

# Volumetric Additive Manufacturing of Composites via Hydrogel Infusion

Presentation for  
MICRO-722: 3D Printing with Light  
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**Paper Title:** Volumetric Additive Manufacturing of Composites via Hydrogel Infusion

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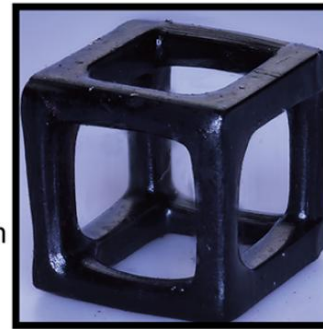
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VAM Printed Hydrogel



Metal-ion  
Infusion  
→  
*In-situ*  
Precipitation

Functional Composite



All scale bars: 1 mm

## Vat Photopolymerization (VP):

- An additive manufacturing (AM) technique that utilizes spatial photopolymerization of a liquid resin in a vat to achieve the fabrication of 3D structures
- Examples are stereolithography (SLA) and digital light processing (DLP)

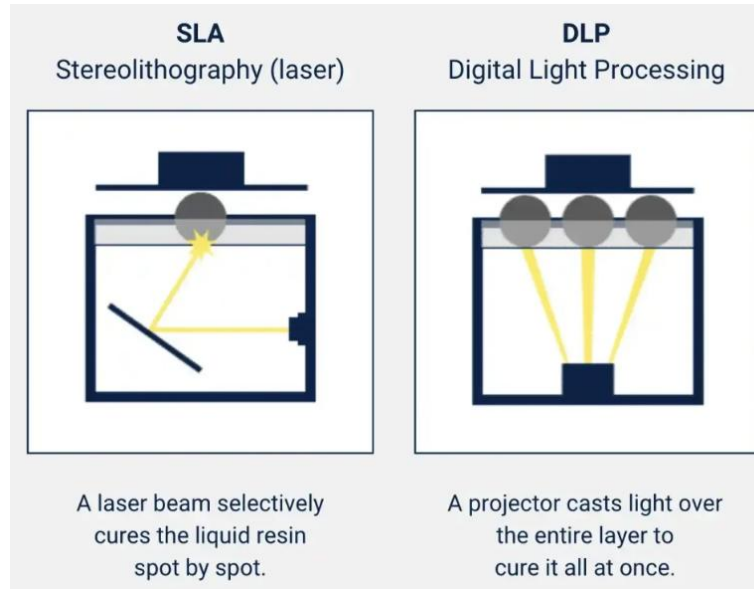


Image from Zongheng3D

## Advantages of VP:

- High resolution (few micron range)
- Relatively fast (tens to hundreds of mm<sup>3</sup>/min)
- Wide material options (acrylates, epoxies, ceramics-in-resin, biomaterials)

## Limitations of VP:

- Layer-by-layer technique (creates stair-step defects, high roughness)
- Anisotropy (material is weaker in one direction)
- Limited viscosity choice (up to ~5 Pa·s)

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## Volumetric Additive Manufacturing (VAM):

- VAM prints whole volumes at once, not by layers
  1. Tomographic VAM: uses computed projections from many angles (like a CT scan in reverse)
  2. Dual-wavelength VAM (**xolography**): uses two colors of light that must overlap to trigger polymerization

## Characteristics of VAM

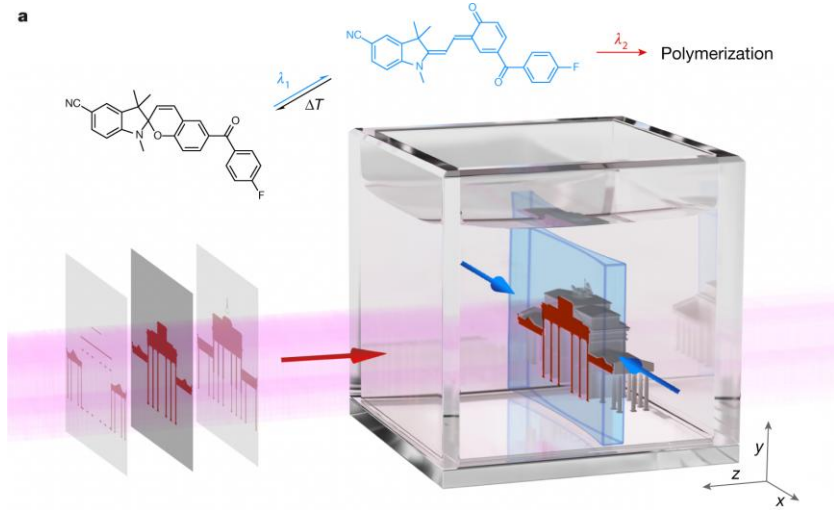
- Smooth surfaces: no layer lines → useful for optics, microfluidics, bioprinting.
- Isotropic properties: material behaves the same in all directions.
- Viscous resins possible: expands material palette (e.g., soft gels, viscous polymers).

