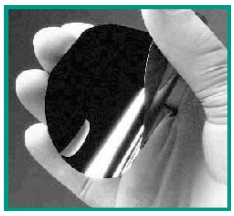
MEMS@KTH

Göran Stemme
Microsystem Technology Lab
School of Electrical Engineering
Royal Institute of Technology

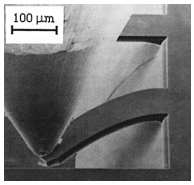
Why silicon MEMS?

- Small
- Identical
- Large volumes (low cost per unit)

Silicon is a strong material...

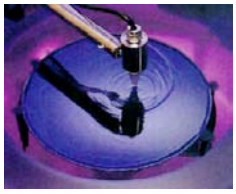


10 µm thick silicon wafer
(Virginia Semiconductor Inc.)



SEM-picture of the deflection of a silicon cantilever beam (Material Science, Uppsala University).

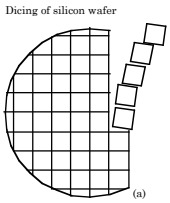
Photolithography

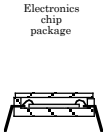


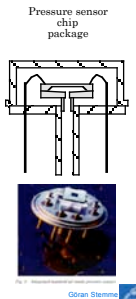
Photoresist spin-on process

From Madou Talks

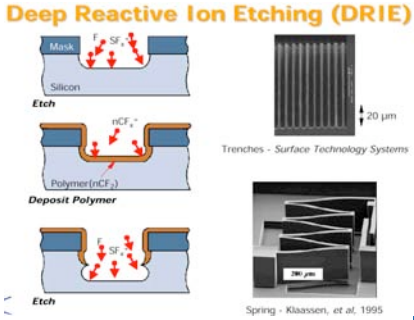
Dicing and packaging





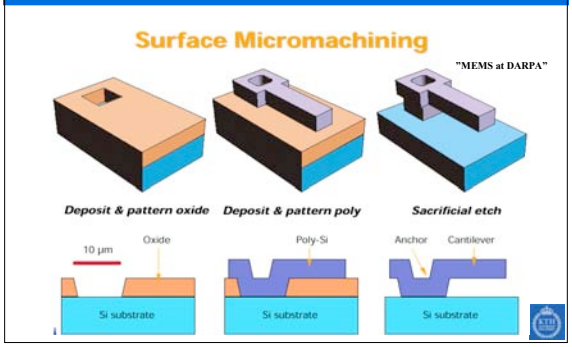


Micromachining



"MEMS at DARPA"

Micromachining

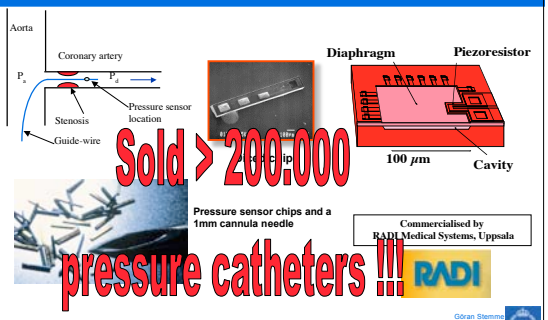


Our Main Research Areas

- MED-MEMS
- BIO-MEMS
- OPTO-MEMS
- RF-MEMS

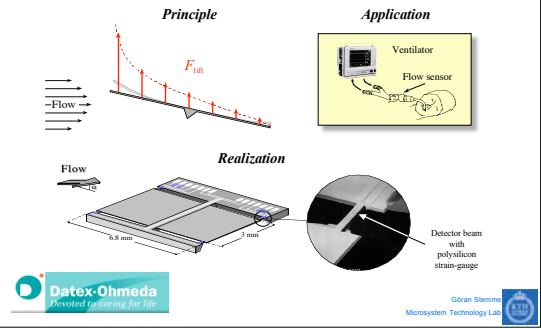
"MED-MEMS"

