



*The Abdus Salam*  
**International Centre for Theoretical Physics**

  
United Nations  
Educational, Scientific  
and Cultural Organization

  
International Atomic  
Energy Agency



**SMR.1670 - 20**

# **INTRODUCTION TO MICROFLUIDICS**

**8 - 26 August 2005**

**Microfluidic Systems: Integration and Interconnection**

**H. Gardeniers**  
**University of Twente, Enschede, The Netherlands**

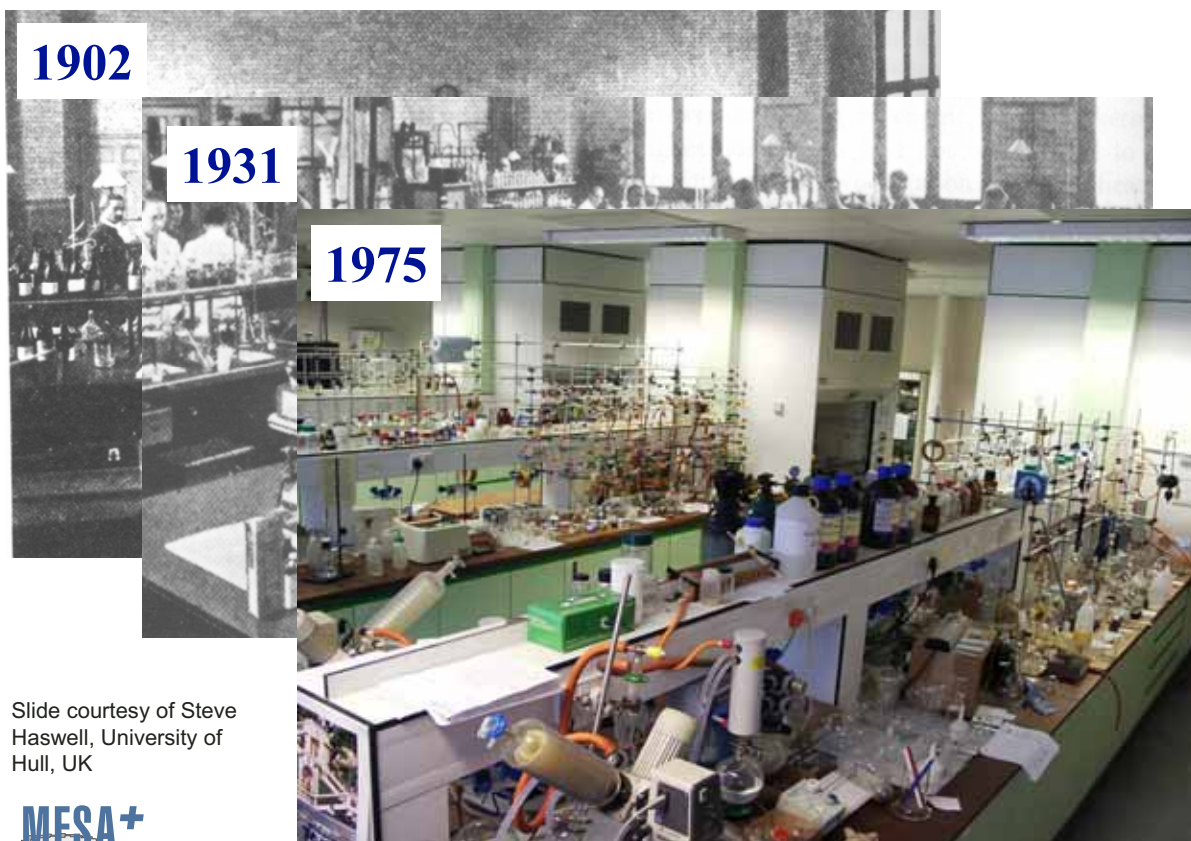
# Microfluidic systems: Integration and Interconnection

Han Gardeniers  
MESA+ Institute for Nanotechnology  
University of Twente

Summer School in Microfluidics  
ICTP, Trieste, Italy



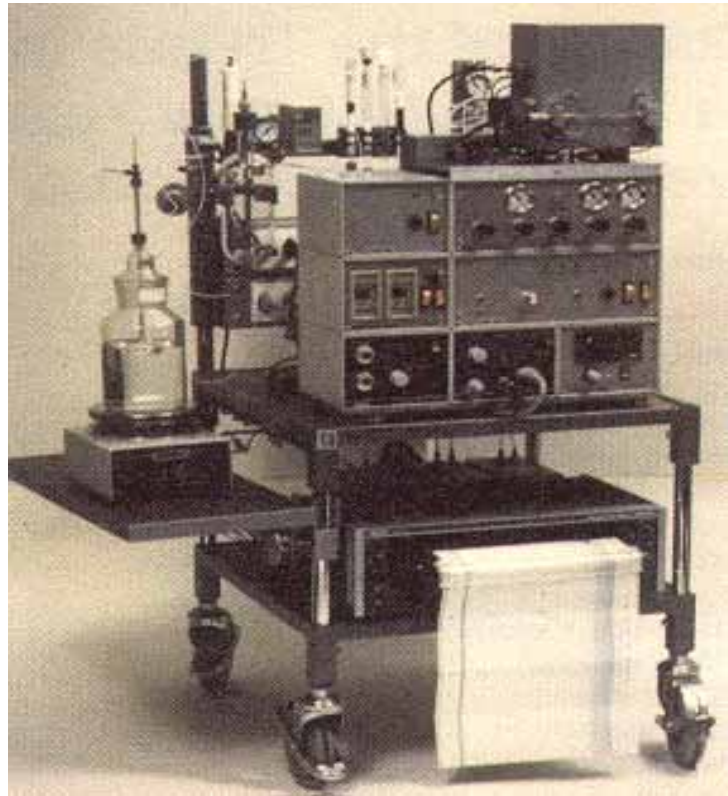
## The chemical lab as it used to be



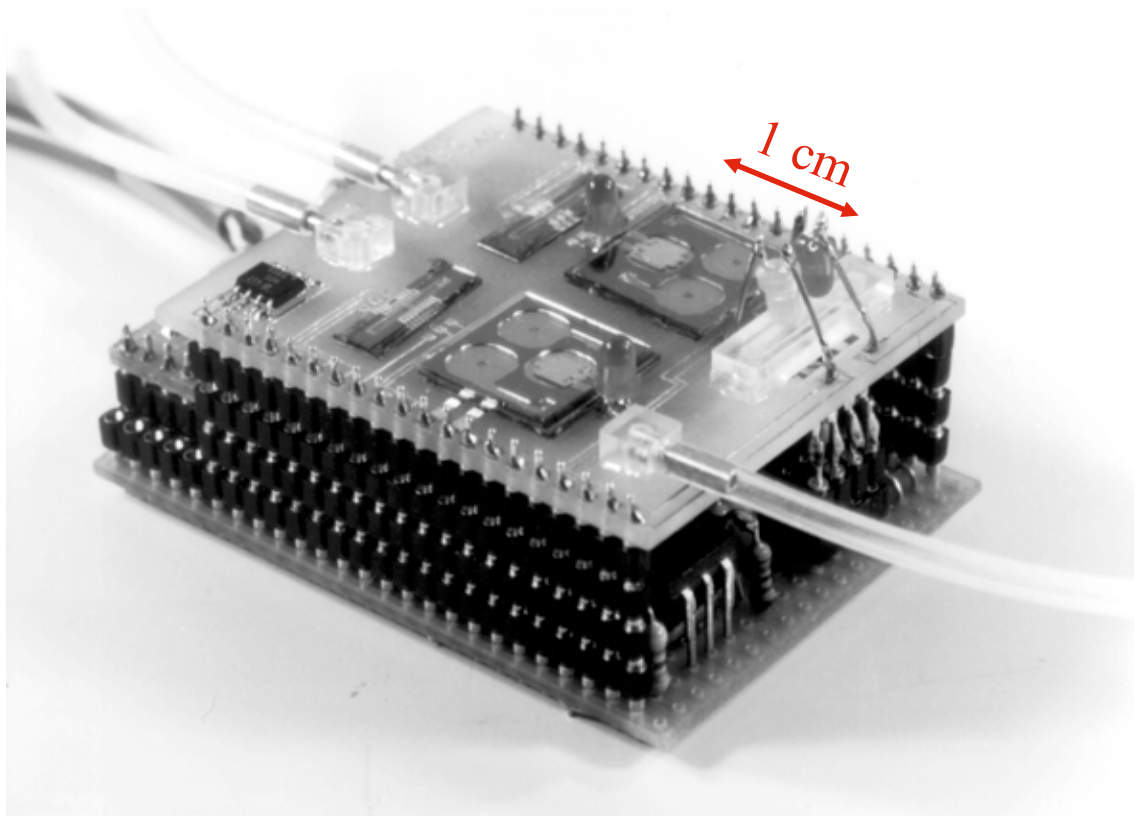
Slide courtesy of Steve Haswell, University of Hull, UK

Measuring  
on the spot  
in the 70's-80's:

hit the road  
with your  
lean & mean  
analysis machine



ca. 1985: microtechnology enters the game





# The 21st century

Slide by Caliper Technologies, Mountain View, CA



MESA+

the "Lab-on-a-Chip"

