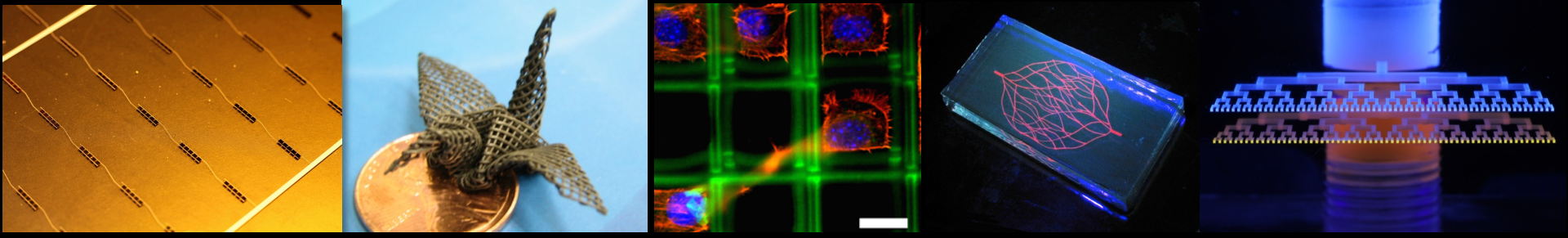


Printing Functional Materials

Jennifer A. Lewis

School of Engineering and Applied Sciences
Wyss Institute for Biologically Inspired Engineering

Harvard University

The Science of Digital Fabrication – 3.7.13

Several advances needed for 3D printing of high performance, functional materials

"Before this personal manufacturing revolution can take place, though, researchers will need to develop a broader array of robust printing materials…"

"… rapidly growing market, $1 B sales…
about 70% of market is prototyping"

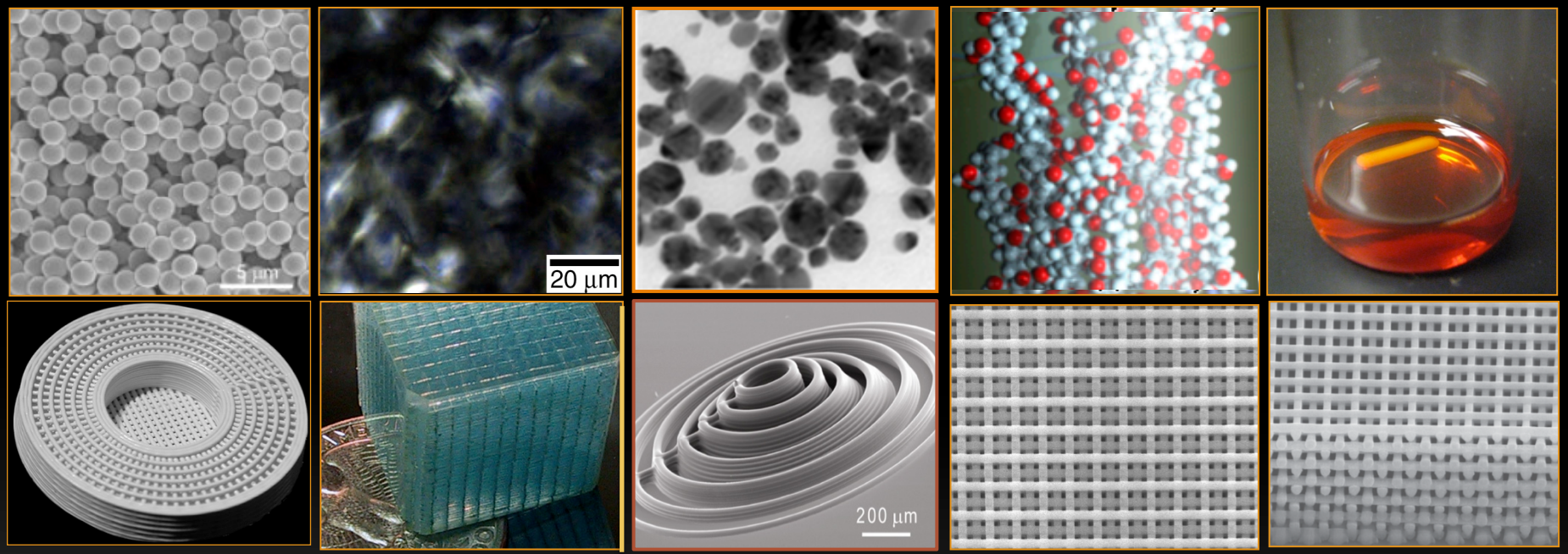
Chemical & Engineering News, Nov 14, 2011 issue

Specific Objectives and Needs

- Broaden materials palette
- Integration of heterogeneous materials
- Digitally specify form and function
- Print and fold - architectural complexity
- Improve feature resolution by 100x
- Improve throughput by 100x

… expedite transformation from rapid prototyping to manufacturing of advanced materials

Functional inks designed for printing



Key Attributes:

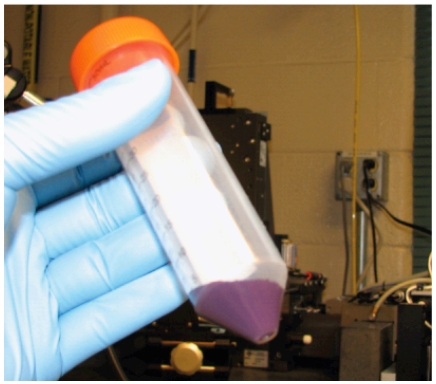
- Highly concentrated, water-based formulations
- Engineered flow and printing behavior
- Specifically tailored for targeted functionality

