Projection Microstereolithography

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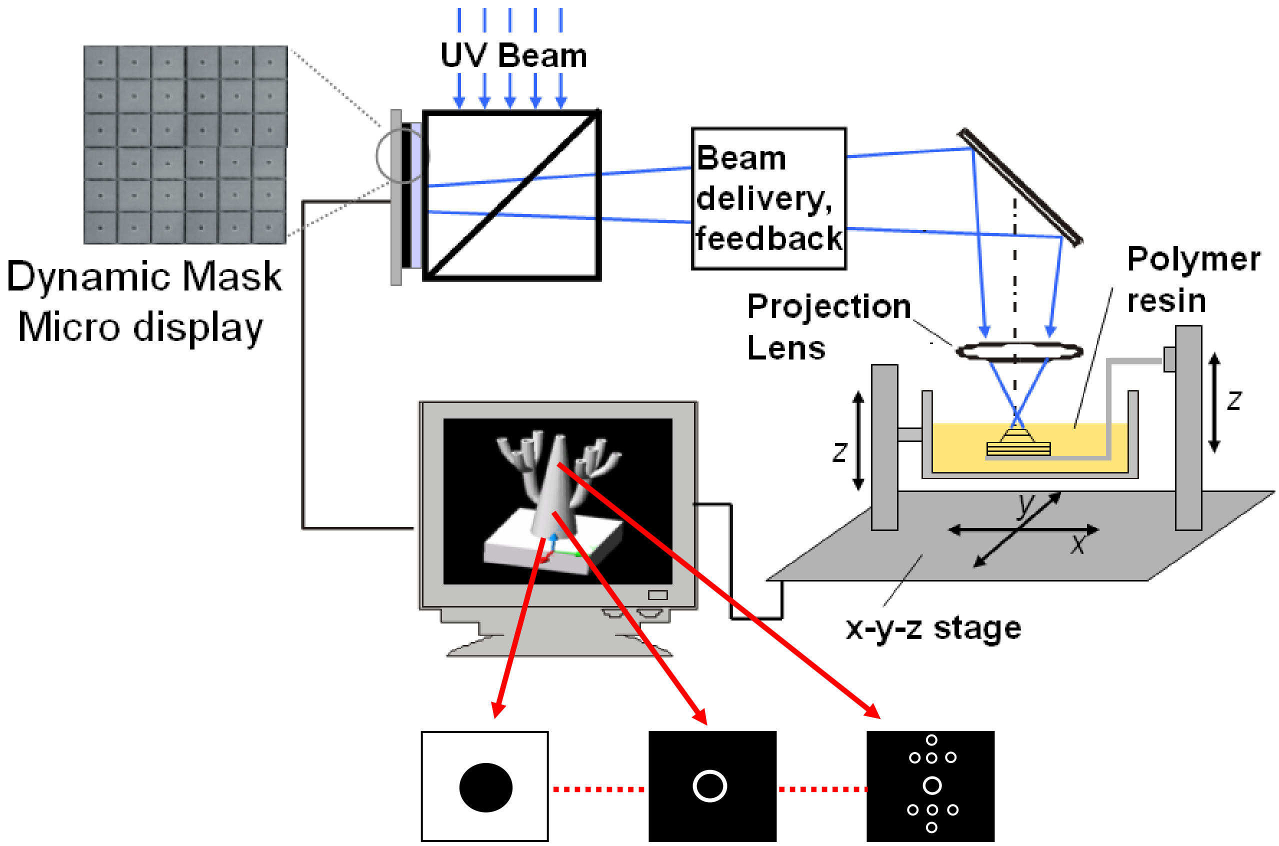


Lee, et al, *The Royal Society of Chemistry,* 2010

Description: 3D microfabrication by projection microstereolithography (PμSL) is a versatile, low cost process that can be used to rapidly create highly complex micro 3-D polymer structures and devices which can be used by themselves, used as molds, electroplated or with resin additives produce ceramic items.