University of Twente  
The Netherlands



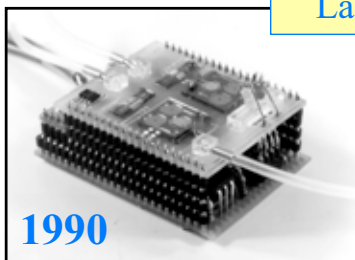
1970

Sample to lab



1980

Lab to sample



1990

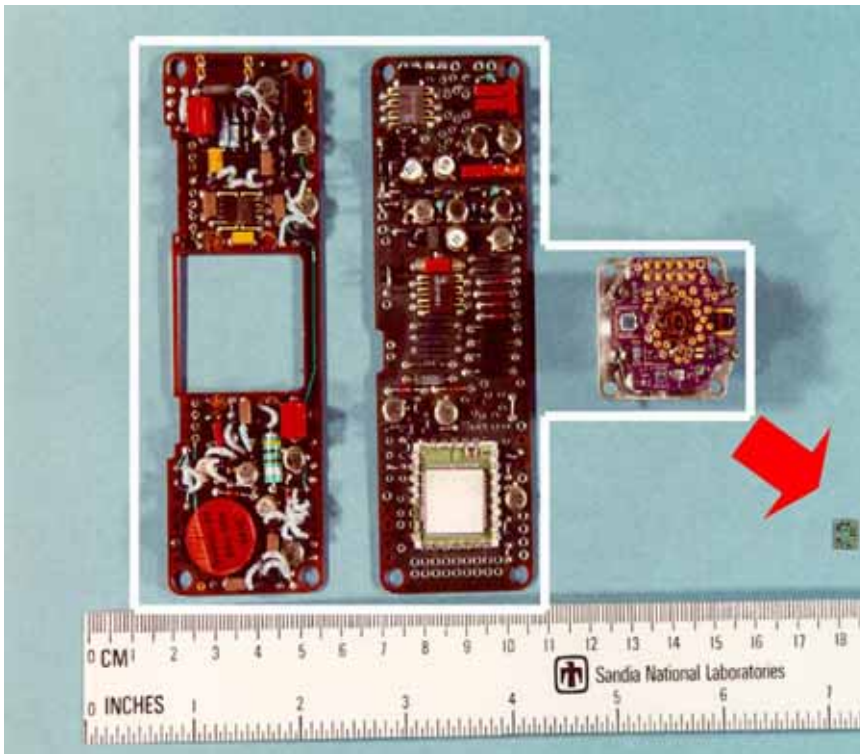
## The "Lab-on-a-Chip" concept



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# Benefits of integration

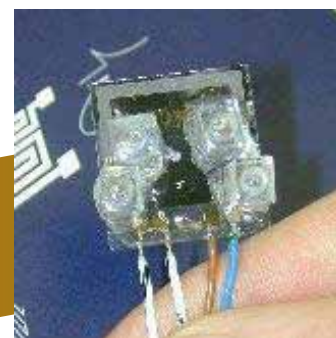
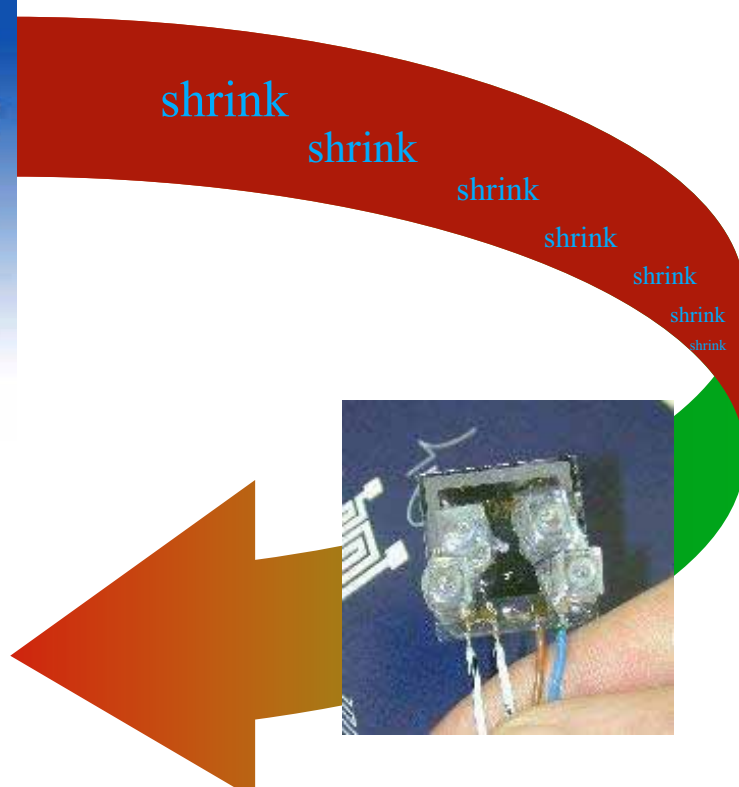
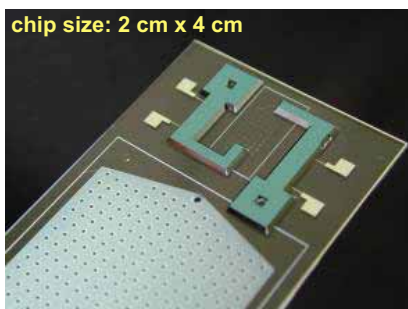


Comparison of an accelerometer built using traditional technologies and MEMS. The single chip is capable of performing the same function as the complex hand assembly pictured

# Miniaturised ammonia gas analyser



chip size: 2 cm x 4 cm

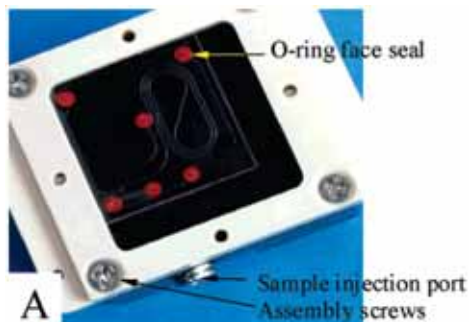




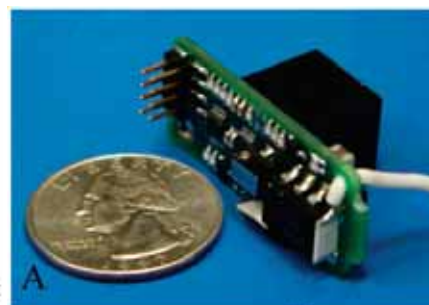
## Hand-held microanalytical instrument for chip-based electrophoretic separations of proteins



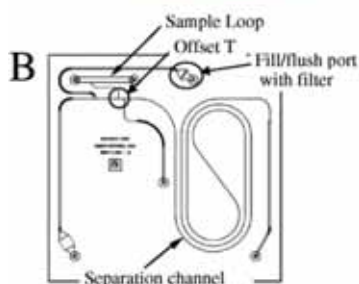
A



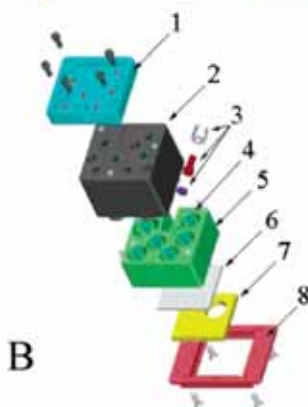
A



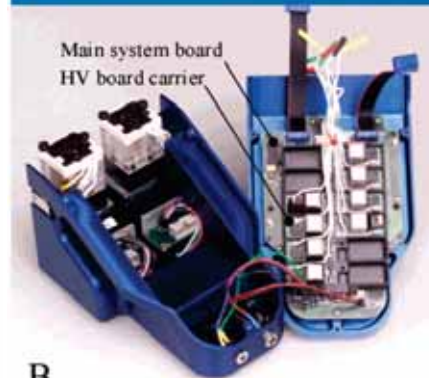
A



$\mu$ ChemLab instrument  
Bottom: 2 cm x 2 cm  
microseparation chip



B



B

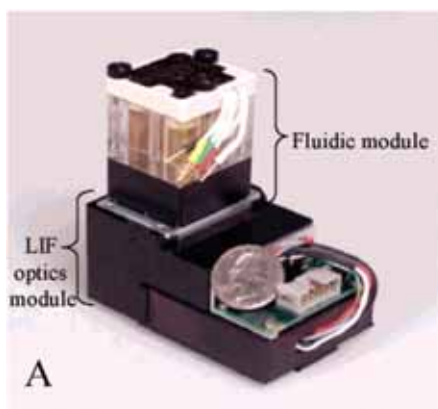
**MESA+**

Renzi e.a. Anal.Chem. 77, 435-441 (2005)

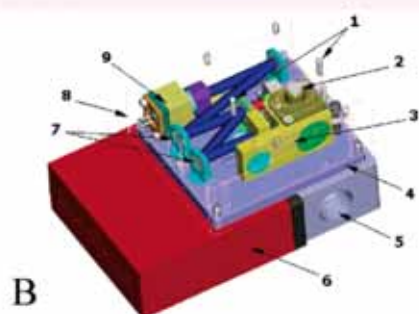
University of Twente  
The Netherlands

## Hand-held microanalytical instrument for chip-based electrophoretic separations of proteins

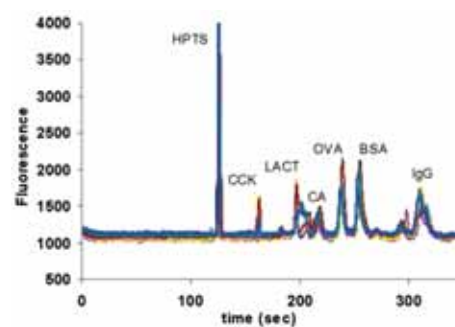
Epifluorescence Laser-Induced Fluorescence detection module connecting directly to the base of the fluidic module



A



B



Repeated measurement on protein samples

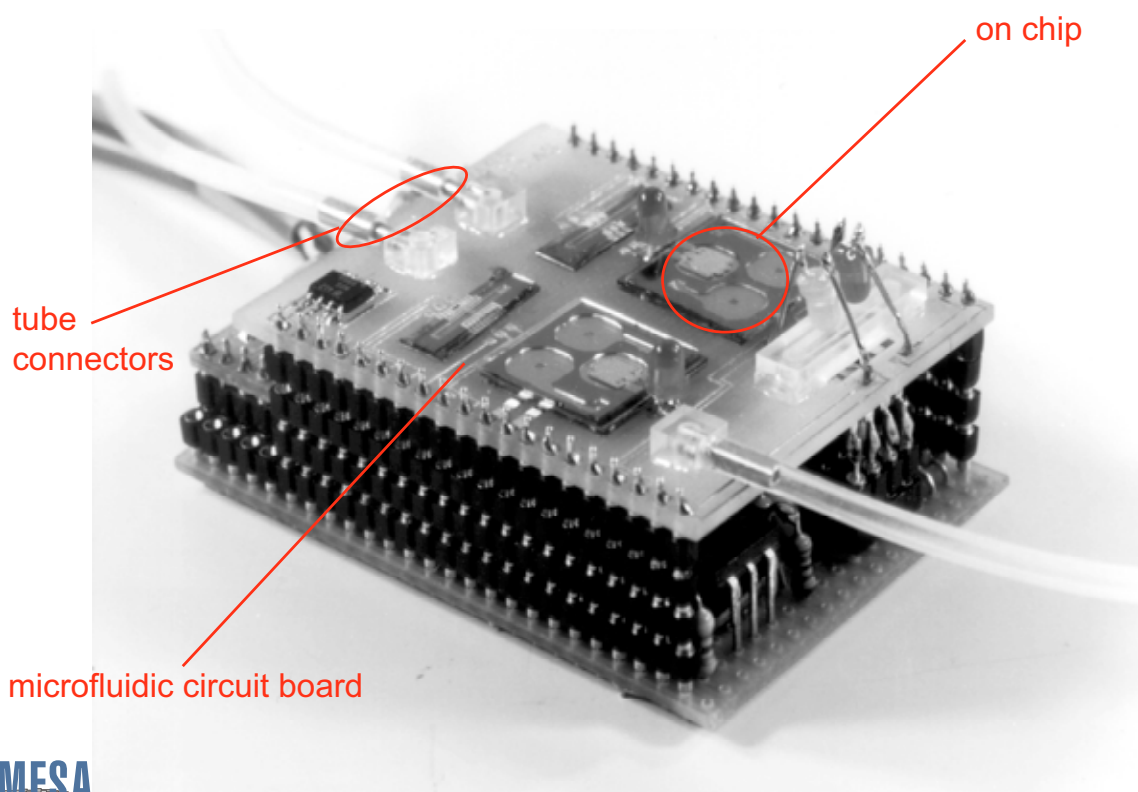
**MESA+**

Renzi e.a. Anal.Chem. 77, 435-441 (2005)

