Laser Micromachining

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Background

The increasing demand for miniaturization in the field of

- Micro-fluidics
- MEMS (Micro-Electro-Mechanical System)
- Micro-optics
- Photonics device
- Biomedical device
- Automotive

and Etching Conventional Photolithography

- Requires photomasks that are expensive and time consuming to fabricate
- For a multilayer structure, masks should be aligned with a lot of time and effort
- All step must be carried out under clean room conditions
- The range of designs is limited to the planar, lay-by-layer geometries
- Choice of material is very limited

Laser Micromachining

- Generally, no mask is required
- Any redesigns can be easily achieved by changing the program that controls the x-y machining stage
- The size of the panels is only limited by the XY stage
- A high degree of accuracy and consistency can be achieved.
- It is possible to fabricate geometries with variable depth and high aspect ratio
- Different laser sources can cut a wide range of materials including polymers, glass, metals and ceramics.

Previous Work

(a) (b)

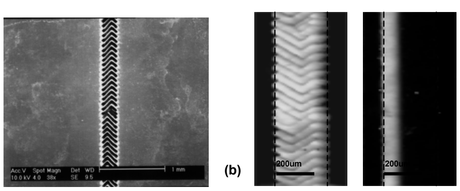
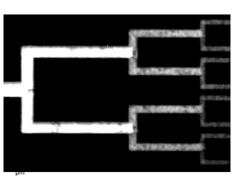


Figure 1. (a) SEM image of staggered herringbone mixer (SHM) viewed from the top **(b)** Fluorescence images viewed from the top of (left) SHM (right) simple flat channel

(a) (b)



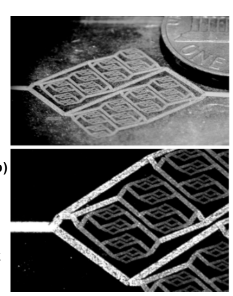


Figure 2. (a) Laser micromachined artificial vascular system, which obeys Murray's law has Multi-depth/ Multi-width **(b)** Eight level multi-width multi-level micro-vascular network

Fabrication

Laser

- Nd:YAG diode-pumped high brightness laser operating at rate of 200Hz and pulse width of 150μs (3% duty cycle)
- Modulation with each spike having a 75 ns full width half maximum (FWHM).
- All processes was carried out in Air.
- Average power ranging from 0.5 W to 3 W.
- Traverse speed of 0.1 mm/s

Post processing

- 40% HF + 30% KOH etching for 10mins.

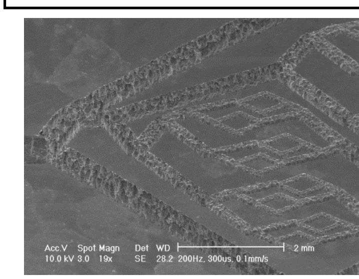
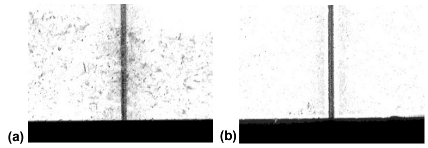


Figure 3. SEM image of eight generation micro-vascular network. The roughness of ablated surface still need to be improved

Femtosecond Laser Machining



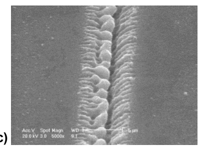


Figure 4. Before **(a)** and after **(b)** chemical cleaning with 30% KOH for 5 second **(c)** SEM image of a 5um wide microchannel fabricated by overlapping 15 vertical passes of beam

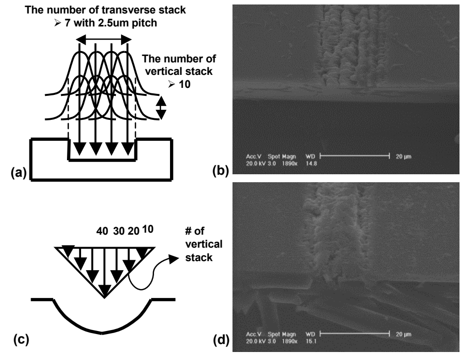


Figure 5. (a) The schematics of the fabrication of wide microchannels **(b)** SEM image of a microchannel with the width of a 20um **(c)** The schematics of the fabrication of microchannels with semi-circular cross-section **(d)** SEM image of a semicircular cross-sectional channel

Fabrication

Laser
- Femtosecond laser (IMRA) operating at rate of 200kHz and pulse width of 371fs
- All processes was carried out in Air.
- Average power of 28mW
- Traverse speed of 30 mm/s

Post processing
- 30% KOH etching for 10sec.

