Neuchatel
Transformation from Watch Industry to MEMS-based Cluster
Role of Universities

Nico F. de Rooij
Sensors, Actuators and Microsystems Laboratory
Institute of Microtechnology
University of Neuchatel, Switzerland
EPFL-STI-IMM
www-samlab.unine.ch
Outline

• Introduction
• Consumer Products (watches)
• Microfluidic Dispensing Systems
• Chemical Sensors
• Tools for Nanoscience
• Optical MEMS
• Power MEMS
• Concluding remarks
University Role/Mission

- **Education**
  - Bachelor, Master, PhD Program

- **Conduct Fundamental and/or Applied Research**

- **Applied Research**
  - University/Industry Collaboration
    - “Successful” Research : Technology Transfer
  - Independent Research
    - “Successful” Research : Technology Transfer
    - Start-up Companies
  - Intellectual Property Right (IPR)
  - Incubators (NEODE)
Institute of Microtechnology
University of Neuchatel (IMT UniNE)

- IMT UniNE started its activities in 1975

- The Jurassic Arc was in an economic crisis, due to massive job losses in the mechanical watch industry (arrival of the quartz watch)

- IMT UniNE’s original mission:
  - Education
  - Applied Research
  - Support Local Industry
Regional Network in MNT

Joint efforts for education and research in the fields of Micro- and Nanotechnology (MNT)

Goal: Benefit from the complementary strengths of the members
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*Complementary missions in MNT*
Mission of the “Pôle”

• Collaboration in educational programmes
• Dual appointments for selected key people
• Establishment of joint research programs
• Co-ordination of investments in laboratory equipment
• Joint research laboratories: CMI and ComLab
• Joint industry cont(r)acts
Global Watch Business

For 2002 / Source: www.fhs.ch

- **Watches, movements and components (globally):**
  - 1.5 Billion pieces / year
  - 16 to 17 Billion CHF  
    \[ 1 \text{ CHF} \approx € 0.64; \ 1 \text{ CHF} \approx \text{US$ } 0.80 ; \ 1 \text{ CHF} \approx ¥87 \]

- **Switzerland:**
  - 120 Mio. watches, movements and components
  - 28 Mio. finished watches = 10.5 Billion CHF
  - Average export price: 362 CHF  
    \[ \text{(J: 30 CHF / HK: 7CHF)} \]

- **Global Production of finished watches:**

\[ \text{Quantity} \]

- China + Hong-Kong: 81%
- Japan: 13%
- CH: 4%
- Others: 2%

\[ \text{Value} \]

- 56%
- 33%
- 6%
- 5%

\[ \text{China + Hong-Kong} \quad \text{Japan} \quad \text{CH} \quad \text{Others} \]
Swiss Export of Finished Watches

For 2002 / Source: www.fhs.ch

Pieces (in Mio.)

- Mechanical
- Quartz anal.
- Quartz digit.

Value (in Mio. CHF)

- Mechanical
- Quartz anal.
- Quartz digit.
Altimeter/Barometer Module

Process features:

- Implanted piezoresistors
- Precise electrochemical etch stop
- Anodic Bonding
Altimeter/Barometer Module

- Altitude variation of 1 m:
  - ~0.1 mbar ≡ ~150 pm

- Resolution:
  - ~3µbar ≡ ~3cm altitude variation

- Sensor power consumption:
  - ~1.3µW
Tissot T-Touch (Tactile Crystal)

- User interface by tactile capacitive touch screen
- Altimeter
- Weather forecast
- Temperature (with US/EU Units)
- Compass, chrono, alarm


www.asulab.ch
Mechanical Watches

www.tagheuer.com
UV-LIGA (SU-8)


Why Single Crystal Silicon?


• Well-known and controlled properties

• Low density (2.33), amagnetic, electrical conductor, easy to overcoat, …

• Machining by Deep Reactive Ion Etching (DRIE).
Elastic behavior of Silicon
Silicon Structures of Watch Components

- Machining of complex mechanisms with sharp edges
- Reduced friction
- Higher lifetime
Dual Wheel Escapement with Si-Wheels
**Dual Wheel Escapement with Si-Wheels**

- Complex silicon wheels with stopper teeth
- Reduced friction
- Reduced moment of inertia
MST based instruments

Spin-off Activities:
μfluidics
chemical sensors
lab-on-chip
Life Sciences: Space Bioreactor

