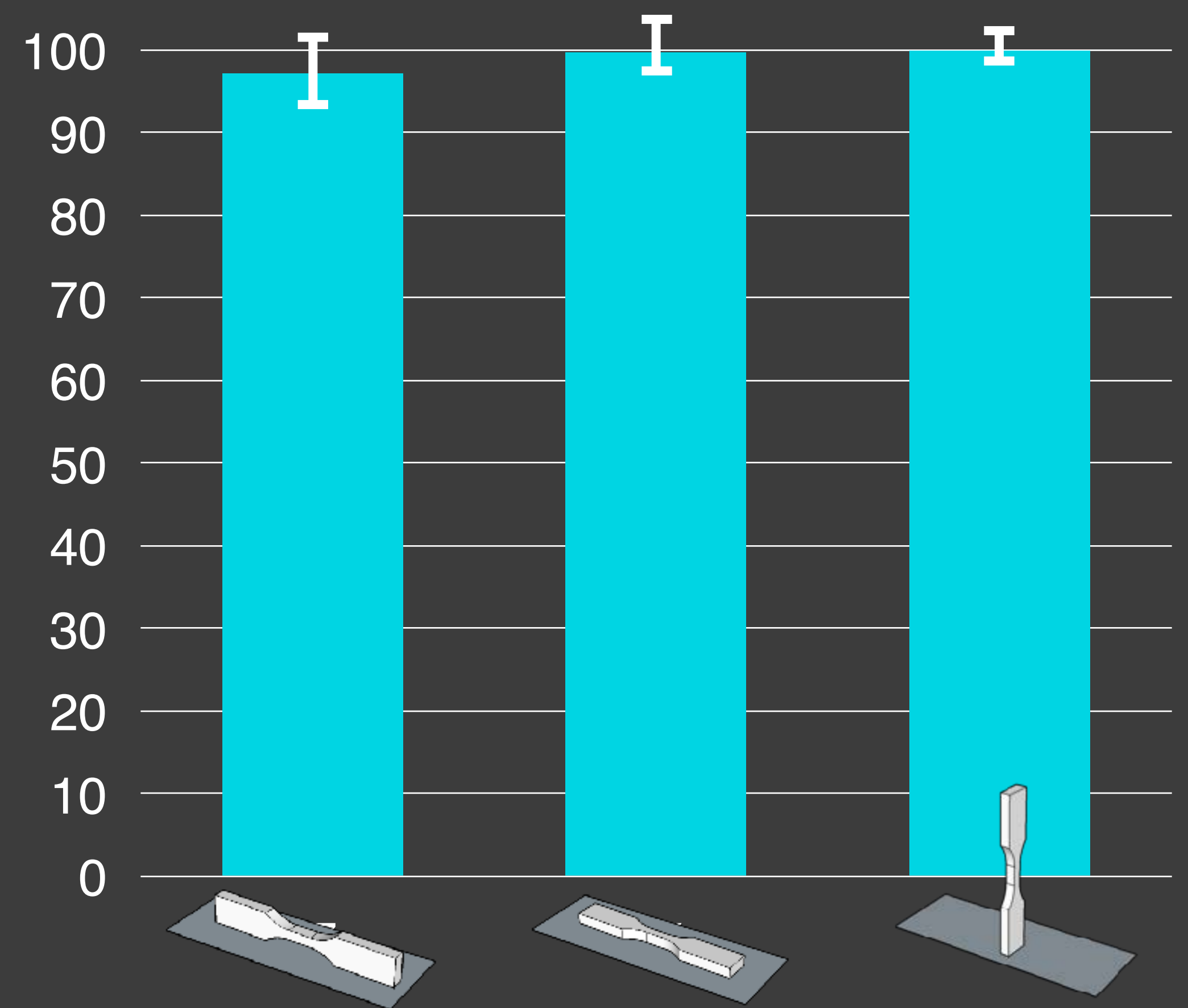




Consistent Mechanical Properties

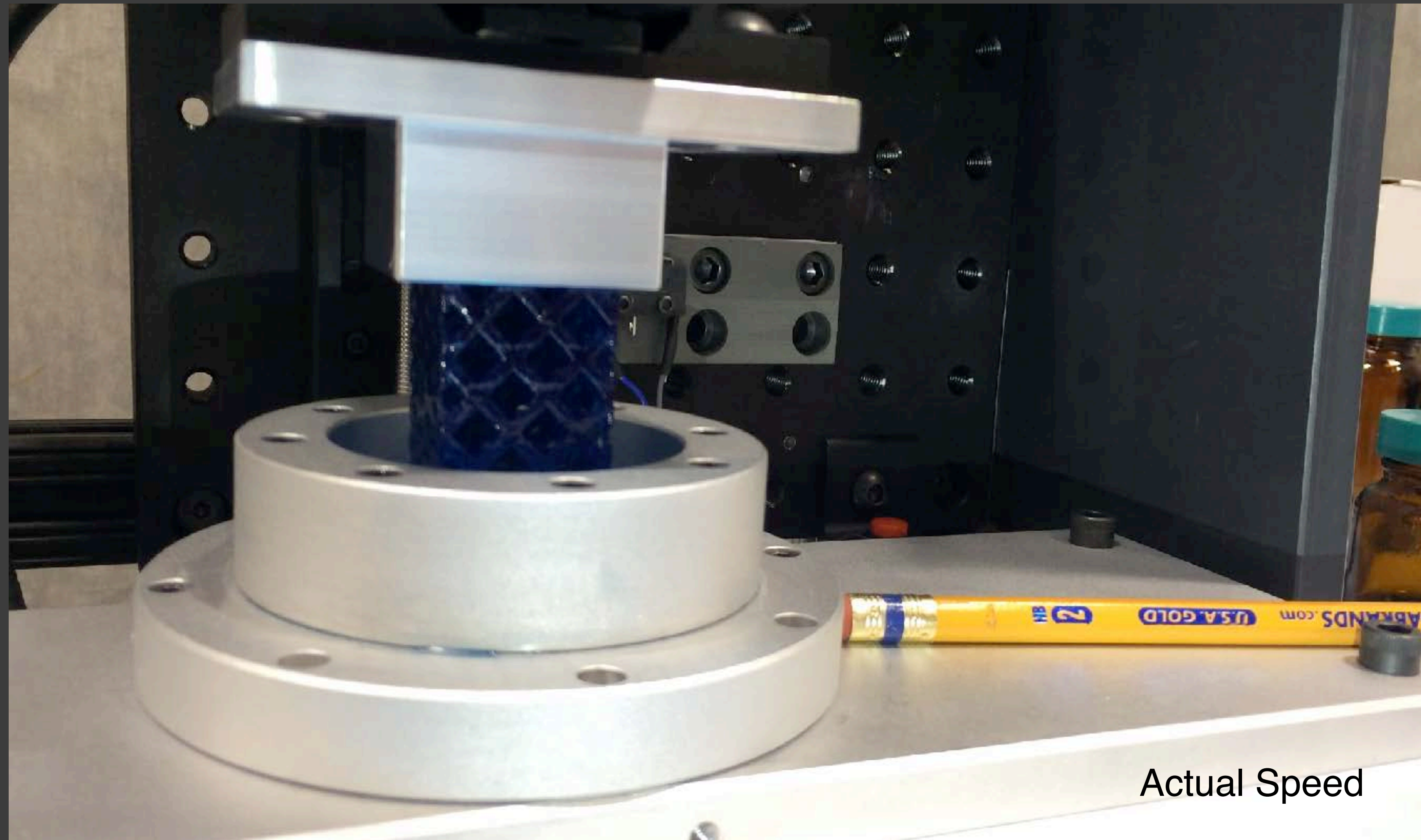


3D Printing



CLIP

Speed Limit May Be Heat of Reaction



Actual Speed

Sol-gel

Polyesters

Vinyl Ether

Acrylate

Polyurethanes

Bio-absorbable Resins

Silicones

Epoxides

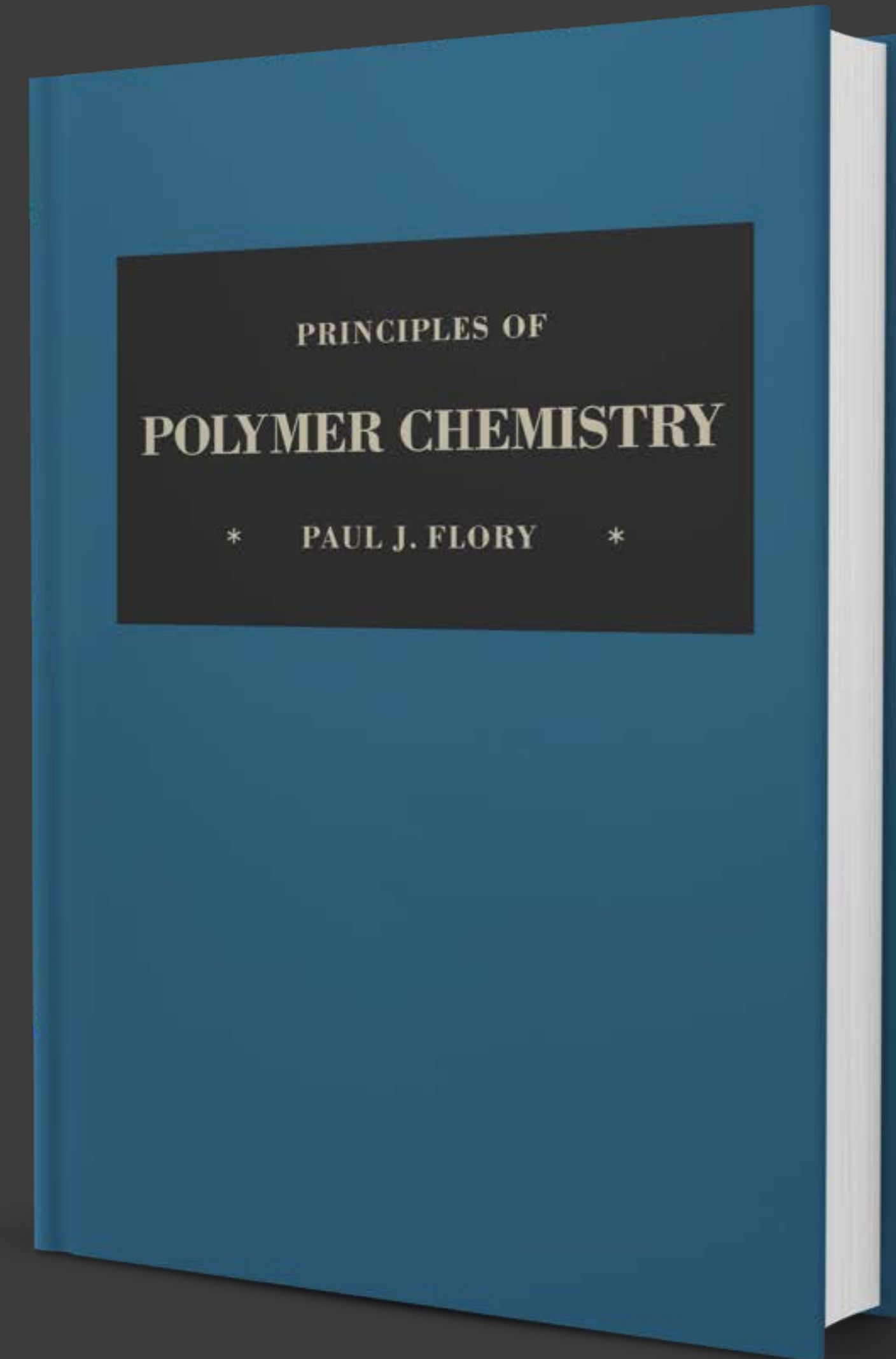
Cyanate Esters

Hydrogels

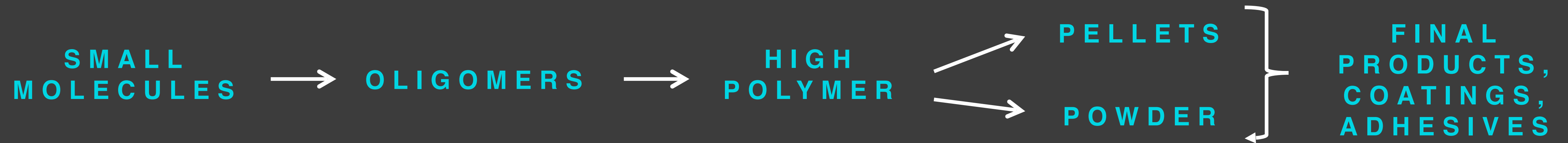
Investment Casting Resins

Polycarbonates

