"MEMS, MOEMS and MNBS – their role in next generation medical diagnostic and therapy"

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- SENSORSYSTEME 2012 -

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Disclaimer:

Images taken from the indicated sources do not reflect a medical device / component ready for market and are purely depicted for the sake of illustrating the message conveyed in this talk

Overview

1. MEMS ->MOEMS ->NEMS
2. Requirements in the medical field
3. (A range of) novel diagnostic and therapeutic applications
4. Visions and pitfalls
5. NEMS for medical – special situation
6. Summary

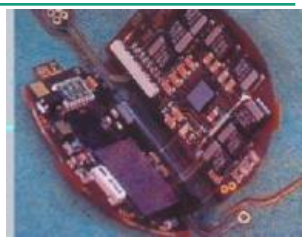
MEMS-> MOEMS -> NEMS

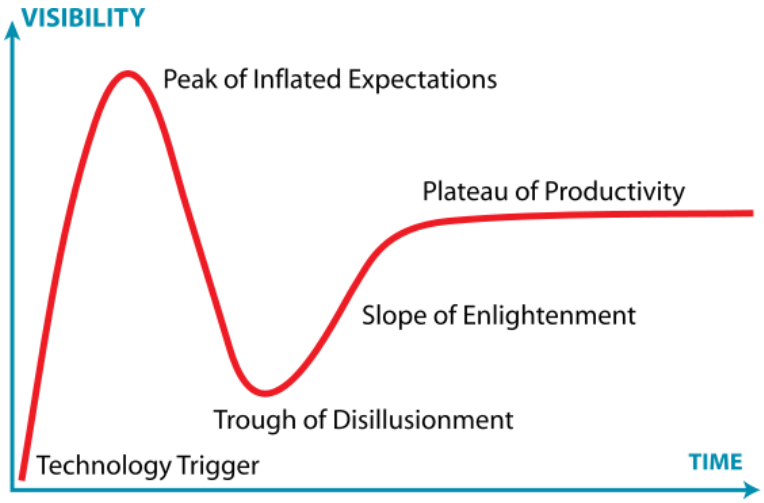
- MEMS – Microelectromechanical Systems – mostly associated with silicon technology, BUT
  - Metal structuring
  - Glass structuring
  - Polymer structuring

  Also in heavy use
- MOEMS – optical functionality included, e.g. lenses, mirrors, focus shifting lenses, SLMs, tunable photonic gratings, ….
- NEMS – towards the nano regime
  - Still in the exploratory stage
  - Material development dubbed „NEMS research“
  - Bottom-up instead of top-down

Medical innovations….
…. and requirements

- Medical technology uses MEMS devices already as components (accelerometers in pace makers, pressure sensors in catheters)
- Typically well known and understood technologies and components (risk minimization) are used
- Innovative components need to prove both function and robustness prior integration into a system – which again needs to prove funtion and robustness as a whole
- Mechanical design more difficult under DfM constraints than pure electronic design
- Medical devices operate under conditions, which cannot be controlled by the manufacturer -> can result in very individual requirements (surgeon´s skill, patient behaviour)





- -> sluggish adoption of novel compoments into the medical market
- -> aggressive marketing strategy for novel devices by startups required but may lead to exaggerated expectations (glucose monitoring)

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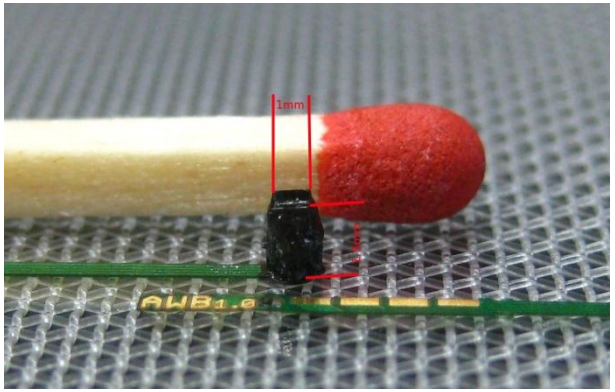
Novel diagnostic applications using MEMS