The process begins with a 3D CAD drawing which is sliced into a set of layers. The image of each layer is sent sequentially to a dynamic mask generator. Then, light from a flood UV source is reflected off the dynamic mask and the beam containing the image is focused on the surface of a UV curable polymer resin through a projection lens which reduces the image to the desired size. Once a layer is polymerized, the stage drops the substrate by a predefined layer thickness, and the dynamic mask displays the next image for the polymerization of the next layer on top of the preceding one. This proceeds iteratively until all the layers are complete. The process can create polymer layers on the order of 400 nm.

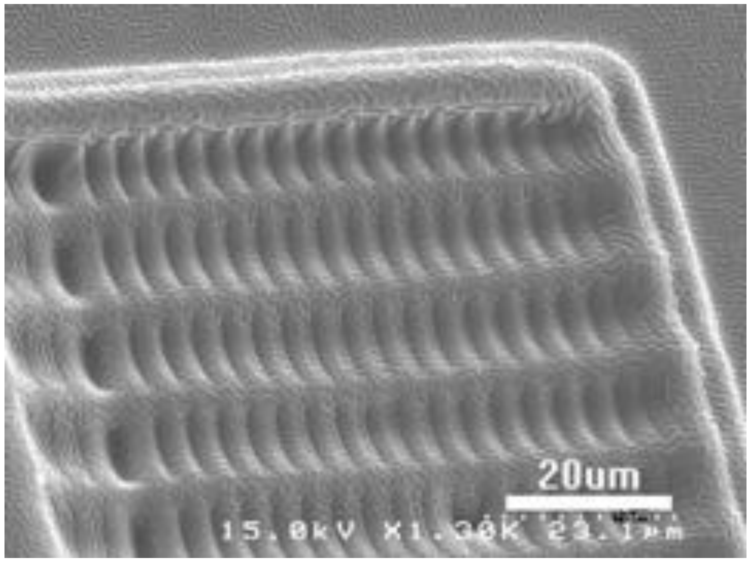
Many applications exist for this technique of nanoscale and microscale manufacturing, including micro-bio reactors to support tissue growth, micromatrices for drug delivery and detection, and biochemical integrated circuits that could eventually simulate biological systems.

This technology has been adopted for use as a highly successful high school experiment and demonstration of a micro-fabrication technology involving computer design with UV cure polymer chemistry.

1. **Resolution:** Depends somewhat on resin polymer and any polymer additives. Minimum dimensions reported:
    a. **Horizontal (in plane):** <2 µm
    b. **Vertical (off plane): <**1 µm
    c. **Feature sizes:** <1 µm
2. **Geometric capabilities:** Complex micro 2D and 3D structures
3. **Materials**: UV or photo initiated polymers
4. **Process**
    a. **Environment:** ambient temperatures and atmospheric pressure though nitrogen atmosphere improves polymerization
    b. **Rate:** 4 cu mm/hr (limited by resin viscosity)
    c. **Control:** Cross-linking density and rate can be controlled by light intensity
    d. **Pattern fabrication:** CAD, PowerPoint - any program that generates bimaps
5. **Dimensional capabilities:**
    a. Lateral dimensions and fidelity limited by modulation of projection optics
    b. Vertical dimensions unlimited
6. **Uniqueness:**
    a. Additive process to make highly complex structures not possible via etching or other removal processes
    b. No physical masks required
    c. Can produce very high aspect ratio structures (>10) without limit in vertical direction
    d. Process highly compatible with CAD
    e. Relatively simple fast process to make very complex 3D microscale structures with simple low cost apparatus
7. **Competition:**
    a. Soft lithography
    b. Micromachining
    c. Direct Ink Write
8. **Limitations:**
    a. Limited to photo-initiated polymers
    b. There must a connection between successive layers
    c. Proximity of fine details limited due to stiction from capillary action
9. **IP Status:** Patents applied for
10. **Potential Applications:**
    a. Micro-bioreactors to culture tissues in vitro and tissue scaffolds
    b. Micro-actuators powered by polymer swelling
    c. Mold for making metal structures by casting or electroplating
    d. Micro-ceramic structures are possible by mixing green powder with liquid resin
11. **Current Research Focus:**
    a. Exploring new structures
    b. Exploring different polymer systems
    c. Techniques to reduce dimension resolution further
    d. Combining technology with other technologies to produce new fabrication processes