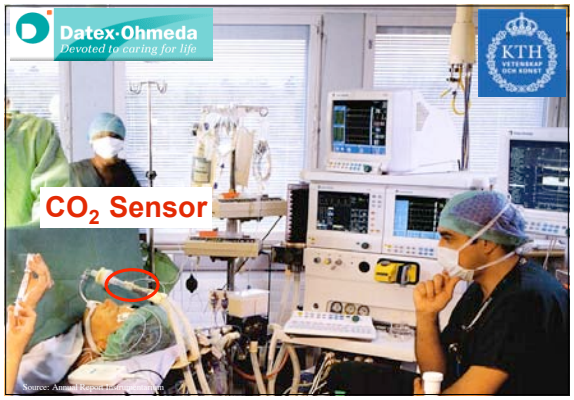
Ultraminiaturized Blood Pressure Sensor



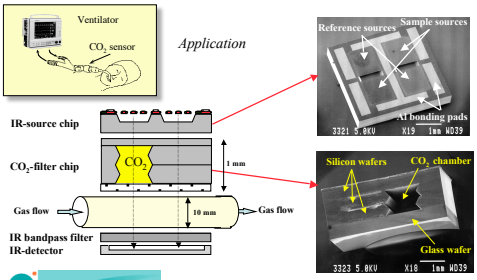
Sold > 200.000 pressure catheters !!!

A Lift Force Gas Flow Sensor

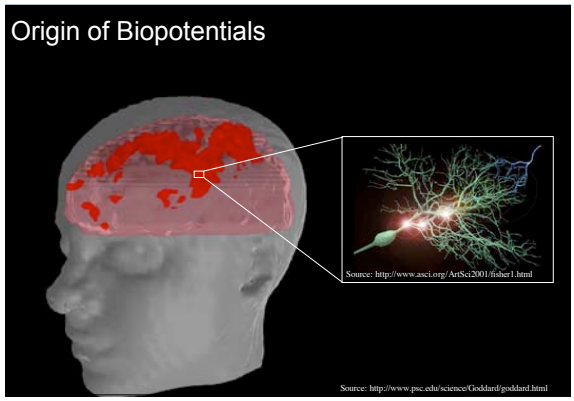




An integrated IR gas analysis system

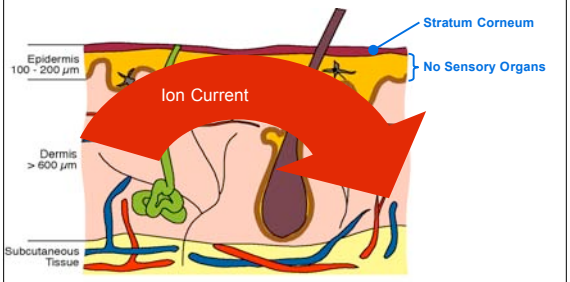


Origin of Biopotentials



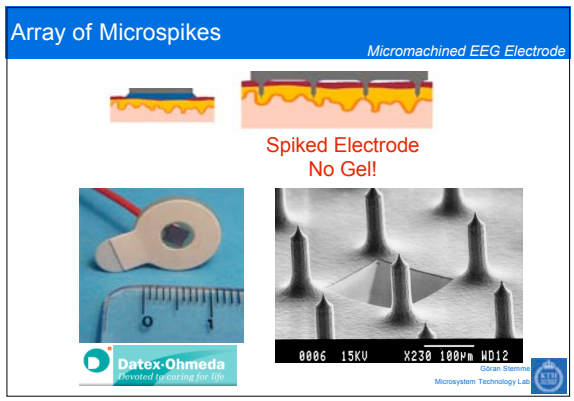
The Outer Skin - An Electrical Insulator