- *Pill size endoscope*
  - *Reviewing the gastrointestinal tract (GERD, Crohn´s Disease, CC)*
  - *No need for anesthetics*
  - *Micro optics, micro energy supply (inductive), micro integration*
  - *MEMS now for location control (accelerometers)*
  - *Pressure sensor for local pressure measurement*
  - *Light guidance (panoramic illumination)*

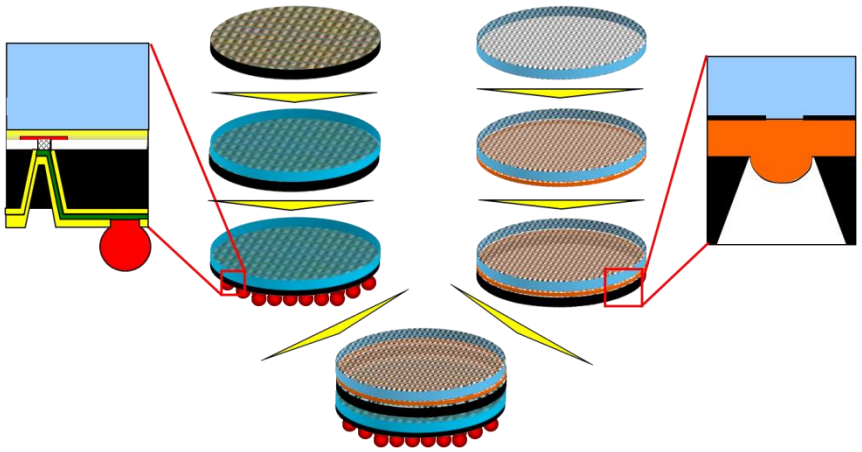
Image taken from Given Image, Valtronic, IZM

Novel diagnostic applications using MEMS

- *Endoscope camera, ultrasmall*
  - *Combining microelectronic CMOS imaging chip*
  - *with microoptical lenses*
  - *MEMS bonding technologies*



- *Microbumps for attachment to flex*



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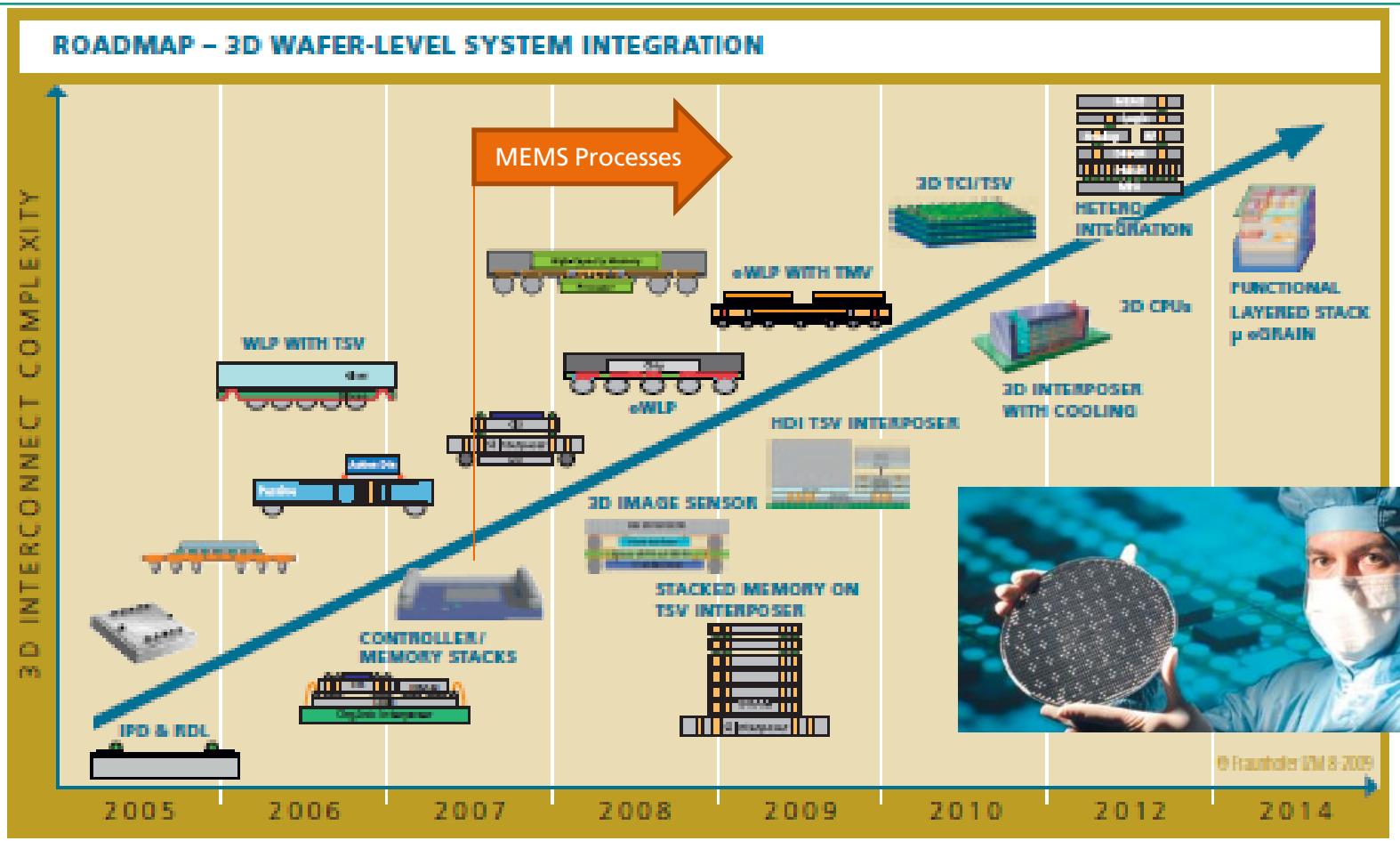
MEMS technology pushing HeteroSystemIntegration …FhG ASSID in Dresden



