

# Computational Fabrication

CS 491 and 591

Professor: Leah Buechley

[https://handandmachine.cs.unm.edu/classes/Computational\\_Fabrication\\_Spring2021/](https://handandmachine.cs.unm.edu/classes/Computational_Fabrication_Spring2021/)

# Weekly Researcher: Emily Whiting

Shape Lab, Boston University: <https://shape.bu.edu/publications>

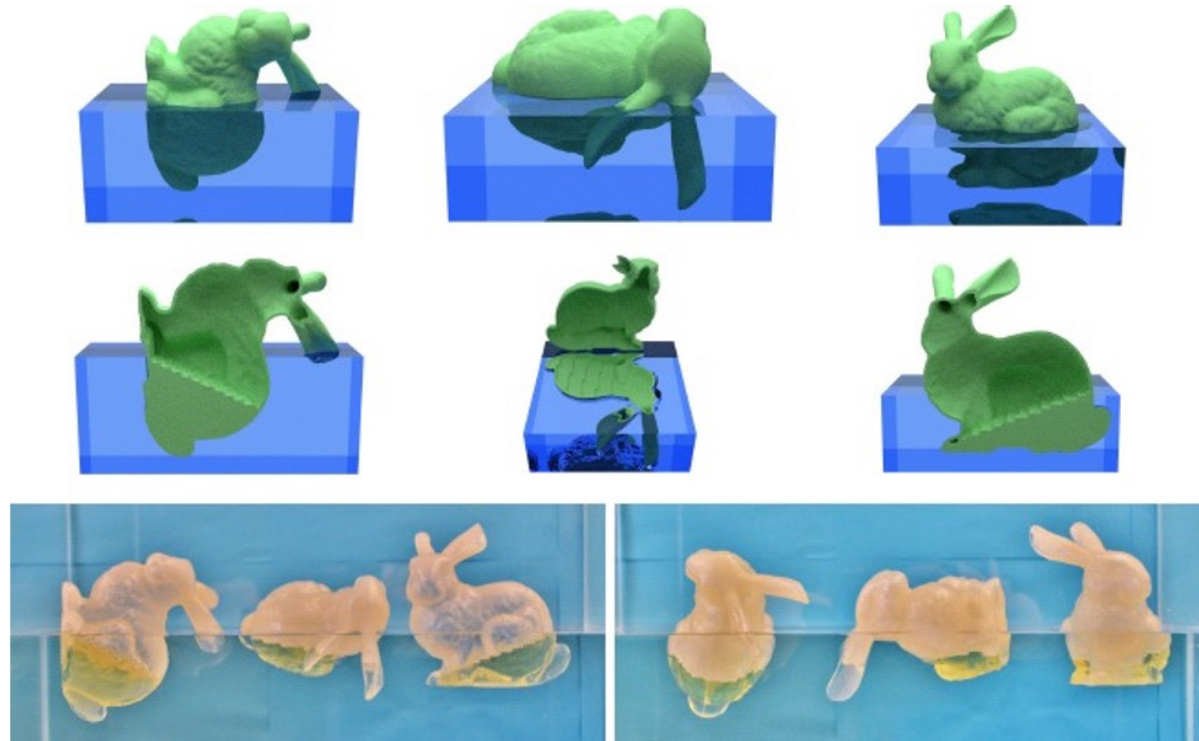
Computer Graphics, Physics, Digital Fabrication

# Make it Stand



<https://igl.ethz.ch/projects/make-it-stand/make-it-stand.mp4>

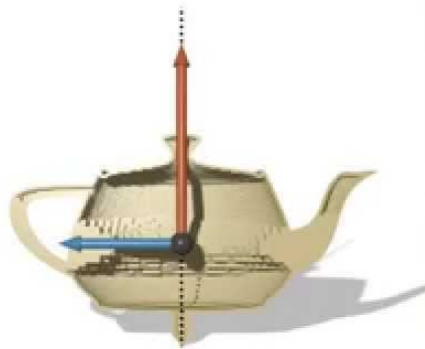
# Bouancy



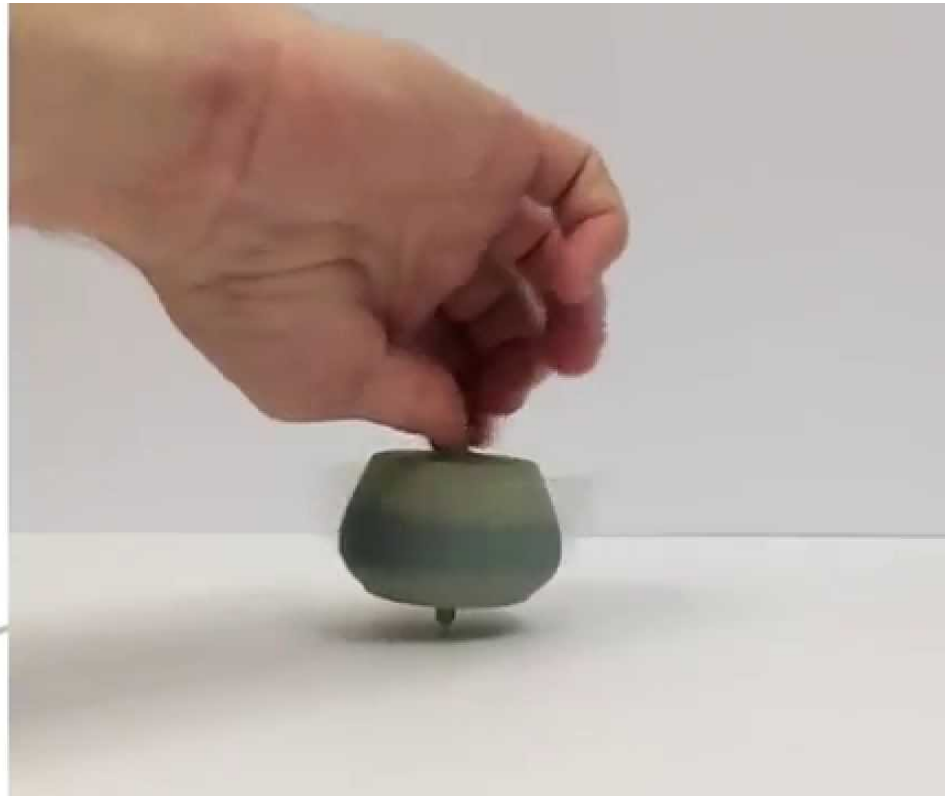
<https://onlinelibrary-wiley-com.libproxy.unm.edu/doi/full/10.1111/cgf.12810>

# Spinning

optimized result



© Disney



Today: 3D Printing

# 3D Printing is Additive

Additive: add material to construct something

Subtractive: remove material to construct something

# Types of 3D Printing

## Extrude a material

- Fused Deposition Modeling (FDM)/Fused Filament Fabrication (FFF)
- Direct Write/Robocasting/Paste Extrusion: Clay, Cement, and Adobe Printers