Micromachined EEG Electrode

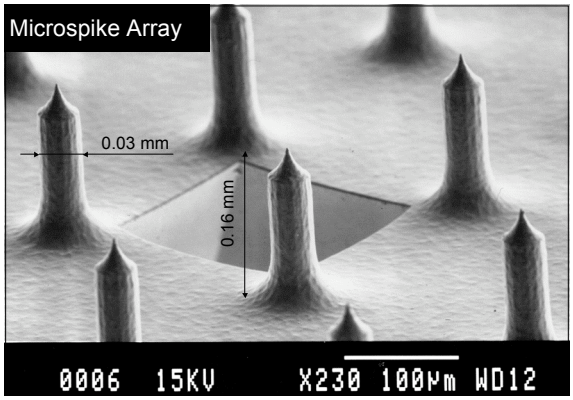


Array of Microspikes

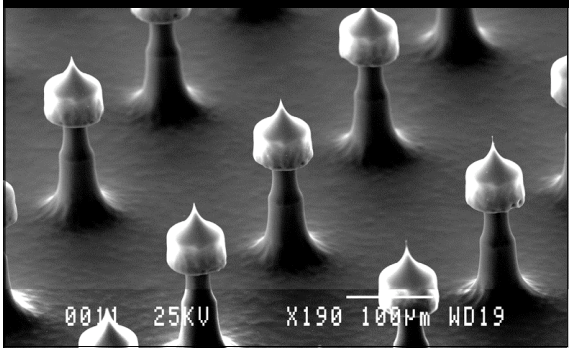
Micromachined EEG Electrode



Microspike Array

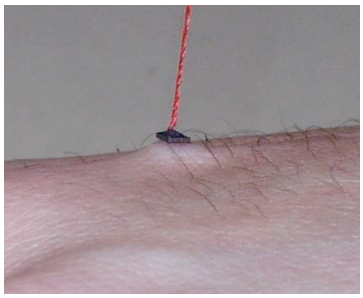


Barbed Spikes for Chip Skin Attachment



Attachment Performance

Micromachined EEG Electrode



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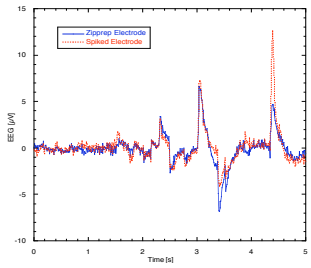
EEG Recording

Micromachined EEG Electrode



Similar Signals

Measured with
Datex-Ohmeda S/5 Monitor

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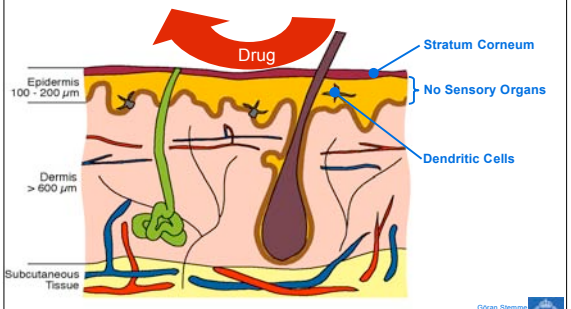
Microsystem Technology Lab

The Outer Skin - A Biochemical Barrier

Transdermal Liquid Delivery



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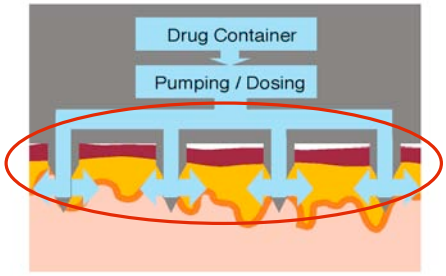
Standard Hypodermic Needles

