Packaging of Microfluidic and Optical Systems

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Fundamentals of Micromachining

Overview

- Considerations in Biomedical Analysis Systems
- Packaging in Biomedical Analysis Systems
- Packaging of Microscale Bioreactors
- Packaging of Micropipettes
- Packaging of Microneedles
- Packaging of Microchromatography Systems

Considerations in Microscale Biomedical Analysis Systems

- Biocompatibility
  - Defined for each application and system
  - Cells, proteins, DNA, tissues all have different requirements
  - Typically low protein absorption, no leaching, "non-reactive"
- Harsh chemicals and environment
- Small sample handling
- Interfacing with macroscale world
- Pumps, valves, flow control
  - High pressures, flow rates, and volumes possible
- Sample injection
- Multimodal: Fluids, Electrical, Optical, etc.
- Interfaces with existing systems (standards)

Modular Microsystems

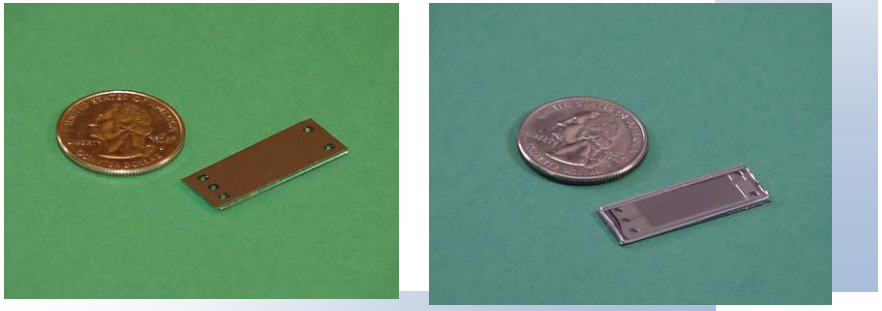
- The wide range of biomedical applications will require the use of modular microsystems
- Multi-chip modules allow optimization of each component in a serial chain
- Components include: separation, mixing, reaction, sample injection, sample preparation, various detection methods, pumping, flow control, control, intelligence, and other analysis
- Parallel systems for high throughput
- Standardization of platforms and connections

Packaging of Analysis Systems

- Biocompatibility encourages use of polymers
- Requirements for biocompatible electrodes
- Current interface method is a well
  - Clumsy, imprecise, and wasteful
- Sample injection occurs at a "T"
  - Small sample tested
  - Most of the sample wasted
- Separation of contaminants and particles (clogging)
- Reservoirs- both pre- and post-
- Added functionality on package

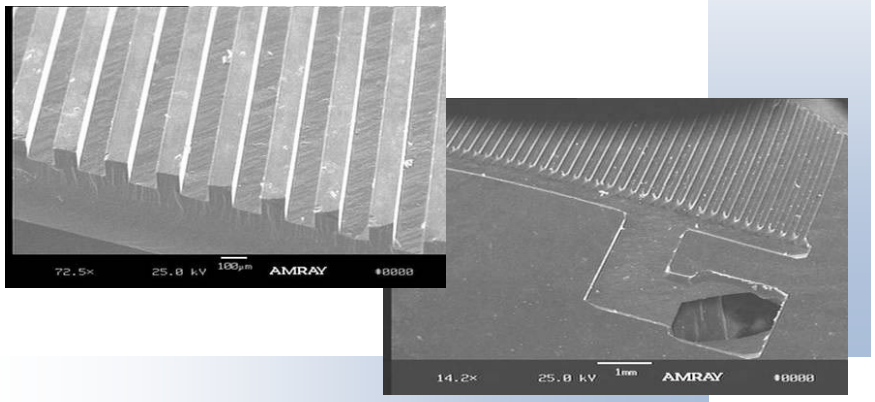
Microreactors

Fluidic vias through wafer, anodically bonded Pyrex cover, microchannel reaction zone