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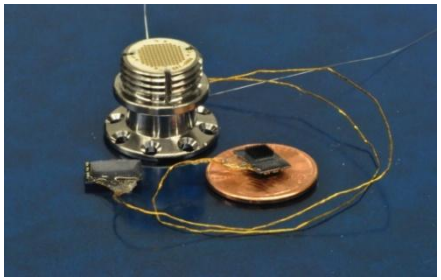
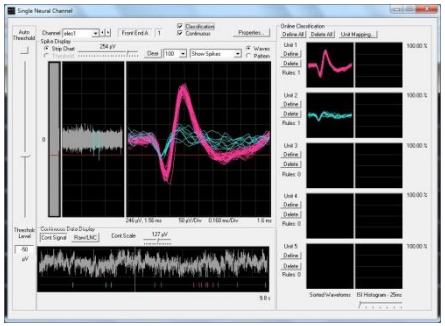
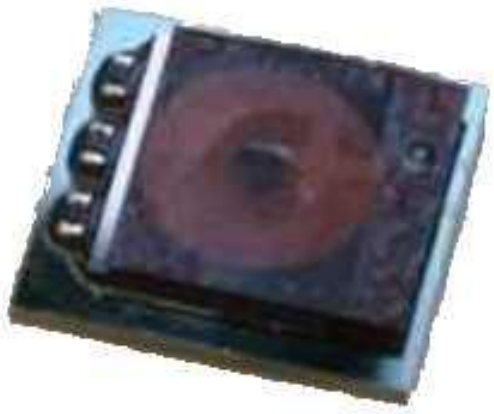
Novel diagnostic applications using MEMS

- *Silicon micromachined needle array for BCI*
  - *Capturing neural signals in the cortical area as well as in peripheral nerve*
  - *Multiple micromachining steps*
  - *Integration using advanced packaging technology*







Images taken from Univ. Utah, John Hopkins University, Blackrock LLC, Fraunhofer IZM

