Three-dimensional nanoparticle printing for fabrication of micrometric patterns

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Underlying Principle

- Nanoparticles/ions are mixed/dissolved into solution
- A focused laser heats up the solvent
- Microbubbles form at laser focus point
- Convection currents flow around the microbubble
- Deposition occurs where the bubble meets the solvent

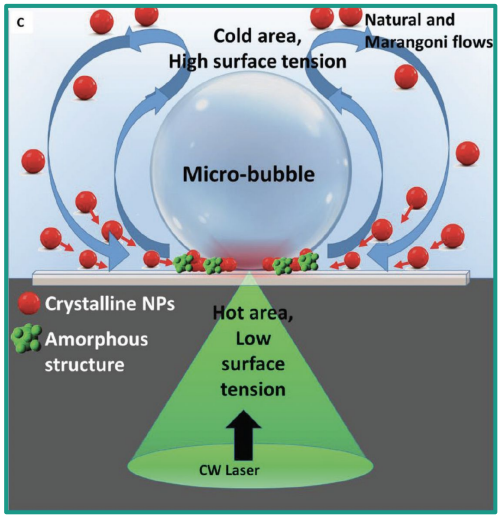

Figure 1.1 - Laser and bubble printing mechanism

System

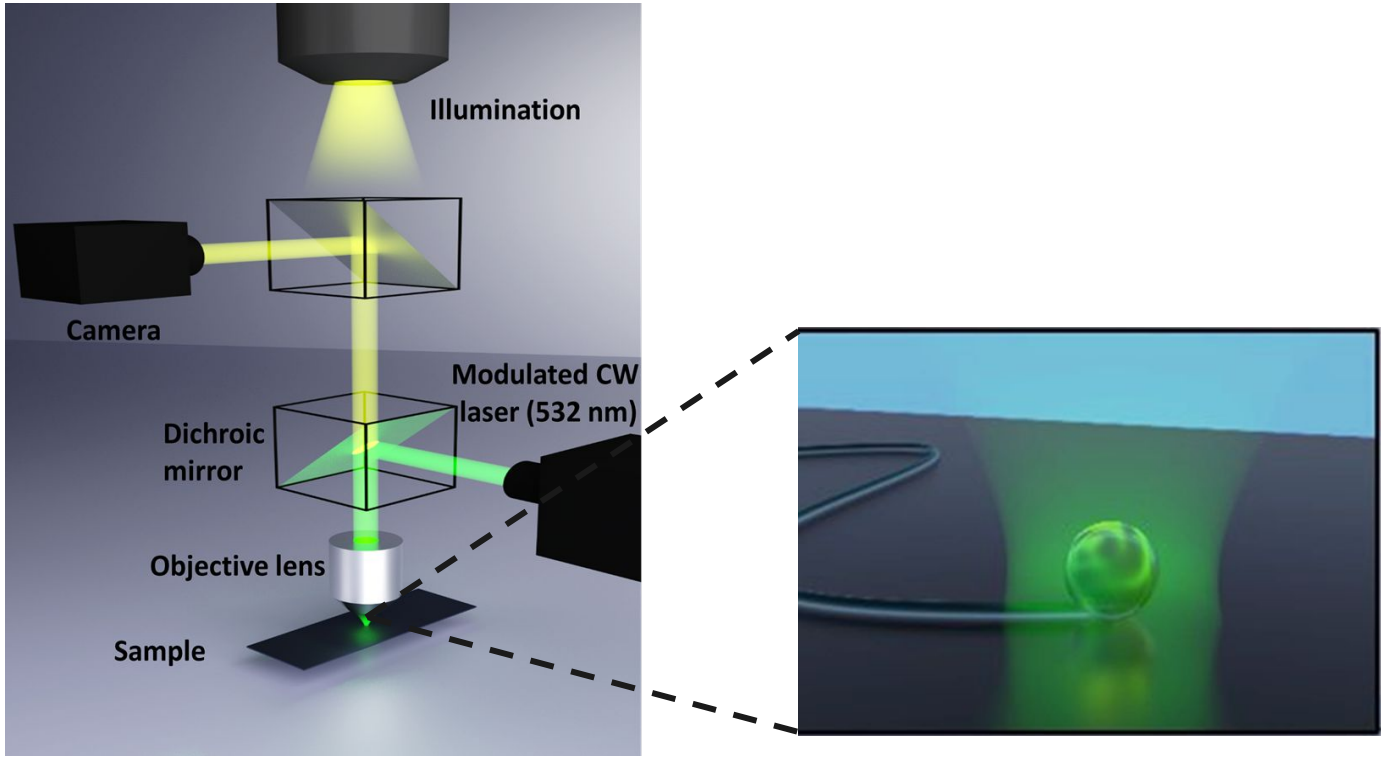

Figure 1.2 - Optical system consisting of modulated CW laser and optically inverted microscope

Two Dimensional Printing