**BUT:** VAM requires light to pass through whole vat → only transparent resins.

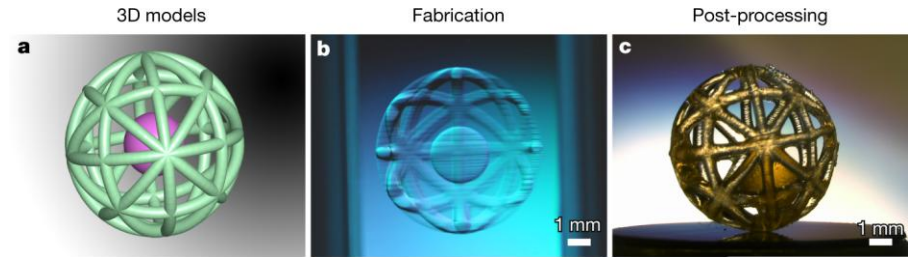
→ Transparency requirement is the bottleneck for composites.

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## Xolography



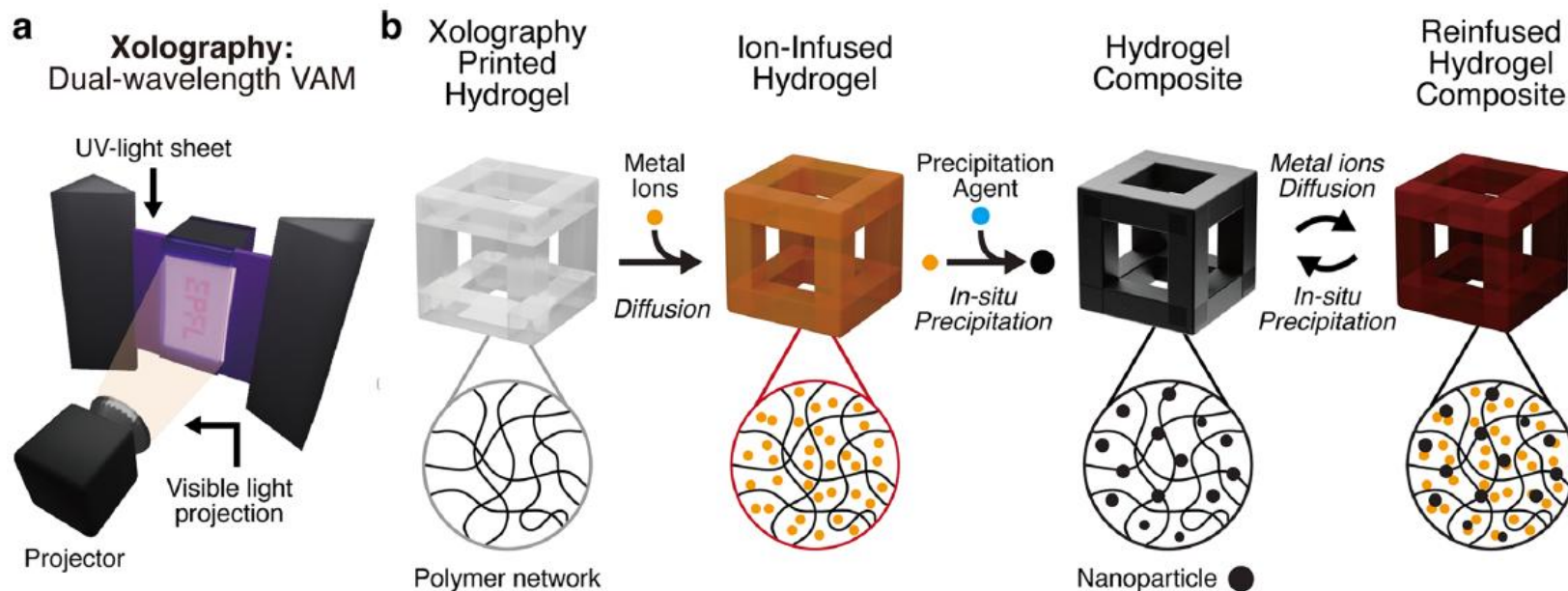
Regehy, *Nature*, 2020



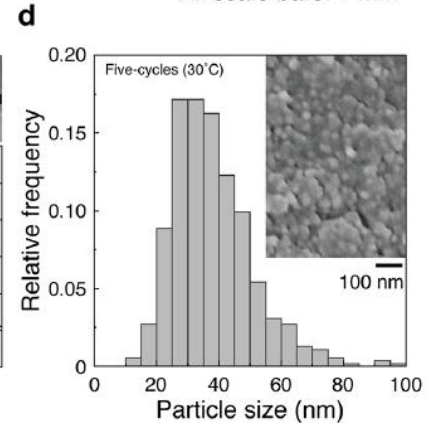