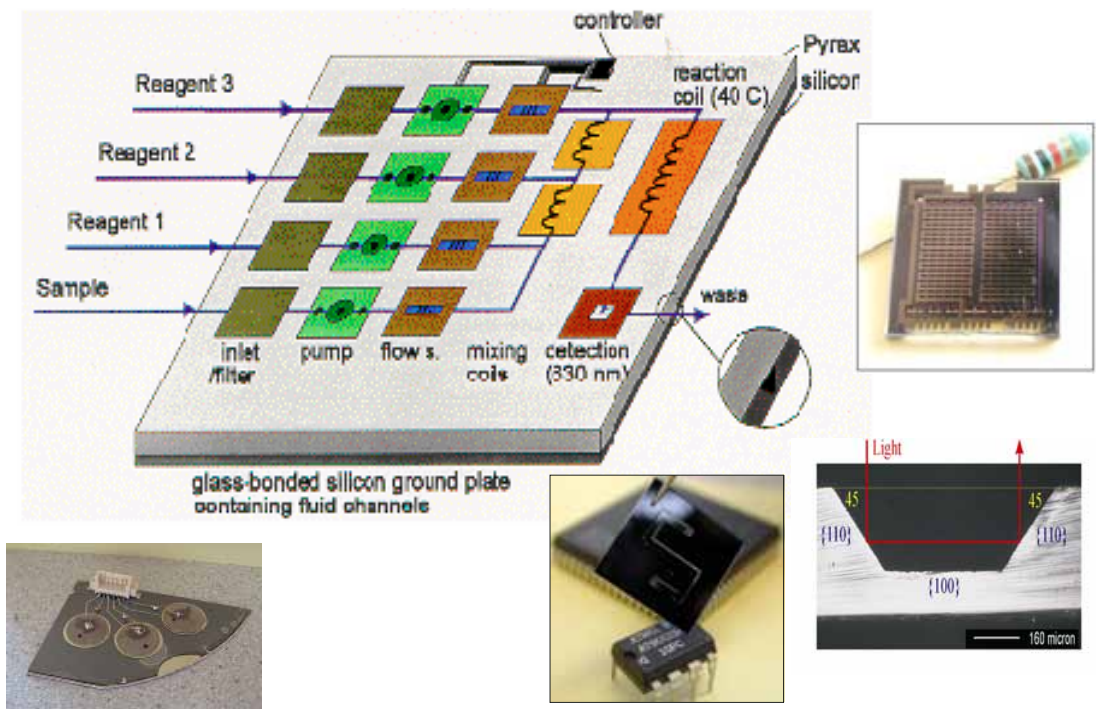
University of Twente  
The Netherlands

# Integration concepts

## Interconnection levels



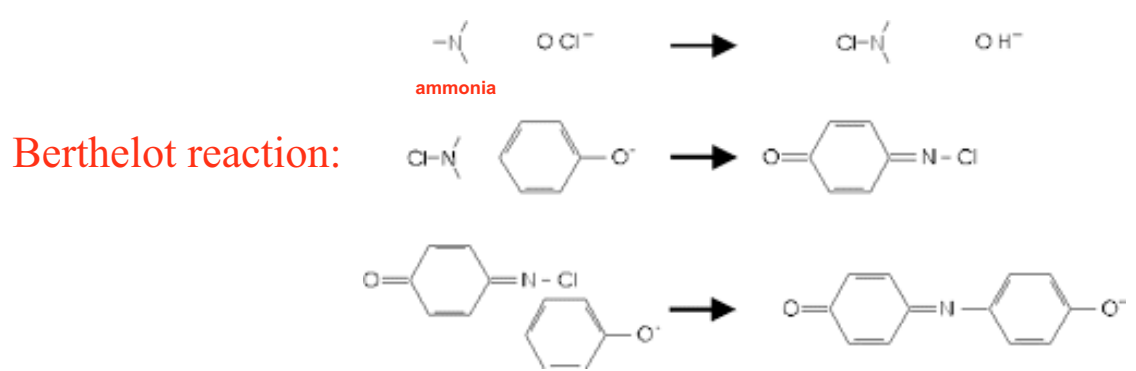
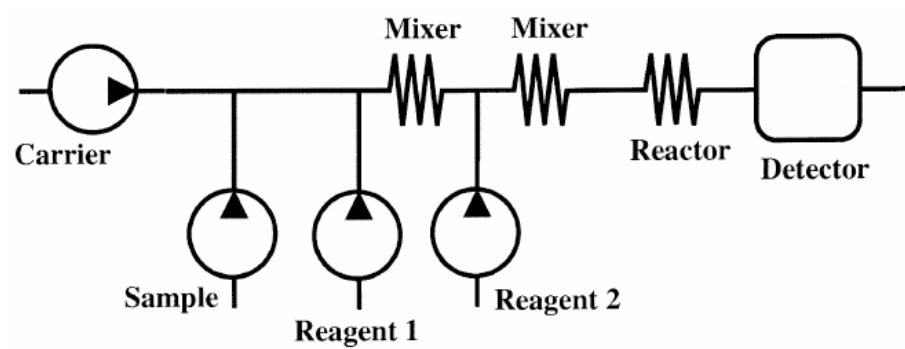
# "MAFIAS" $\mu$ Ammonia Flow Injection Analysis System



Tiggelaar e.a. Sens.Act.B. 92, 25-36 (2003)



# "MAFIAS" $\mu$ Ammonia Flow Injection Analysis System

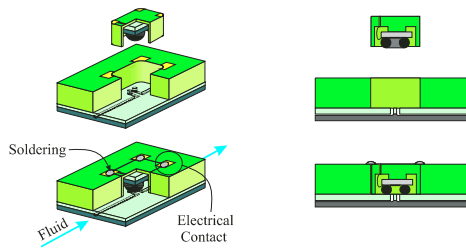
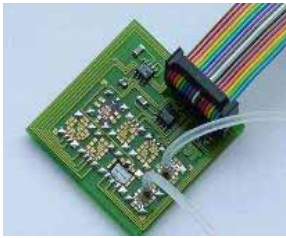
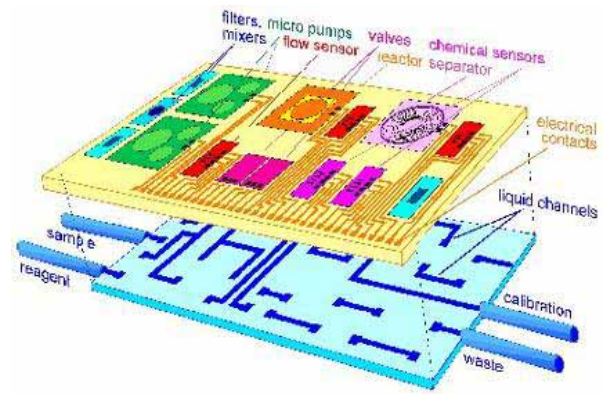
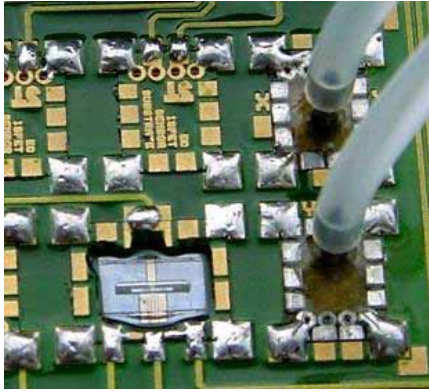


Tiggelaar e.a. Sens.Act.B. 92, 25-36 (2003)





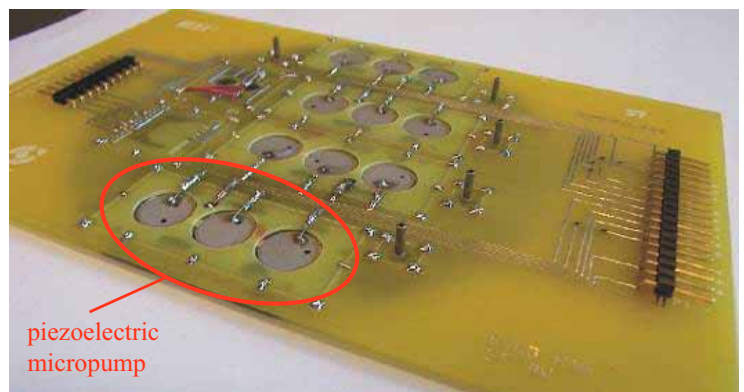
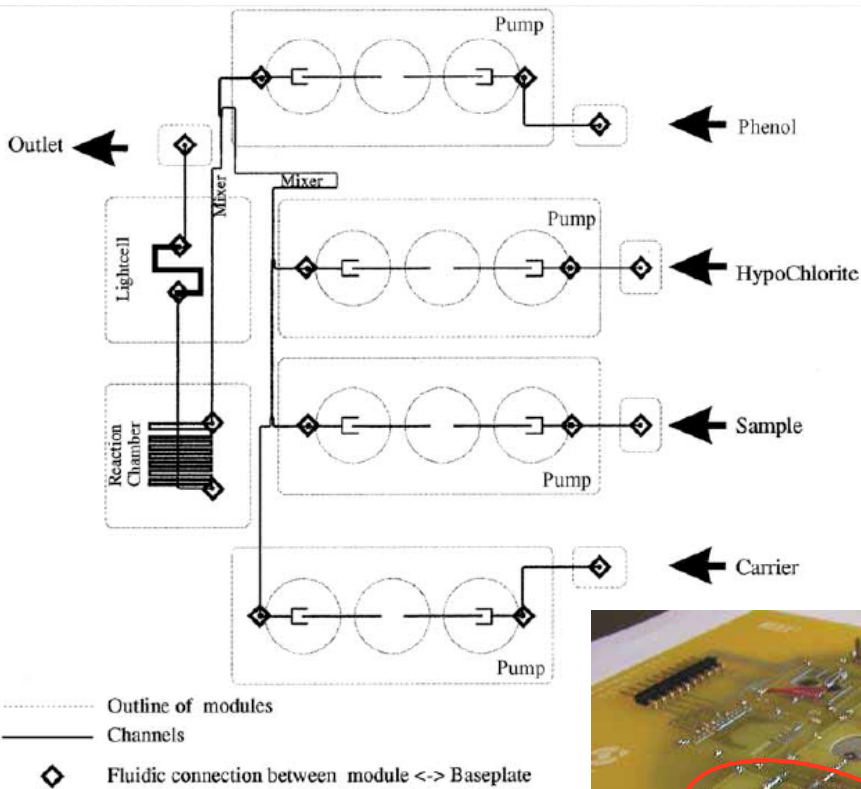
# Modular assembly



"MATAS" by Lionix B.V. (formerly 3T BV), Enschede, NL



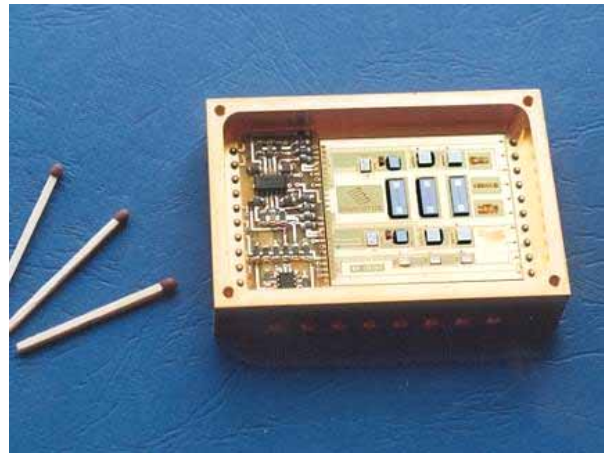
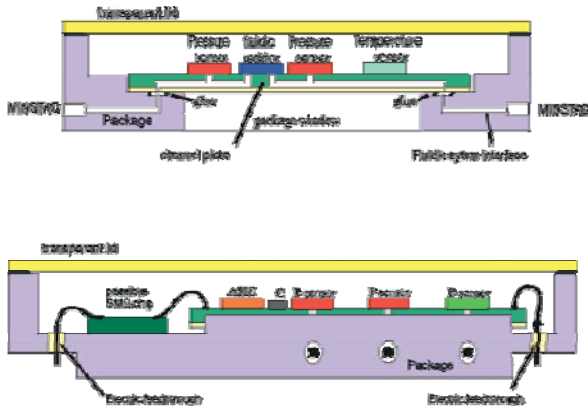
# Modular assembly