Thiol-ene

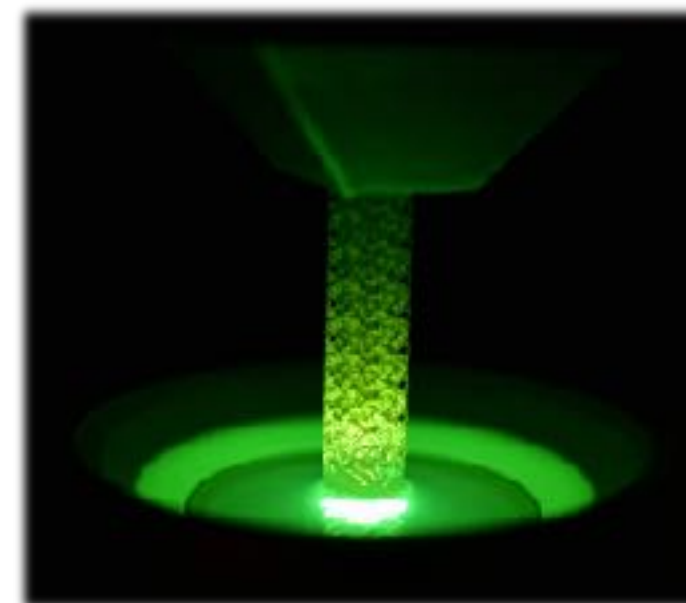


Today's Polymer Industry



- Energy intensive to process high polymers into products
- Properties of products limited to “fixed” properties of high polymers used

Tomorrow's Polymer Industry: Manufacturing with Light

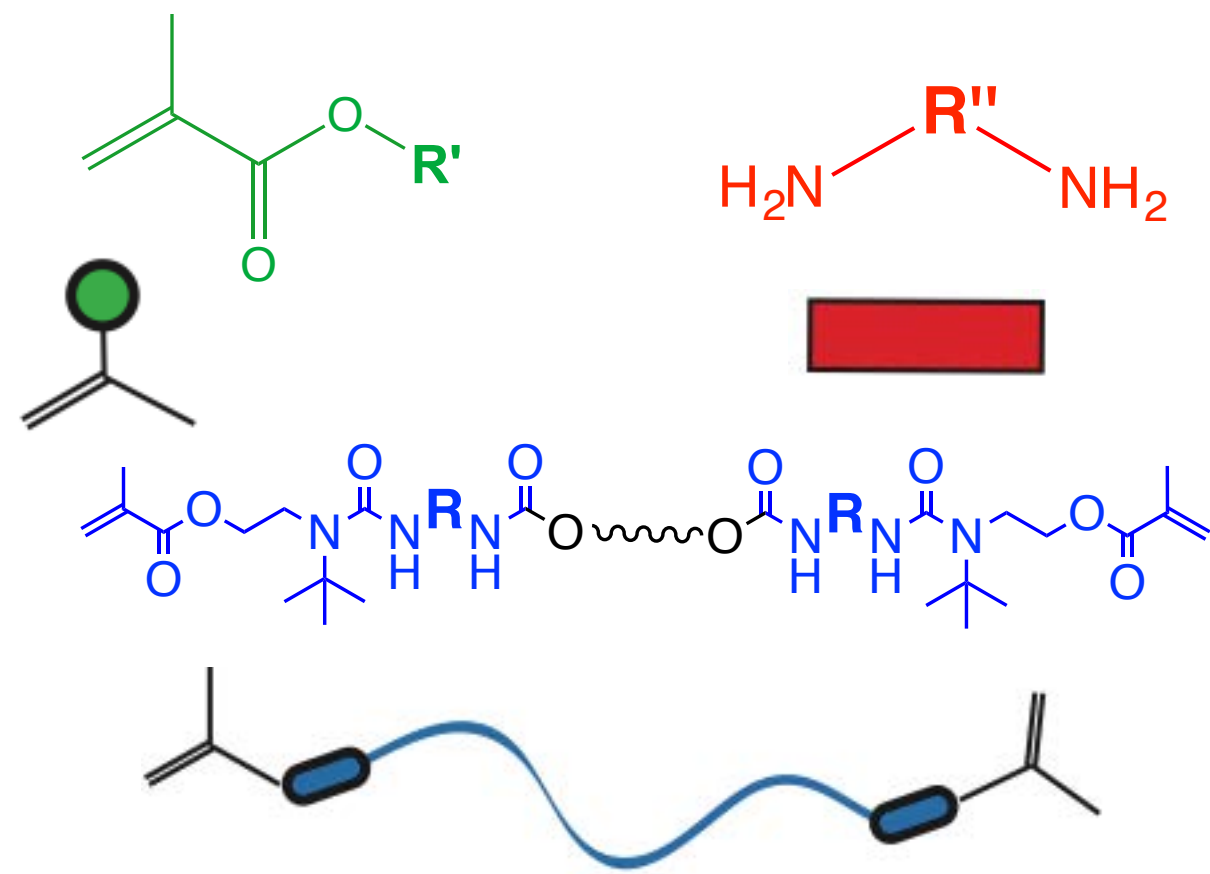


- Energy efficient
- Less waste
- Complexity is free
- New properties achieved while crafting the final object
- “In place” fabrication?