- Modulated laser provides smooth printing
- Benefits
  - Narrow and precise lines
  - Ability to utilize and transition seamlessly between many different nanoparticles

Figure 1.3 - Printing design example

Printing Styles

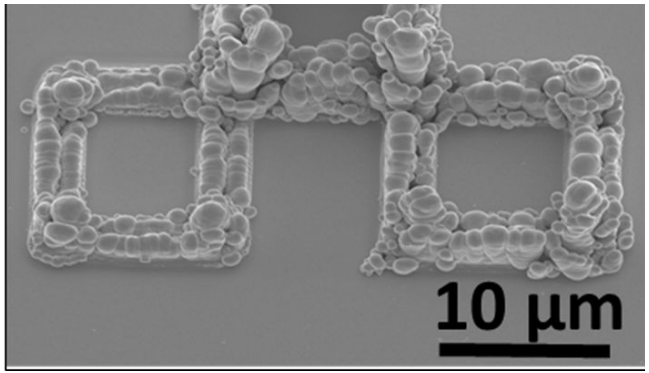

Figure 1.4 - Layer by layer printing

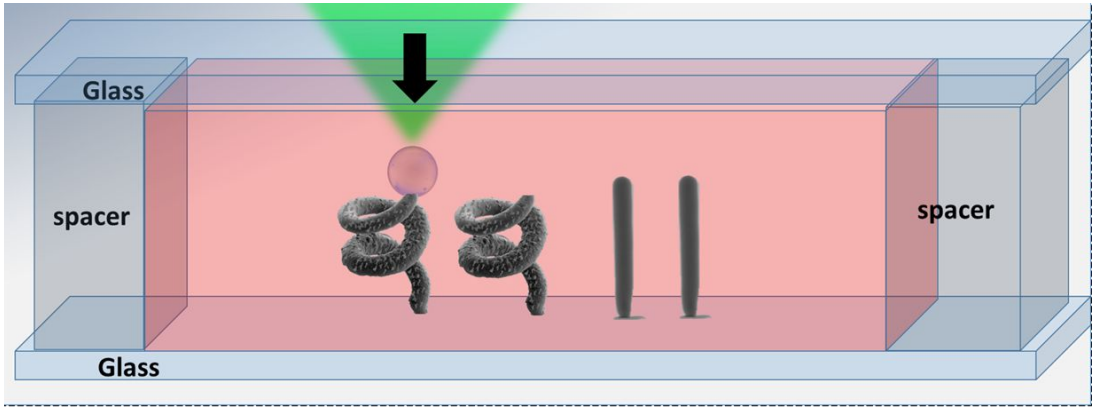

Figure 1.5 - Vector printing

Laser modulation for layer-by-layer 3D printing

Problem

- Inconsistent deposition on previous layer due to “sinusoidal” patterns
- On areas with hills, more deposition occurs than in valleys
- Increase in high/low range leading to inconsistent wall formations