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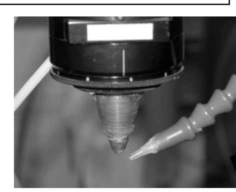
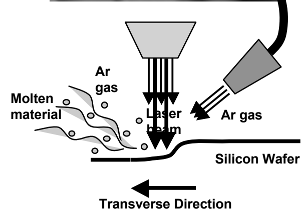
Molten Material and Surface Roughness

- Molten silicon remaining in the channel blocks energy transfer from laser to target surface so that desired shape of channel cannot be obtained.
- The solidification of molten silicon causes rough surface and then leads to non-uniform absorption of energy. Thus the surface roughness gets worse.
  - ➢ In order to make a silicon molder, the surface roughness shown in micromachining with ns laser should be solved
  - ➢ In biomedical applications, the surface roughness can cause formation of clot and increment of hydraulic resistance

Coaxial Shielding and Side Shielding Gas

- To effectively eject molten material out of channel, an assist gas flowing from side is utilized.
- Inert gas as an assist gas prevent formation of an oxide, so we need not use HF to clean silicon oxide in post processing.





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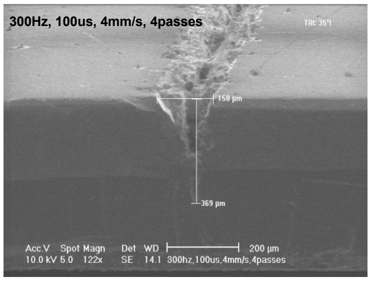
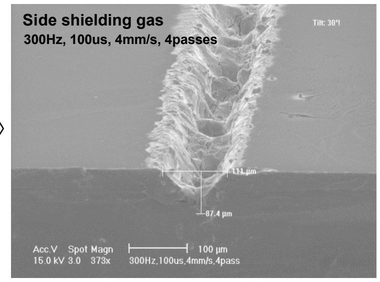
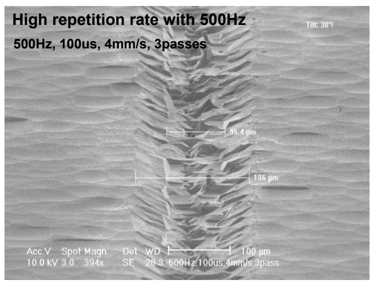
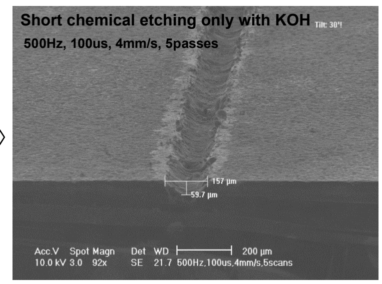
Improving Process









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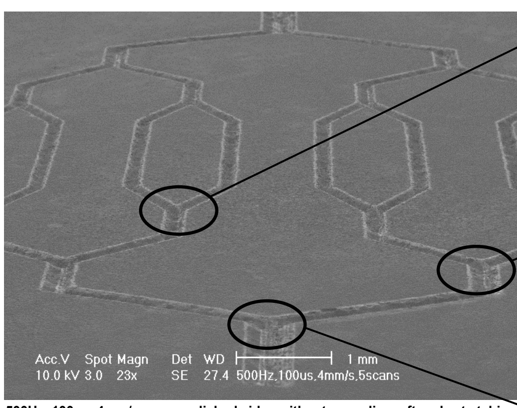
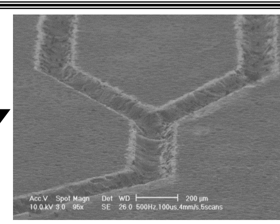
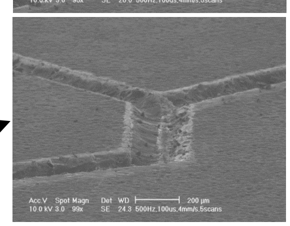
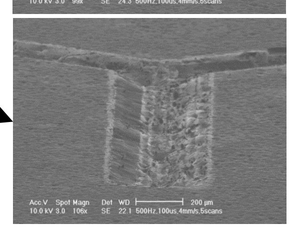
Microchannel networks



500Hz, 100us, 4mm/s, on unpolished side, without annealing, after short etching







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Future Work

- Develop physic of micro-machining with femtosecond laser
  - Mathematical model
  - Process physics characterizing
- Frequency doubling of our Nd:YAG laser to pattern on polymer like PDMS
- To reduce laser beam spot size to about 10μm to get more fine structures
- Endothelializing test for our microvascular network
- To apply the shielding gas to the micromachining with femtosecond laser (IMRA)
- Develop laser parameters vs. surface smoothness for smooth channels