



Rapidly-Prototyped Three-Dimensional Nanofluidic Channel Networks in Glass Substrates

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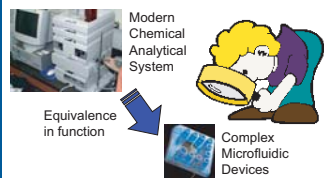
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1. Abstract

Microfluidic and nanofluidic technologies have long sought a fast, reliable method to overcome the creative limitations of planar fabrication methods, the resolution limits of lithography, and the materials limitations for fast-prototyping. In the present work, we demonstrate direct 3D machining of sub-micron diameter, sub-surface fluidic channels in glass, via optical breakdown near critical intensity, using a femtosecond pulsed laser. No post-exposure etching or bonding is required; the channel network (or almost any arbitrary-shaped cavity below the surface) is produced directly "from art-to-part". The key to this approach is to perform the femtosecond laser machining in the presence of liquid. Microbubbles that expanding as a result of laser energy deposition gently extrude machining debris from the channels. These bubbles are in a highly damped, low Reynolds number regime, implying that surface spalling due to bubble collapse is unimportant. We demonstrate rapid prototyping of three-dimensional "jumpers", mixers, and other key components of complex 3D microscale analysis systems in glass substrates

2. Motivation



Application

- Diagnostics
- Chemical analysis
- Sensors
- Drug discovery
- Microreactors

Current Limitations

- Material
- Planar fabrication
- Space limitation
- Cross path without mixing

PDMS	Glass
<ul style="list-style-type: none"> • Lack of solvent resistance • Leaching • Protein adsorption • Inability to contain high pressure 	<ul style="list-style-type: none"> • Withstand high pressure • Withstand organic solvents • Low adsorption • Relatively inert
3D Multilayer Soft Lithography	LIMITED FABRICATION METHOD

3. Method

Direction of glass movement

$\lambda = 527\text{nm}$

Water	Bubble	Debris	Glass
High N.A. Obj.	Femtosecond Laser		

Laser
<ul style="list-style-type: none"> • IMRA/Intralase • 500/800fs • 522/527nm • 14/28 nJ/pulse • 200/1.5 kHz Rep. Rate

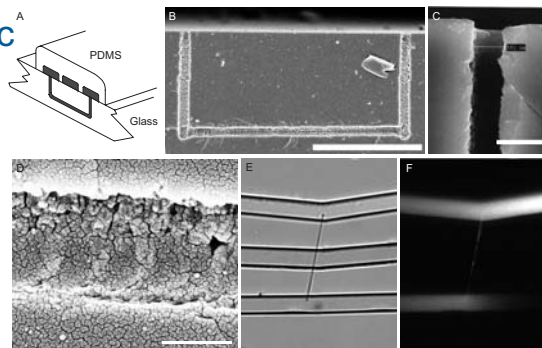
Microscope objective
<ul style="list-style-type: none"> • 1.3N.A. • 100x

Nanostage
<ul style="list-style-type: none"> • Madcity

4. Results

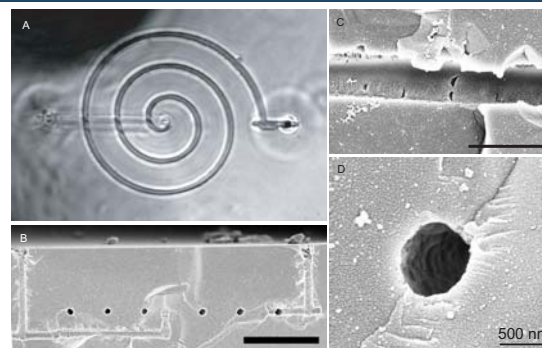
Nanofluidic jumper

- Bypass, from anywhere to anywhere
- Out of plane, cross path without mixing



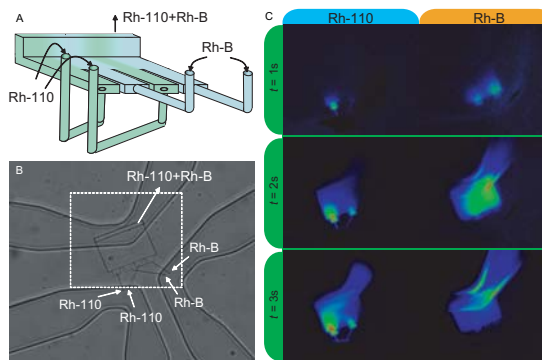
Spiral channel

- Long channel, small space
- Multiple layers, arbitrary geometry



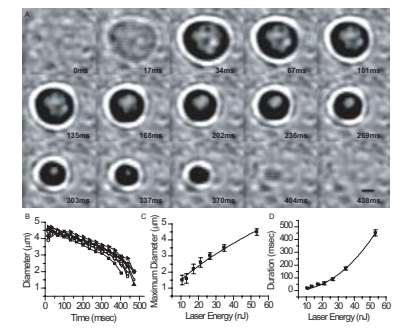
Mixer

- Three-dimensional channel network
- Interdigitated outflows
- Rapid prototyping



4. Results

Bubble plays a key role in clearing the debris



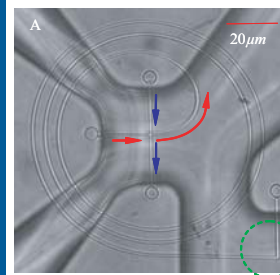
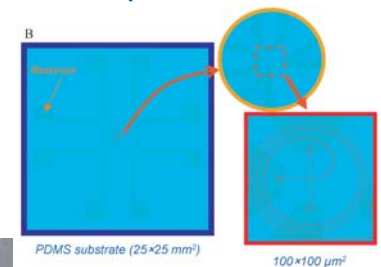
5. Conclusion

OCI nanomachining of analytical devices in glass, with femtoliter fluid volumes, enables rapid "art-to-part" construction of micro- and nanofluidic devices with potential to dramatically accelerate development of μ TAS applications such as integrated HPLC devices, micro scale sensors, and integrated nanopores for patch-clamp studies of cells.

6. In Progress

Nano Capillary Electrophoresis (NCE) devices

- Active area: 100 μm square
- Separation Channel: 851 μm
- Protein separation speed to be tested



Others WIP

- Surface roughness
- Surface coating
- CE
- CEC
- HPLC