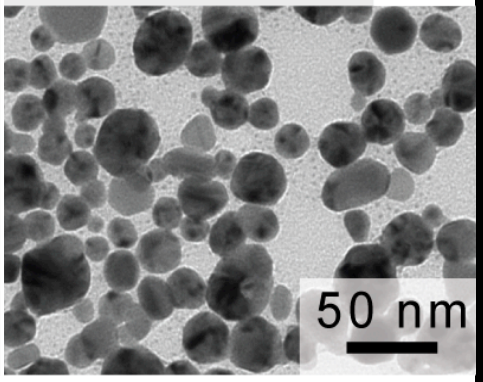
Lewis group

Conductive inks for printed electronics

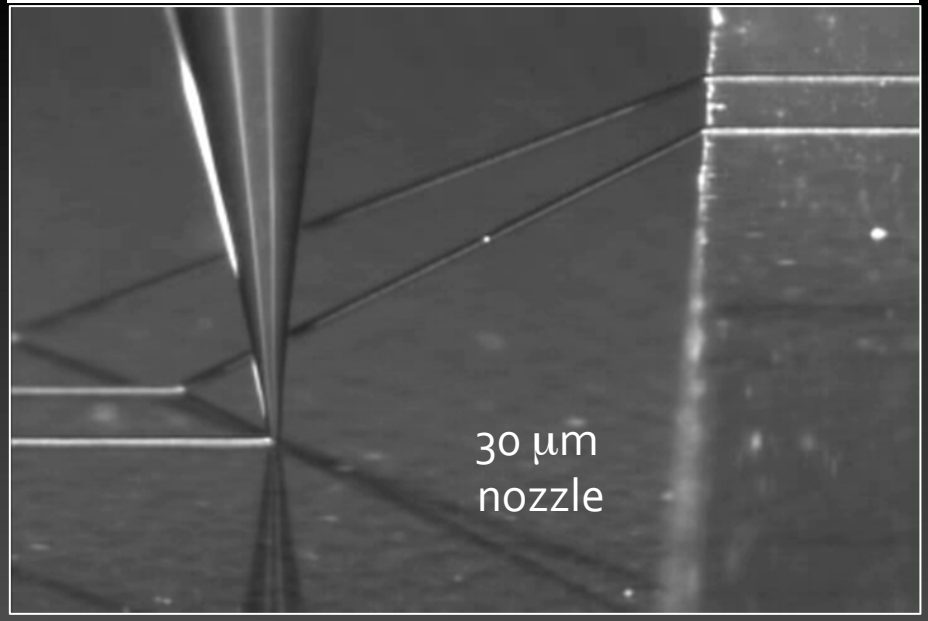
Silver Particle Inks

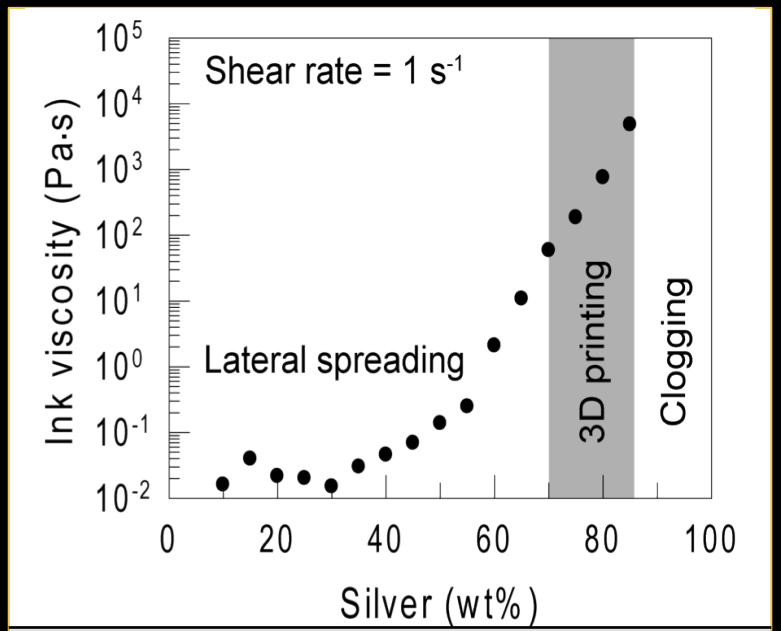
Sonication (60 °C, ~2 h)