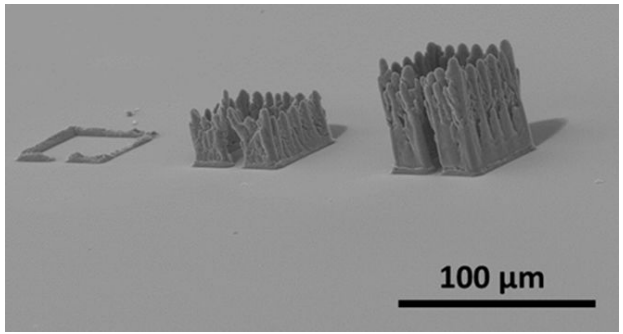

Figure 2.1 - Stages of wall defect progression

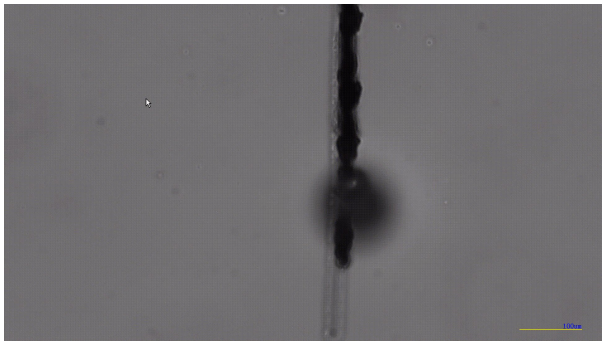

Figure 2.2 - “Jumping” microbubble

Determining ideal parameter values for layer-by-layer printing

- All lines printed at 100 kHz (previously 1 kHz)

Figure 2.3 - Two ideal lines

	Line 1	**Line 2**
Duty Cycle	20%	25%
Intensity	60 mW	73 mW
Velocity (stage)	0.001 mm/s	0.002 mm/s

Proposed Solution

- Program the stage to speed up and slow down depending on the place in the pattern
- Speed up near peaks and slow down in troughs
- Function of stage speed is directly proportional to the period of height graph (if periodic)