Set Shape vs Generate Properties

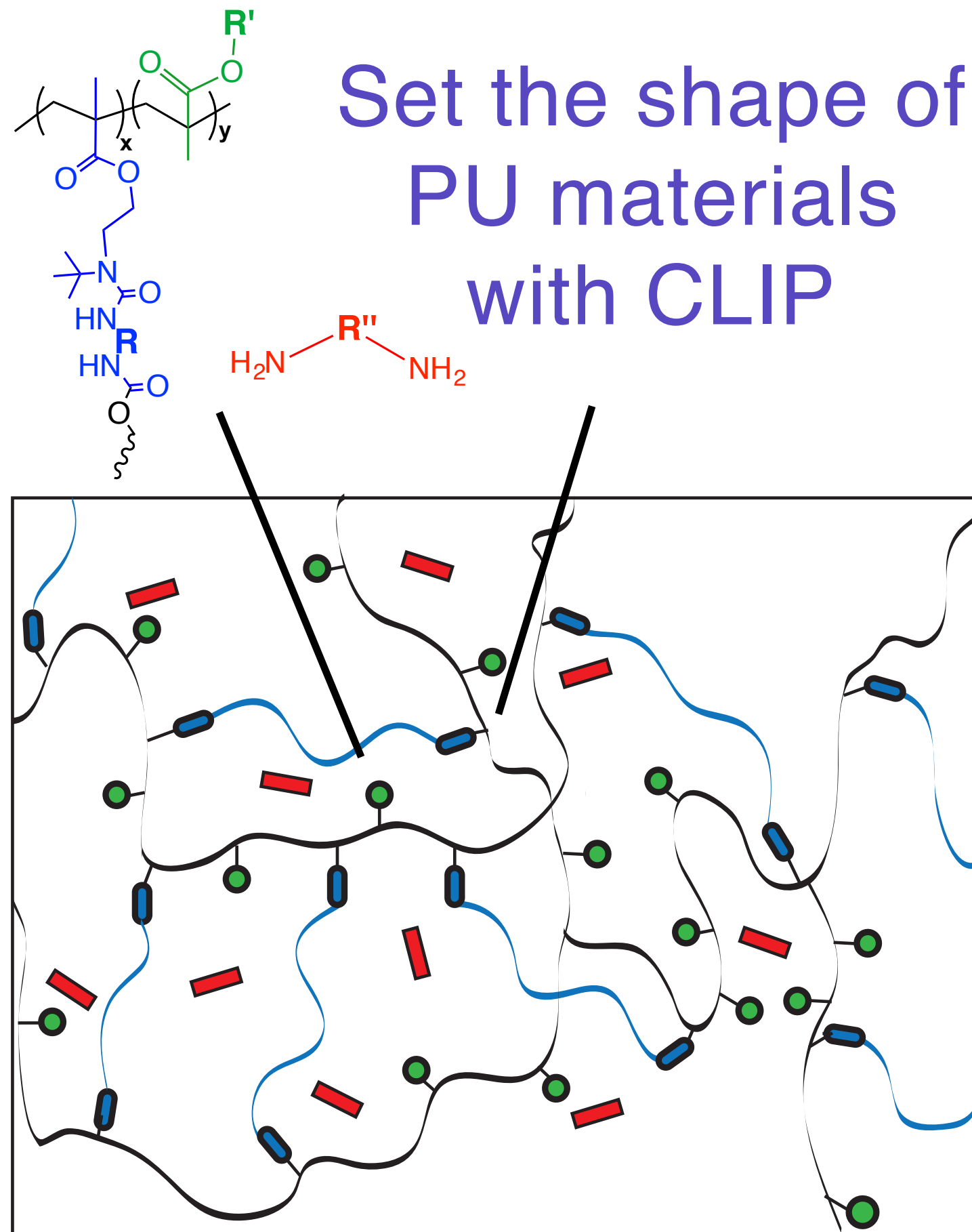
CLIP Poly(methacrylate)-Polyurethane IPNs

TPU formulations are comprised of ABPU materials, reactive diluents, and diamine chain extenders