Transdermal Liquid Delivery

- Painful
- Intradermal delivery difficult

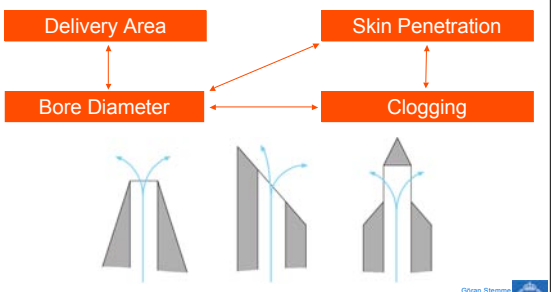
Transdermal Drug Delivery System

Microneedles

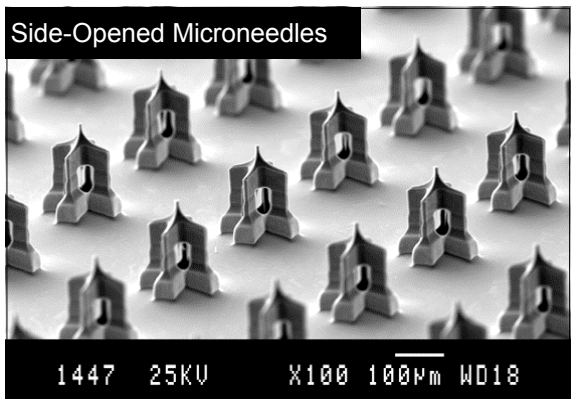


Hollow Microneedle Design Issues

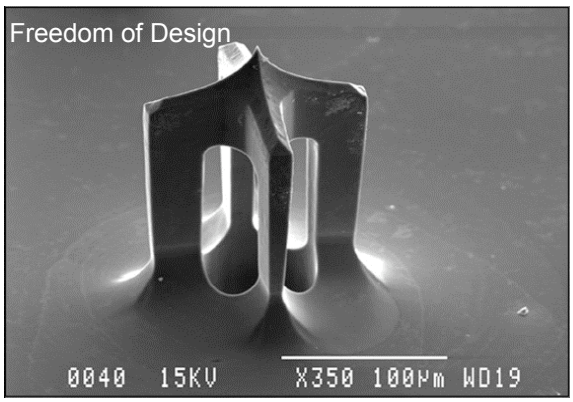
Microneedles



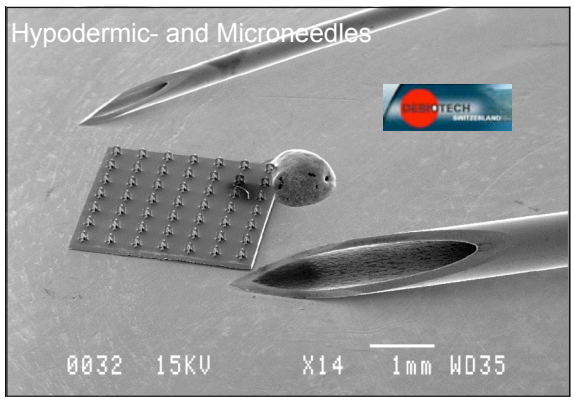
Side-Opened Microneedles



Freedom of Design

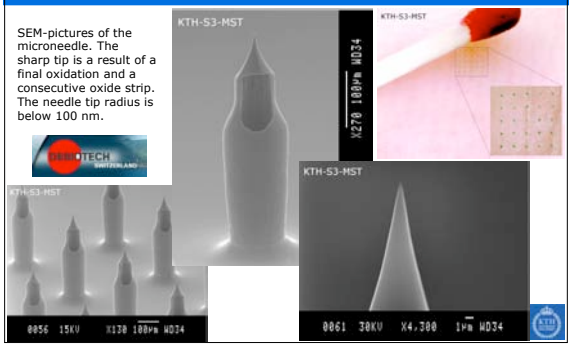


Hypodermic- and Microneedles

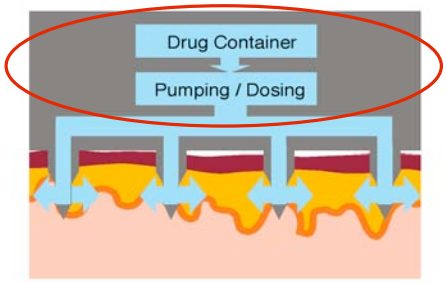


Nano-Sharp Hollow Microneedles

SEM-pictures of the microneedle. The sharp tip is a result of a final oxidation and a consecutive oxide strip. The needle tip radius is below 100 nm.