Tiggelaar e.a. Sens.Act.B. 92, 25-36 (2003)



# Microfluidic system circuit board



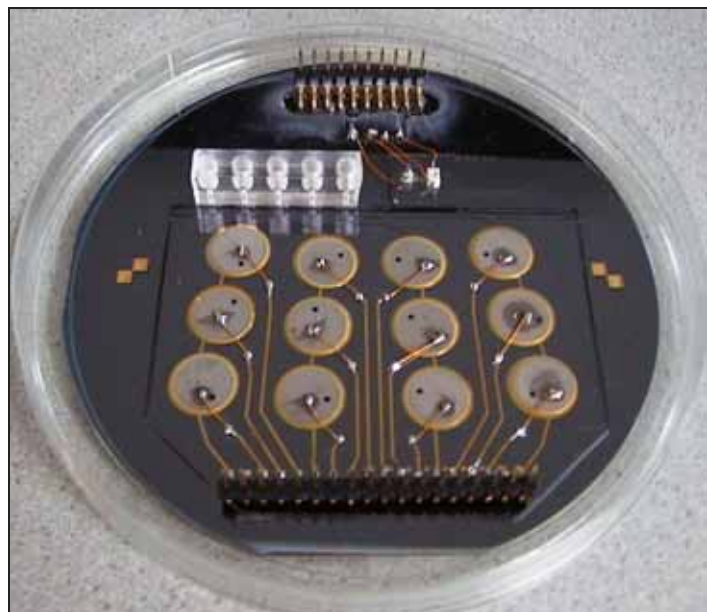
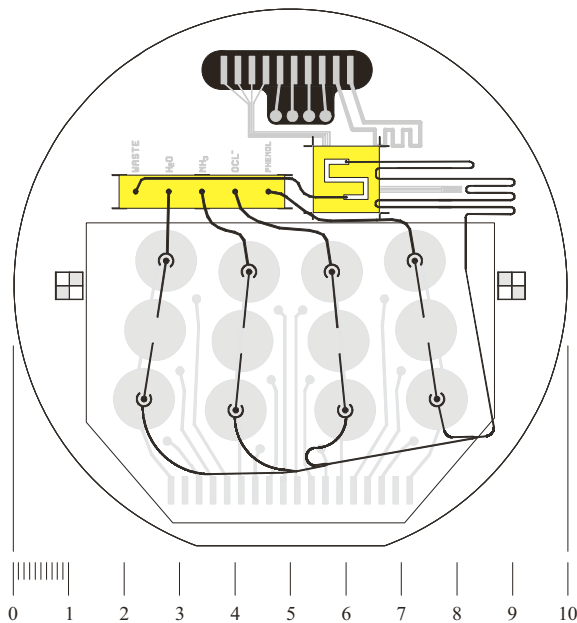
Design lay-out and photograph of a Micro Fluid System demonstrator with P-sensors, T-sensors, flow restrictors, flow sensors, in/outlets and electronics on a channel plate.



www.c2v.nl



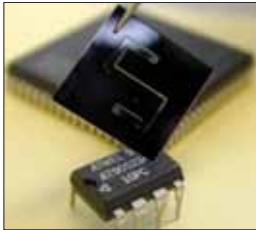
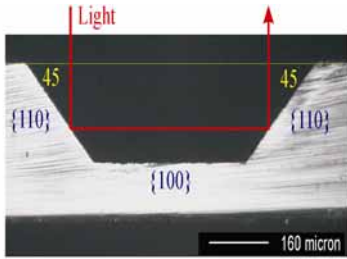
# "Monolithic" MAFIAS



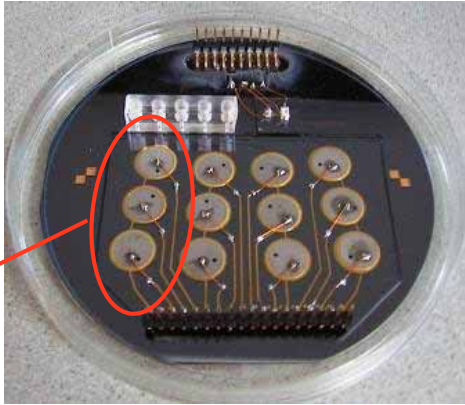
Tiggelaar e.a. Sens.Act.B. 92, 25-36 (2003)



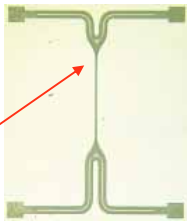
# Monolithic integration



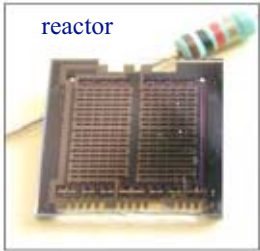
optical absorbance cell



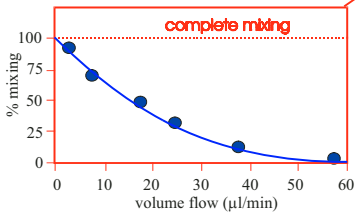
piezoelectric micropump



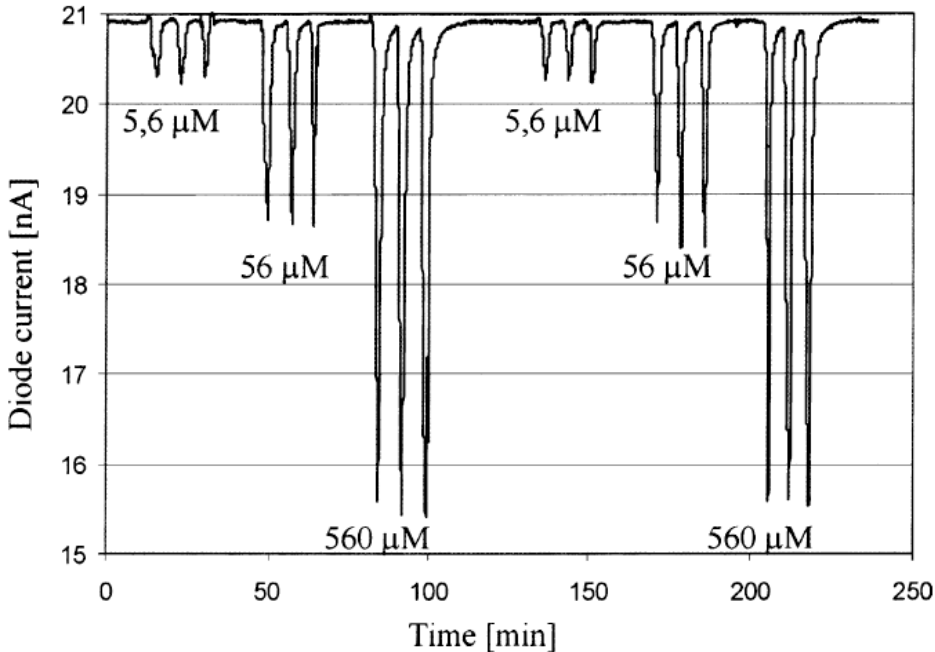
mixer



reactor

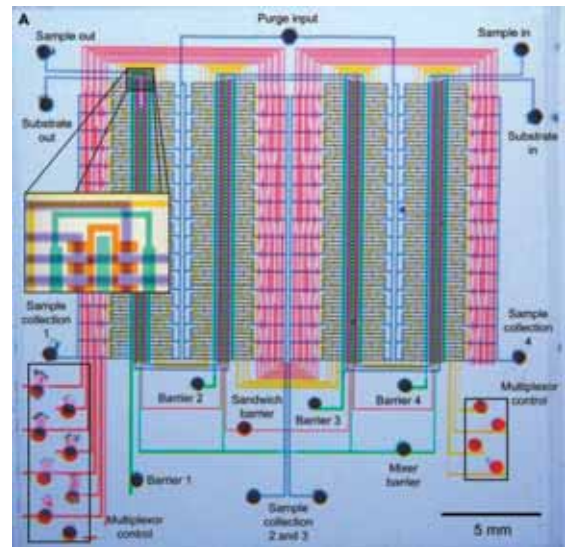
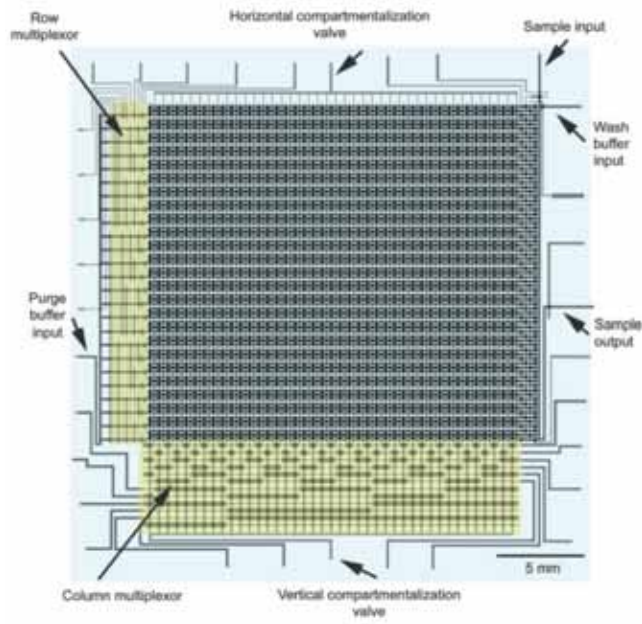


# Measurement example





# VLSI microfluidics?

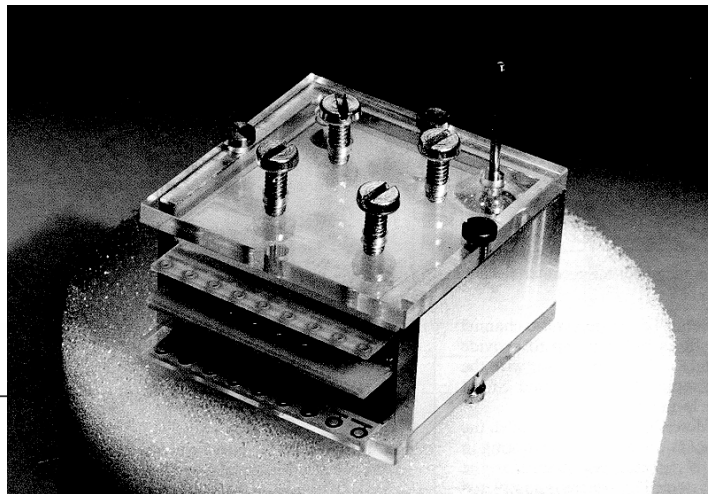
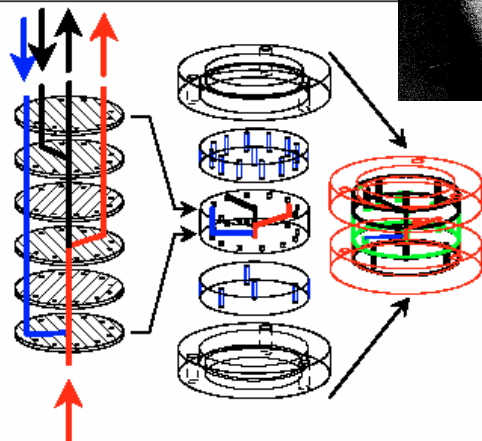


Thorsen e.a. Science 298, 580-584 (2002)



# Stacked concept

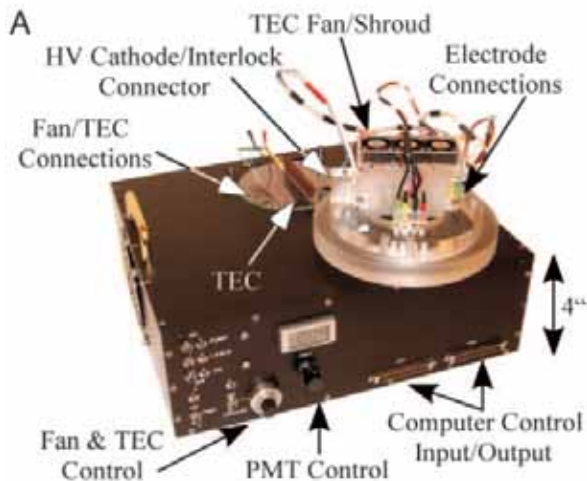
Stacked FIA systems: Concept



Ref: J.C. Fetting et al., *Sensors & Actuators B* 17 (1993), 19-25.