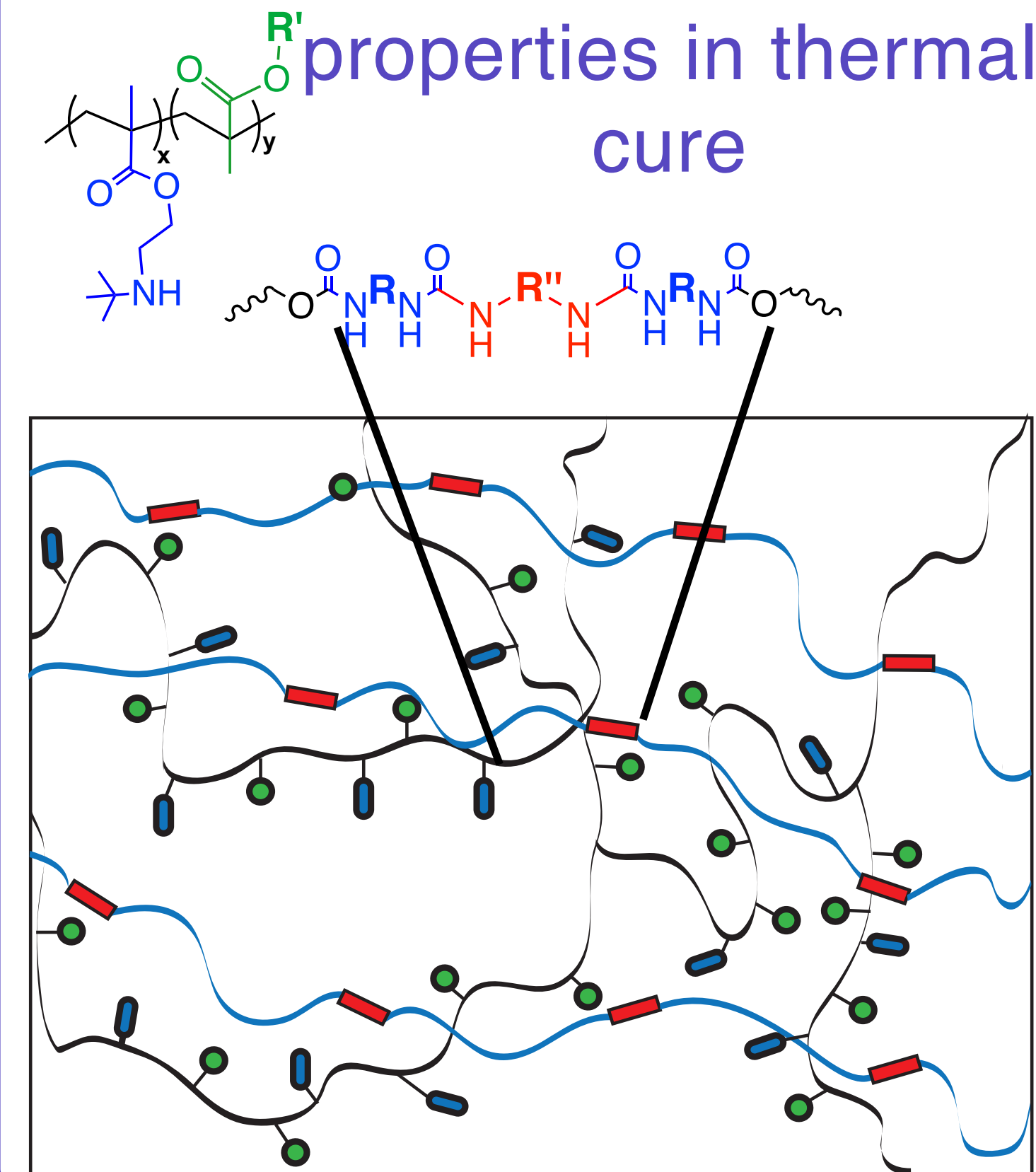
CLIP

Set the shape of PU materials with CLIP



120°C,
2-4h

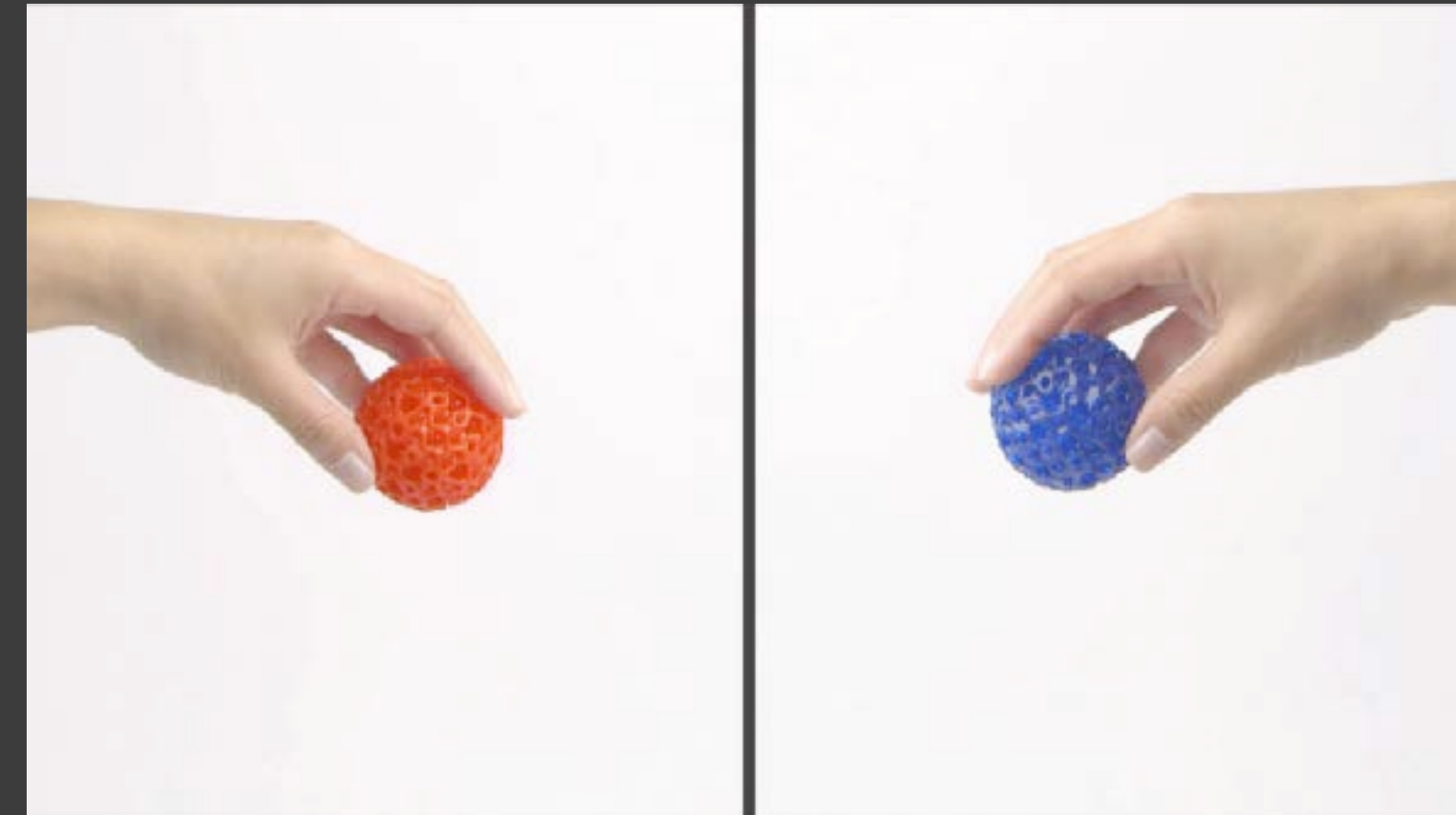
Set the mechanical properties in thermal cure



Polyurethane Elastomer

	Tunable Range
Tensile Strength	1 - 30 MPa
Modulus	1 - 20 MPa
Elongation	50 - 700%
Viscosity	2000 - 10,000 cP

Resilient vs Damping



Grips



Gaskets



Cushioning

Rigid Polyurethane

	Tunable Range
Tensile Strength	25 - 60 MPa
Modulus	1000 - 2000 MPa
Elongation	5 - 200%
Impact Strength	120 - 150 J/m
Viscosity	2000 - 10,000 cP
Flexural Strength	30 - 60 MPa
Flexural Modulus	500 - 1000 MPa
Heat Deflection Temperature	50 - 75 °C



Auto (non-engine)