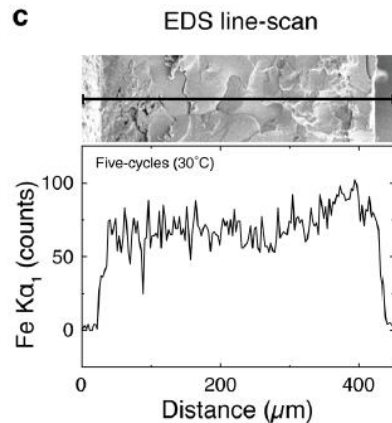
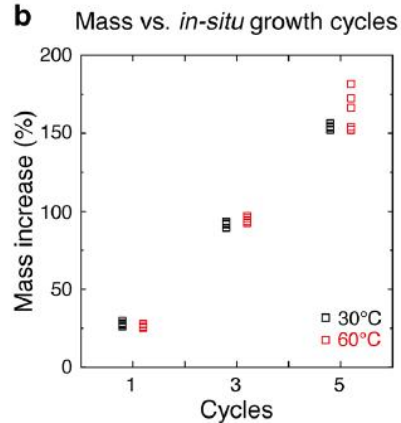
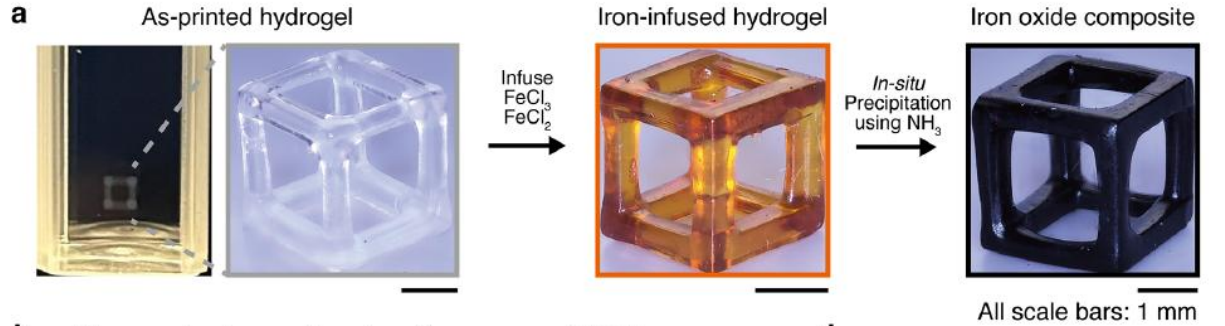
- **Limitation:** resin must be optically clear (transparent) to both wavelengths, which excludes composites.  
→ This paper uses xolography but overcomes its transparency constraint. The authors show a way to integrate fillers after printing, avoiding transparency issues.