## Harden a liquid

- Stereolithography (SLA)
- Digital Light Processing (DLP)

## Bind or fuse a powder

- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM)
- Direct Metal Laser Sintering (DMLS)
- Binder Jetting (BJ)

## Spray/Jet a material

- PolyJet
- Material Jet (MJ)

## Cut and glue layers

- Laminated Object Manufacturing (LOM)



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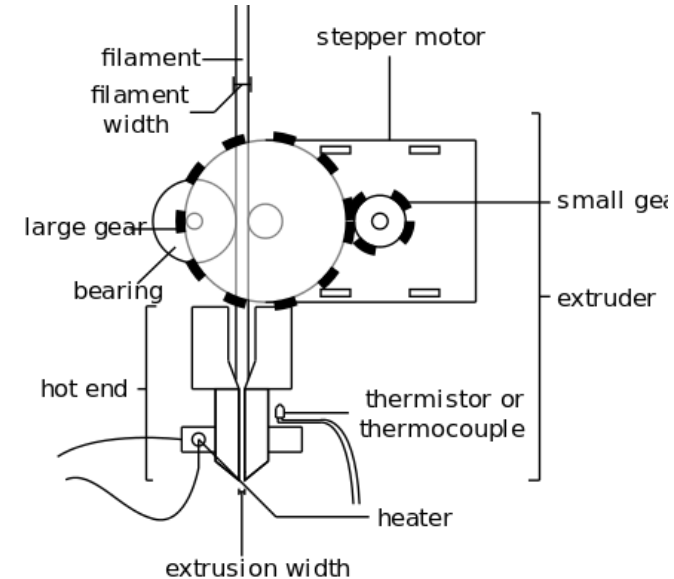
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# Fused Deposition Modeling (FDM) Fused Filament Fabrication (FFF)

- Essentially a glue gun attached to an XYZ table.
- Invented in 1988 by Scott Crump, co-founder of Stratasys
- “FDM” is trademarked by Stratasys, hence “FFF”
- Patent expired in 2009, which is part of what led to development of cheap desktop printers
- Our Ender 3D printers are FDM/FFF machines
- Cheap and accessible



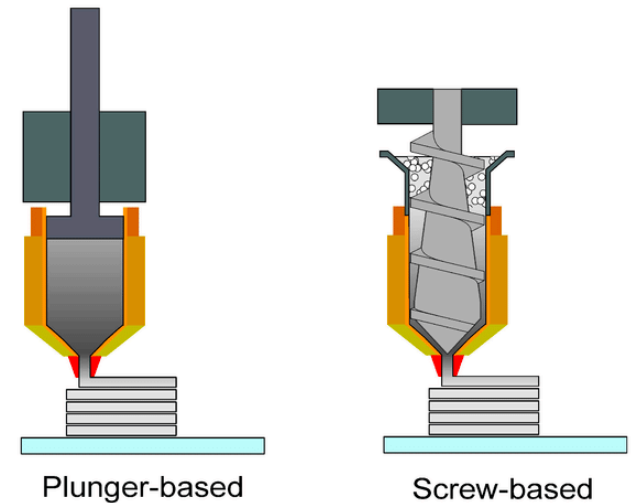
# Materials

- Thermoplastic polymers (plastics that melt when heated): PLA (what we're using), ABS, PC, HDPE, PETG, etc.
- Thermoplastic Polyurethane (TPU): A fairly new flexible material that can be used in FDM printers (see Alan's post)
- Thermoplastic composites, thermoplastics with additives: wood, coffee, carbon fiber, sandstone, metal powders, glass, hemp...
- Other materials: wax, conductive PLA, polycarbonate...
- Nice examples: <https://proto-pasta.com/>

# Other Extrusion Based Printing

Direct Write (DW), Direct Ink Write (DiW), Paste Extrusion

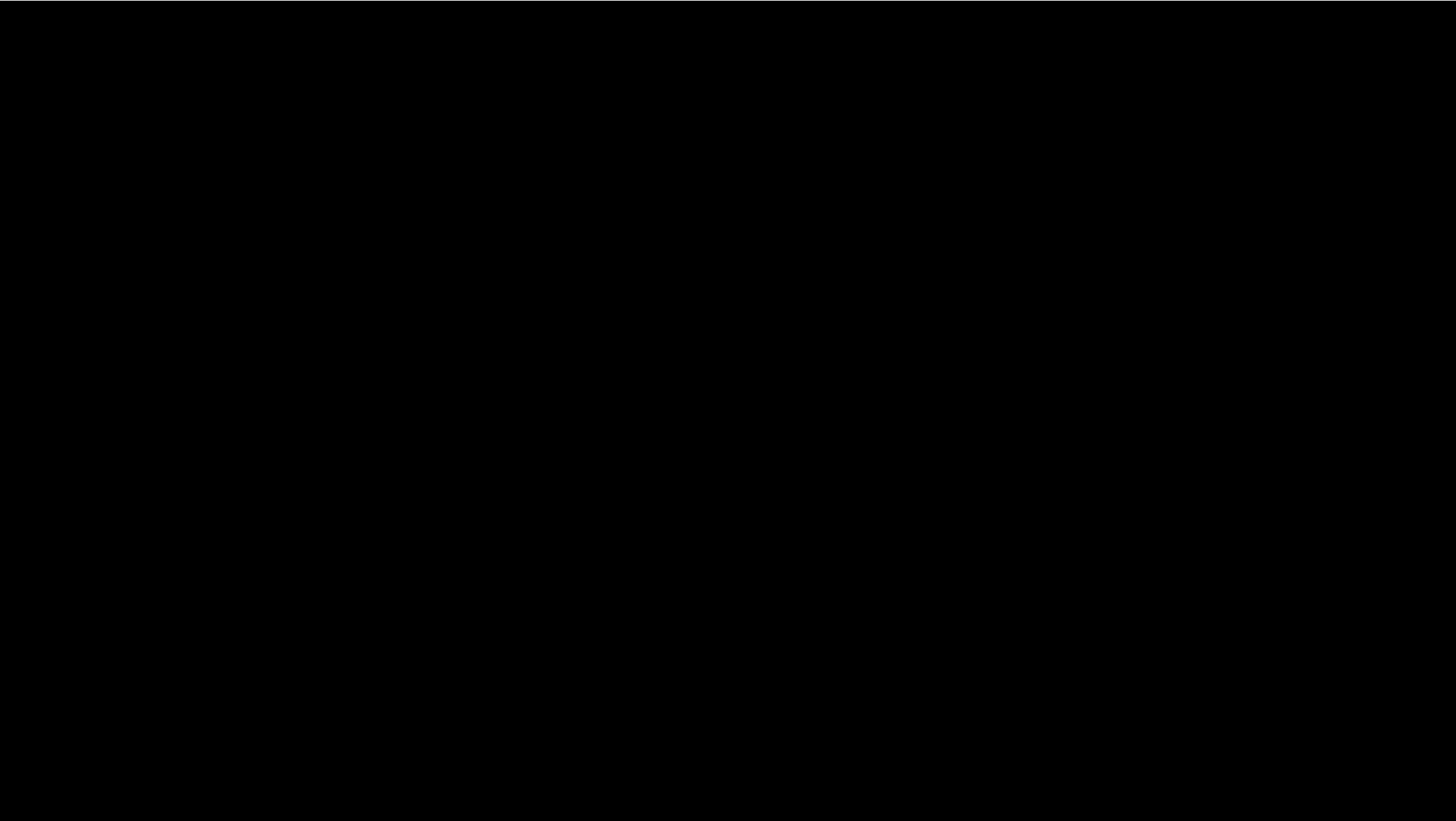
- Essentially any extruder attached to an XYZ table, or other 3d machine (ie: a robot arm).
- Plunger-based extrusion: squeeze a material through a tube.
- Screw-based extrusion: use a screw to move material to the print head (ie: for hose-fed applications)