Orthotics









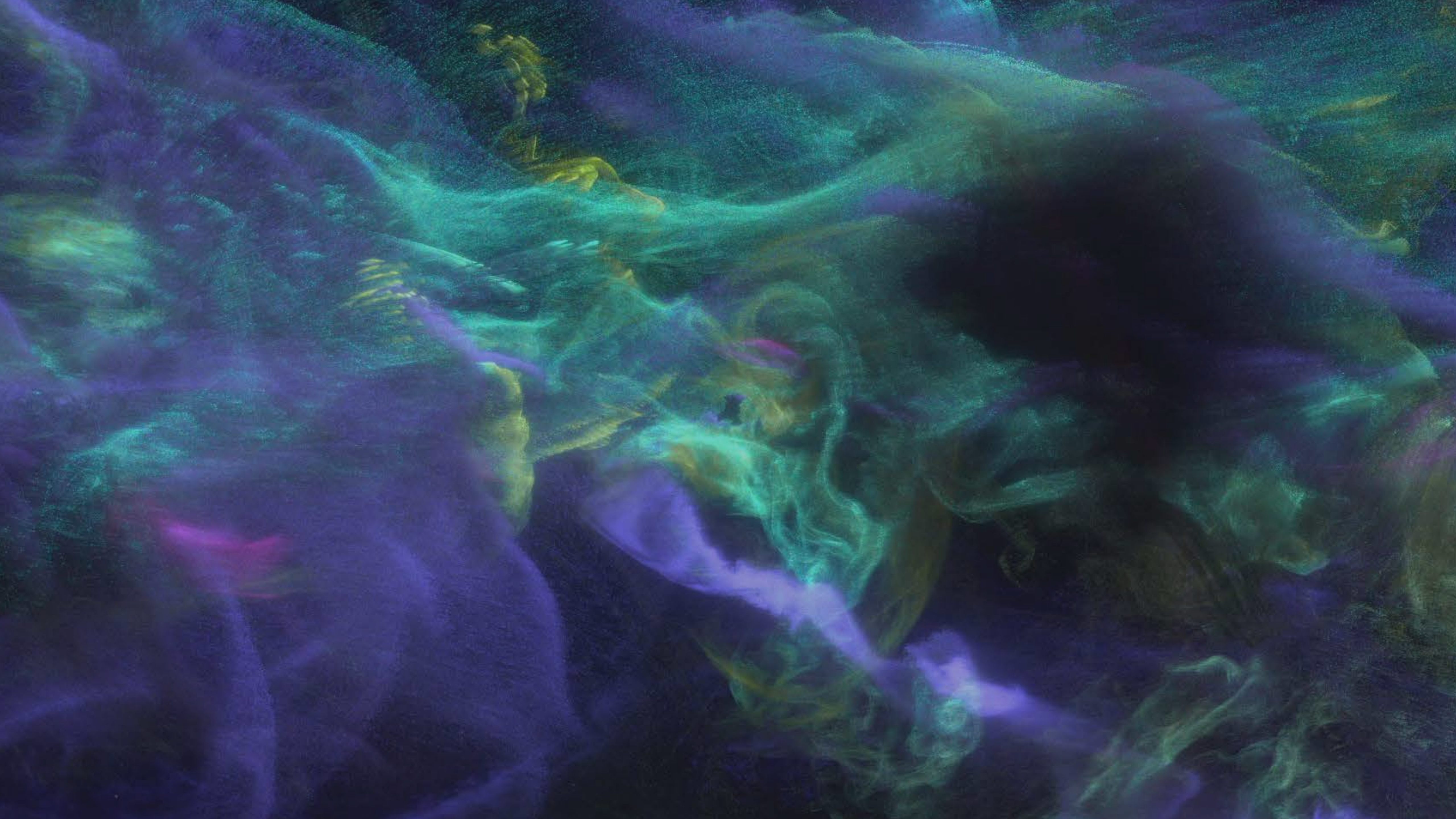
High strength to weight ratio

Resins for Initial Launch

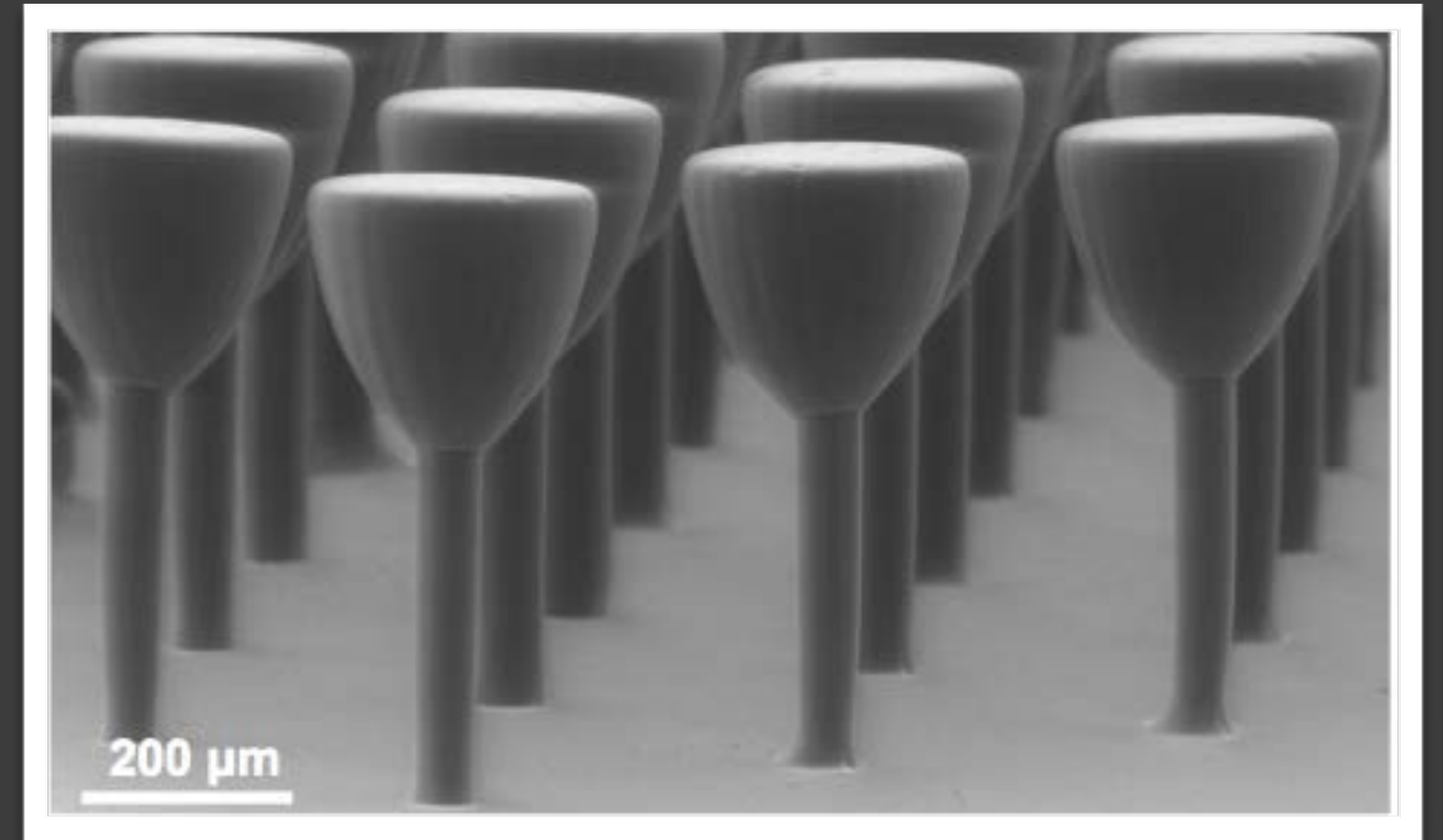
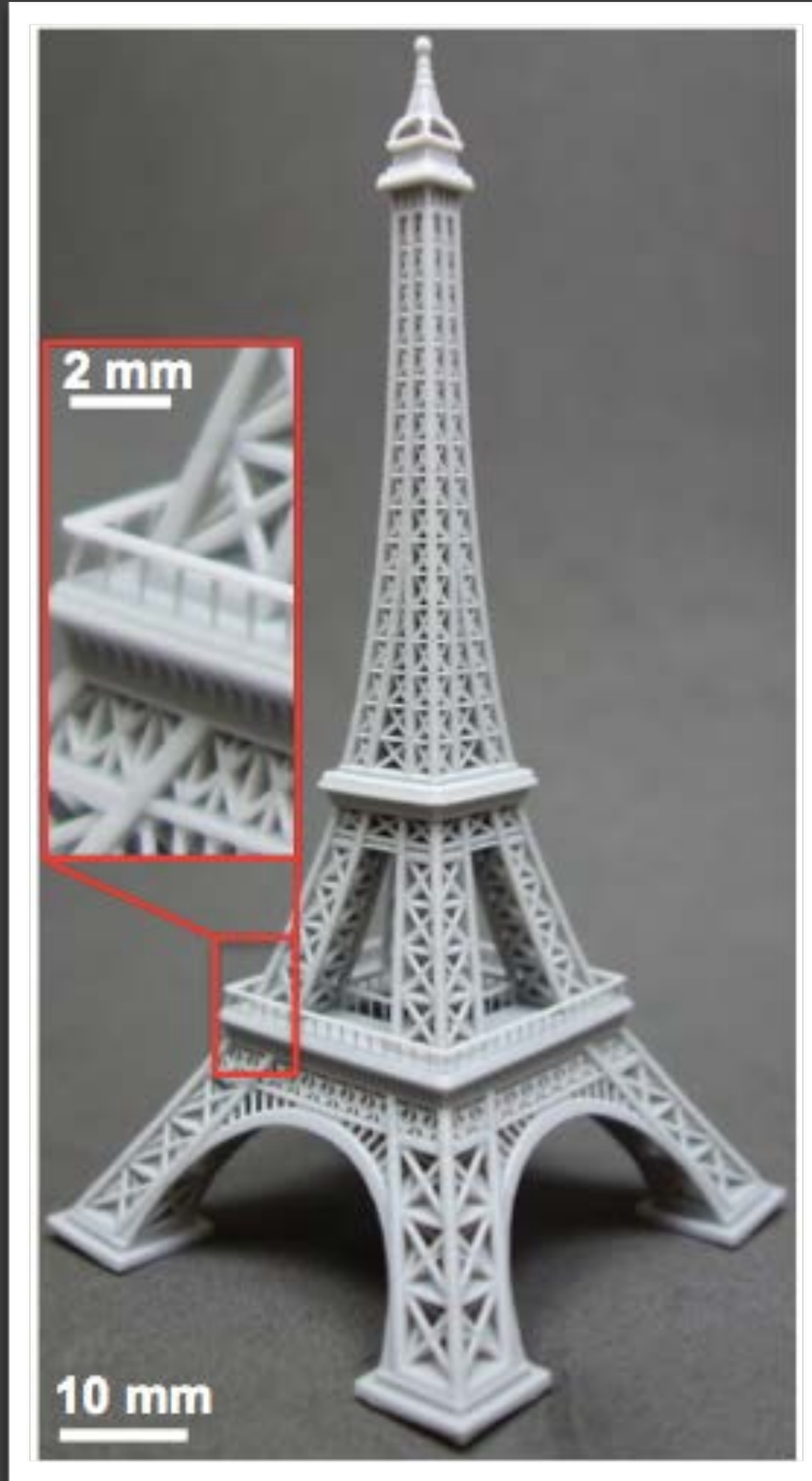
	Sample Applications		Tensile Strength (MPa)	Elongation at Break (%)	Young's Modulus (MPa)	Impact Strength (J/m)	Viscosity (cP)
Urethane Acrylate	General Prototyping Dental		58 +/- 2	23 +/- 2	2090 +/- 90	26 +/- 4	2000
Polyurethane Elastomer	Footwear Gaskets Grips		7 +/- 1	465 +/- 15	7 +/- 1	N/A	5000
Rigid Polyurethane	Auto (interior) Orthotics Connectors		48 +/- 1	160 +/- 7	1700 +/- 190	142 +/- 8	5500
Semi-rigid Polyurethane	Living Hinges Clips		25 +/- 1	251 +/- 2	715 +/- 33	133 +/- 8	2000
Investment Casting	Jewelry Dental Aerospace		N/A	N/A	N/A	N/A	500

Next Generation Resins

	Polyurethane	Huge range of mechanical properties, tough and flexible
	PLGA/PLAA	Bio-absorbable, biocompatible
	Silicones	Soft, biocompatible elastomers
	Polyimides & Cyanate Esters	High temp. stability
	Epoxy	Rigid, chemically resistant plastics
	PEG Hydrogel	Soft, water permeable; tunable charge