Transdermal Drug Delivery System



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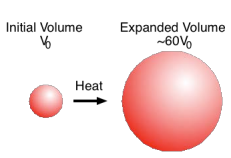
Microsystem Technology Lab

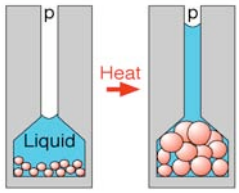
Expandable Microspheres

Dosing and Actuation Unit

Principle



Application



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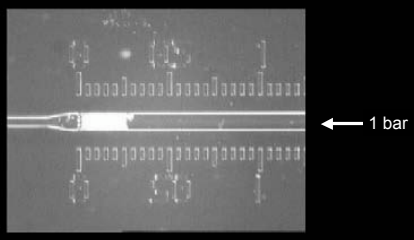
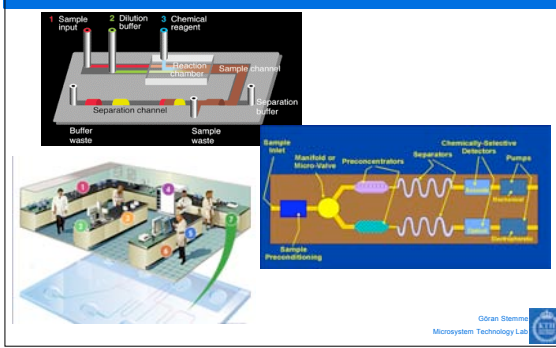
Test Result



”BIO-MEMS”

“Lab-on-a-Chip”



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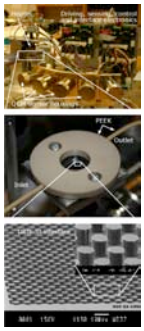
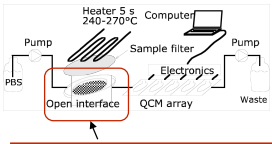
Microsystem Technology Lab

Biosensor System for Drugs and Explosives



A MEMS Air-to-Liquid Particle Collector



The interface was incorporated in an electronic nose system and successfully detected heroin and cocaine samples

In collaboration with *Biosensor Applications Sweden AB* (www.biosensor.se)

Thermally responsive PDMS composite

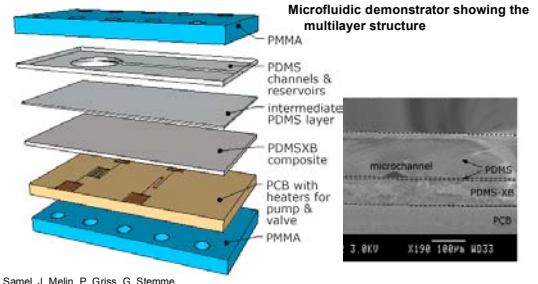
Expandable beads mixed with PDMS (XB-PDMS)

Large thermal expansion (> 100%)

- High flexibility inherited from the silicone elastomer PDMS
- Non-toxic and chemically inert
- Highly integrable actuator
- Allows for various fabrication methods e.g. soft lithography, casting, spinning