Profilometer Results

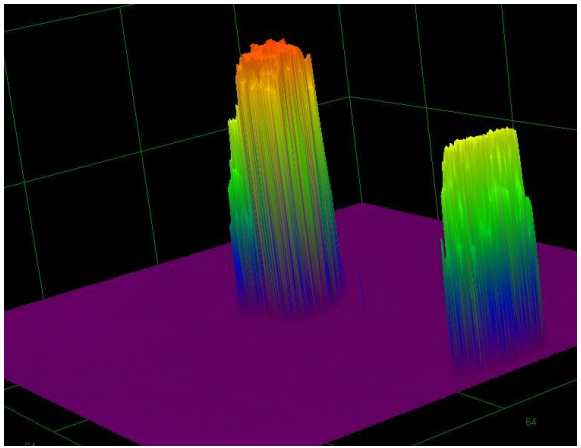

Figure 2.4 - Wall 1 on right and wall 2 on left

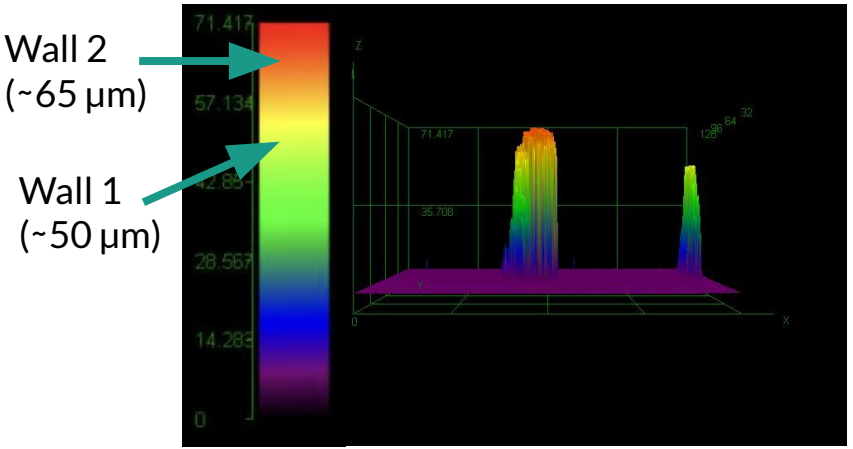

Figure 2.5 - Side views

SEM Wall 1

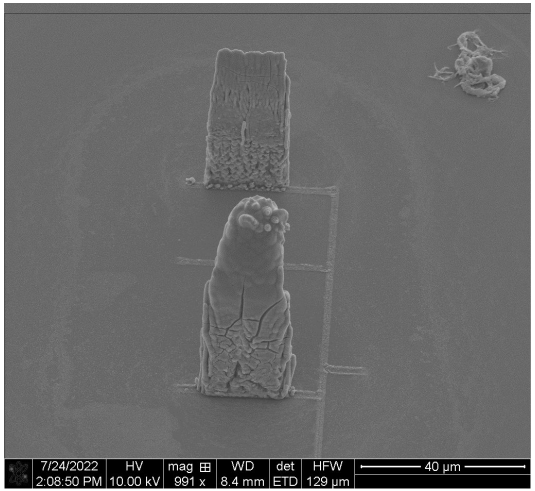

Figure 2.6 - Lines 1 and 2

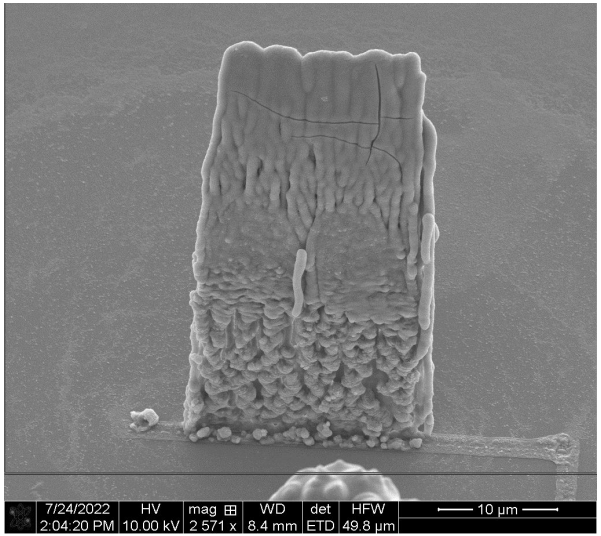

Figure 2.7 - Side 1

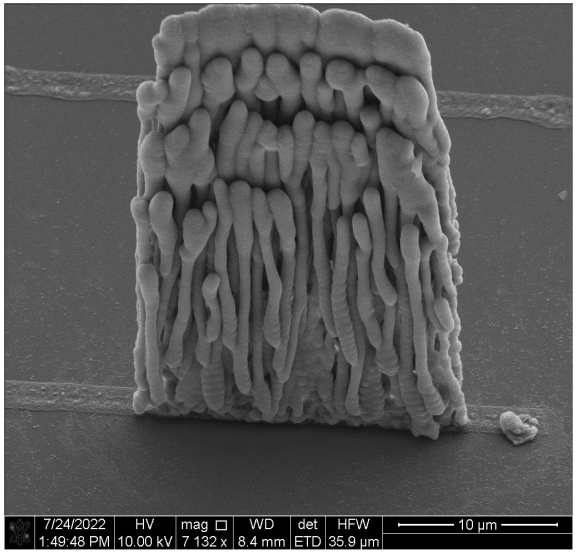

Figure 2.8 - Side 2

SEM Wall 2

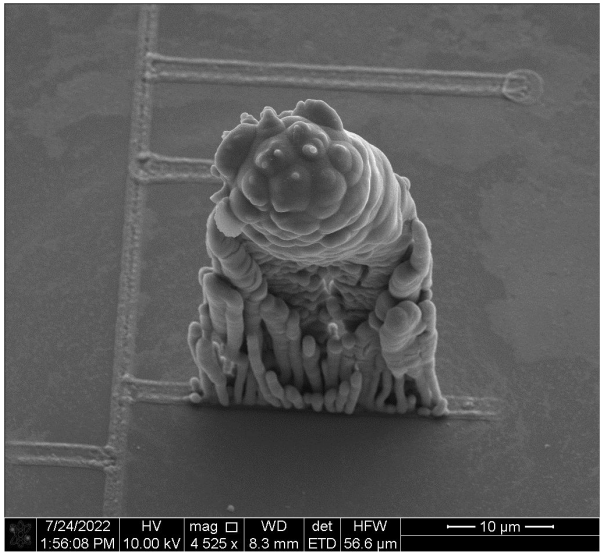

Figure 2.9 - Side 1

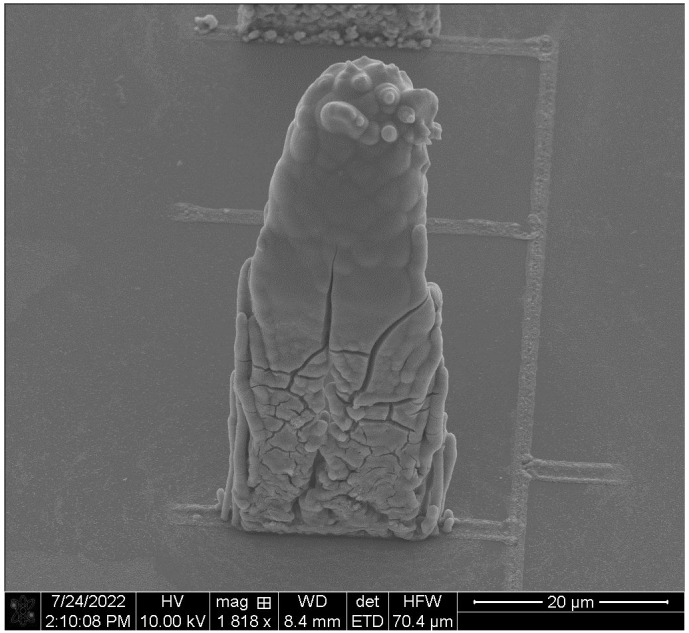

Figure 2.10 - Side 2

Results and Observations

- 100 kHz improves regularity over prior 1 kHz