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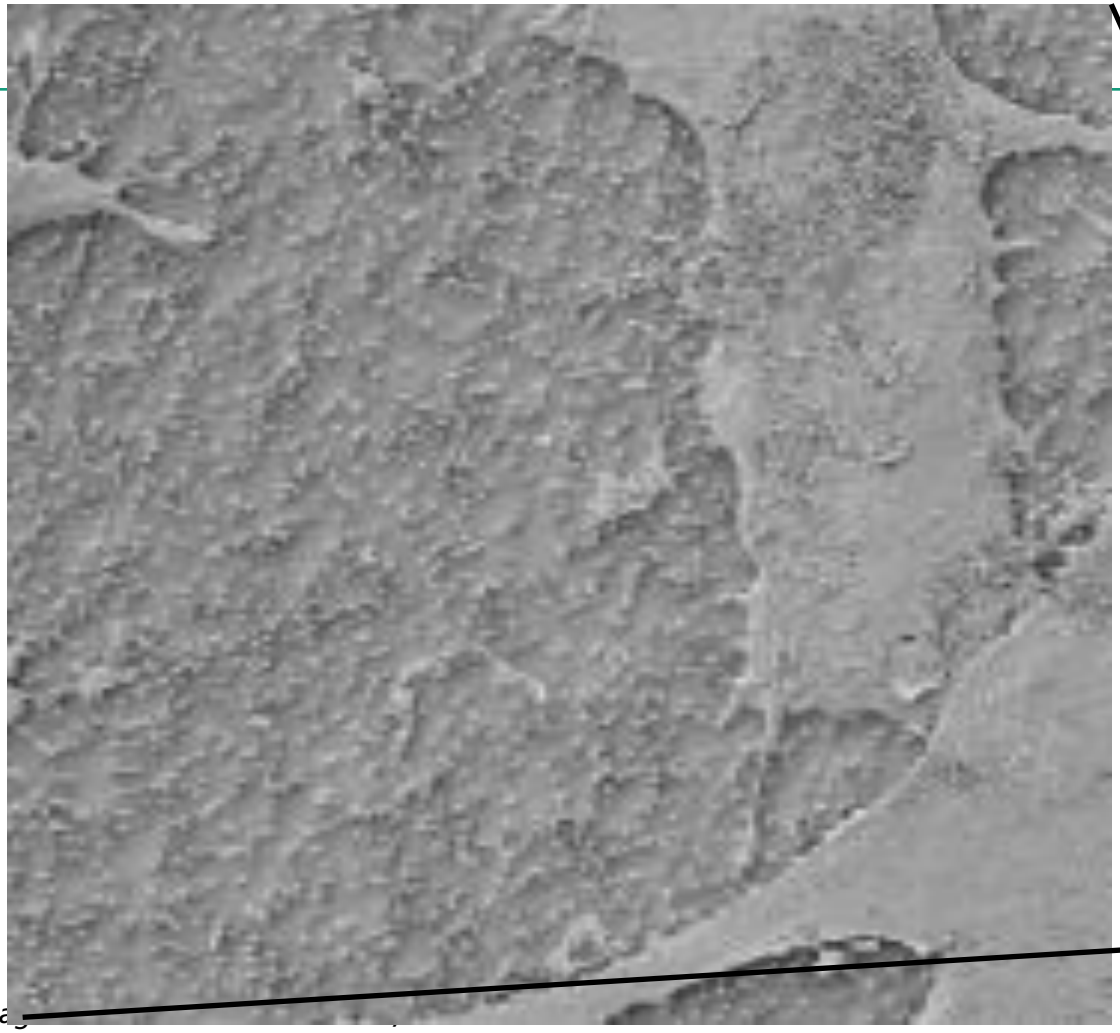
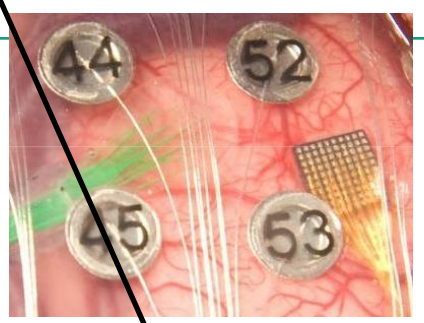
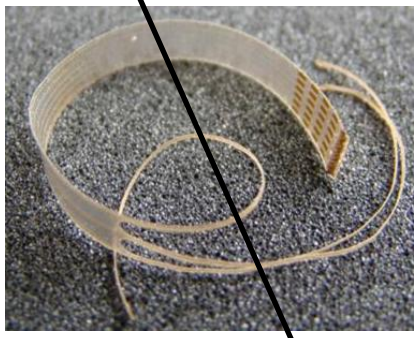
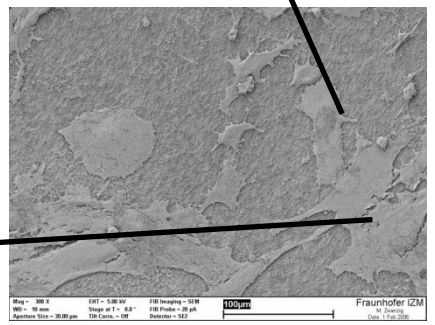
Novel diagnostic applications using MEMS