Built to evaluate the growth characteristics of yeast cells in microgravity
Working principle

control electronics

pH control

sensors (pH, T, redox)

flow sensor

micropump

fresh medium
100 ml

3 ml reactor chamber

output valve

stirrer

Used medium

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Flow Sensor

- dual piezo-resistive low pressure sensor
- 4.75 x 9.5 x 1 mm³
- 5 mL/h full scale
- accuracy ~ 2%
Dispensing Systems

Advantages:
- **Control of the liquid quantity at the dispensing site.**
- **Direct, real time measurement of the aspirated or dispensed volume.**
- **Status/diagnostic of the system functionality (clogging, etc.).**
Sensor Controlled Liquid Handling

Drug Discovery, medical diagnostics

- Liquid sample transfer from nL to µL
- Dispenser footprint fits standard industry format
- Modular assembly 8 to 96 channels
Working principle

- Control electronics
- Flow sensor
- Micropump
- Fresh medium (100 ml)
- 3 ml reactor chamber
- Stirrer
- pH control
- Sensors (pH, T, redox)
- Output valve
- Used medium
single sensors  
**pH-ISFET**

multiple sensors  
(pH, ORP, Conductivity, T)

**ThermoOrion**
Dynamic FLASH Titration Process (1)

Acidity Titration

\[ \text{H}_2\text{O} - 2e \rightarrow 2\text{H}^+ + \frac{1}{2} \text{O}_2 \]

Platinum Generating Electrodes

1mm

ISFET

2H\text{O} + 2e^- \rightarrow 2\text{OH}^- + \text{H}_2

ThermoOrion Flash Titrator
Nanotools
Phoenix mission to Mars: 2007
AFM on MARS
Tuning Fork based AFM Probes

New probe concept
Tuning fork + Cantilever

1.5 inch square wafer
about 350 tuning forks

Conventional setup
Batch fabrication of the probe

(a) (b) (c)

SiN cantilever
\( k = 0.01 - 1 \, \text{N/m} \)

Si cantilever
\( k = 1 - 550 \, \text{N/m} \)

Length = 125 – 700 \( \mu \text{m} \)
The A-Probe (The Akiyama Probe)

1. Technology Transfer initiated
Optical MEMS
MEMS for Fiber Communication

Optical MEMS

- Size of Single Mode Fibers
- Integrated Passive Alignment
- Low Polarization Sensitivity
- Low Cross-talk
- Reliable
Actuator, Grooves, Mirror

Magn 126x IMT Prof. de Rooij - Fiber Switch

200 µm
Switch Details

µ-mirror:
- Silicon
- 75 - 100 µm high
- ≤ 1 µm thick
- metal coated
- optically flat
Latching Multimode Fiber 2x2 Switch

μ-mirror:
- 100 µm high
- ≤ 1 µm thick
- Gold coated
Latch on Multimode Switch

92 V

52 V
Power MEMS using Solid Propellant Based Actuators
Microthrusters for Nanosatellites/Picosatellites

http://www.aero.org/technology/etd.html
Solid Propellant Technology

• **Combustion**: large quantity of energy from small volume

• **Solid fuel**: no leakage, stability in time

• **No moving parts**, eliminating frictional force and making technological fabrication easier

• **The chamber is not pressurised**, the reservoir does not need to be massive
Microthruster : Principle of Operation

• Microthruster parts
  – Nozzle
  – Igniter
  – Chamber
  – Seal

• Operation
  – Chamber filling with solid propellant
  – Propellant heating by Joule effect and ignition
  – Combustion, gas production and thrust force

• Requirements
  – ignition temperature : ~ 200°C
Microthruster : Principle of Operation

Array of 4x4 microthrusters (16 thrusters)
DEMO Assembling

• Filling of the parts with propellant
  – Igniter with ZPP
  – Sealed chamber with GAP

• Bonding
  – Thermal gluing (epoxy glue)
    at low temperature (60-80°C)
DEMO: Ignition Tests

- Ignition tests
  - Ignition power: 100 – 150 mW
  - Ignition time: 20 – 130 ms
  - Combustion time: ~ 320 ms

Videos made at LAAS, Toulouse, France
Conclusions

• Turn ideas into demonstrators
• Advance the technology base
• Encourage start-up initiatives
  – Seyonic (1998), Sercalo Microtechnology (1999), NanoWorld (2000), ...
• Encourage technology transfer
  – Intersema (pressure sensors), MicroFlow Engineering (Inhalers), CSEM, Colibrys, ...
Recent Start-up Companies

**Sercalo Microtechnology SA**
Production of Optical MEMS Switches and Attenuators

**Seyonic SA**
Engineering and manufacturing of microfluidic devices and systems for life sciences and space research

**NanoWorld SA**
Nanotools for Scanning Probe Microscopy
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