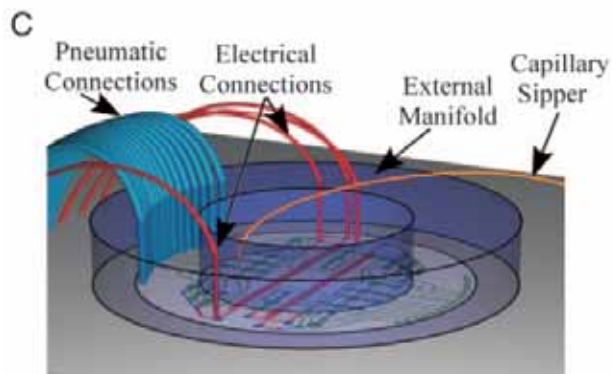
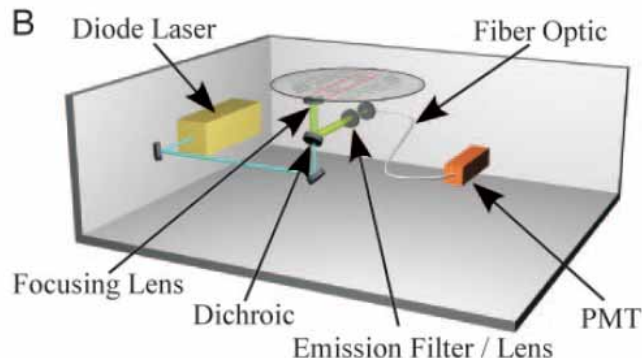


# Microsystem to Mars



TEC=thermoelectric cooler  
 PMT=photomultiplier tube  
 HV=high voltage

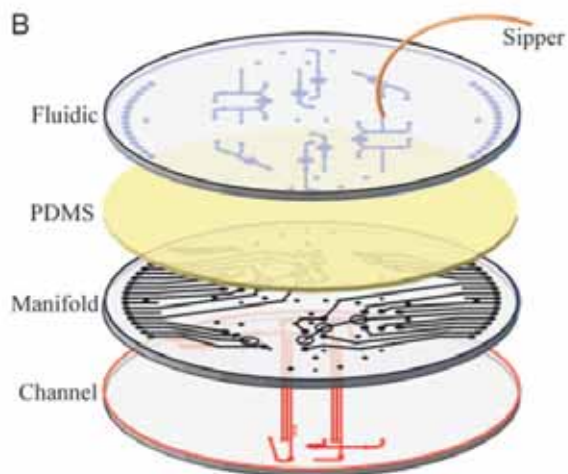
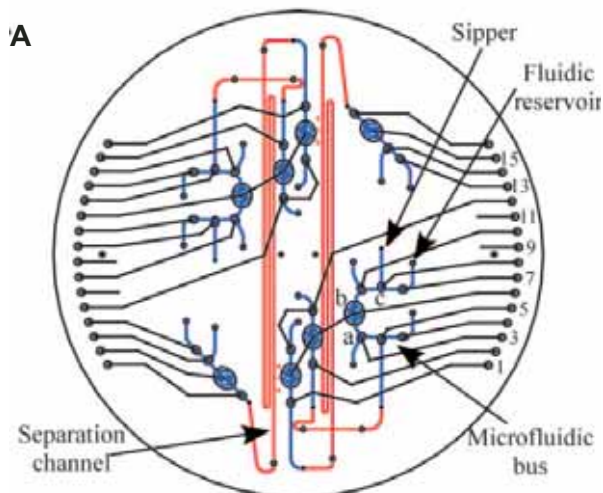
Instrument for amino acid analysis based on CE;  
 mass 11 kg, peak power consumption 15 W



Skelley e.a. PNAS 102, 1041-1046 (2005)



# Microsystem to Mars



(A) Top view showing registration of the CE channel (red), pneumatic manifold (black), and fluidic bus wafers (blue).

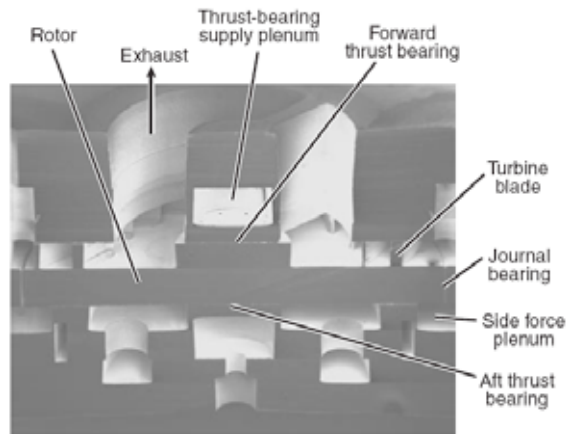
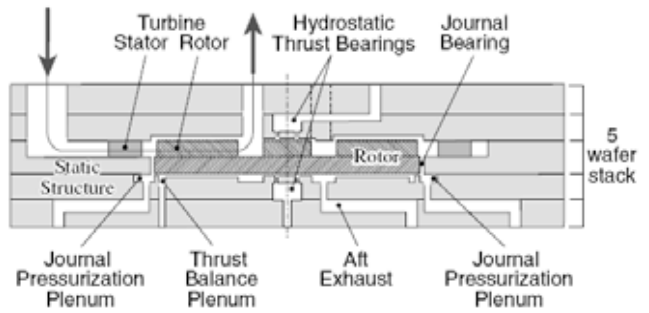
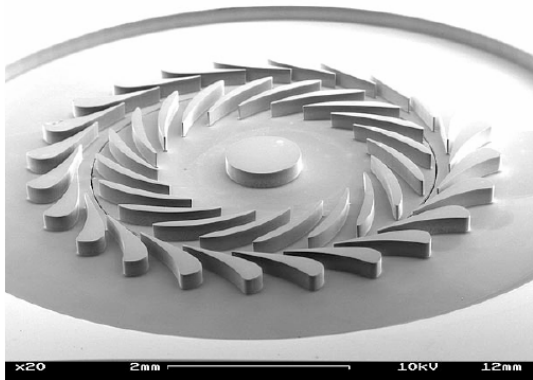
(B) Expanded view showing the microfabricated device assembly. The channel features are formed by thermally bonding the etched glass channel and manifold wafers. The manifold and fluidic wafers are held together by the PDMS membrane to create on-chip valves, pumps, and reservoirs



Skelley e.a. PNAS 102, 1041-1046 (2005)



# Stacking by wafer bonding



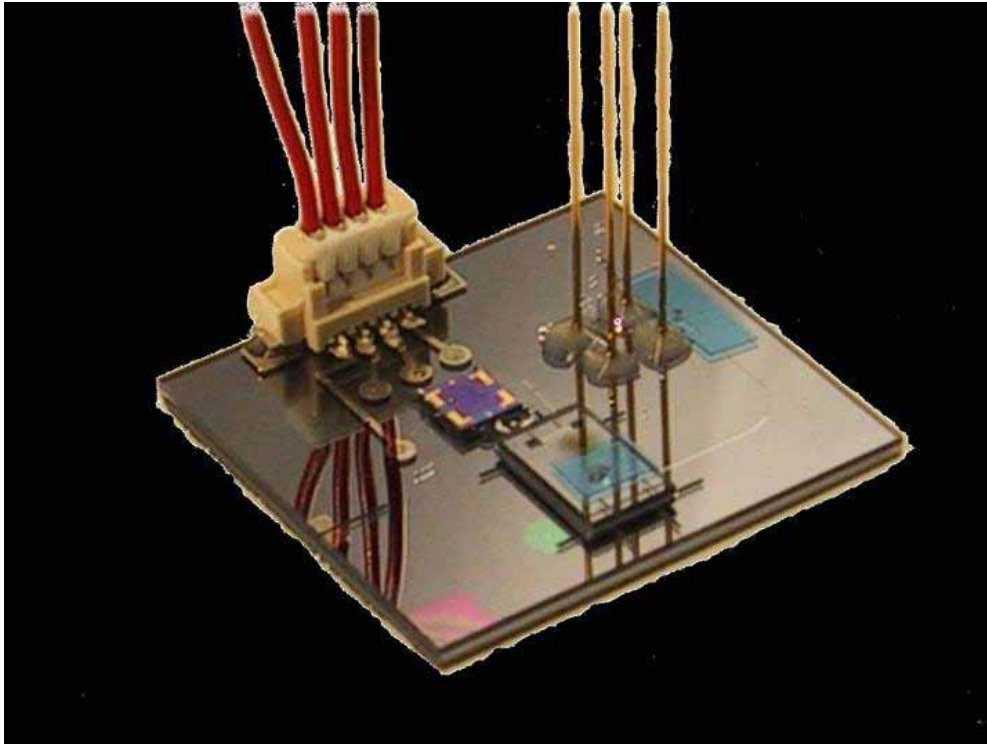
From review "Millimeter-scale, MEMS gas turbine engines", Epstein, Proc. ASME Turbo Expo 2003 Power for Land, Sea, and Air, June 16-19, 2003, Atlanta, Georgia, USA



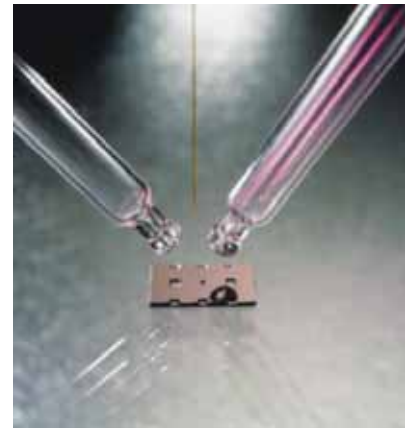
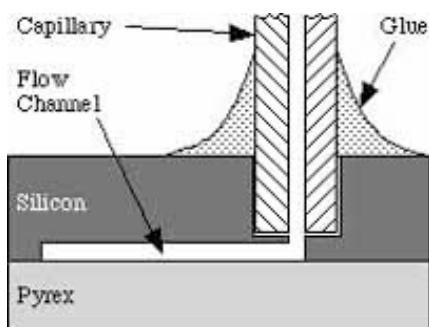
## "World-to-chip" Microfluidic interfacing



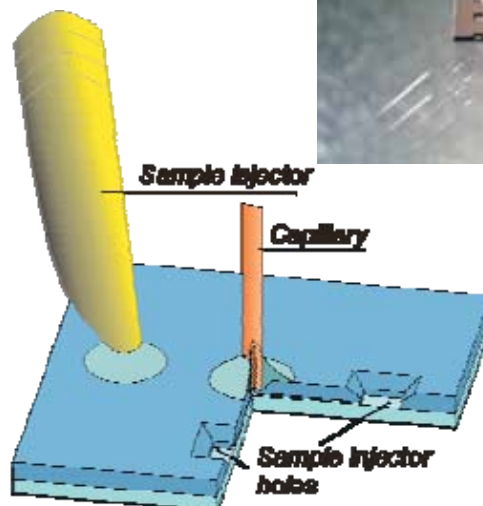
# Many possibilities...