# Materials (!)

- Any paste that cures, dries, or can be cooked, fired, etc.
- Any meltable substance that hardens
- Food: Chocolate, Pasta, Marzipan, Candy, etc.
- Resins: epoxy, silicone, composite materials
- Clay, adobe, cement, etc.
- Hand and Machine lab research:
  - Biomaterials: eggshells, sawdust, yard waste, orange peels, ...
  - Metals: copper, bronze, ...
  - Glass

# Hand and Machine research



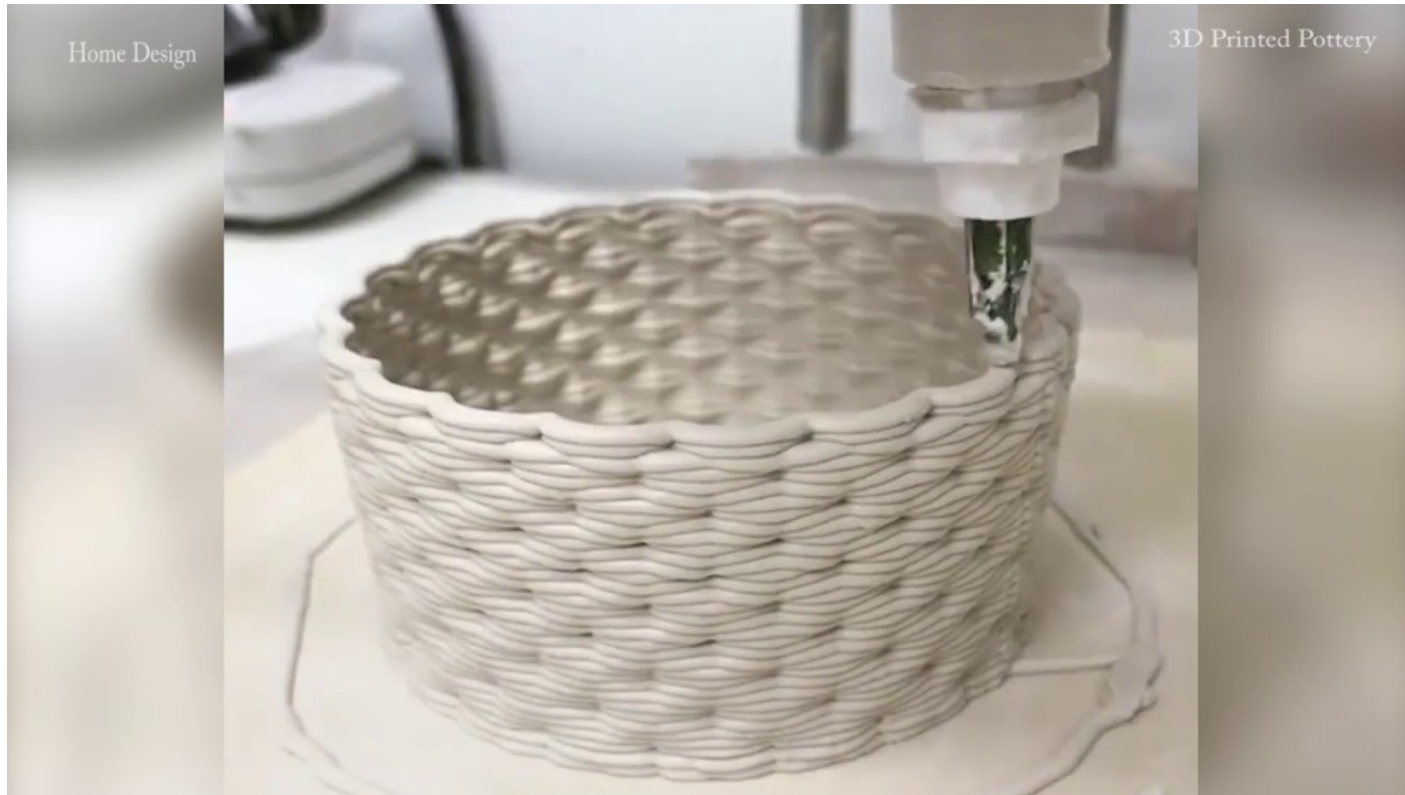


# **CeraMetal: Metal 3D Printing with Bronze Clay**

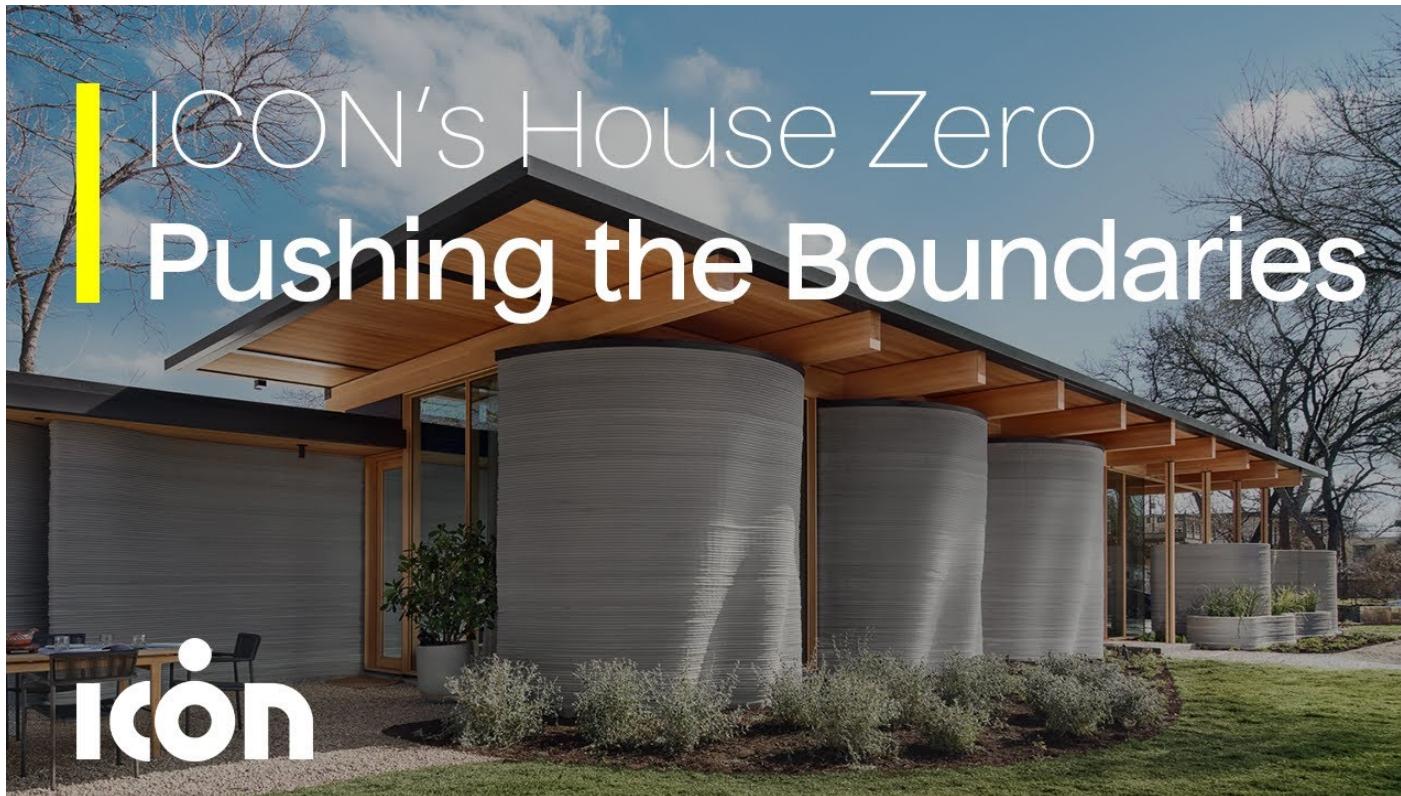
Leah Buechley, Jaime Gould, and Fiona Bell, Hand and Machine Lab  
Department of Computer Science, University of New Mexico



# 3D Printing Clay



# 3D Printing Concrete



<https://iconbuild.com/>