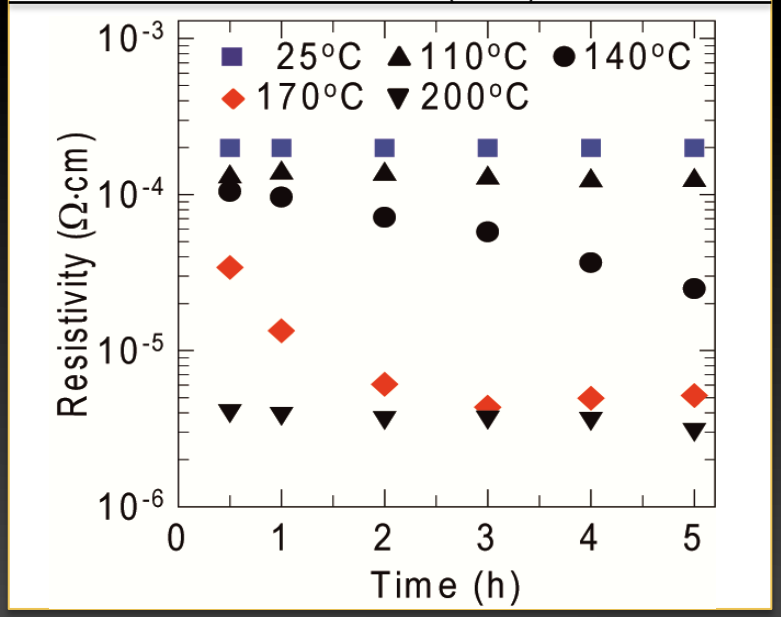




20 nm average , 5 – 50 nm distribution



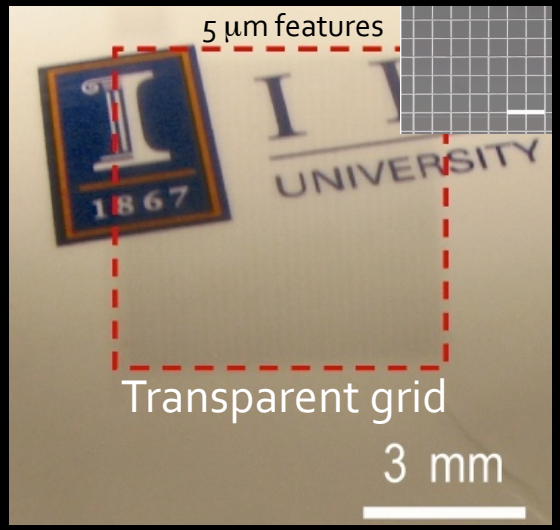


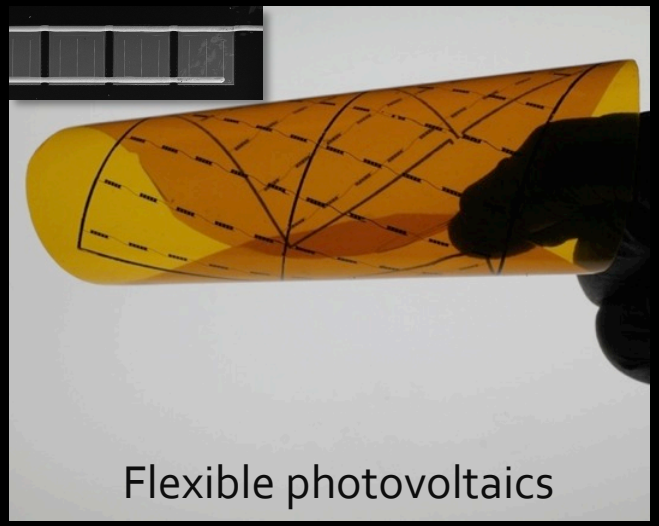


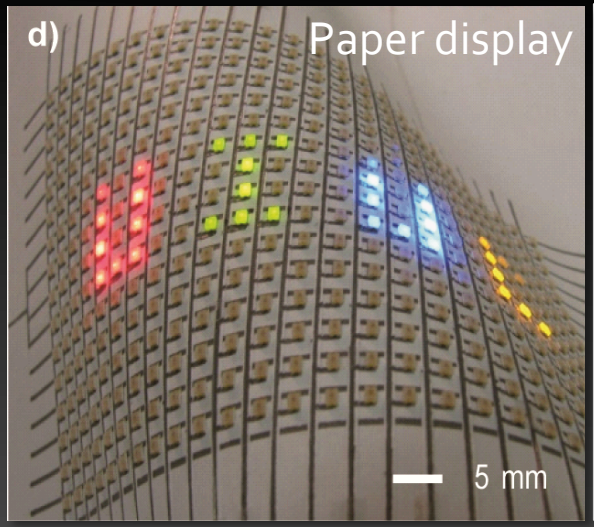
Ahn, Duoss, Nuzzo, Rogers, Lewis, et al., *Science* (2009); Ahn, Duoss, and Lewis, US-Patent 7,922,939