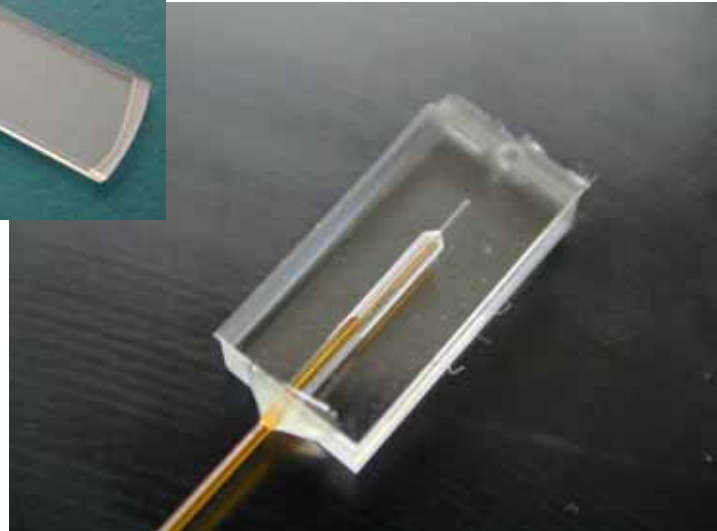
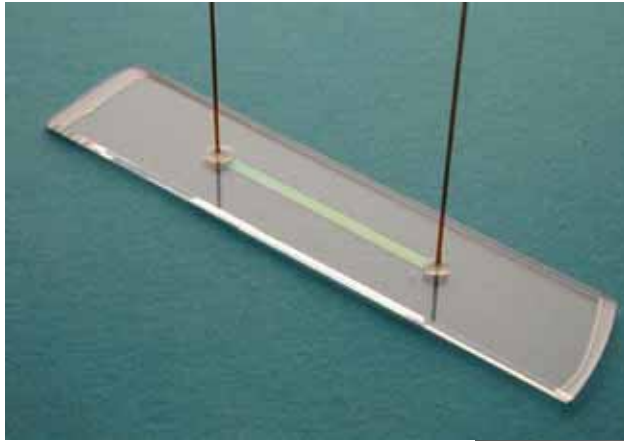
## Glued capillary connector



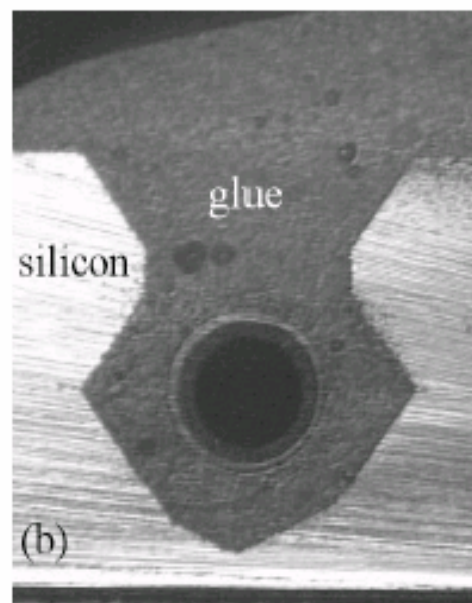
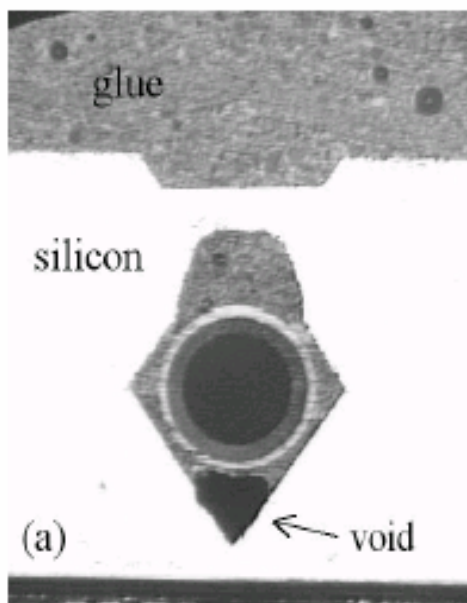
Low dead volume  
Electrically insulated  
Used for (correlation) capillary zone electrophoresis



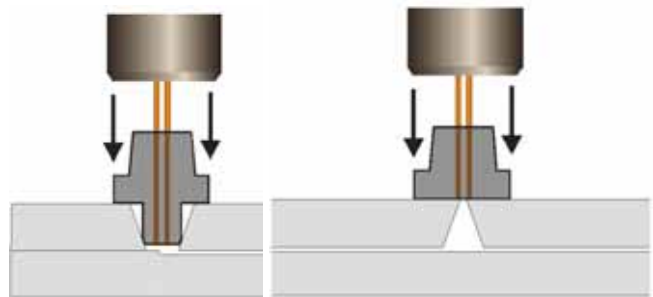
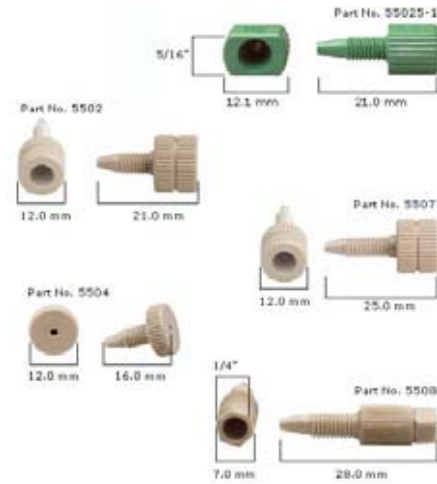
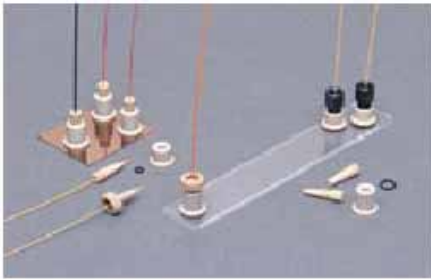
## More glued capillaries



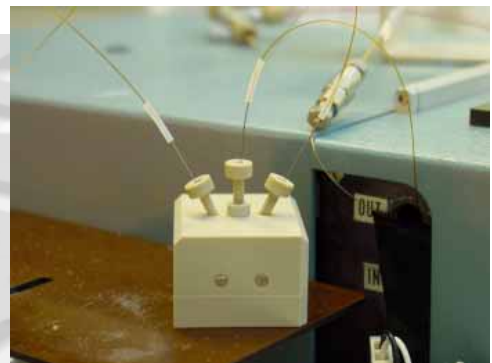
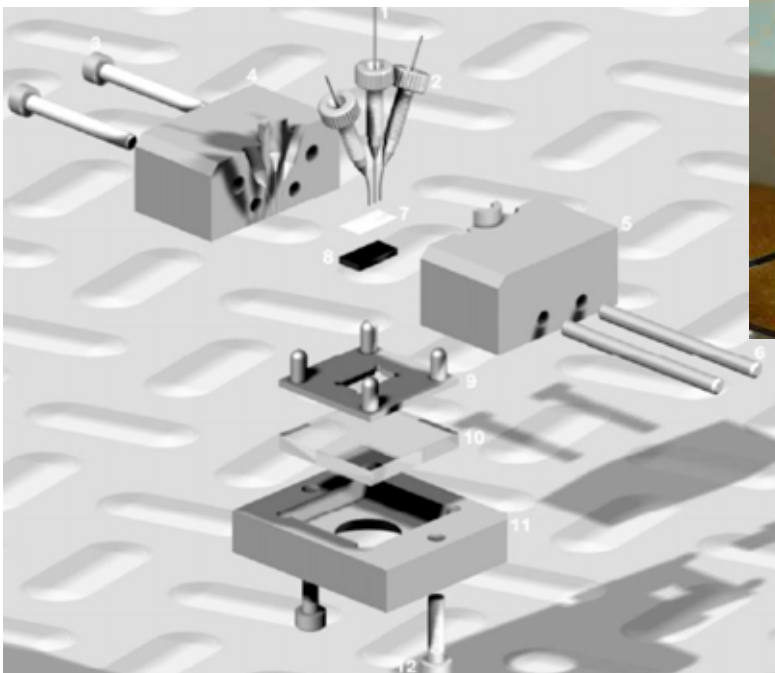
## Glued capillary-to-chip connection