XB-PDMS Actuator Prototype

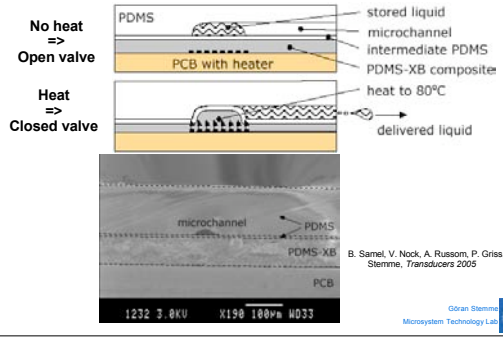
Expandable Beads



B. Samel, J. Melin, P. Griss, G. Stemme
IEEE MEMS 2005

XB-PDMS Actuator Operation

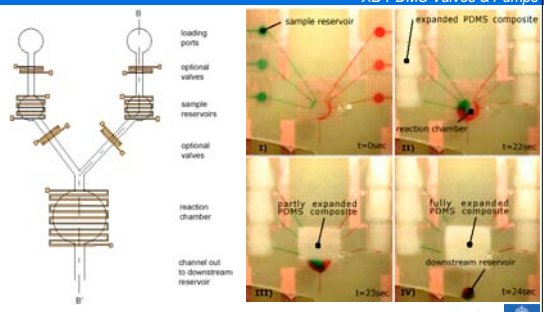
Expandable Beads



B. Samel, V. Nock, A. Russom, P. Griss, G. Stemme, *Transducers 2005*

Microfluidic Network

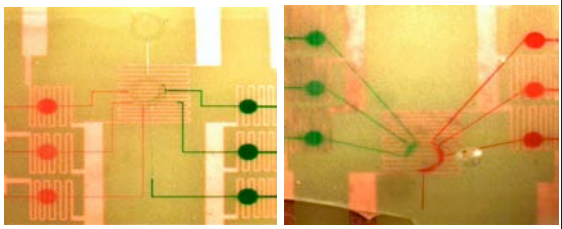
XB-PDMS Valves & Pumps



B. Samel, P. Griss, G. Stemme, *Transducers 2005*

XB-PDMS Lab-on-a-Chip Movies

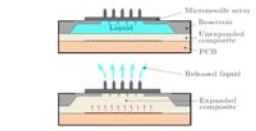
XB-PDMS Valves & Pumps



B. Samel, P. Griss, G. Stemme, *Transducers 2005*

Transdermal Drug Delivery Patch

Figure 2. Schematic view of the micromachined drug delivery device in development by KTH.



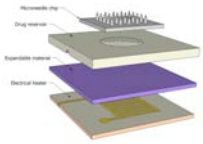
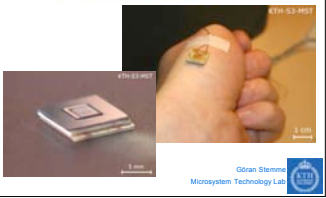


Figure 2. Schematic view of the micromachined drug delivery device in development by KTH.



"OPTO-MEMS"

Micro Mirror Optical Router

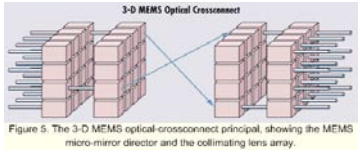


Figure 5. The 3-D MEMS optical-crossconnect principal, showing the MEMS micro-mirror director and the collimating lens array.

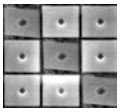
Each mirror in Lucent's Wave-Star LambdaRouter is capable of moving on two axes to provide intricate adjustments in connecting wavelengths from fiber to fiber.

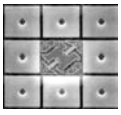
The micro-mirrors route information in the form of photons to and from any of 256 input/output optical fibers.

Source: "Light-Wave Magazine", Vol.17, No. 1, 2000

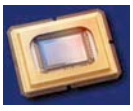
Lucent Technologies Inc.

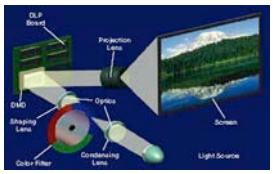
Digital Mirror Device





Board contains a 2000 x 1000 array of 16 x 16 µm micromirror devices





Texas Instruments Inc.