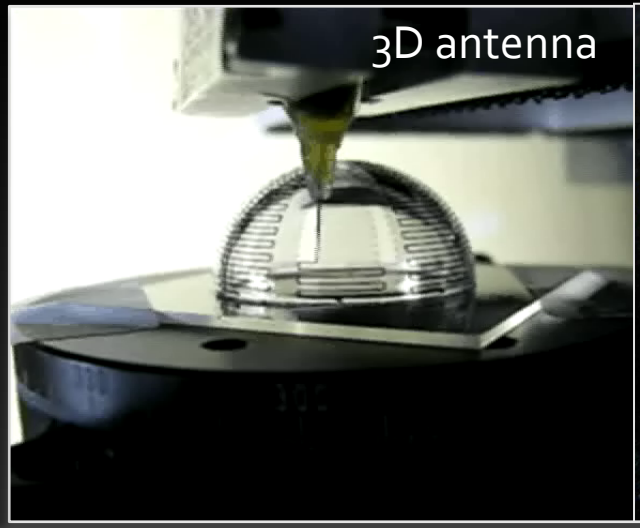
Conductive inks for printed electronics

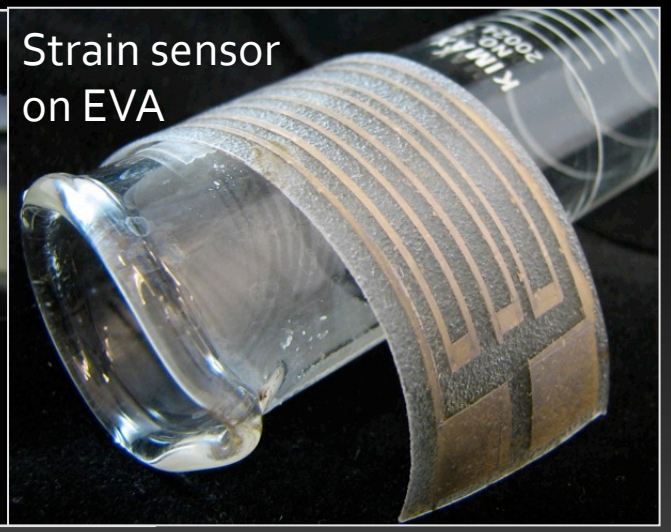
Pen-on-Paper Flexible Electronics





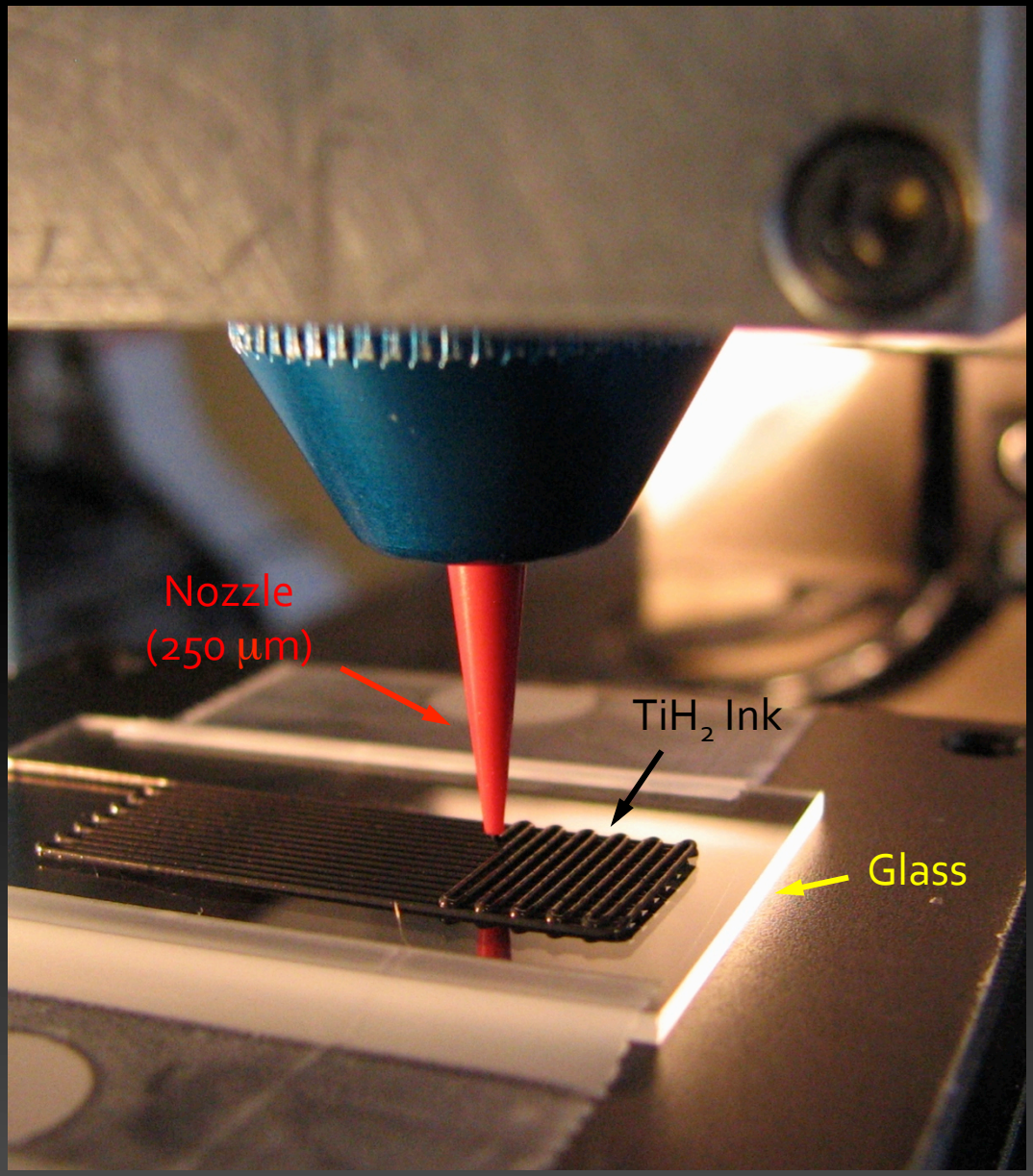


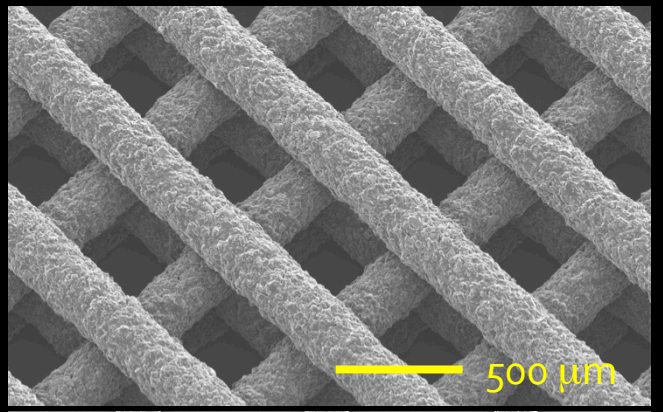


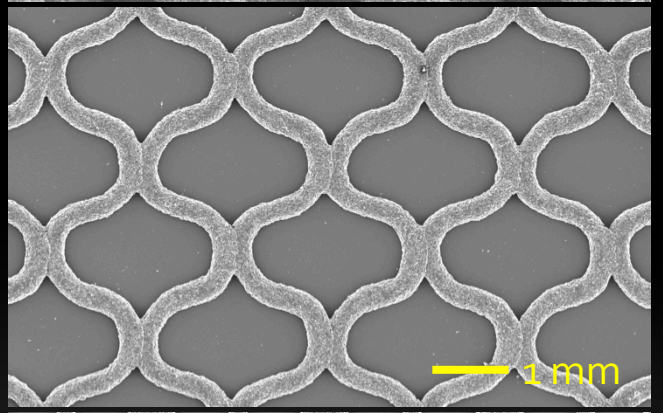


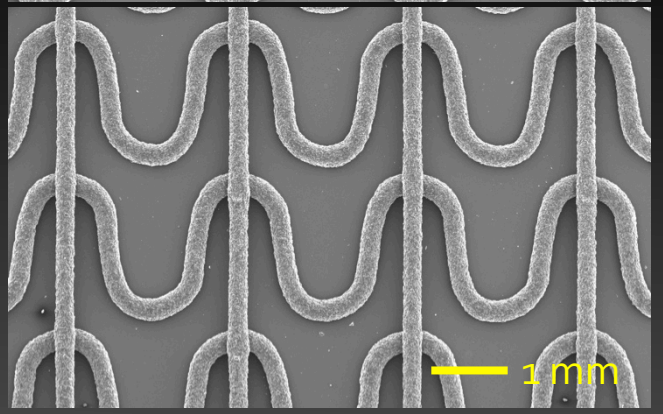
Lewis et al.,Science (2009); *Advanced Materials* (2011); *Nanoscale* (2011); *JACS* (2012)