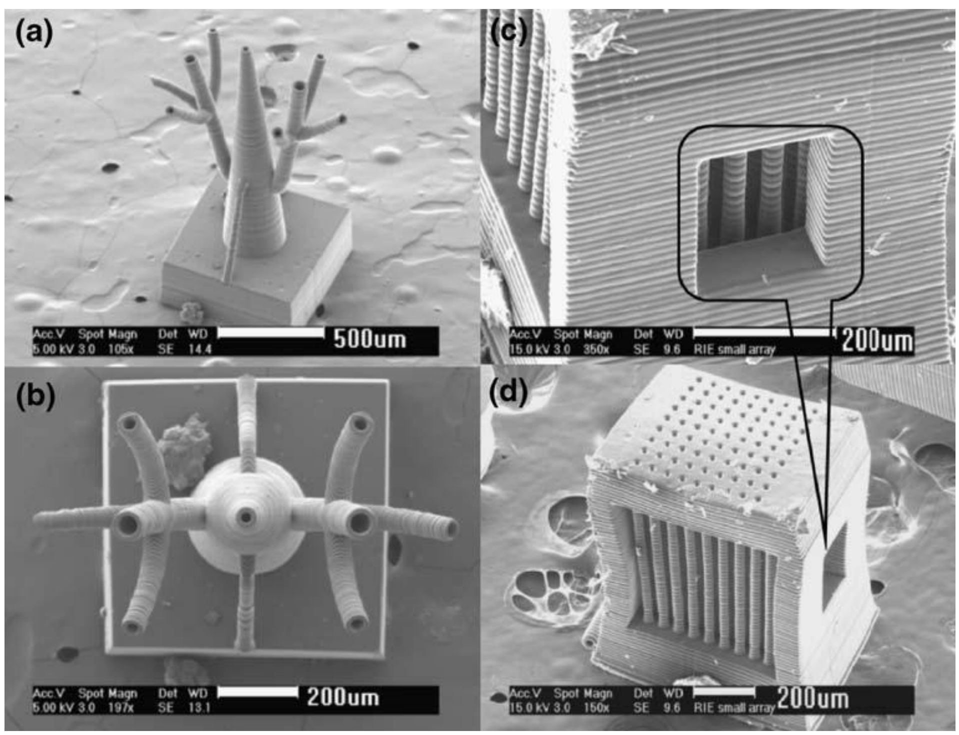
12. Microstereolithography examples:

a. Micro patterning examples:



Freestanding polymer micro-network with pores as small as 2 µm at spacing to 2 µm.

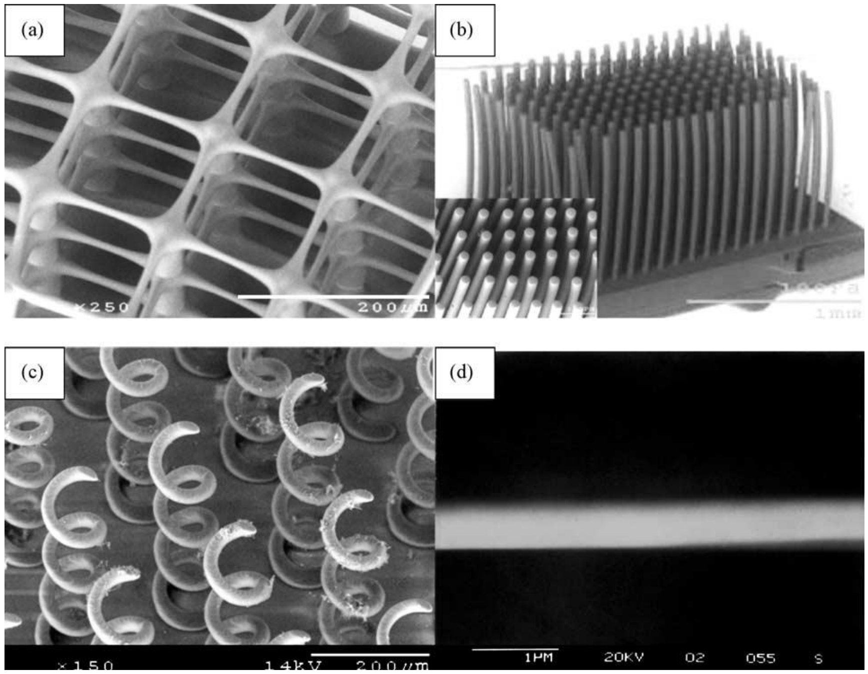
b. Complex bioreactor structures:



(a, b) Highly branched capillary network structure (inner radius of capillaries vary 10- 30 µm, (c, d) 9 X 9 capillary array with 10 µm inner radius, 20 µm outer radius, 80 µm spacing and 800 µm Length.