Range in Part Geometry and Size

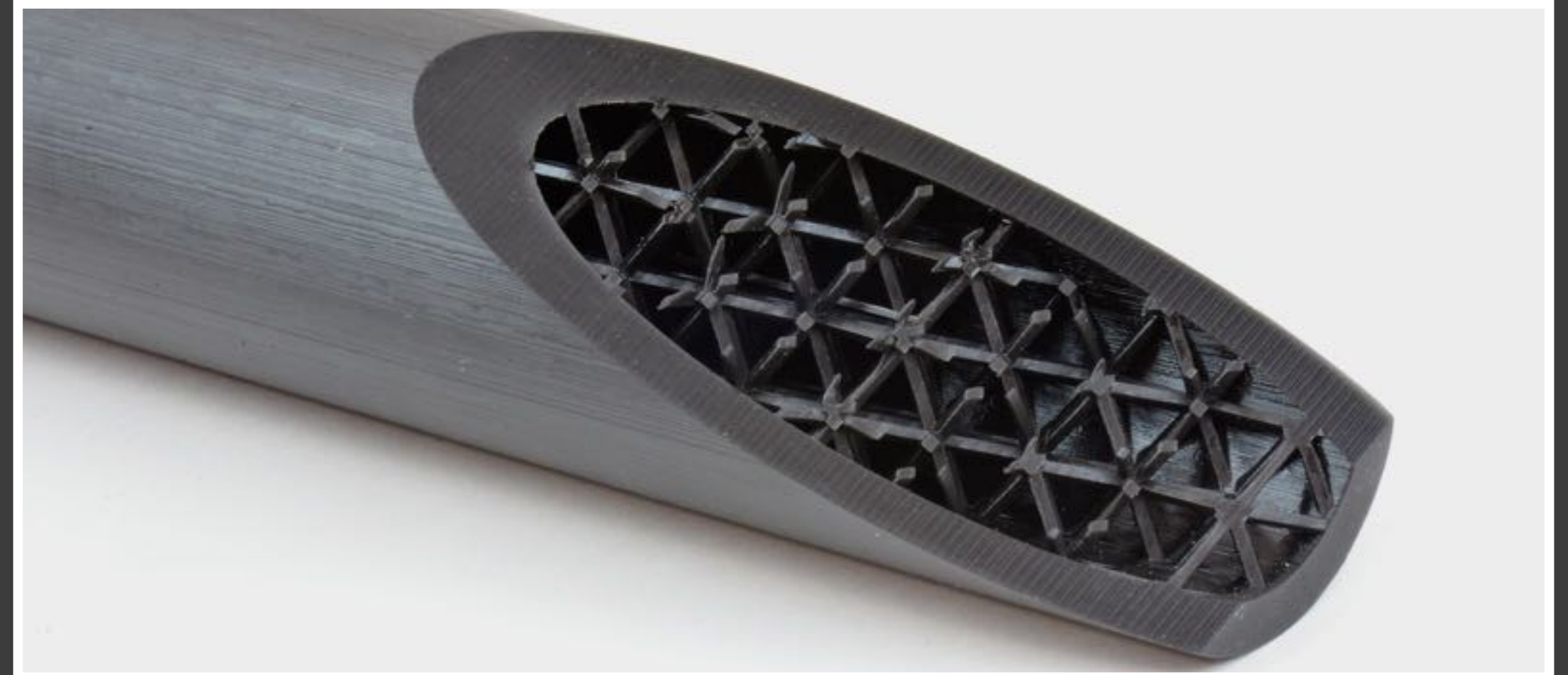


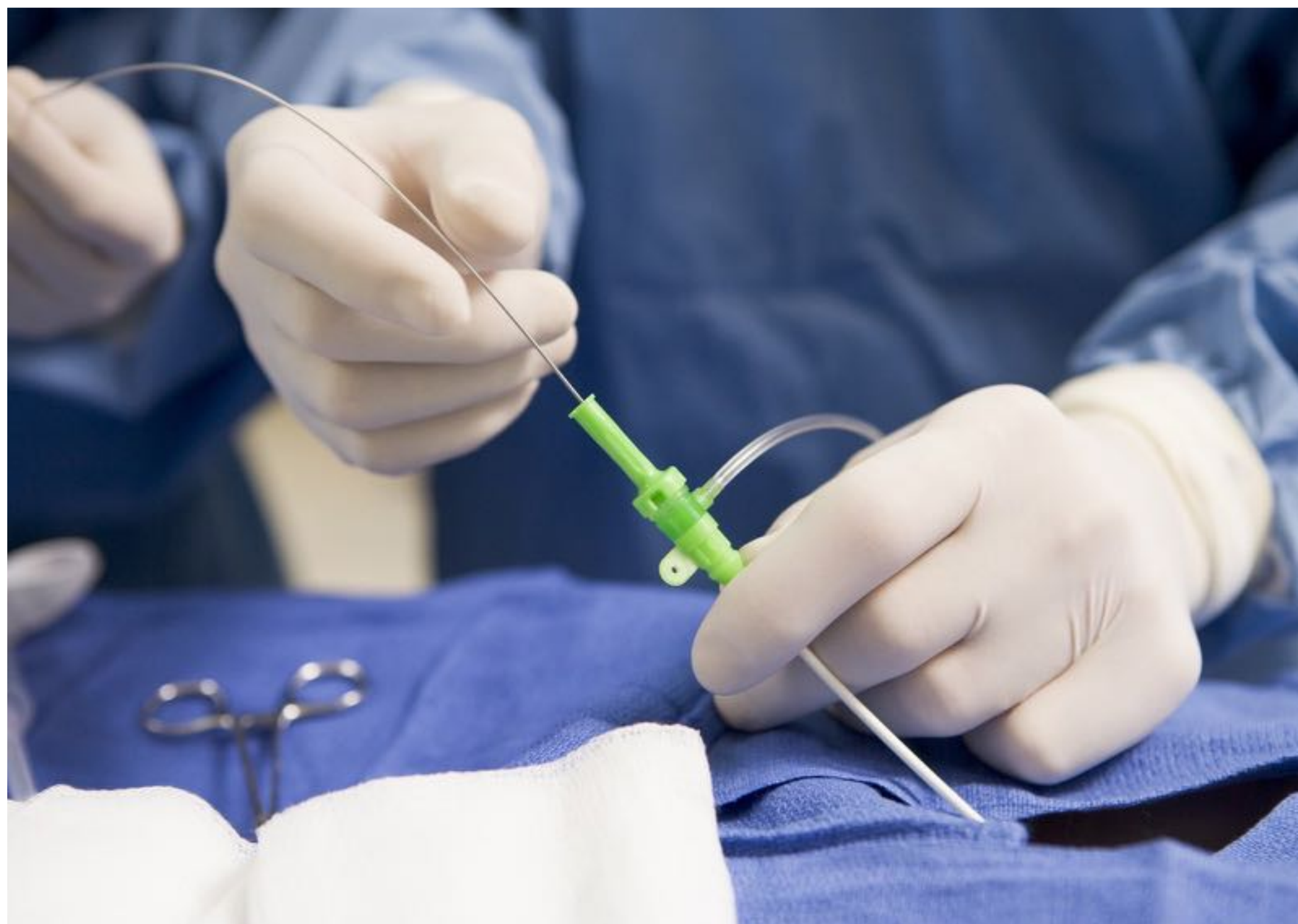


Digital Manufacturing



High Strength-to-Weight Ratio



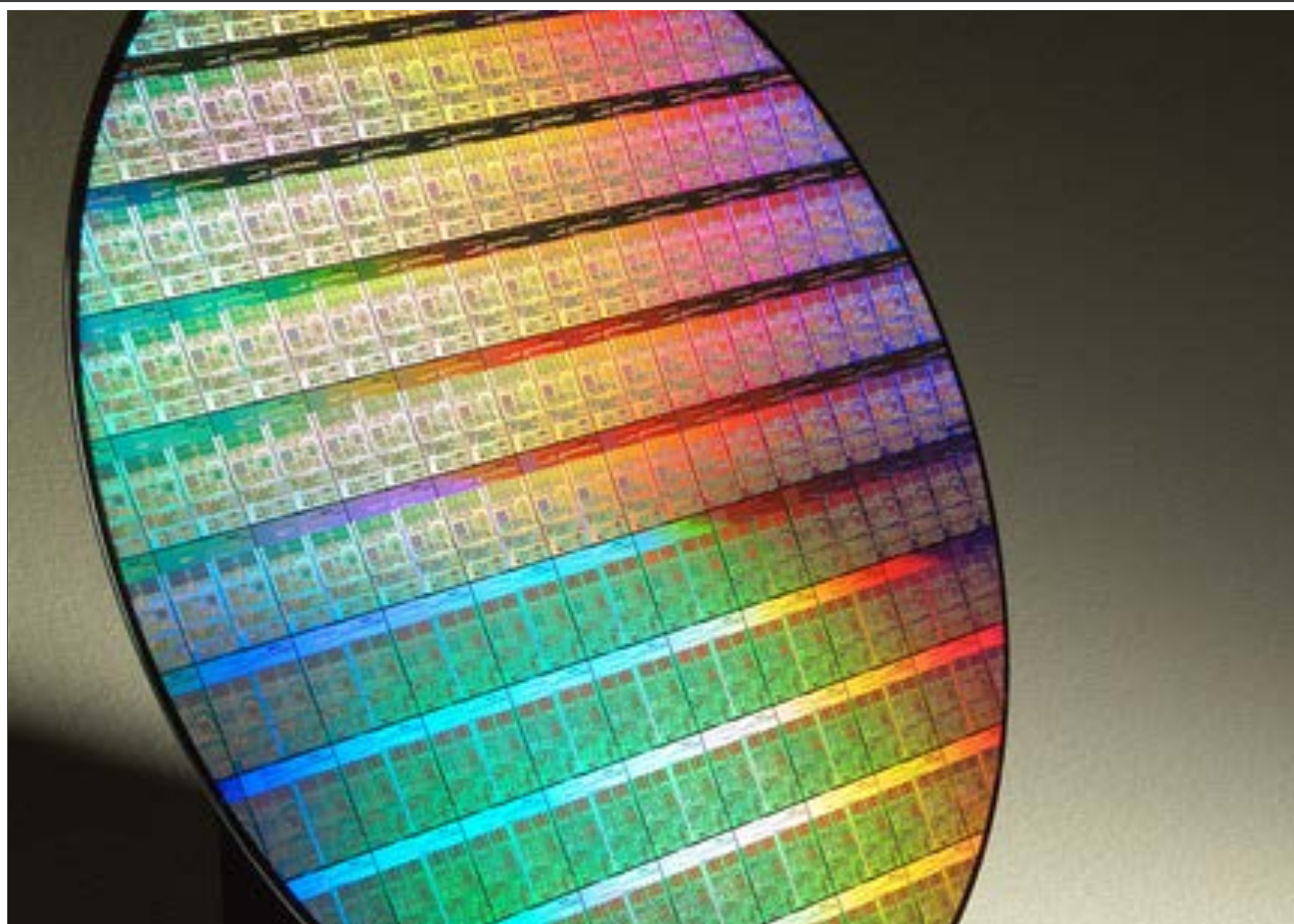