# Nanoports (UpChurch)

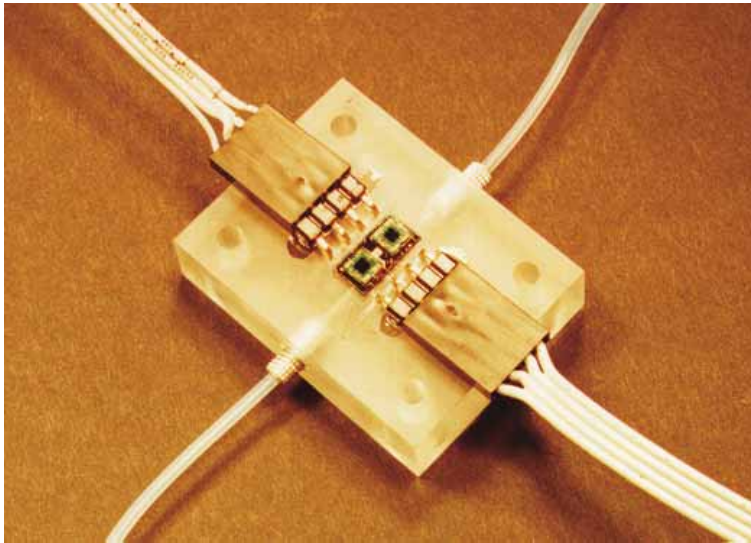


# Chipholders using commercial connectors





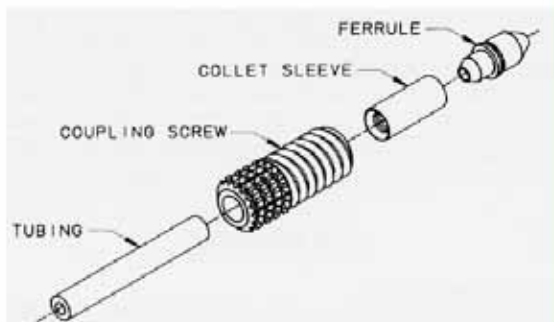
# Connections in PMMA block



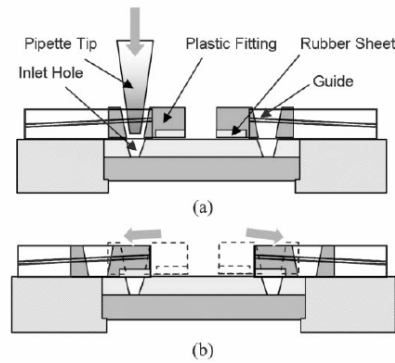
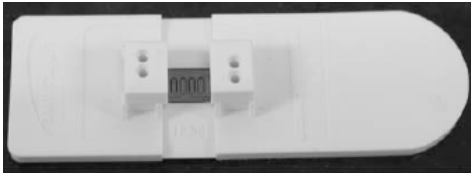
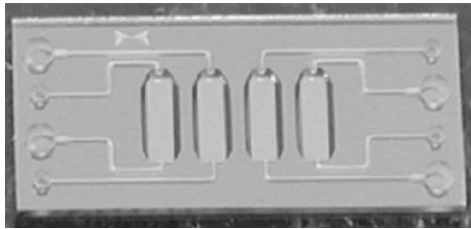
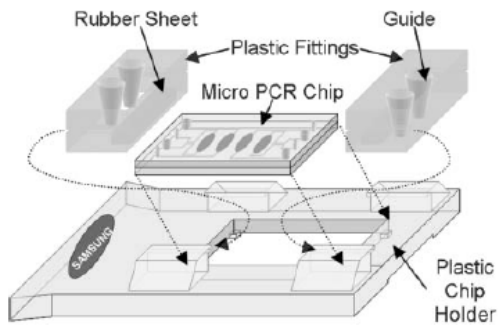
## LEE MINSTAC system

- The company Lee provides various connection and tubing systems
  - Easily applicable to microfluidic systems if joints fitting to 0.8 mm MINSTAC 062 System are provided

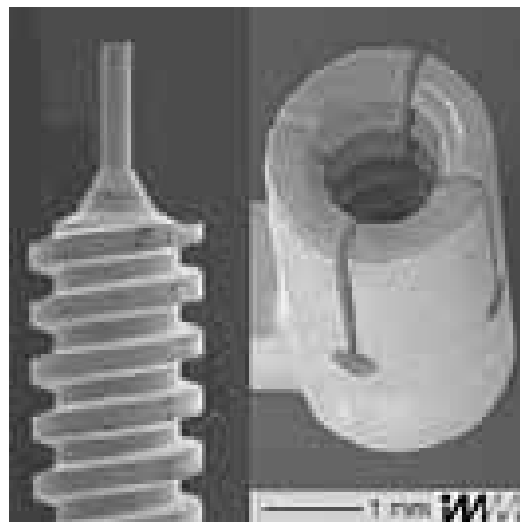
### MINSTAC 062 System



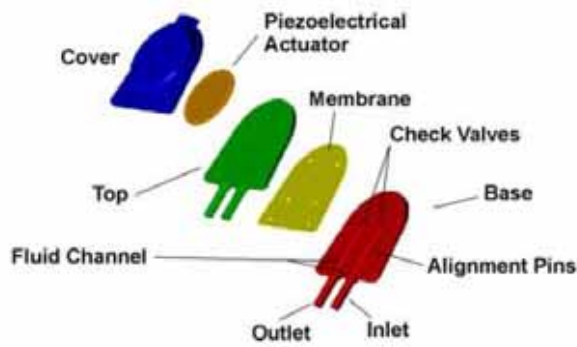
# PCR chip holders



# Micro injection molded connection



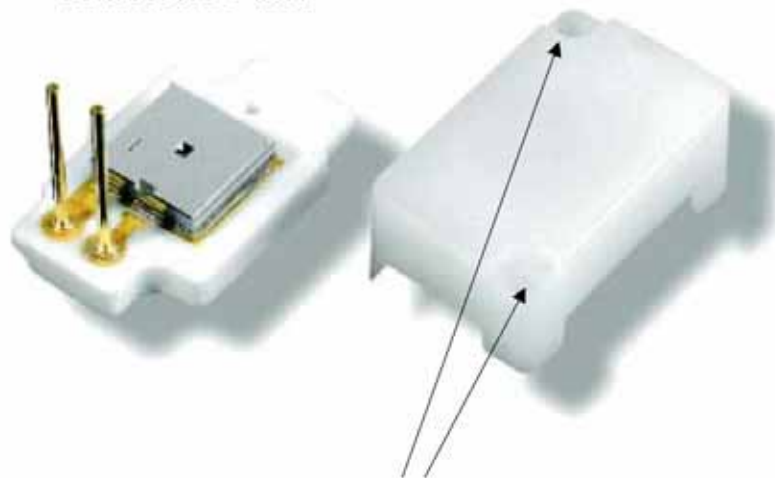
# Hermetic plastic package



# Solder connections to ceramics



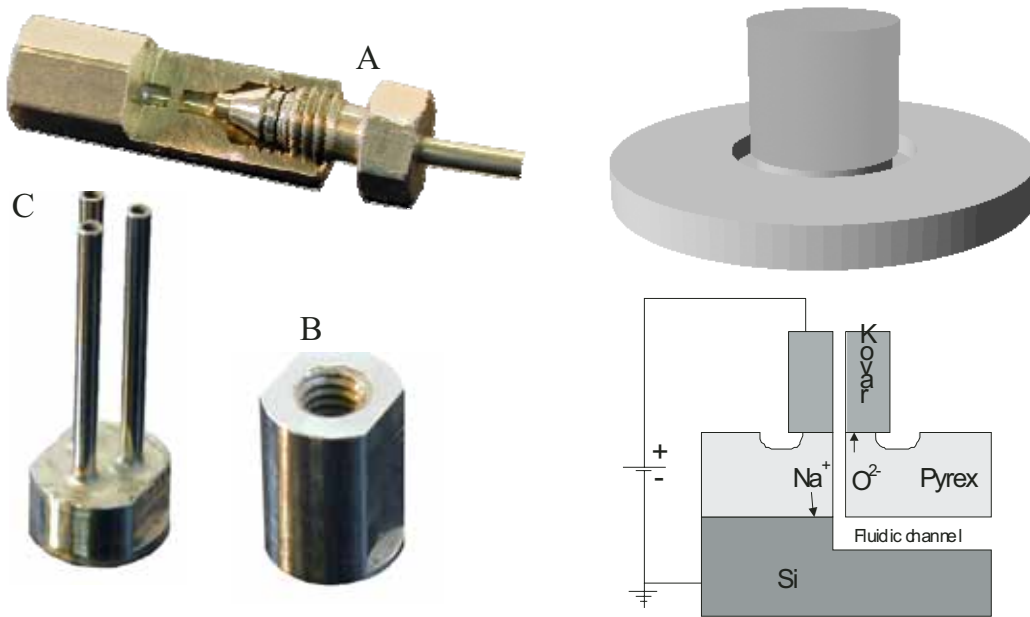
Pneumatic valve: MegaMic  
Source: HSG-IMIT



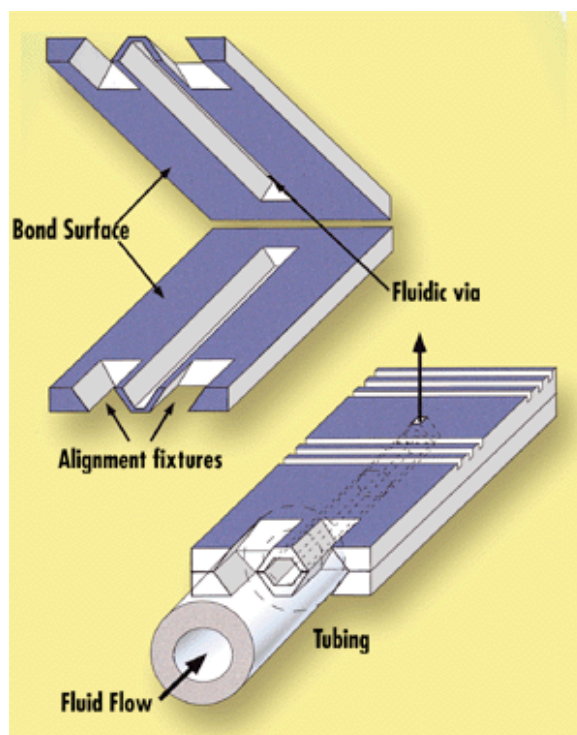
Flange joints by screw connection through housing, pressure resistant up to 20 bar



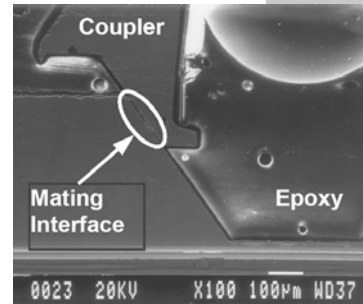
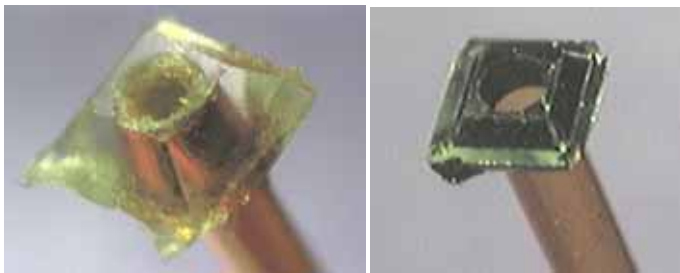
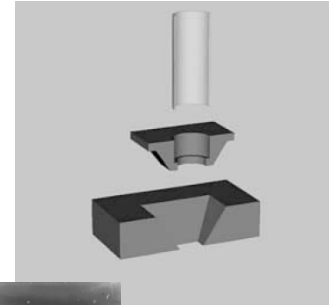
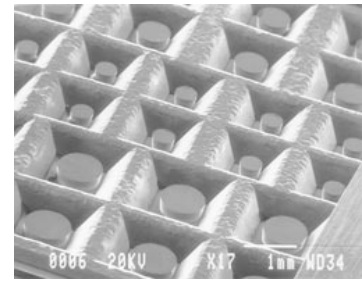
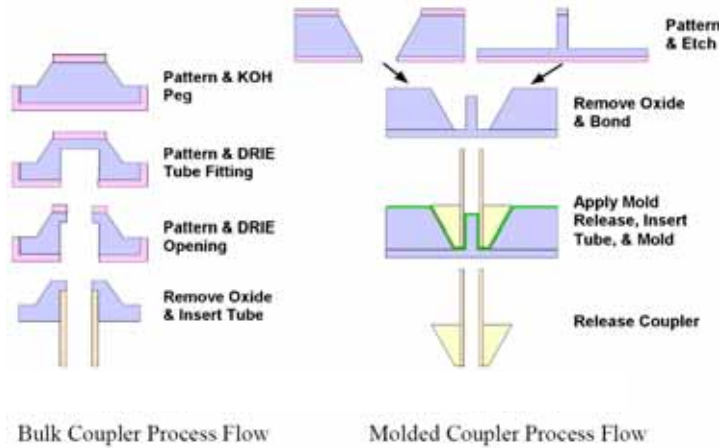
## Local (anodic) bonding of Kovar to Pyrex