Printed origami – simple route to complex 3D forms



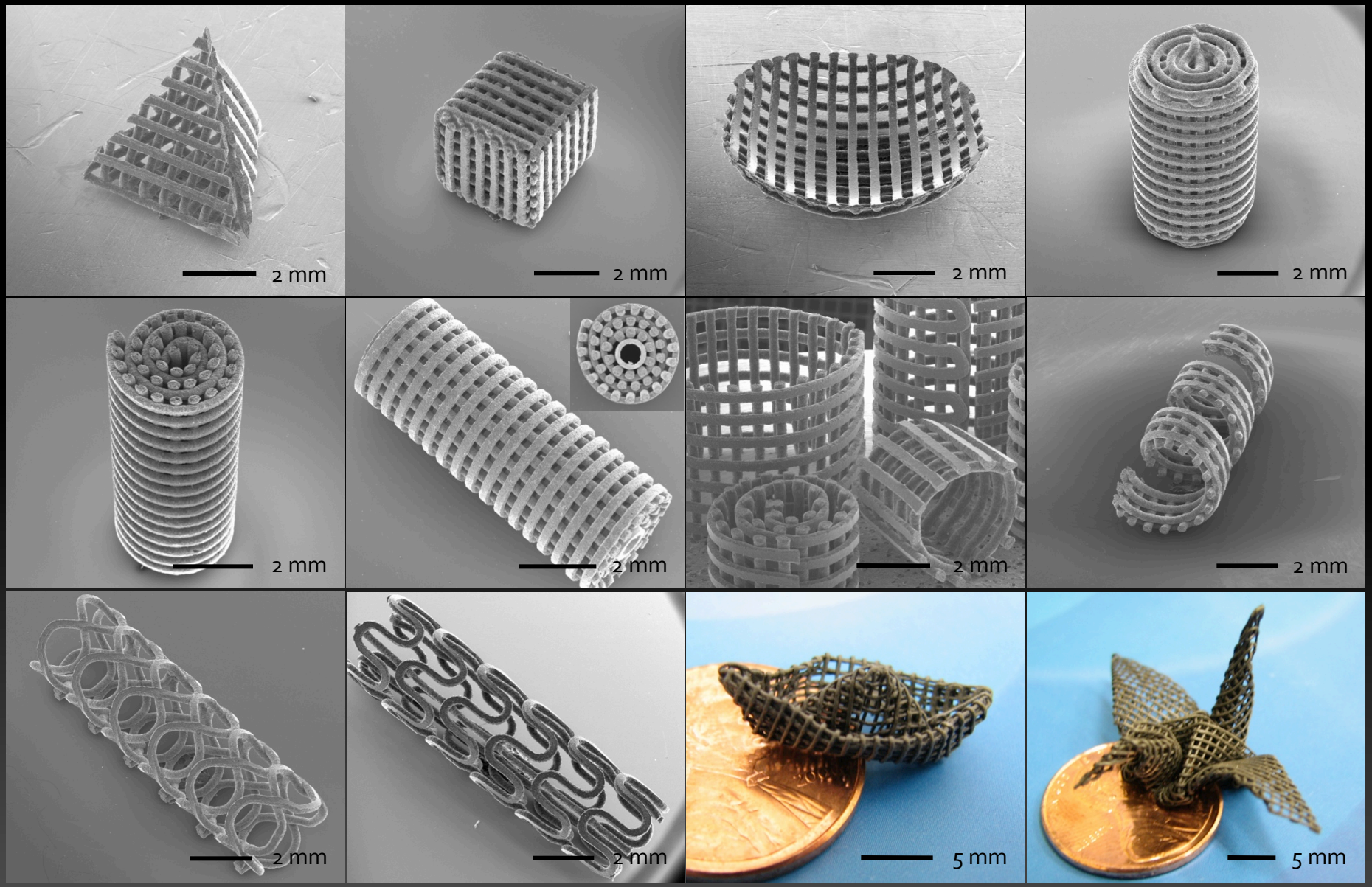






Ahn, Shoji, Hansen, Hong, Dunand, Lewis, *Advanced Materials* (*2010*); *Advanced Engineering Materials* (2011)

Printed origami structures



Ahn, Shoji, Hansen, Hong, Dunand, Lewis, *Advanced Materials* (*2010*)

Embedding microvascular networks enables multifunctionality

2D

3D

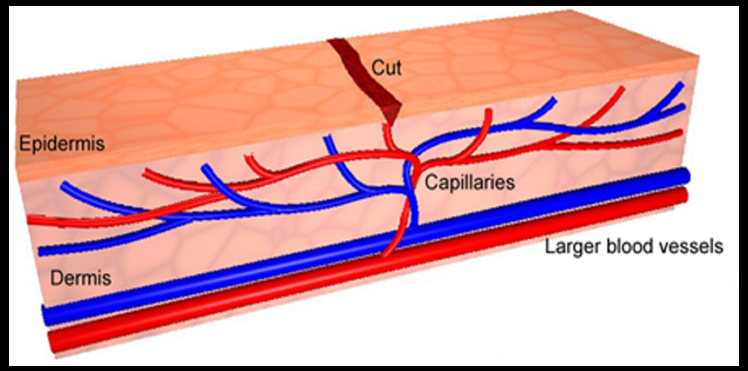
Vascular networks enable important biological functions:

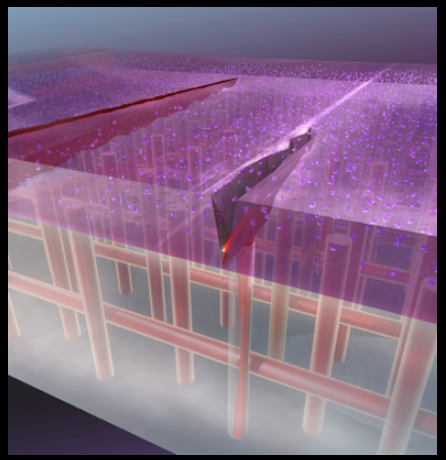
- Nutrient transport
- Temperature regulation
- Healing tissue damage