- The walls have “areas”: the bottom part is rougher and more pillar-like while the upper part is smoother
- Future questions
  - What other parameters affect wall regularity?
  - Does some periodicity present itself if we print longer walls?

Multi-axis stage rotation for three-dimensional vector printing

Problem

- Only successful when printing pillars
- When deviating from pillar (incline/curve), structure loses stability and consistency

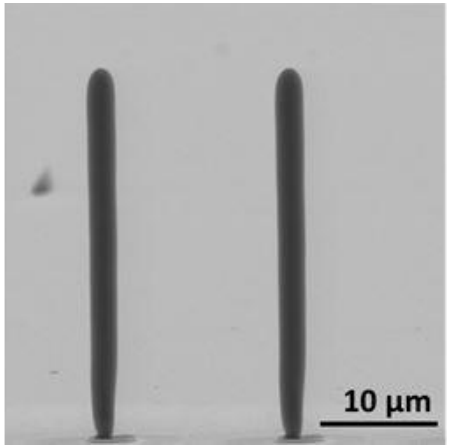

Figure 3.1 - Vector printed pillars

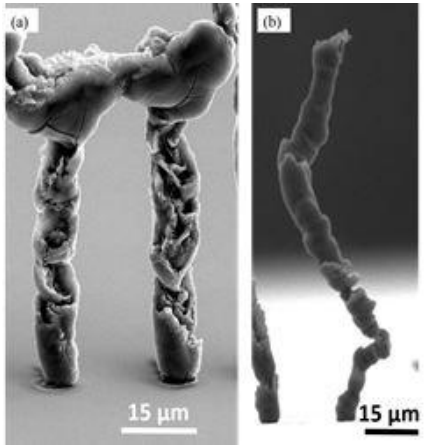

Figure 3.2 - Arch (left) and slant (right)