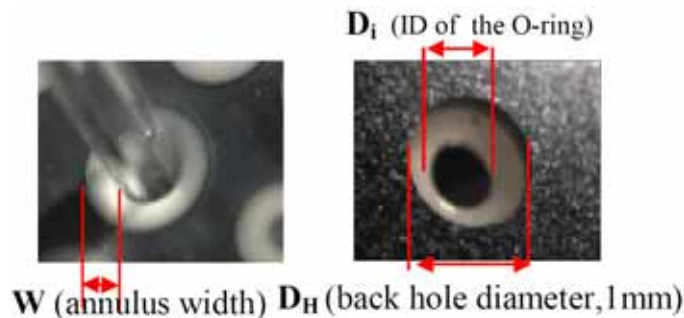
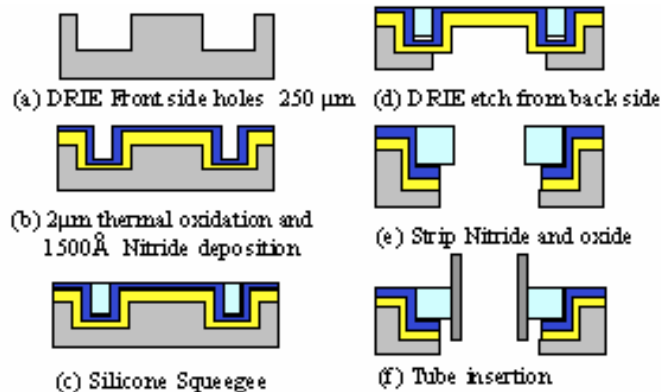
## Silicon bulk-micromachined connection



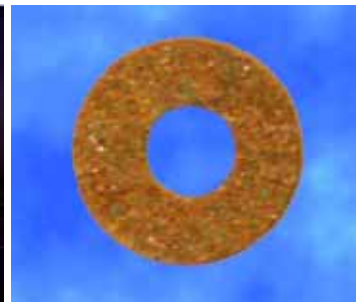
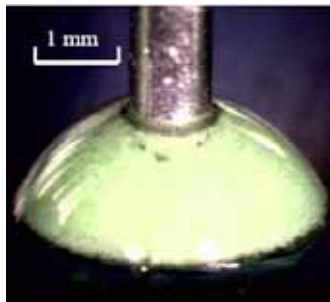
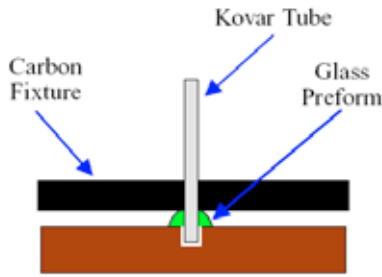
# Micromachined fluidic couplers



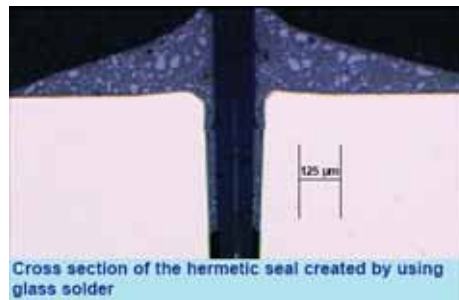
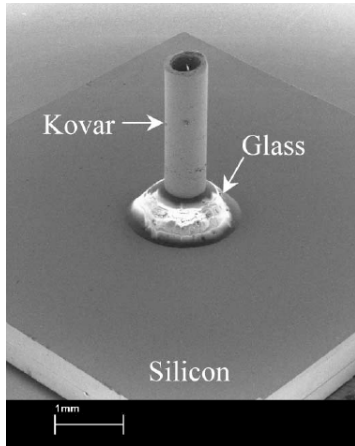
# Micromachined Rubber O-ring Micro-Fluidic Couplers



# Glass preform seal for high temp<sup>s</sup>. (~500 °C)



Increasing T from 200 - 400 °C



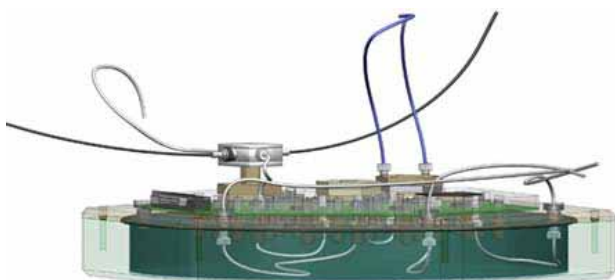
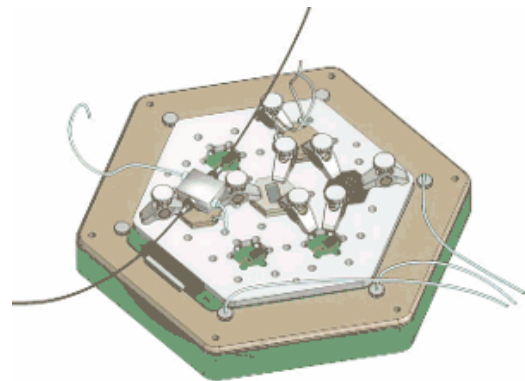
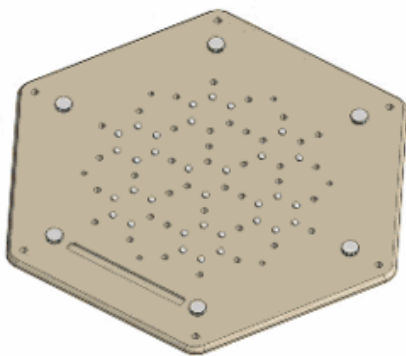
Cross section of the hermetic seal created by using glass solder



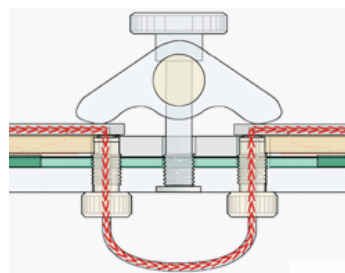
Peles e.a. J.MEMS 13, 31-40 (2004) & www.ozoptics.com



# Complete "plug-and-play" microfluidics



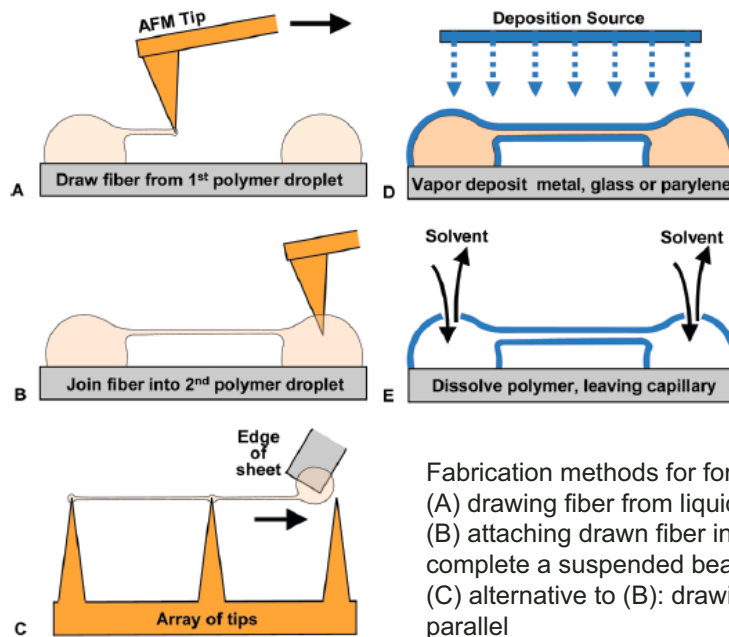
temperature control



Fraunhofer "FAMOS" system; www.microreaction-technology.info

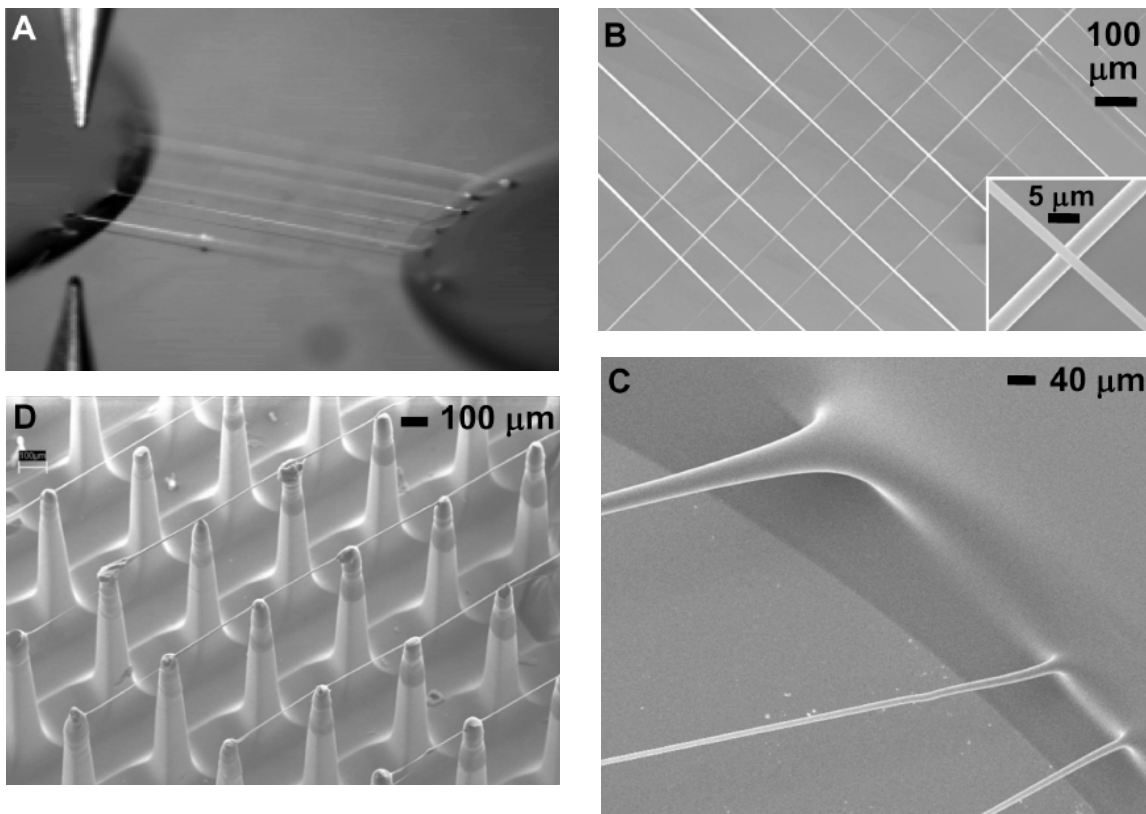


# Sci-Fi: nanofluidic interconnections



Fabrication methods for forming and using polymer fibers.  
 (A) drawing fiber from liquid polymer droplet  
 (B) attaching drawn fiber into second droplet to complete a suspended beam  
 (C) alternative to (B): drawing multiple suspended fibers in parallel  
 (D) overcoating polymer network  
 (E) dissolution of the polymer to produce a suspended capillary network

# Nanofluidic interconnections



# Nanofluidic interconnections