Potential Impact: self healing/cooling, tissue engineering, soft robotics…

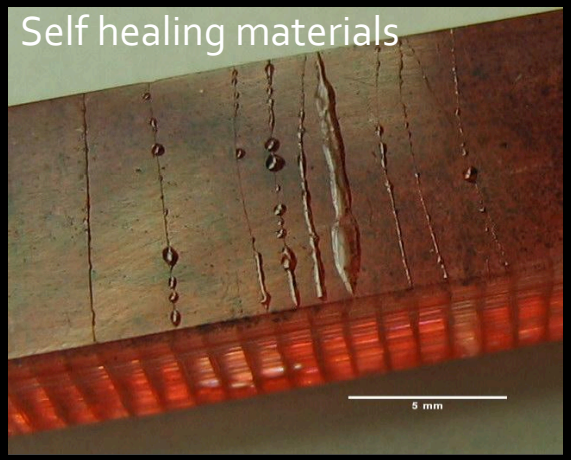
3D microvascular architectures

Bioinspiration



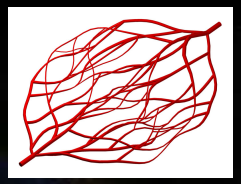


Self healing materials

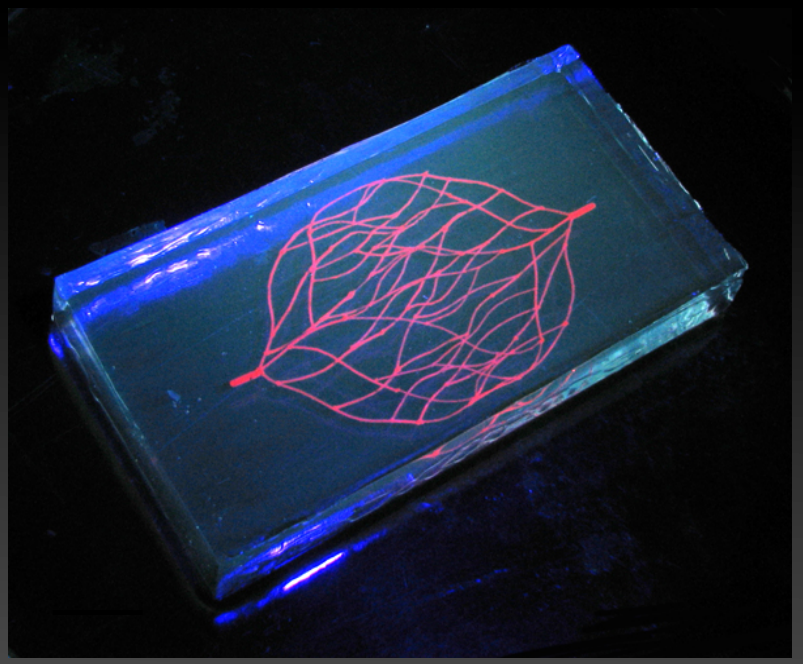


Toohey, Sottos, Lewis, Moore, White., *Nature Mater.* (2007).

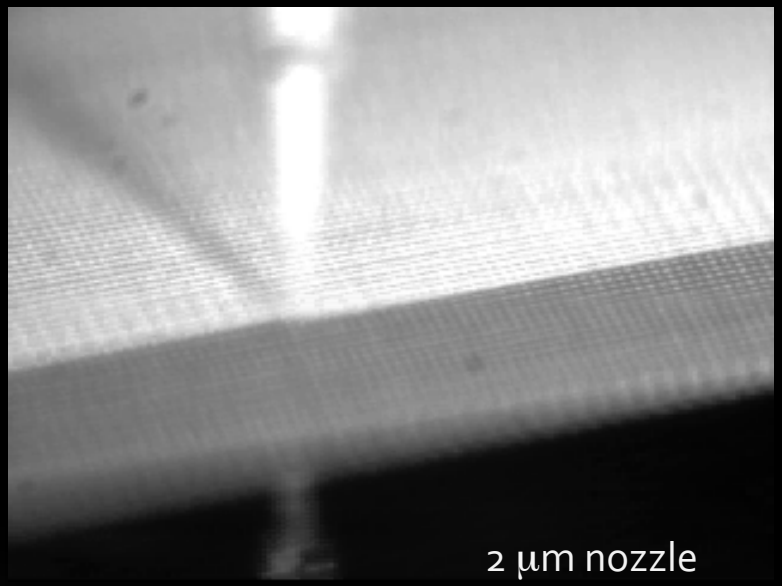
Biomimetic vascularization

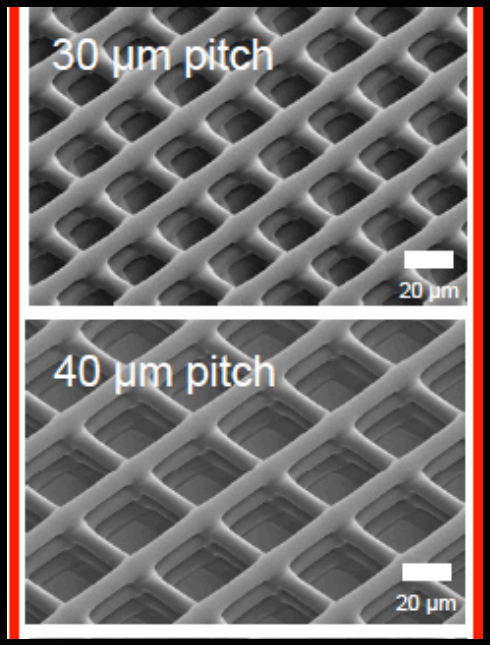


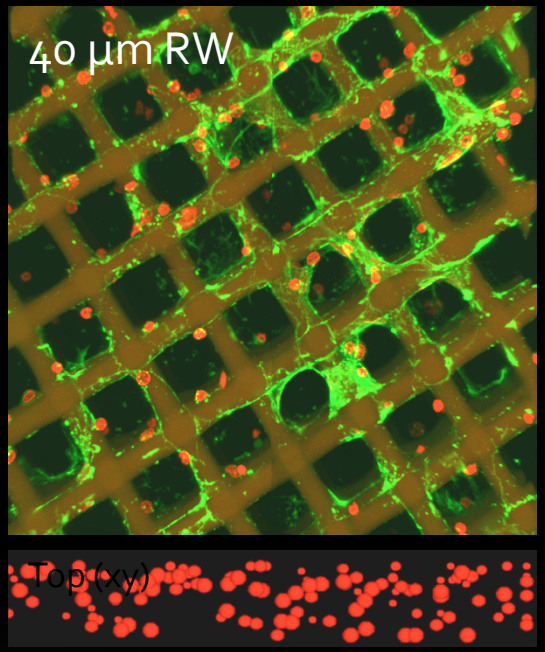
Wu, Deconinck, Lewis., *Adv. Funct. Mater.* (2011).

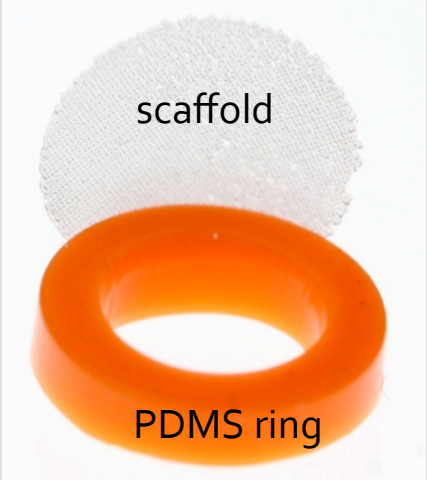


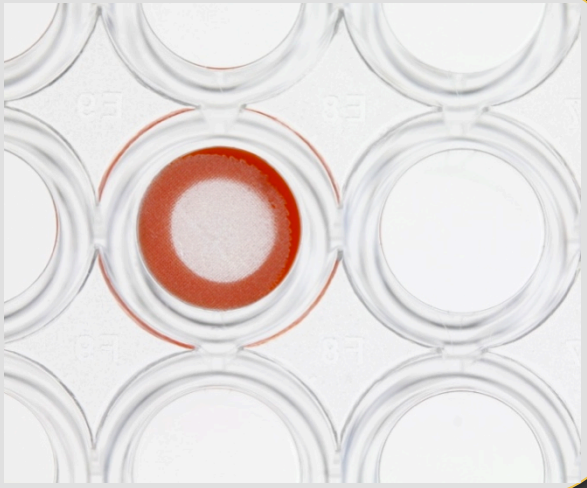
3D hydrogel scaffolds for tissue engineering