# 3D Printing Concrete

## Printing lab at UNM puts school ahead of the curve

BY KEVIN ROBINSON-AVILA / JOURNAL STAFF WRITER  
Monday, June 3rd, 2019 at 12:02am

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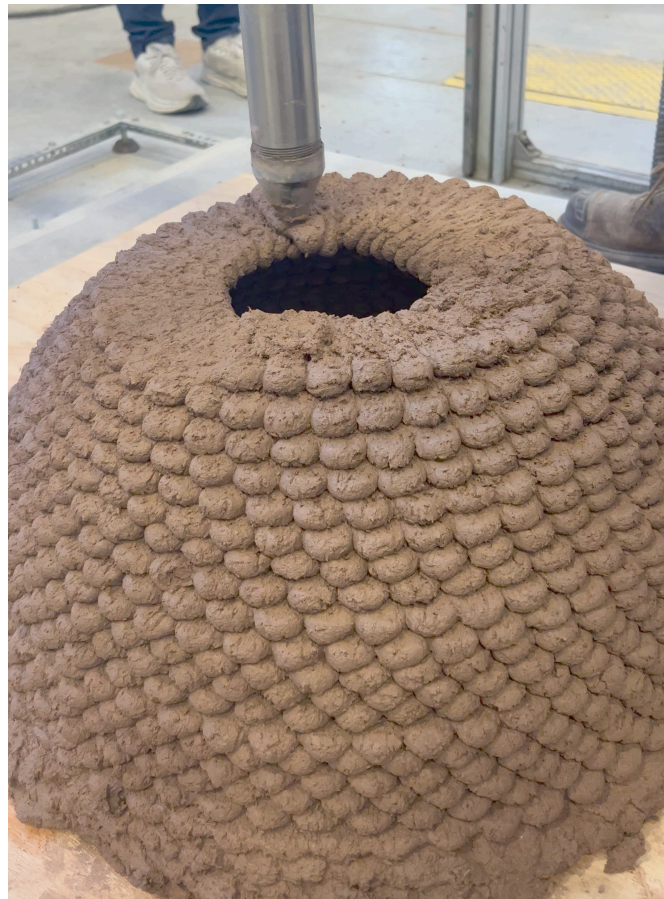
Civil engineer and doctoral candidate Daniel Marcia, left, and civil engineer Dr. Moneeb Genedy operate UNM's new 3D concrete printer. (Courtesy of UNM)

# 3D Printing Adobe

Hand and Machine

+

Advanced Sustainable  
Construction Lab



# 3D Printing Meat Alternatives



<https://www.youtube.com/watch?v=zQSCzHaMcTg>

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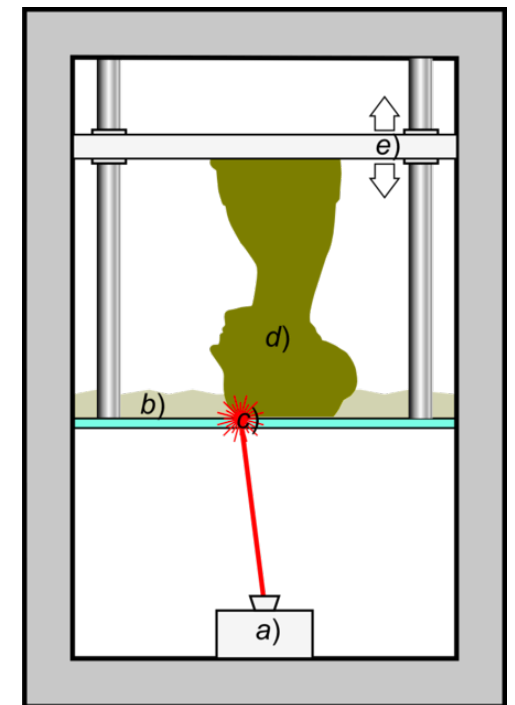
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- Material Jet (MJ)