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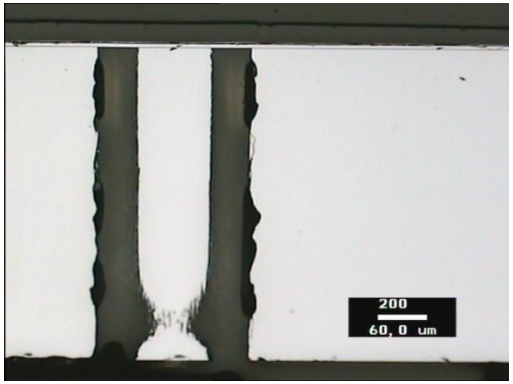
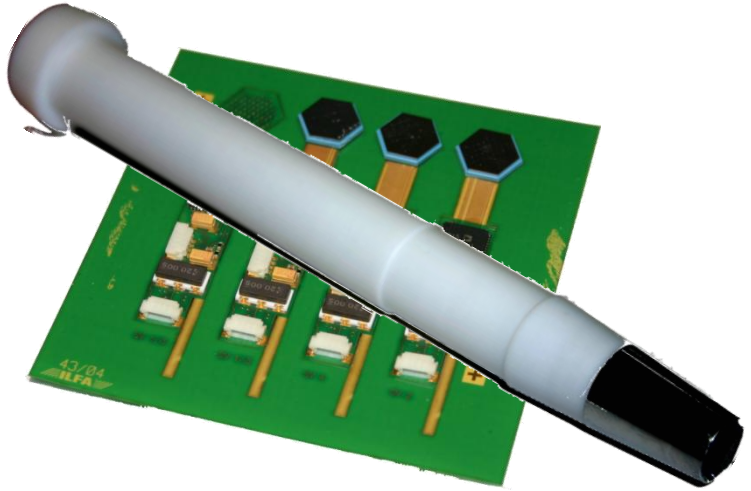
Novel diagnostic applications using MEMS

- *Eye pressure measurement*
  - *Glaucoma prevention*
  - *Diabetes control*

  - *Intraocular lens integrated pressure sensor and energy supply*
  - *Arrayed pressure sensor for electronically documented „Goldman“ Method*

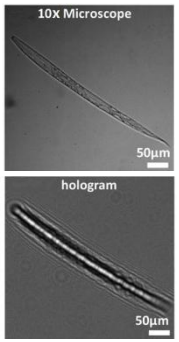


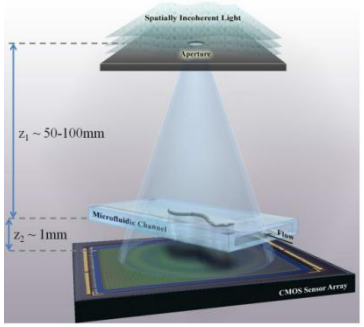


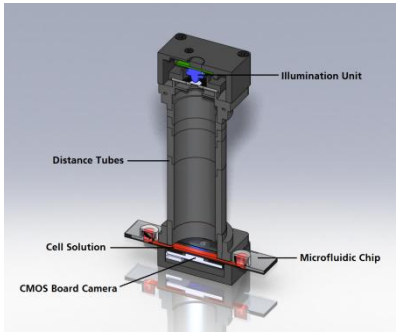
Images taken from Mesotec, CMT, SIS and Fraunhofer IZM