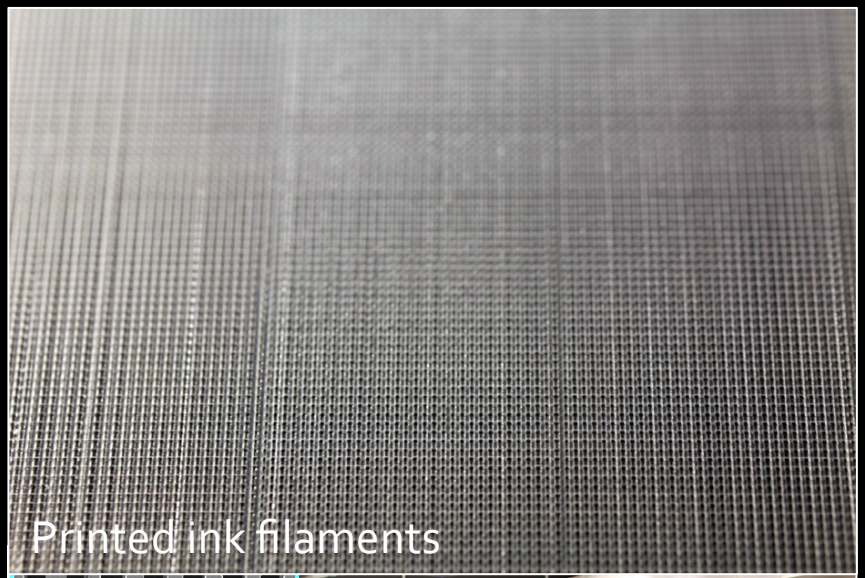


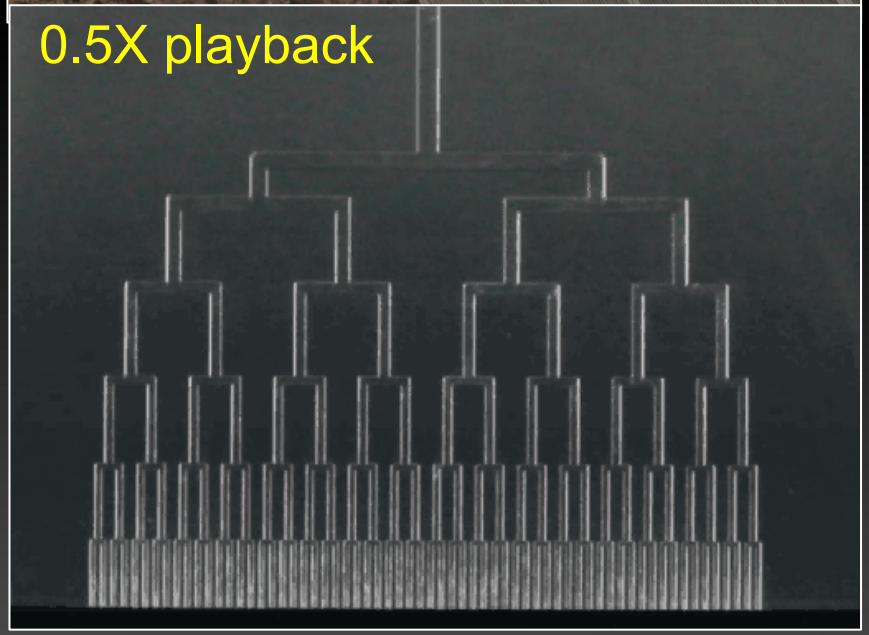


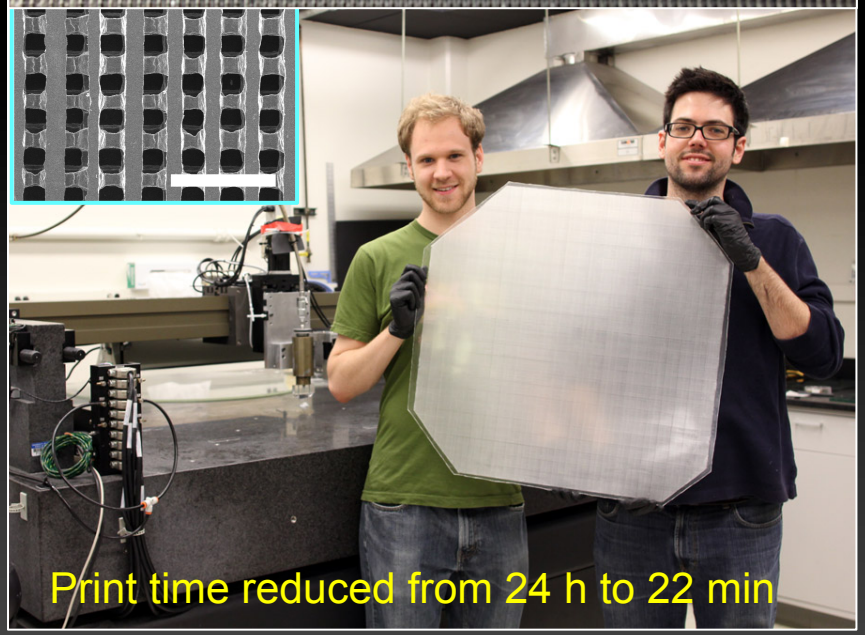


Shepherd, Barry, Hansen, Wiltzius, Nuzzo, Lewis, *Advanced Materials* (2009)