## Cut and glue layers

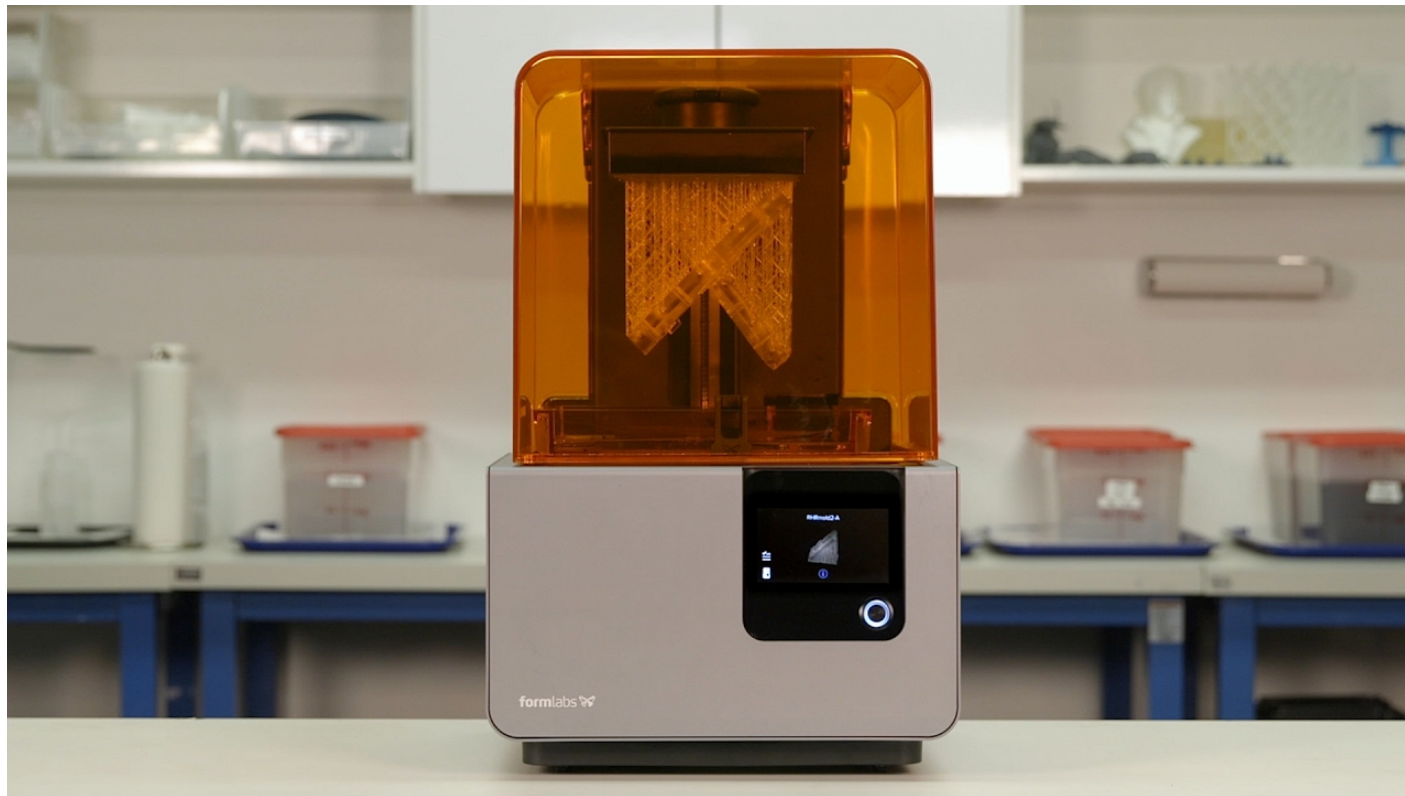
- Laminated Object Manufacturing (LOM)

# Stereolithography (SLA)

- Invented by Hideo Kodama in the early 1980s
- First 3D printing method developed
- Patented by Chuck Hull in 1986, founder of 3D Systems, the first 3D printing company
- Laser light hardens a liquid resin
- A laserbeam traces out path for each layer in a vat of liquid layer, hardening the resin
- Part is lifted out of the resin as it is built
- FormLabs developed first desktop SLA printer in 2012



# Stereolithography (SLA)





# SLA vs. FDM/FFF

- SLA: High precision parts, 85 vs. 250 microns
- Different range of materials
- Available in desktop versions later (later patent + more complex tech)
- Messy awkward process
- Slightly more expensive



# Example cheap desktop SLA printer

[Back to results](#)



8 VIDEOS



ELEGOO Mars 4 MSLA 3D Printer with 7" 9K Monochrome LCD, UV Resin Photocuring Printer, Multiple Print Modes, Printing Size of 6.04 x 3.06 x 6.89 inches

[Visit the ELEGOO Store](#)

4.5 ★★★★★ [3,576 ratings](#) | [Search this page](#)

100+ bought in past month

**-15%** \$189<sup>99</sup>

Typical price: ~~\$223.99~~

Or **\$19.09**/mo (12 mo). [Select from 1 plan](#)

**prime** Two-Day

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**Extra Savings** Save 10% on ELEGO... [3 Applicable Promotion\(s\)](#) [v](#)

Size: **Mars 4 DLP**

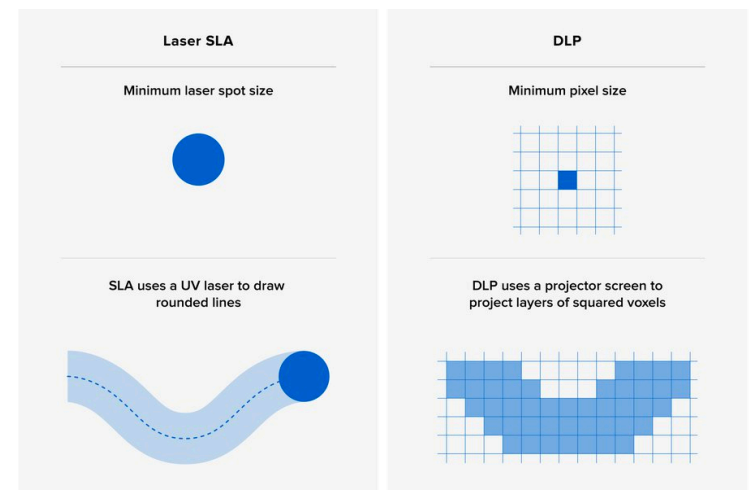
<b>Mars 4 9K</b> \$189.99 <del>\$223.99</del> FREE Delivery Thursday	<b>Mars 3 4K</b> \$149.90 <del>\$177.99</del> FREE Delivery Thursday	<b>Mars 4 DLP</b> \$297.49 <del>\$390.99</del> FREE Delivery Thursday
<b>Mars 4 Max 6K</b> \$267.95 <del>\$315.99</del> FREE Delivery Thursday	<b>Mars 4 Ultra 9K</b> \$239.95 <del>\$329.98</del> FREE Delivery Thursday	

Bundles with this item



# Digital Light Processing (DLP)

- Very similar to SLA, but each layer is exposed all at once via projection instead of via laser drawing
- Faster than SLA for large or densely packed parts
- <https://formlabs.com/blog/resin-3d-printer-comparison-sla-vs-dlp/>