Micrographs of Test Chip

Fluidic via, 100 μm microchannels

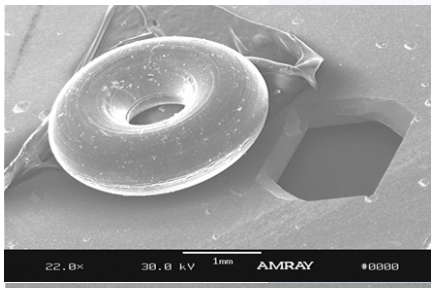


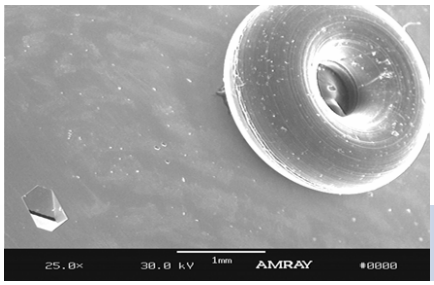
Microreactor Considerations

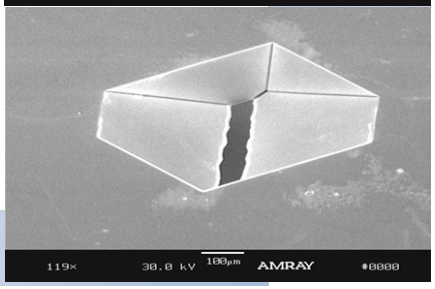
- Gas and liquid flows
- Pressures from 10^{-2} to 10^{5} torr
- Some applications require high temperatures (200-500°C)
- Sensitivity to alignment of packaging systems

Seals for Packaging

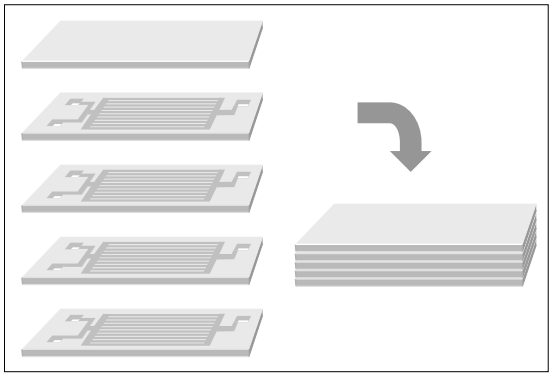
- Vias modified to accept packaging
- Standard connections possible
- Custom steel jig for attachment
- Functions up to 300°C







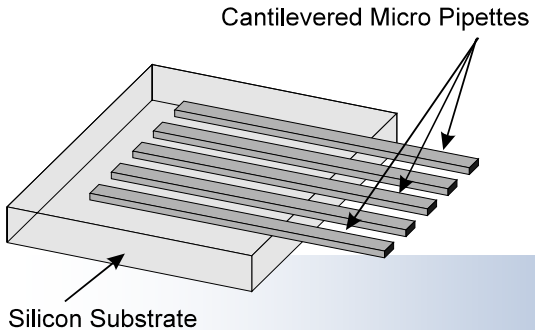
Scale Up and Packaging

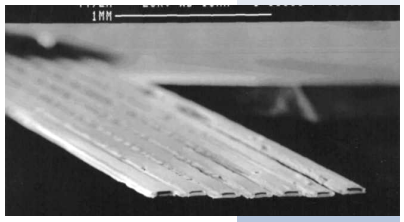


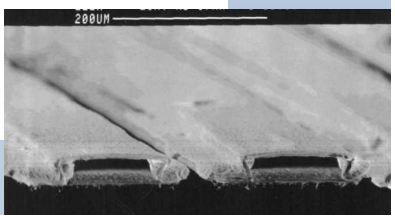
- Linear scale up
- High process density
- Effects of natural variation in micromachining
- Thermal and fluidic uniformity
- Applies to most microfluidic systems