High throughput printing of 3D architectures

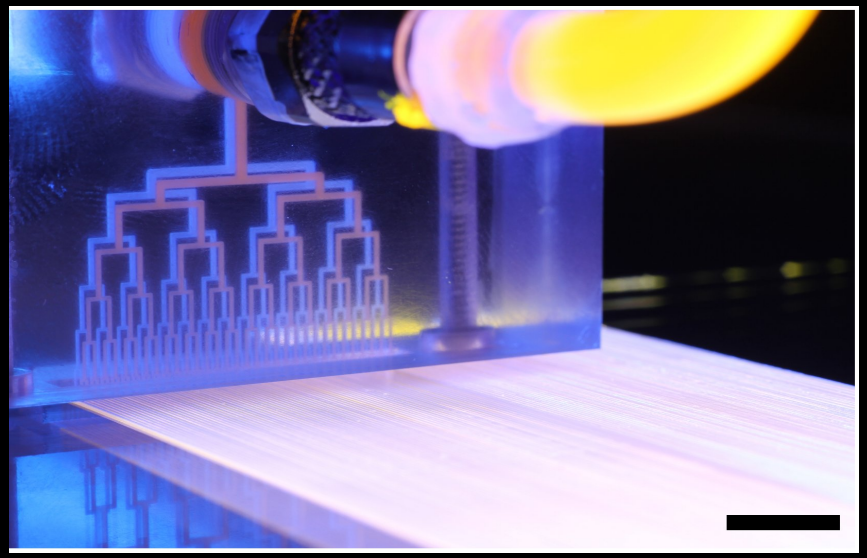


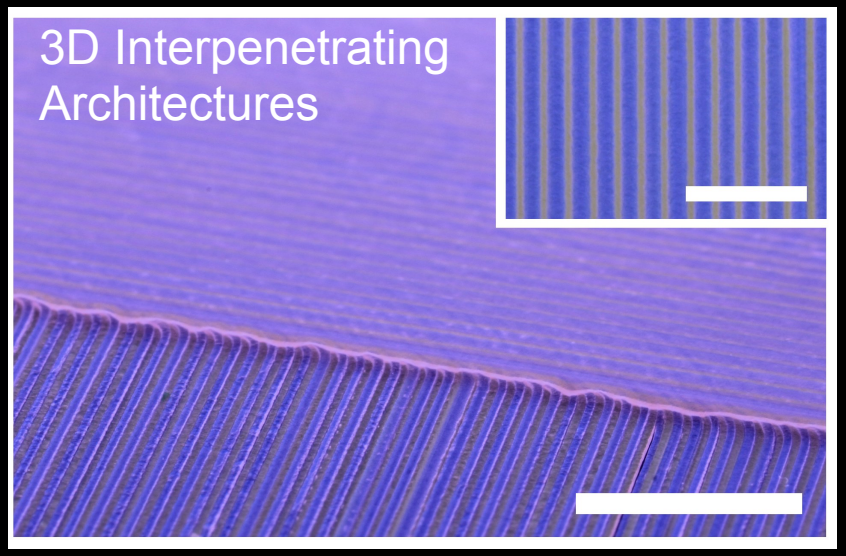


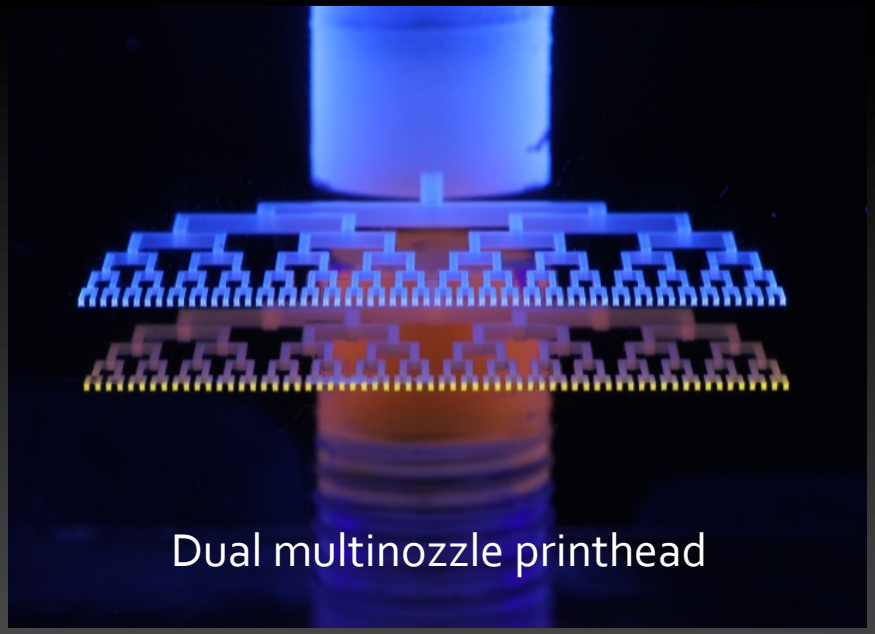


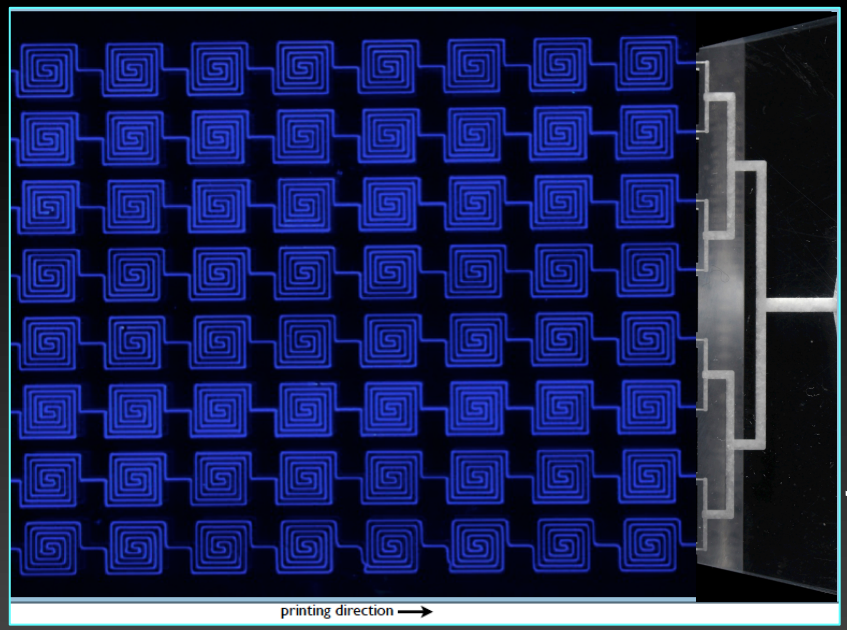
Large-area (1 m^2) 3D structures printed in minutes using multinozzle printheads

High throughput printing of 3D architectures









Large-area (1 m^2) 3D structures printed in minutes using multinozzle printheads

Thank you!

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