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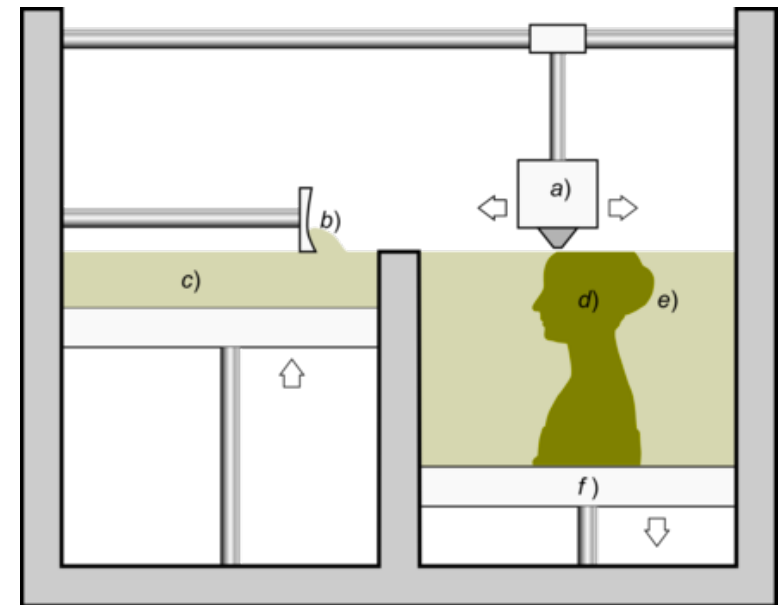
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# Binder Jetting

- Developed at MIT by a team led by Ely Sachs
- Patented in 1993
- ZCorporation (ZCorp) founded in 1994, acquired by 3D Systems in 2012
- Based on inkjet technology
- An inkjet head moves across a bed of powder, solidifying the material wherever it deposits ink
- First use of the term “3D printing” to describe the process



# Materials

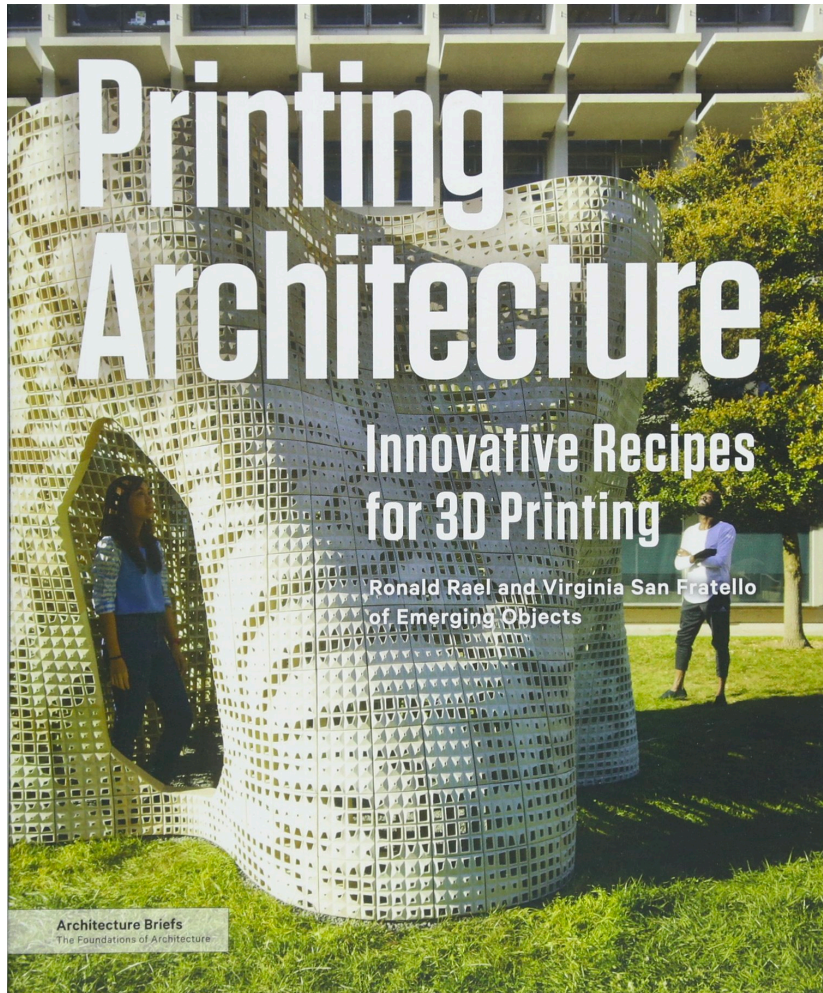
- Originally a starch powder bound with traditional printer inks
- Using printer inks, full color capable
- Very hackable!
- Any powder material that hardens when exposed to a companion liquid
- Unfortunately ZCorp machines are no longer manufactured. Rebranded Color Jet.

