Fabrication and Packaging of Polymer-Based Microfluidics

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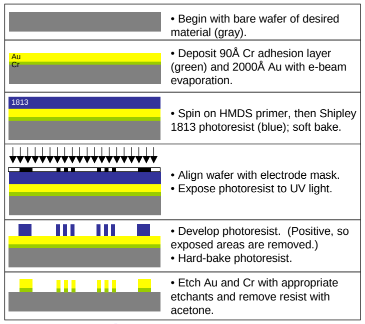
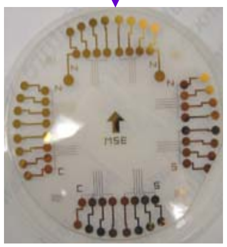
Project Overview

1. **BioMEMS microchannels**
   - *fabricate microchannels in various materials with electrodes in channels*
   - *explore effects of channel geometry and material on fluid flow*
2. **Microfluidics packaging design**
   - *design mechanism for leak-tight sealing of microchannels*
   - *design input/output methods*
3. **Packaged microfluidics testing**
   - *test packaging designs at various stages*
   - *measure fluid flow rates and electrical properties of connections*
   - *improve leak-tightness of design*
   - *use packaged microfluidics for future biofunctionalization of surfaces*

BioMEMS Microchannels

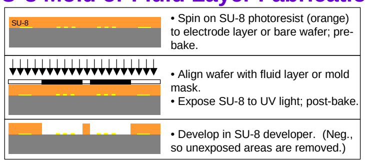
Electrode Fabrication





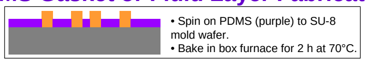
Au/Cr electrodes patterned on Pyrex substrate

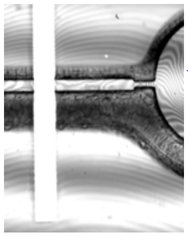
SU-8 Mold or Fluid Layer Fabrication



SU-8 master for molding PDMS fluid flow layers

PDMS Gasket or Fluid Layer Fabrication





PDMS fluid flow layer aligned and assembled with electrodes patterned on Pyrex substrate

PDMS Delamination and Assembly

- Gently loosen edges of cured PDMS with razor blade
- Submerge PDMS wafer in dish of methanol
- Hold one edge of PDMS with tweezers and gently pull from wafer (keeping in methanol as much as possible)
- Remove wafer from dish and allow PDMS to float
- Slide (electrode) wafer to be assembled under PDMS layer in dish
- Coarse align PDMS to wafer while in dish
- Remove wafer and PDMS from dish and align carefully by hand or under microscope, dropping methanol on if sticking occurs, then let dry.

Microfluidics Packaging Design

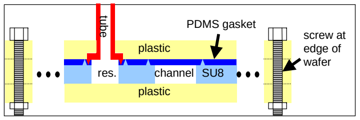
Packaging Requirements:

- **leak-tight sealing** → *gasket; clamping mechanism; SU-8 or PDMS bonding*
- **transparency** → *plastic or Pyrex wafer; plastic packaging plate; exposed wafer*
- **inlet/outlet fittings** → *flanged microtubing; threaded fittings*
- **accessible electrodes** → *smaller cover plate; spring-loaded electrodes*

Longer-term Goals:

- **4 of 4 requirements met**
- **on-chip micropumps and microvalves**
- **individual channel and electrode addressing**
- **controllable apertures for vacuum sensing**
- **extremely robust design for leak-tightness**
- **on-chip integration of optical investigation techniques (*e.g.*, interferometry, waveguides)**

Packaging Design Stages

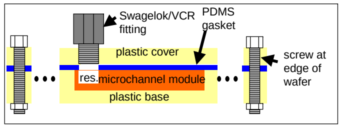


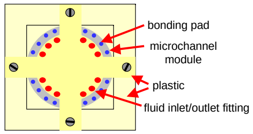
Stage 1 (initial concept):

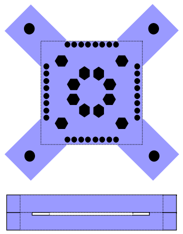
- 3 of 4 requirements (exposed electrodes?)
- difficult to fabricate
- depends on availability of flanged microtubing

Stage 2 (modular concept):

- 4 of 4 requirements
- channels/reservoirs milled in plastic – easier to fabricate
- modular design avoids waste
- plastic lid can be tapped, allows for standard Swagelok fittings
- all pumping external





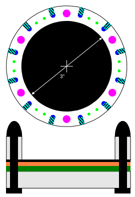


Stage 3 (X packaging):

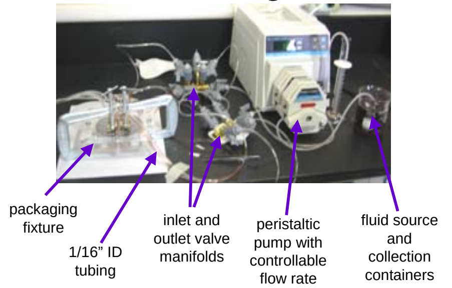
- 4 of 4 requirements
- channels patterned on a wafer that drops in to depression in packaging
- modular design avoids waste
- plastic lid tapped for microfluidic fittings
- electrical connections through packaging and via alligator clips
- all pumping external

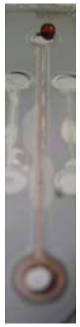
Stage 4 (ring packaging):

- 4 of 4 requirements
- channels defined on plastic wafer sealed with SU-8 or PDMS bonding
- upper plastic ring holds microfluidic and electrical fittings, clamping screws
- Neoprene gasket for sealing fluid I/Os
- all pumping external



Packaged Microfluidics Testing



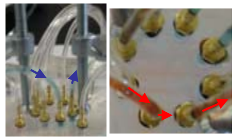


Red color in microfluidic channel shows fluid flowed through

Stage 3 packaging (with a few modifications) provides leak-tight flow of fluid. Fluid path:

inlet container →
main inlet tubing →
inlet valve manifold →
specific inlet tubing →
microchannel →
specific outlet tubing →
outlet valve manifold →
main outlet tubing →
outlet container

Inlet and outlet fluid containers for flow rate measurement



Successful flow of fluid (blue at left; red at right) through fixture and microchannels. Channel width is 500 microns.

Conclusions

1. **Microchannels can be easily fabricated in either SU-8 or PDMS on a variety of substrates (silicon, Pyrex, Kapton, etc.) with or without electrodes.**
   Future work: expand "toolbox" of microchannel, substrate, and electrode materials for future inexpensive all-polymer devices; explore sealed microchannels.
2. **Iterative packaging design has resulted in steady improvements from initial concept to viable fixtures.**
   Future work: fabricate Stage 4 packaging, apply experience to future packaging stages.
3. **Initial testing of packaging fixture reveals leak-tight sealing of microfluidic channels.**
   Future work: test Stage 4 packaging with sealed microchannels, improve leak-tightness timescale, integrate optical elements (waveguides, reflectivity experiment) into wafer and packaging.