Micropipettes

- Used to interface prepared samples and miniaturized analysis systems
- Enabling technology that allows high density analysis systems to be interfaced in parallel
- Picoliter to nanoliter volumes

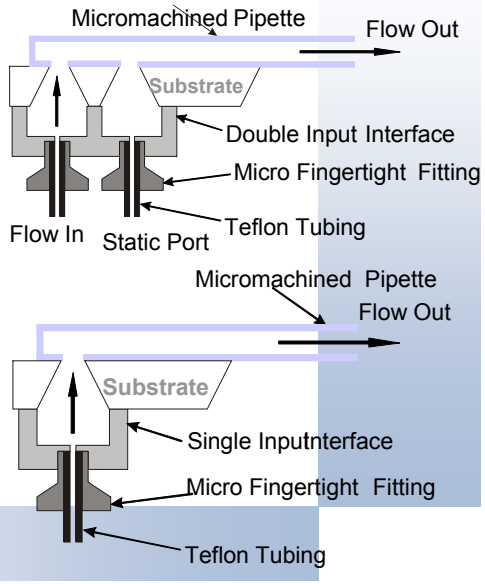






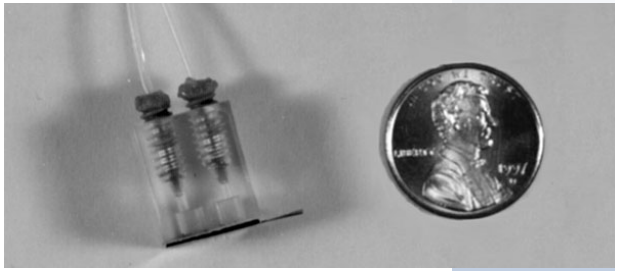
Packaging of Micropipettes

- Single and double interface systems
- Second port allows pressure measurement and mixing
- Each port interfaces all micropipettes
- Custom made acrylic interface
- Standard micro fingertight fittings from Upchurch Scientific
- Connects teflon tubing or capillary tubing



Micropipettes

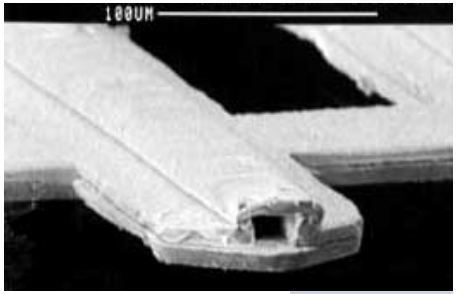
- Double interface

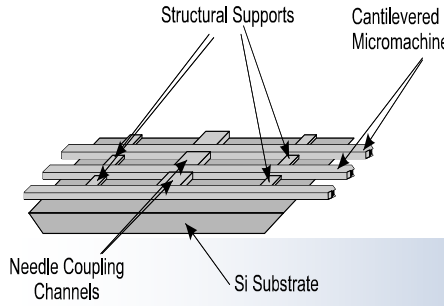


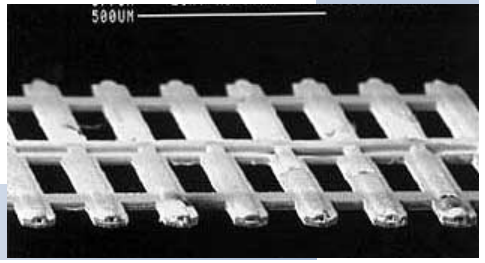
- Single interface

Microneedles

- Microneedles allow collection and dispensing of microsamples
- Large array required to dispense and collect necessary volumes
- Packaging the primary limitation