# Binder Jetting (BJ)



Time: 1:04

# Hacked Binder Jet (ZCorp) Printers

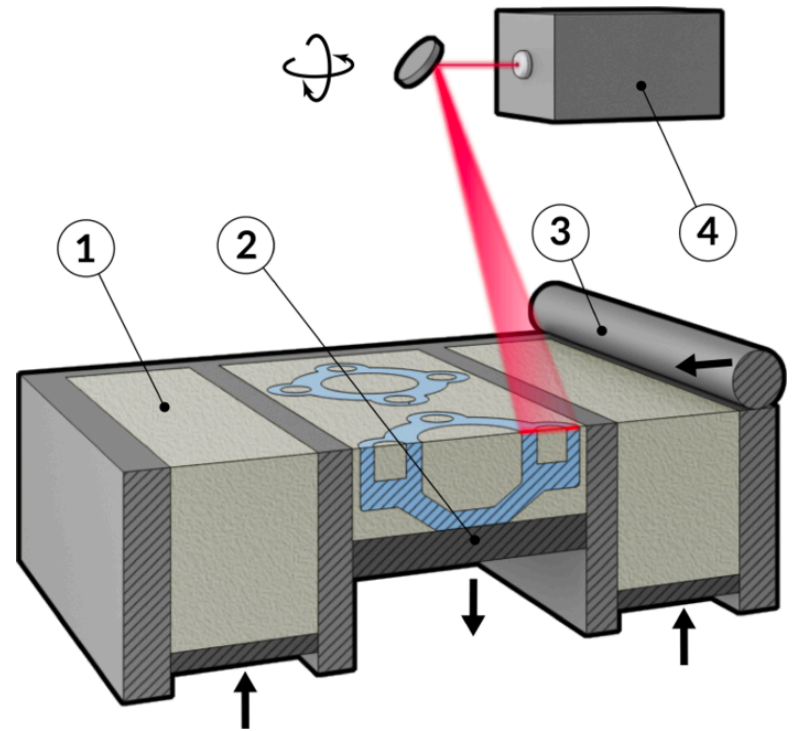


Rael San Fratello

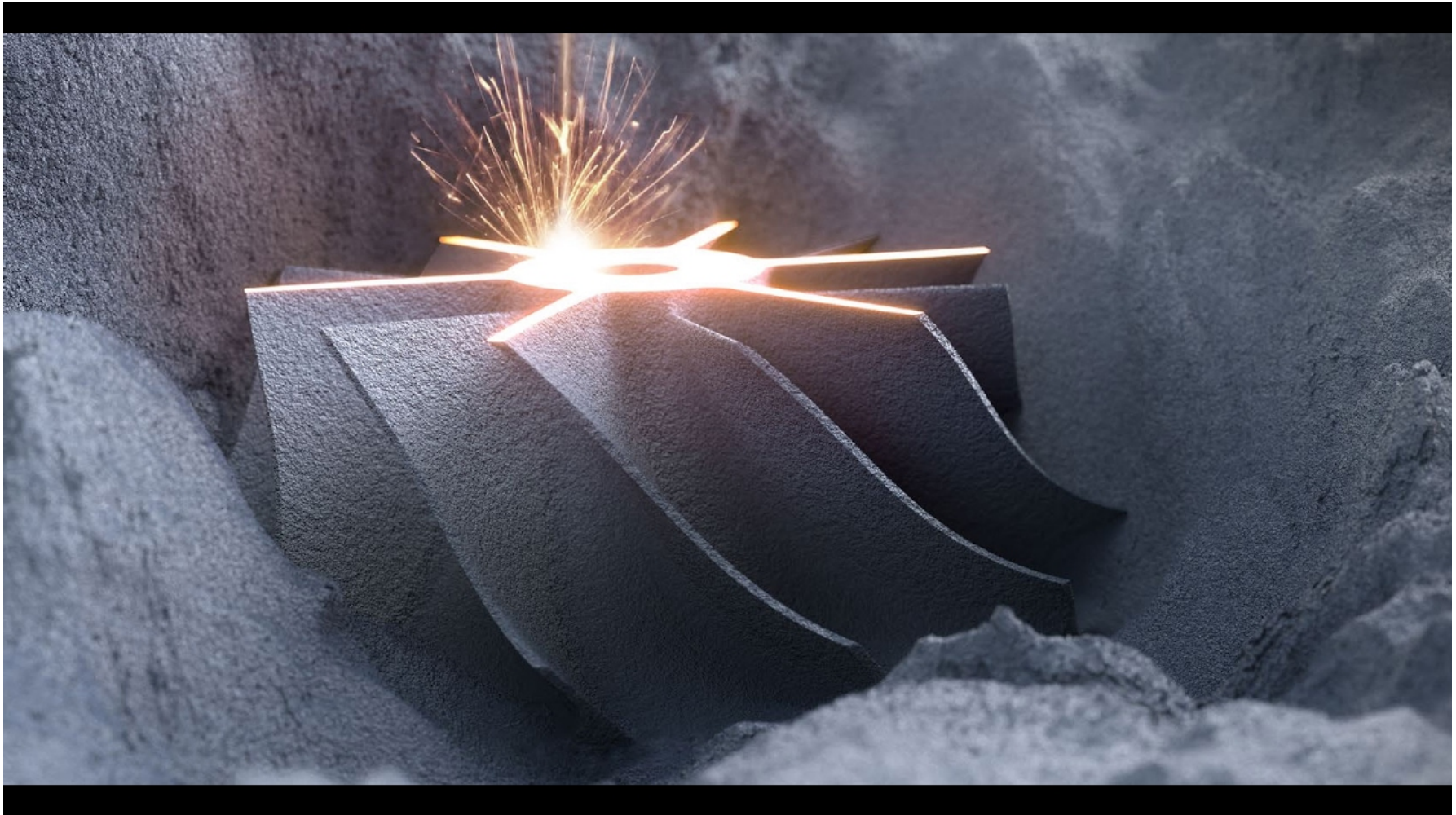


# Selective Laser Sintering (SLS) Selective Laser Melting (SLM)

- Invented by Carl Deckard and Joe Beaman at UT Austin in 1980s
- Patented in 1987, DTM company, acquired by 3D Systems in 2001
- A laser beam traces out a path for each layer in a bed of powder, melting/sintering the powder together
- DMLS = SLS with metal powder
- Newly available desktop machines