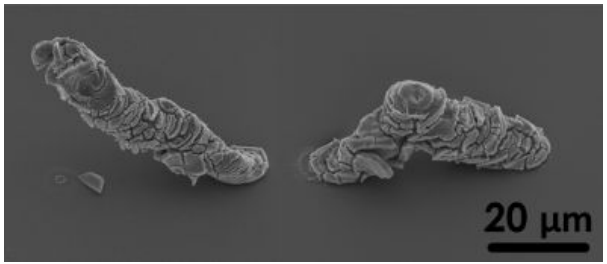

Figure 3.3 - Slant (left) and triangle (right)

Solution

- Double-axis rotating stage
- Programmable cage rotators
- Constantly ensures printing is parallel to gravity

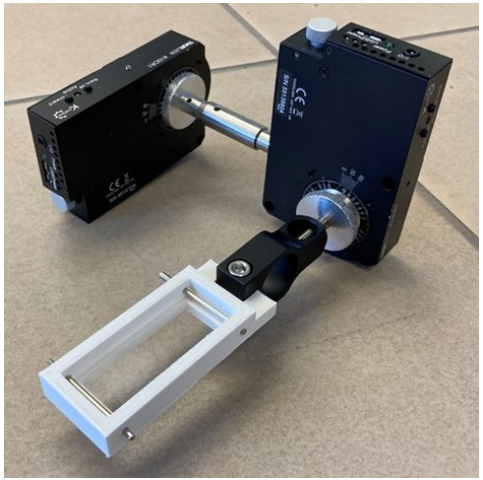

Figure 3.4 - Double-axis stage

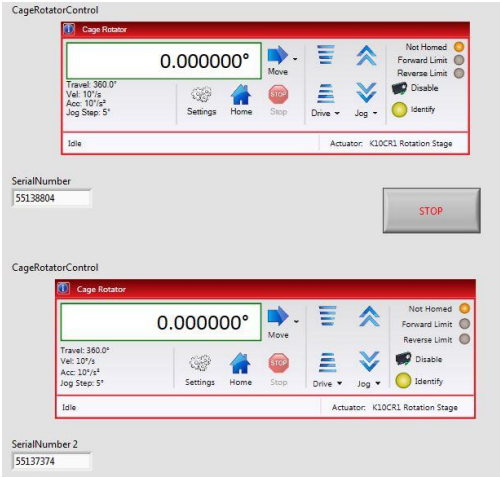

Figure 3.5 - Control panel for motors

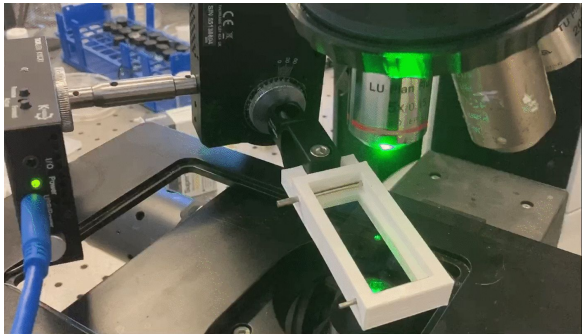

Figure 3.6 - Rotating cage motors

Results and Observations

- Both cage motors can be controlled simultaneously but now focused on combining the cage motor control with the microscope stage
- Future questions
  - For curves, what rotation speed creates which shape curve
  - What is the most efficient way of sending desired shapes to the printer

Recap

Project 1

- Layer by layer printing
- Problem - inconsistent deposition
- Solution - speed modulation of stage

Project 2

- Vector printing
- Problem - structural defects for non-normal orientation
- Solution - double-axis rotating stage

Thank you!

Questions?