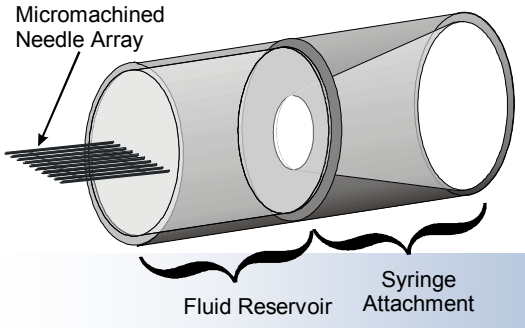


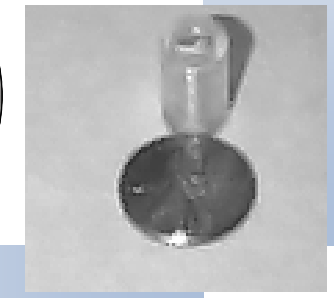




Packaging of Microneedles

- Interface developed to connect to standard syringes
- Acrylic interface with tapered luer
- Slot for microneedles attached with adhesive



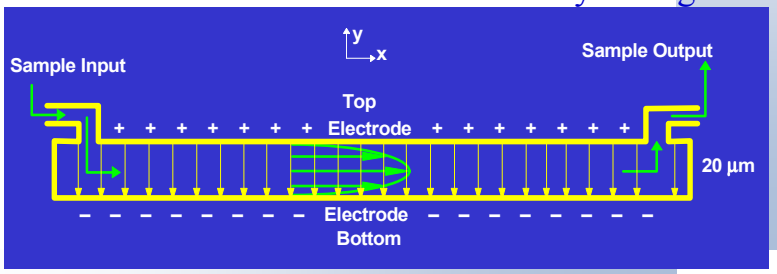


Microchromatography Systems

- Pressure driven flow
- Must inject into flow stream without allowing leaks
  - Flow rate information critical to analysis
  - Minimize disturbance
  - Minimal injection volume
- Both fluid and electrical connections
  - Connect to two bonded substrates
- Require data analysis, control systems, reservoirs, interfaces, pumps, valves, etc.

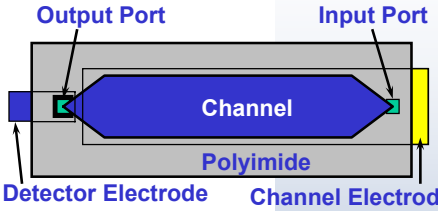
What is EFFF?

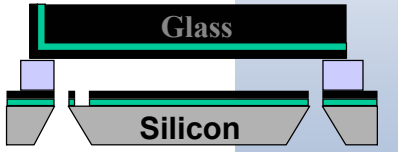
- Electric field forces charged particles towards wall
- Distance from wall determined by "ζ-potential"
- Relies on laminar flow profile to perform separation function
- Distance from wall determines velocity through



System Fabrication

- Top View
- Side View (Cross-section)
- End View (Cross-section)