# Selective Laser Melting



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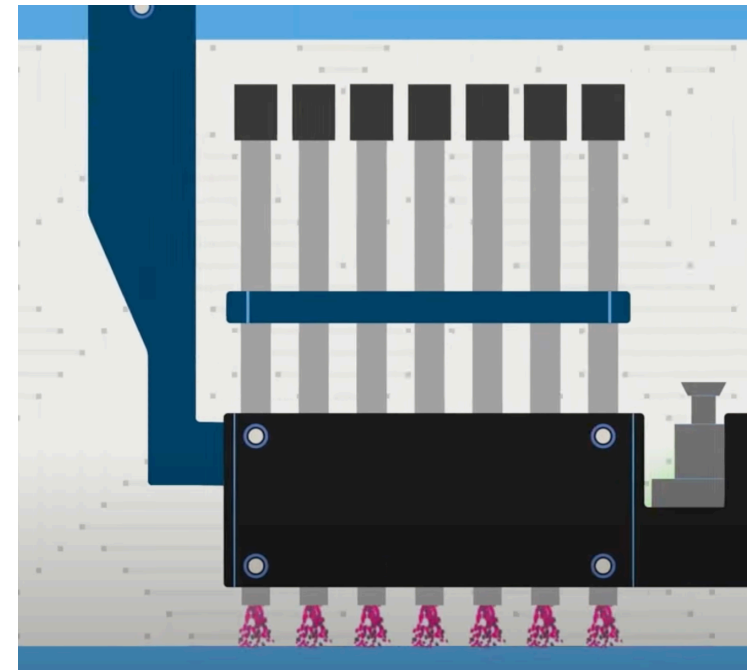
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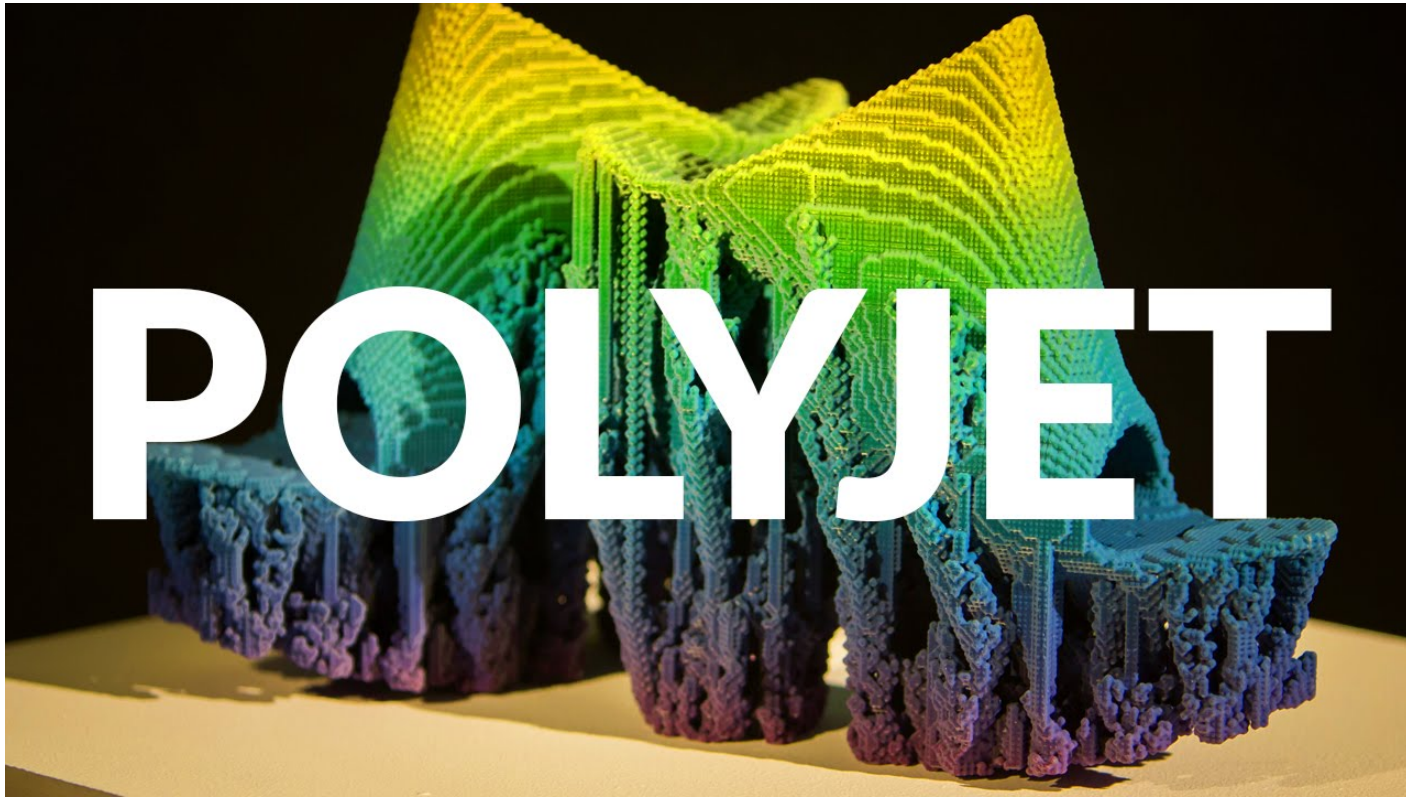
- Laminated Object Manufacturing (LOM)

# PolyJet Printing or MultiJet Modeling

- Developed by Objet Geometries company, founded in 1998
- 2000, raise significant funding, begin to develop multi-material 3D printers
- Acquired by Stratasys in 2012
- Very thin layers of liquid plastic are sprayed/jetted onto a surface. Hardened by UV light.
- Multiple nozzles allow for multiple materials, including material blends



# PolyJet Printing

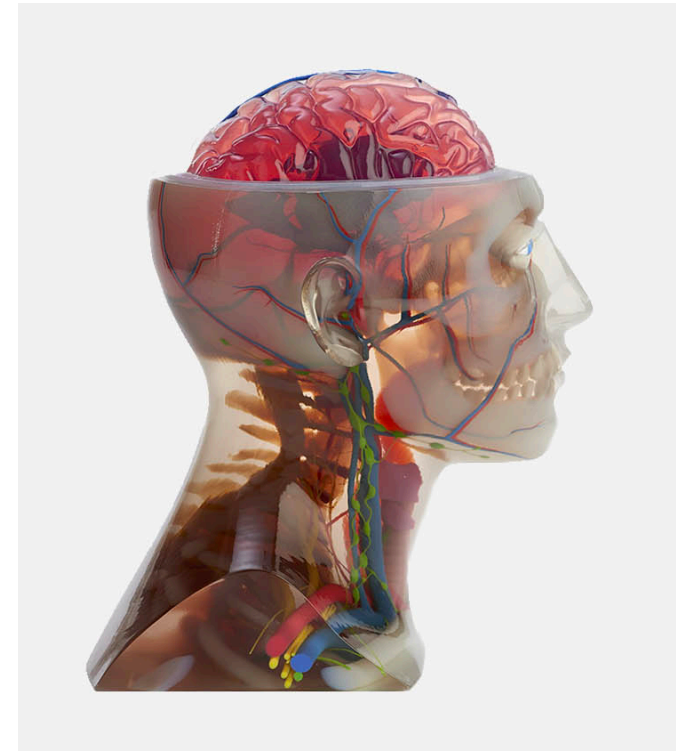




Neri Oxman

# Materials

- A range of materials with different visual and mechanical properties: color, transparency, hardness, strength, etc.
- Full color
- The ability to print many materials at the same time
- **Blend-able** materials for the first time
- <https://www.stratasys.com/materials/>



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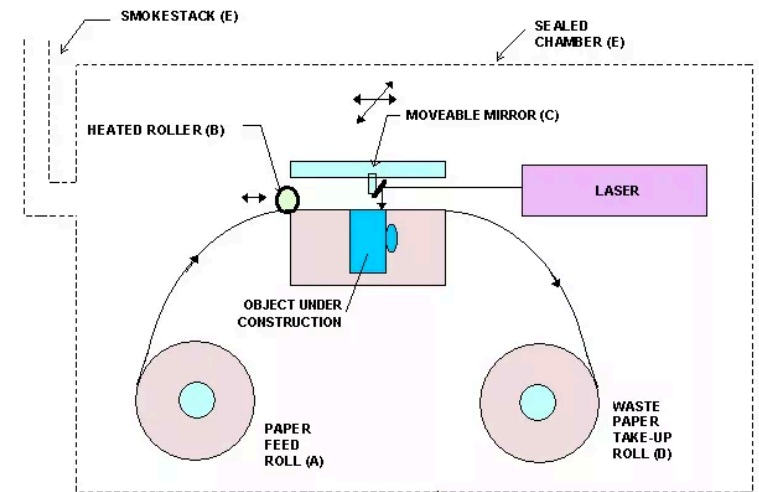
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# Laminated Object Manufacturing (LOM)

- Developed by Helixis (now Cubic Technologies)
- Layers are cut with a knife or laser and glued together in layers to form a part
- Layers can be printed before they are cut to produce full color models
- Can cut thin layers of plastic or (most commonly) paper
- Mcor technologies now manufactures and sells



Laminated Object Manufacturing

# Laminated Object Manufacturing



Time: 0:30

# Laminated Object Manufacturing



Time: 0:30

questions?

# Thank you!

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