Xia, C.; Fang, N. 3D Microfabricated bioreactor with capillaries, *Biomed Microdevices,* **11**, 1309-1315, (2009)

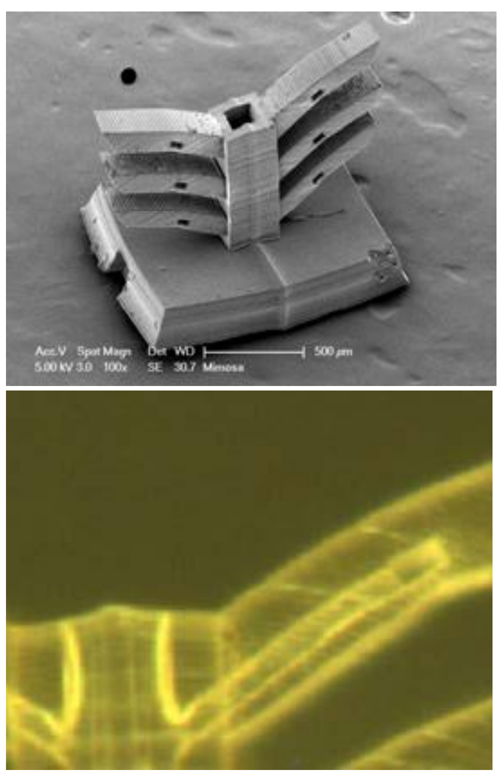
c. 3D structures:



(a) Micro matrix with 150 µm grid dimension and 5 µm line width; (b) high aspect-ratio micro rod array consists of 21×11 rods with the overall size of 2mm×1 mm. The rod diameter and height is of 30 µm and 1 mm, respectively; (c) micro coil array with the coil diameter of 100 µm and the wire diameter of 25µm; (d) suspended ultra fine filament with the diameter of 0.6 µm.

Sun, C.; Fang, N.; Wu, D.M.; Zhang, X. *Sensors and Actuators A 121 (2005) 113-120*

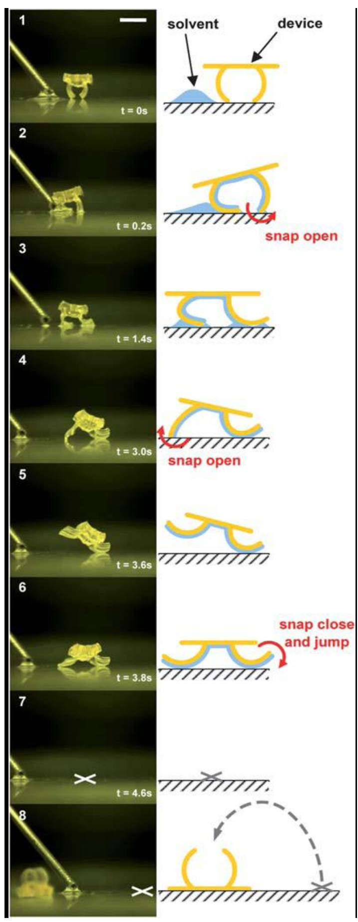
d. Artificial micro Mimosa



Top: Projection microstereolithography fabricated “leaf” beam structure with embedded capillary network. Bottom: Time lapse of folding motion when solvent droplet is applied simulating Mimosa moving mechanism.