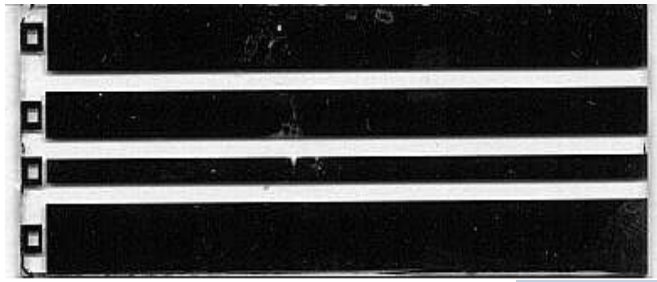




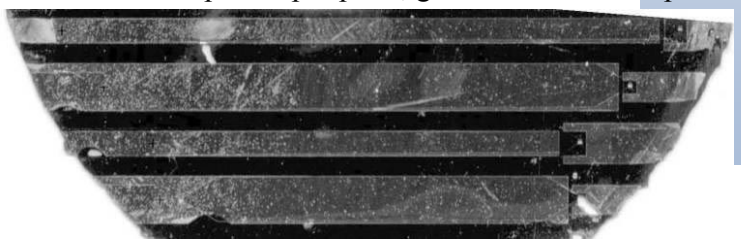
Completed Cross Section

Results- Section Fabrication

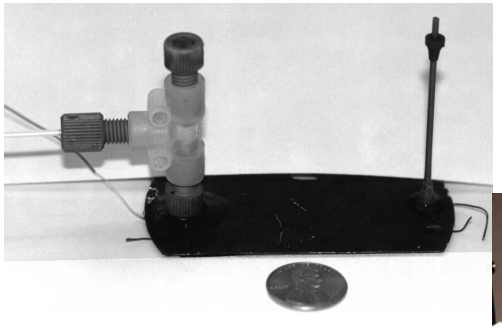
Glass substrate with titanium, gold, and platinum electrode



Silicon substrate with input/output ports, gold electrodes and patterned SU-8

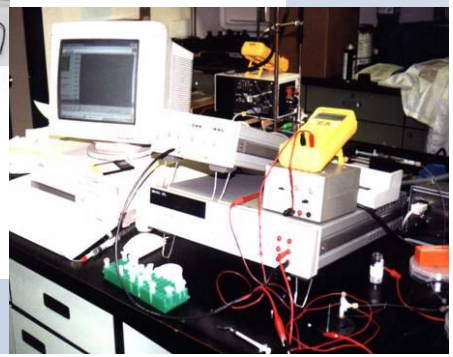


System Assembly



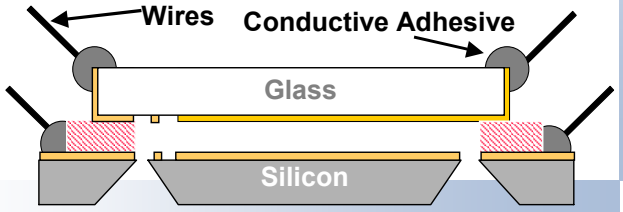
Above- Complete device with input/output port connections

Below- Complete systems with sample and buffer input, µ-EFFF system, and detectors



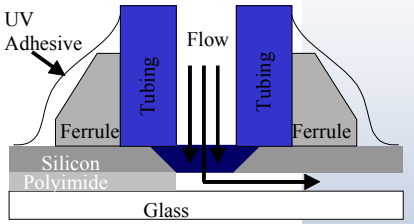
Electrical Packaging

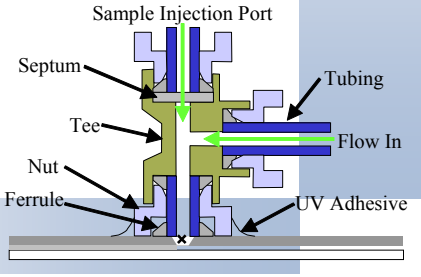
- Conductive adhesive used to attach wires
- Wire bonding could also be used
- Resistance through connections only 2-3 Ω
- Easily automated



Fluid Connections

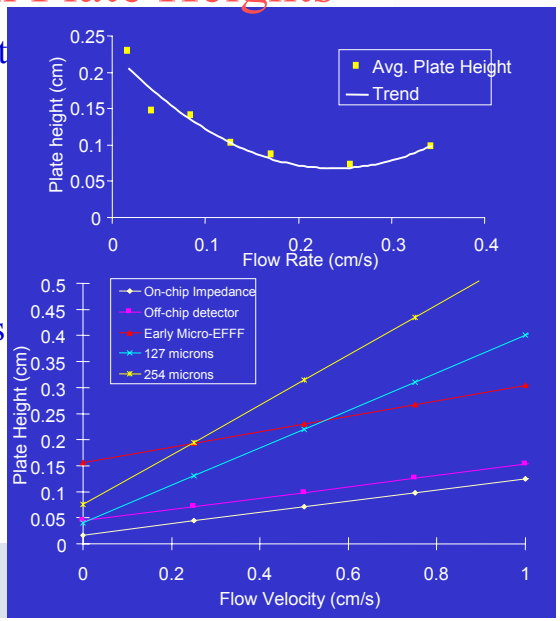
- Standard Upchurch Scientific connections (modified)
- Ferrule bonded over port
- 1/16” tubing inserted in ferrule
- Attached with UV curable adhesive
- Fast, simple, effective
- Easily aligned
- Biocompatible
- Robust
- Teflon tubing resists bonding
- Injection point at entrance to channel