Personalized Medicine

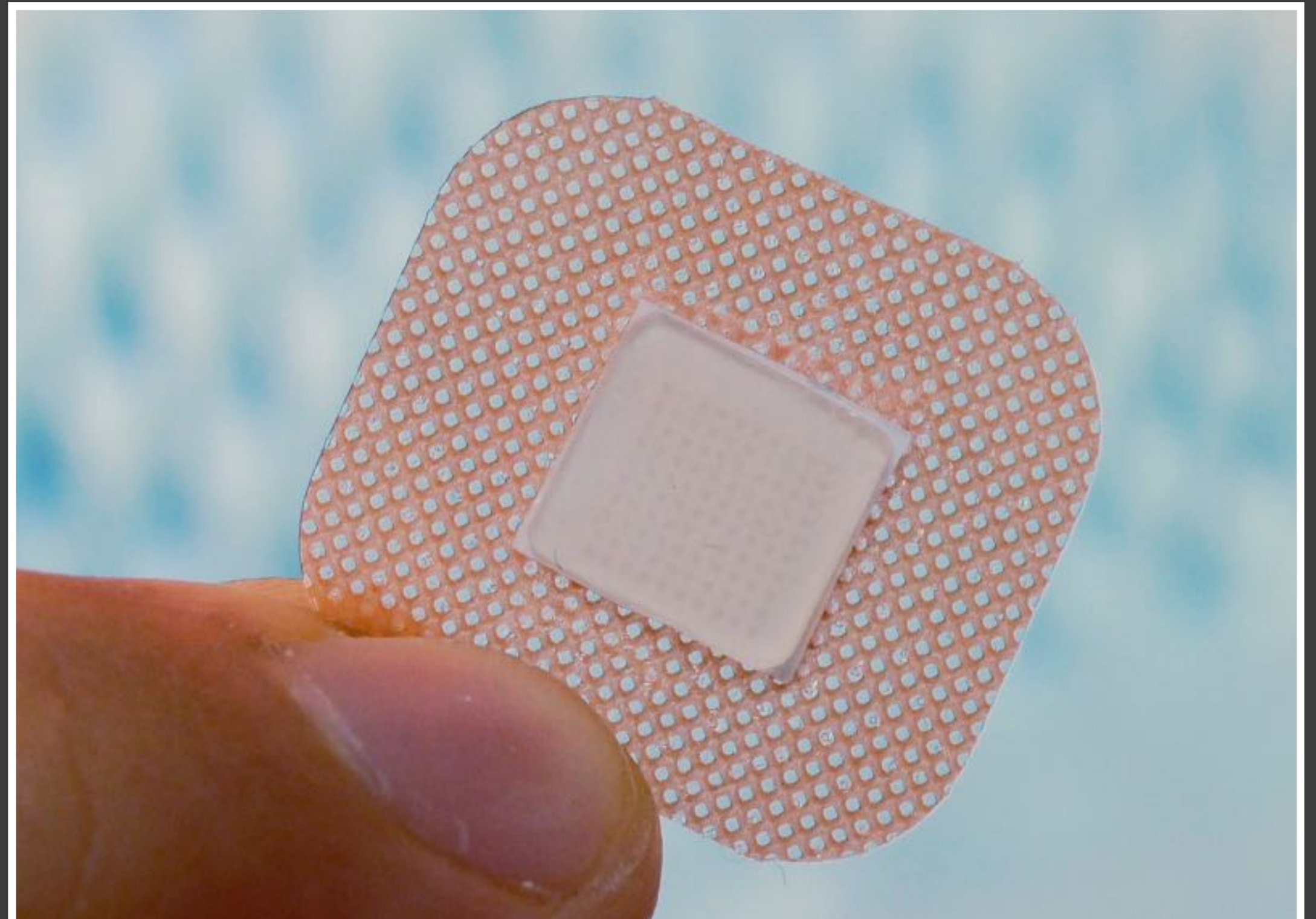


Point-of-Service Manufacturing

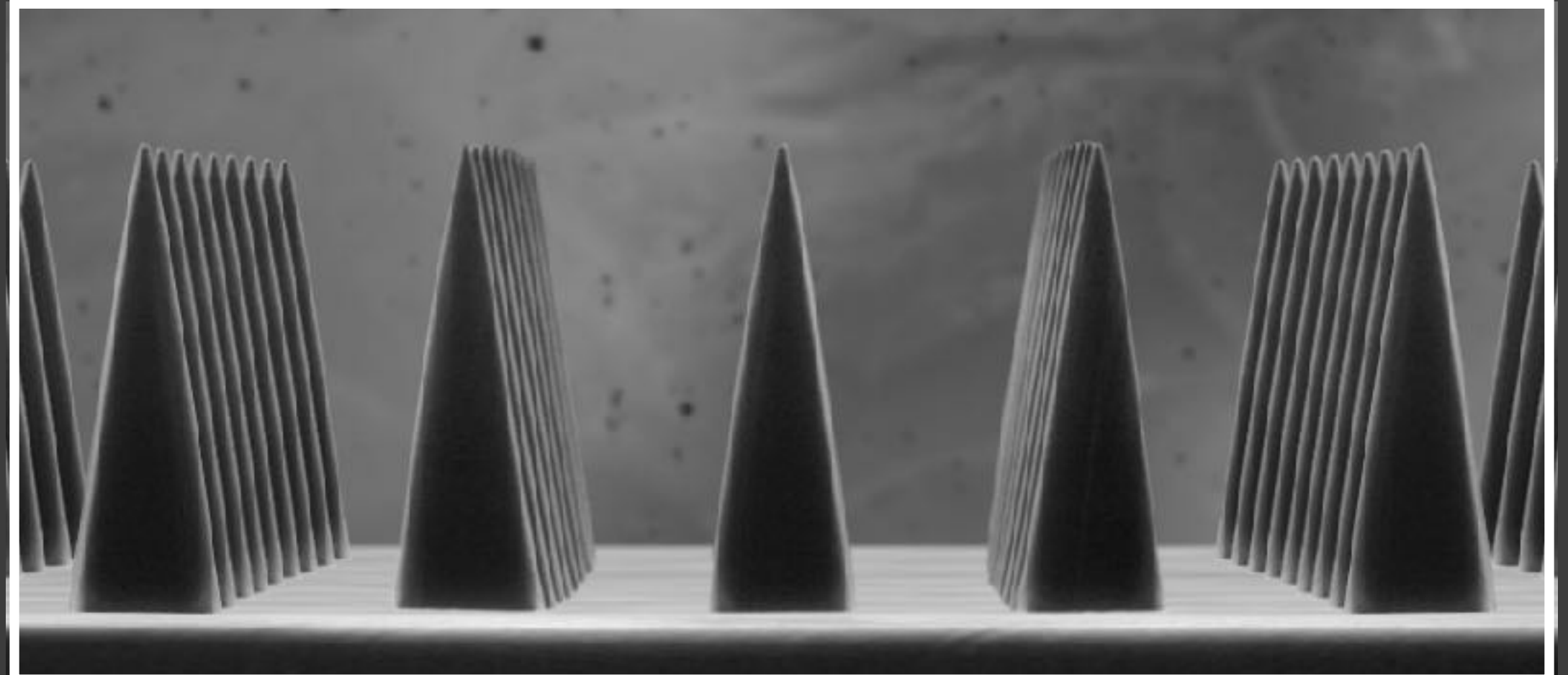
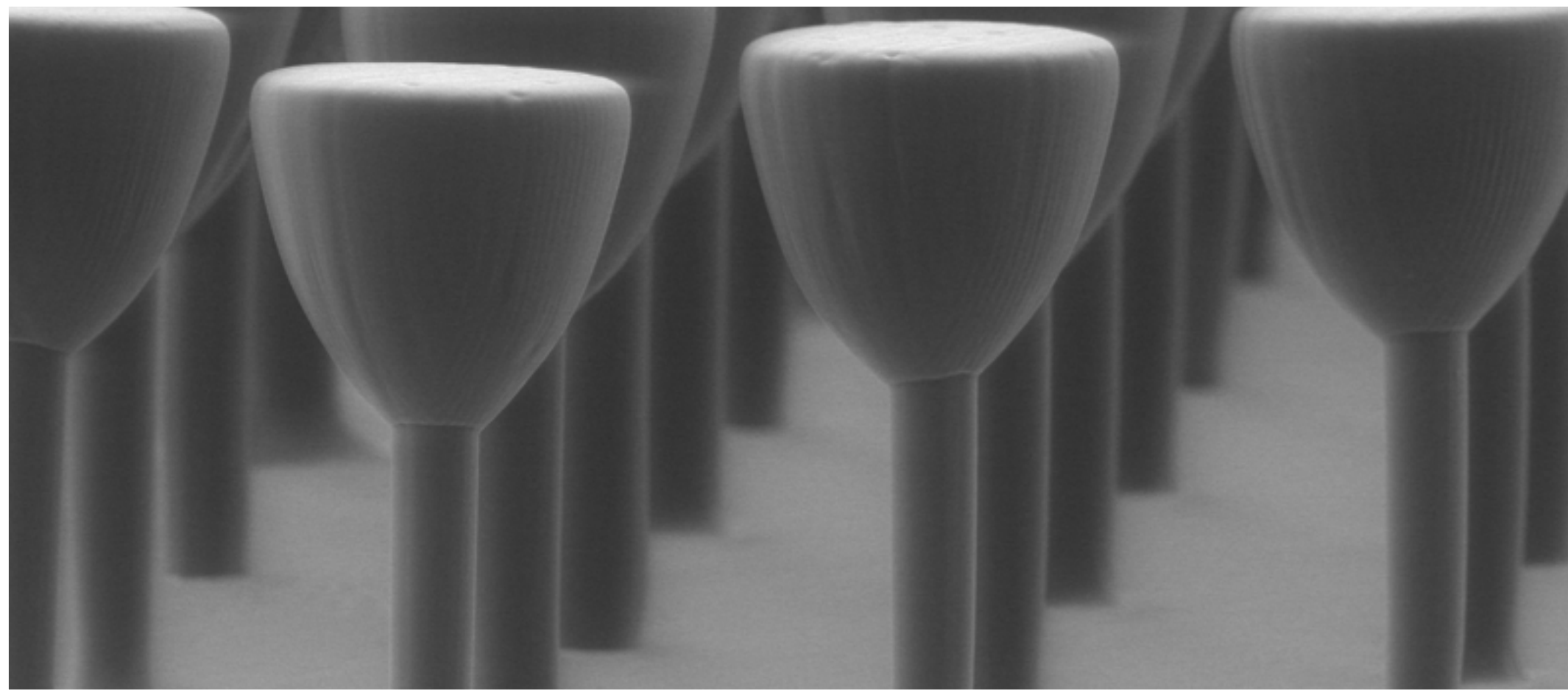