MEMS and IC Compatibility

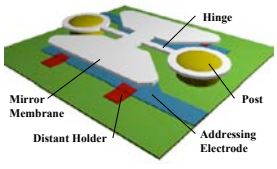
The Task
The integration of "high-performance" MEMS materials with Integrated Circuitry

The Problem
Limited thermal budget, i.e. post IC processes must be below 450°C

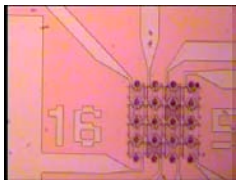
A Solution
Wafer-level film transfer using adhesive bonding

Torsional Monocrystalline Silicon Micromirrors

Concept



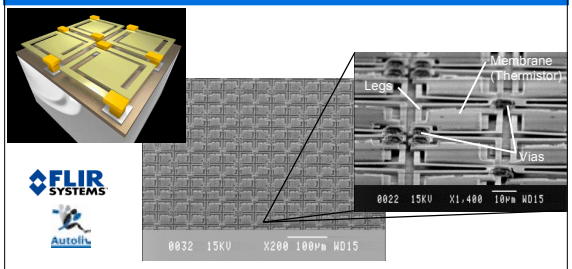
Realization



F. Niklaus, S. Haasl and G. Stemme, S3-MST, KTH

Application Areas:
- Pattern Generators in Maskless Lithography Systems
- Optical Switch and Cross Connector Arrays

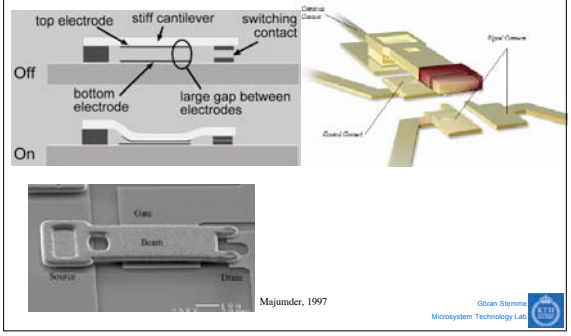
Wafer-Level Integrated IR Detector Arrays with CMOS



- Bolometer arrays with 320x 240 pixels, 0.7 µm thick membranes, 40x40 µm² pitch size and 3x3 µm² small vias.
- Allows the combination of high performance bolometer materials with CMOS read out electronic.

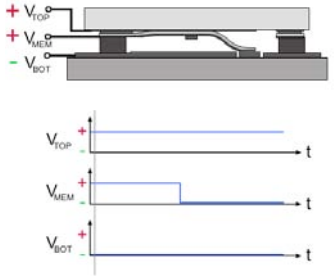
”RF-MEMS”

MEMS Switch (“Conventional”)

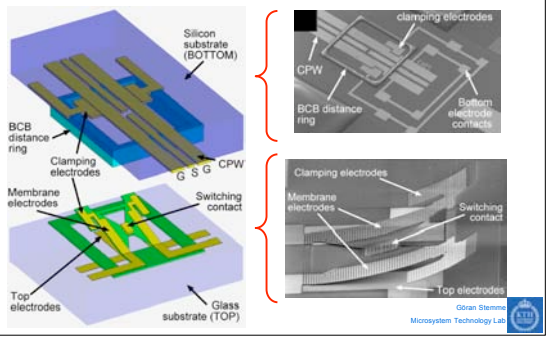


Majumder, 1997

Novel MEMS Switch Concept



Realization of Novel MEMS Switch Concept

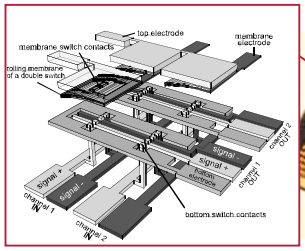


MEMS Switch Projects

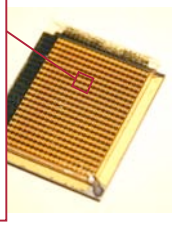
Telecommunication MEMS Switch Projects:

- Automotive Radar (Vinnova)
- Automated Cross-Connects (Network Automation)

MEMS Switch Arrays



switch unit, 2x2(x2)



assembled 20x20(x2) switch array

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MEMS = M€M$?