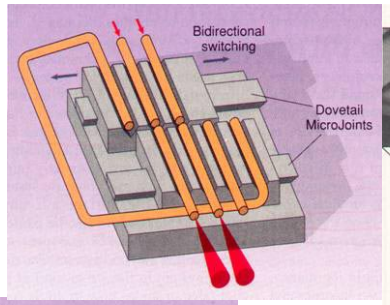
System Plate Heights

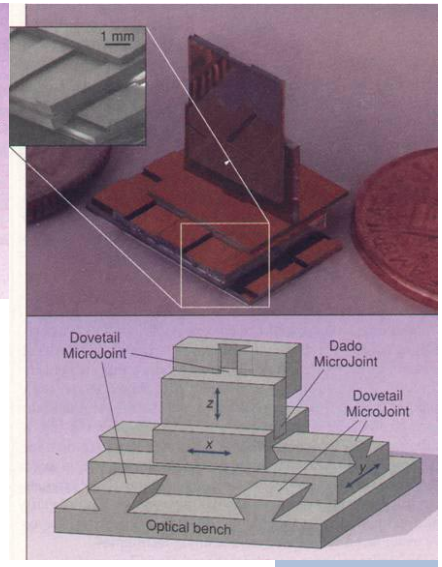
- Off-chip detector not compatible with micro-volumes
- Diffusion effects significant
- On-chip detection reduces plate heights by 3/5 from 450 µm to 180 µm
- New packaging techniques reduce plate heights to 50 µm

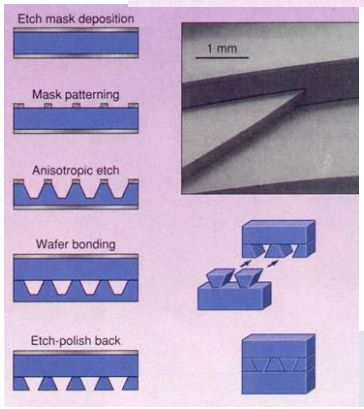


Conclusion

- Packaging improving, but still a major limitation
- Ability to connect to standard, existing macroscale systems important
  - Allows rapid component exchange
  - Reduces complexity and cost
- Packaging plays an important role in system function, especially in chromatography systems
- Standard microfluidic connections would be extremely helpful

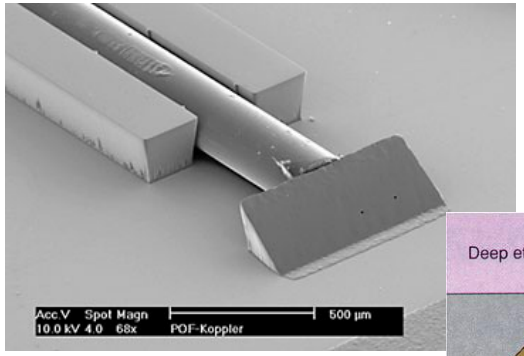


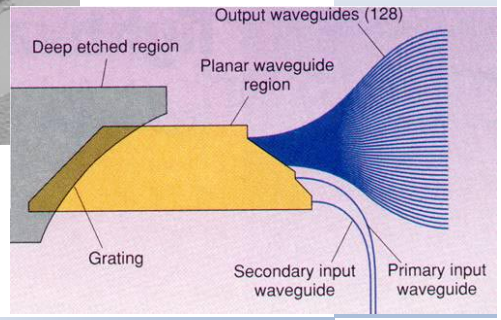




"Microjoinery"

Optical Interconnects





Microfluidics and Optics