Lee, H., Xia, C., Fang, N., Biomimetic Microactuator Powered by Polymer Swelling, IMECE2008-67594

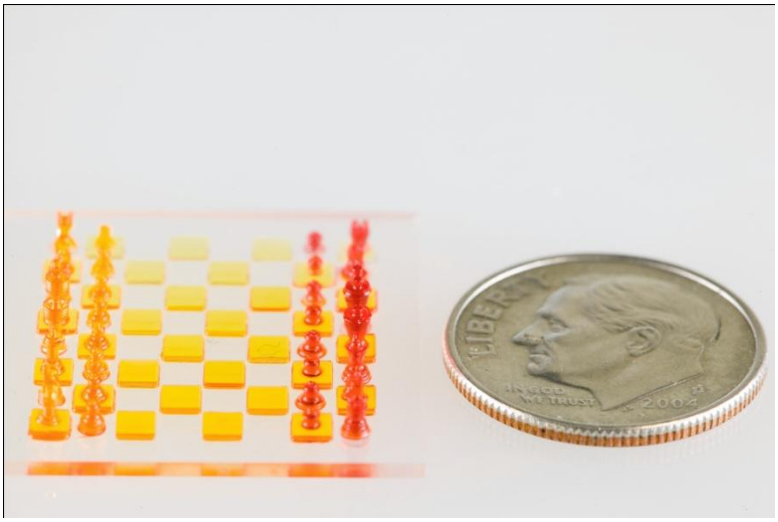
e. Microstereolithography fabricated microgel leaf device jumps when wetting solvent evaporates.

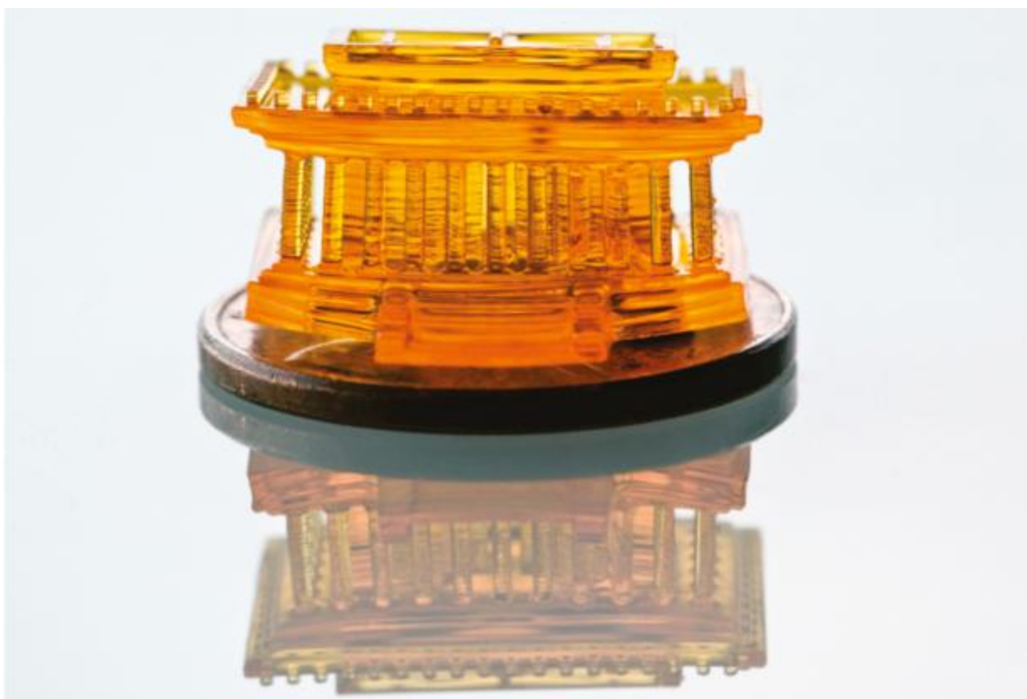


Note: Curved leaf section is 1,200 µm by 1,200 µm, 100 µm thick with convex radius of curvature of 800 µm. There are three 150 µm by 50 µm cross-section micro-channels embedded with 400 µm spacing on the inner surface of the leaf. (1 mm scale bar is in top image.)

Lee, Xia, and Fang, *Soft Matter,* 2010,

f. Items made by high school students





The Lincoln Monument pictured here has just over 50 cross-sectional layers, yet fits on a penny (a U.S. coin ~2 cm in diameter). Although not directly visible in this picture, the statue of Abraham Lincoln sitting in a chair is present behind the center column.

Muskin, J.; Ragusa M. *J. Chem. Educ.2010,* 87, 512-514