## Strategy: Hydrogel Infusion Approach

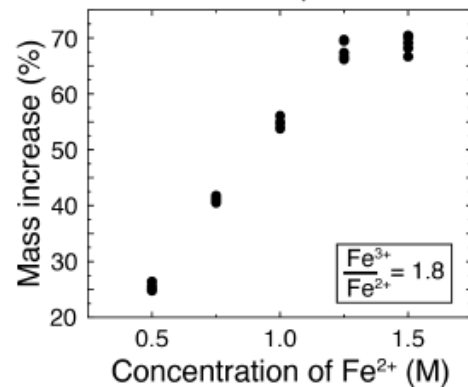
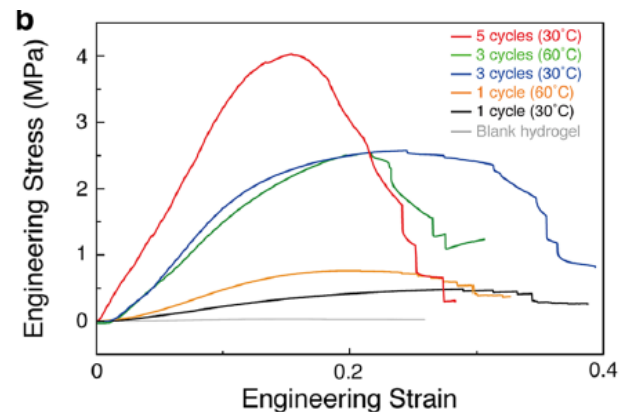
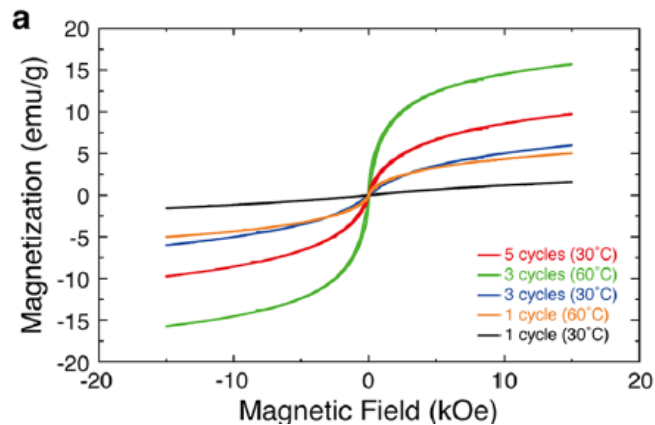
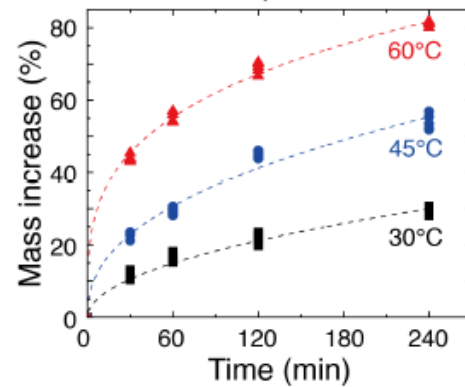
- Print → Infuse → React → Repeat



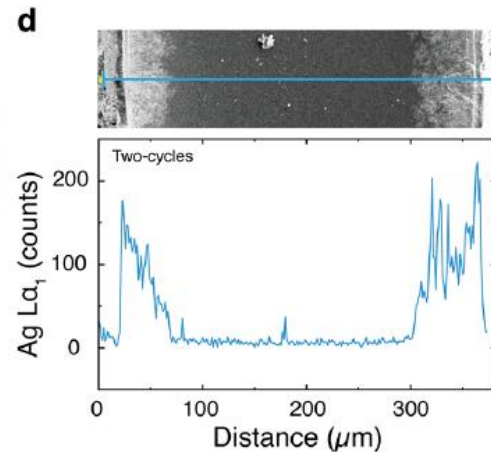
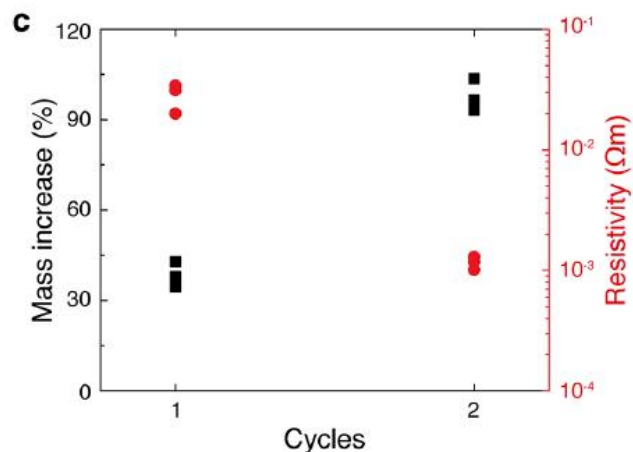
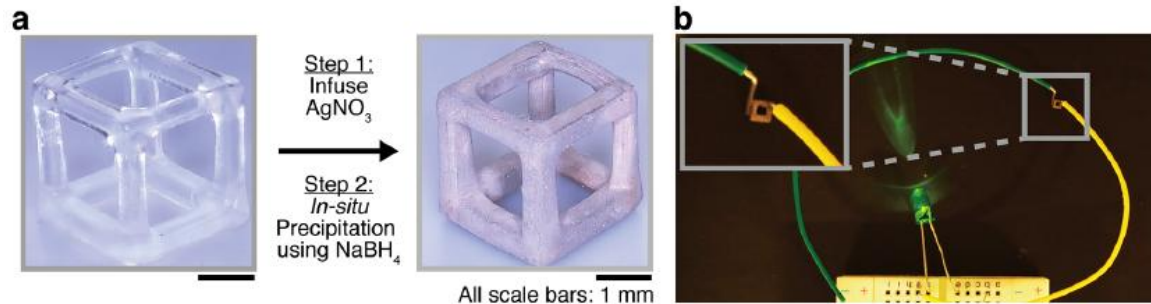
## Iron Oxide Nanoparticles (IONPs)