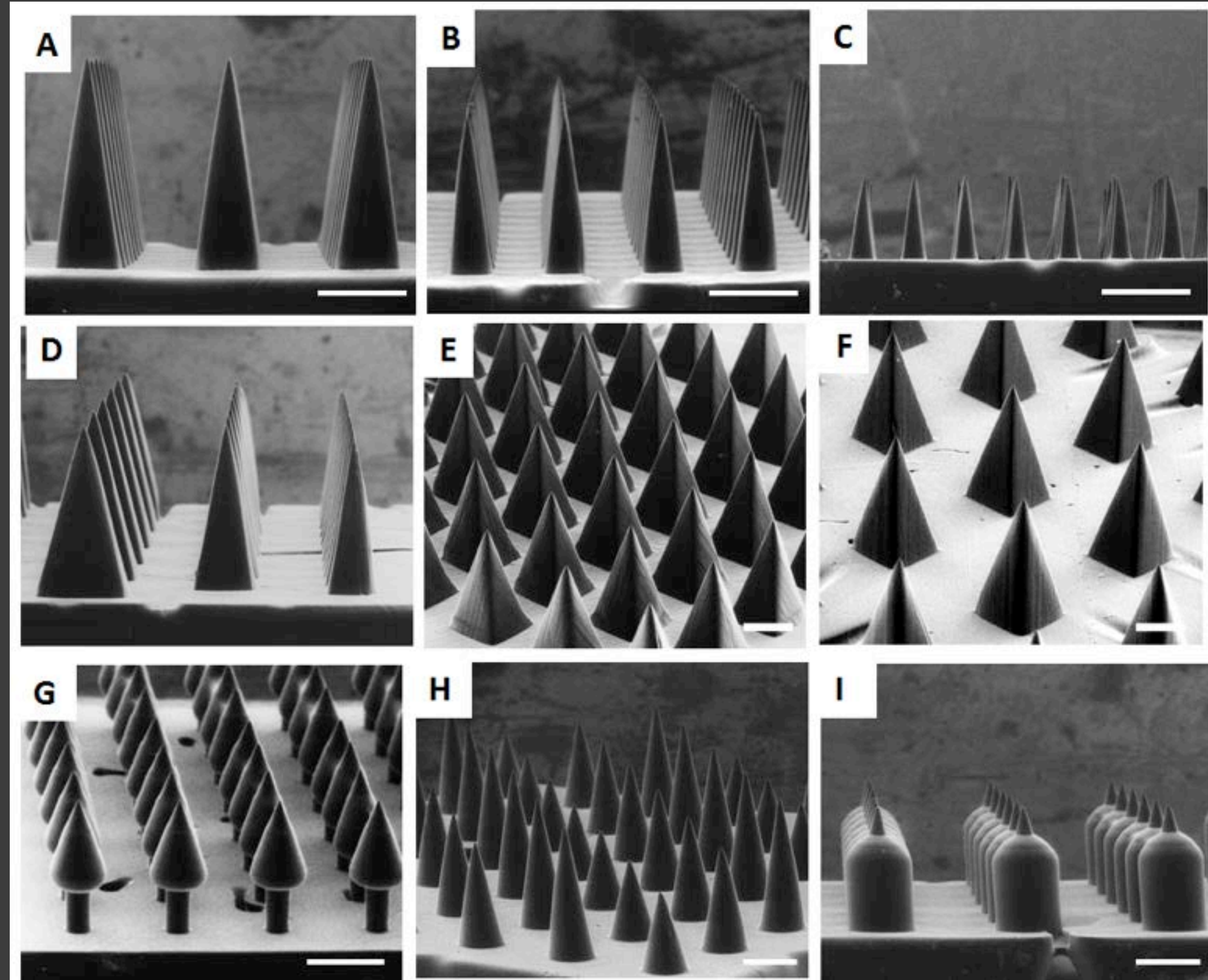
Microfabrication

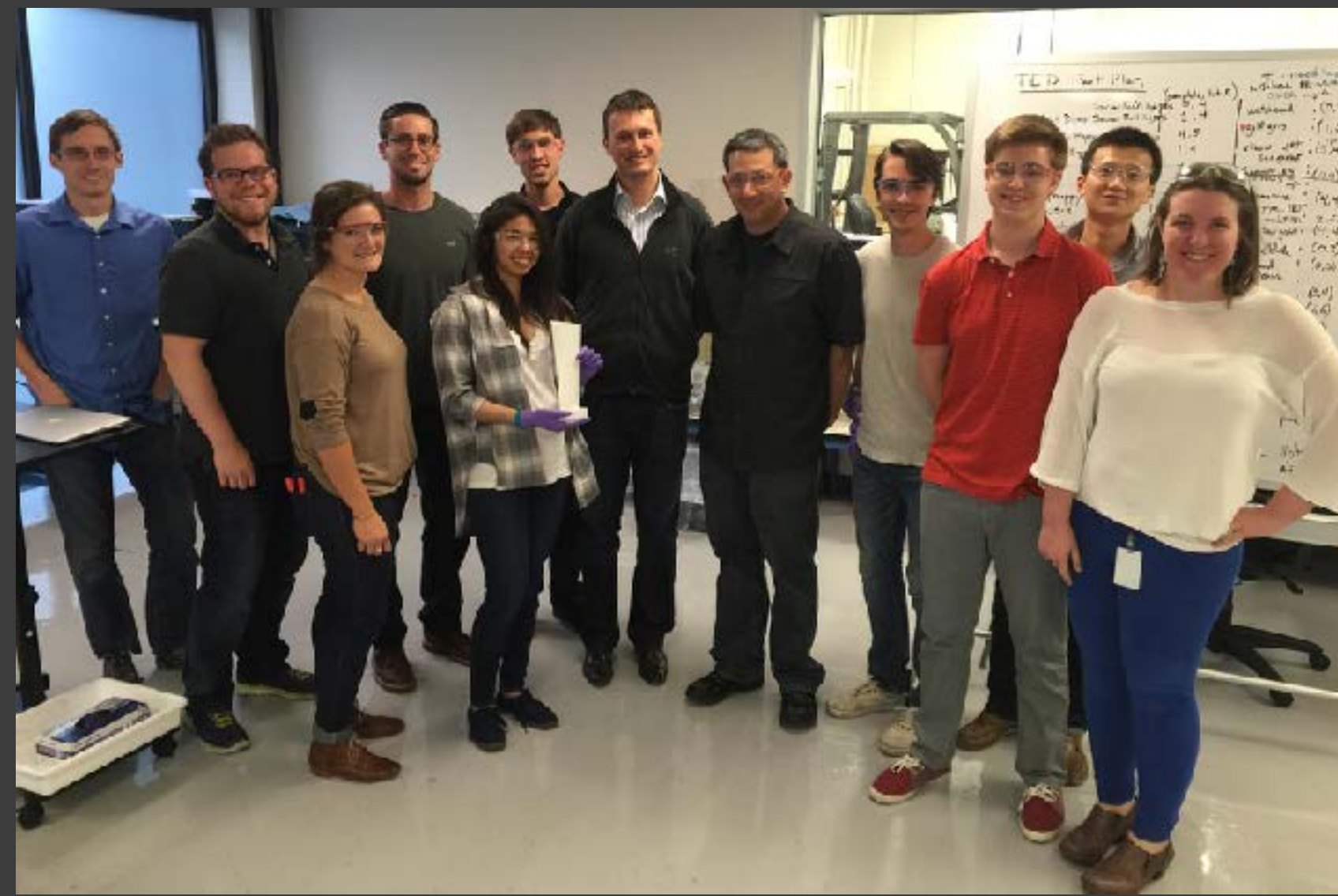


Vaccine & Drug Delivery



Microneedle Designs Improve Insertion Into the Skin





carbon3DTM

CARBON3D.COM | @CARBON3D