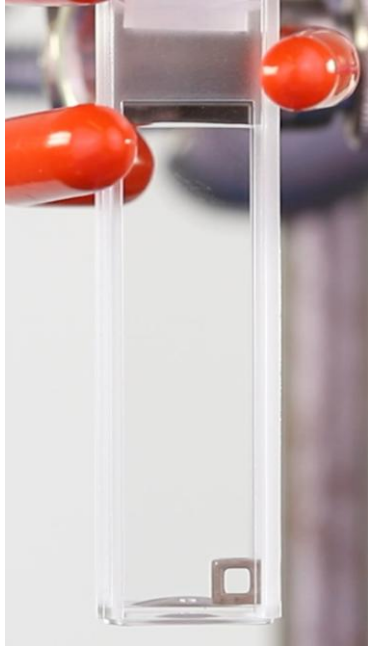
## Properties of IONPs

**a** Concentration optimization**b** Infusion optimization

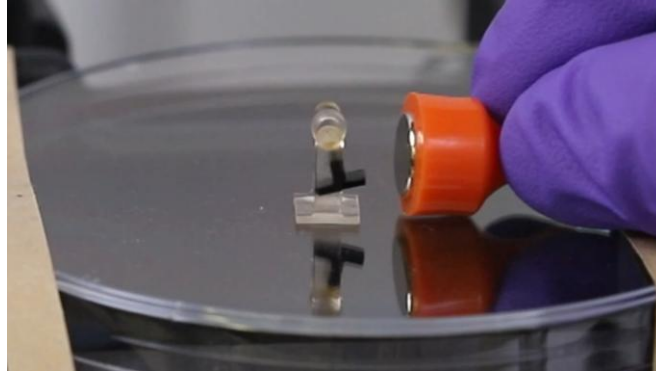
## Silver Nanoparticles composite



## Magnetically responsive IONP-Ag hydrogel composites



IONP-Ag composites



Spatial IONP growth - Pendulum



Spatial IONP growth - Spring

## Contributions

- Bypasses transparency barrier: biggest limitation in VAM.
- High filler loading (65 wt%): far beyond previous attempts.
- One resin, many outcomes: saves time, avoids custom resin formulation.
- Opens path for multifunctional parts without redesigning the printer.

## 1. Limited growth cycles → cracking

- More than 5 IONP cycles at 60 °C caused cracks and fragile parts.
- More than 2 Ag cycles caused cracks due to stresses from silver formation + H<sub>2</sub> gas.

## 2. Dimensional expansion

- Structures swell isotropically as fillers grow inside.
- Expansion: ~5% (1 cycle) → ~20% (5 cycles).
- This reduces dimensional accuracy; CAD needs compensation.

## 3. Property trade-offs

- Higher coprecipitation temperature improves magnetic crystallinity, but worsens mechanical strength (more defects).

## 4. Polymer degradation

- Acidic Fe salts + basic NH<sub>3</sub> hydrolyze PEGDA hydrogels, leads to surface pitting, cracks, and reduced durability.

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