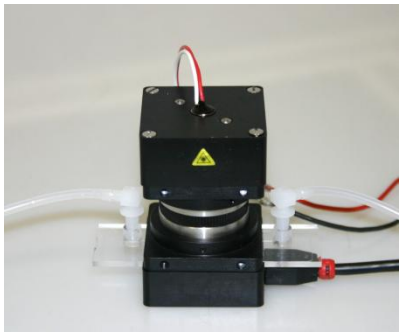
Novel diagnostic applications using MEMS

- Lens-less microscope
  - *Microfluidics in direct contact with CMOS imager*
  - *SLM to realize a collimated coherent illumination*
  - *Micro lens array for direct imaging*









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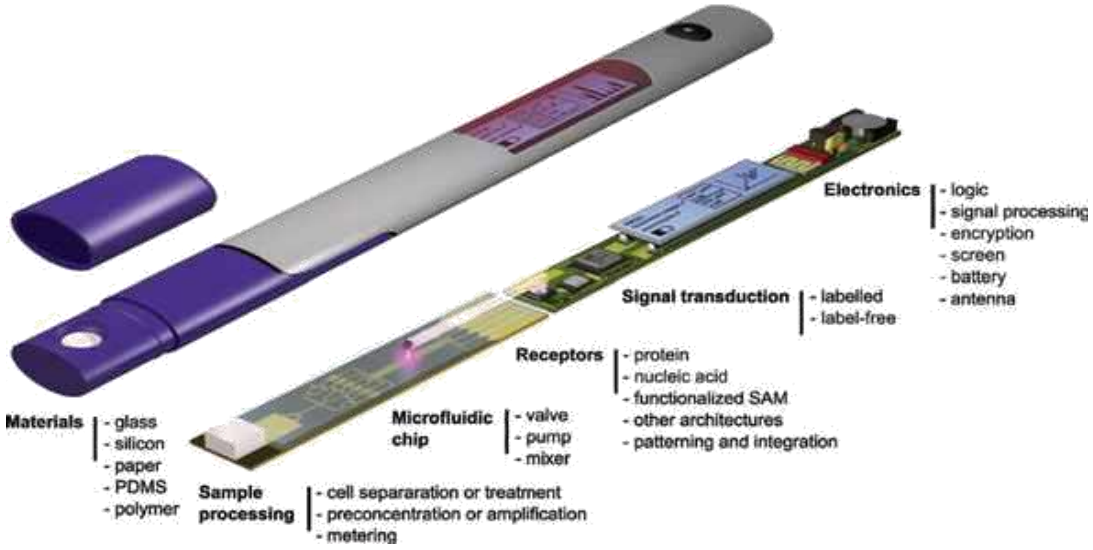
Novel diagnostic applications using MEMS

- **PoC diagnostic platform**
  - *Micro-actuators (MEMS pump, MEMS valve)*
  - *Micro-sensors (µ electrodes, SAW)*
  - *Micro energy supply (inductive coil, on-chip battery)*



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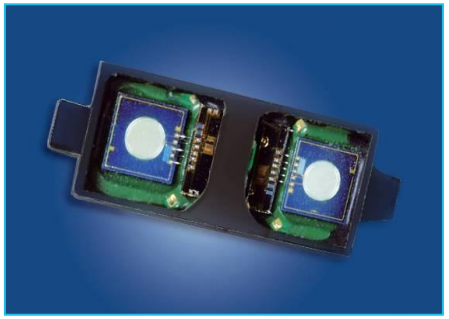
Novel therapeutic devices

- ***ePill : Medication dosing***
  - *Project concept by Philips*
  - *Not marketed until now*
  - *Micro pumps, micro sensors, micro energy supply*

Image by Philips

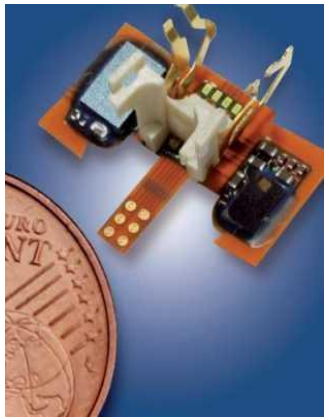
Novel therapeutic devices

- *In ear hearing aid*



  - *Directional dual MEMS microphone*
  - *Enabling improved directional hearing*

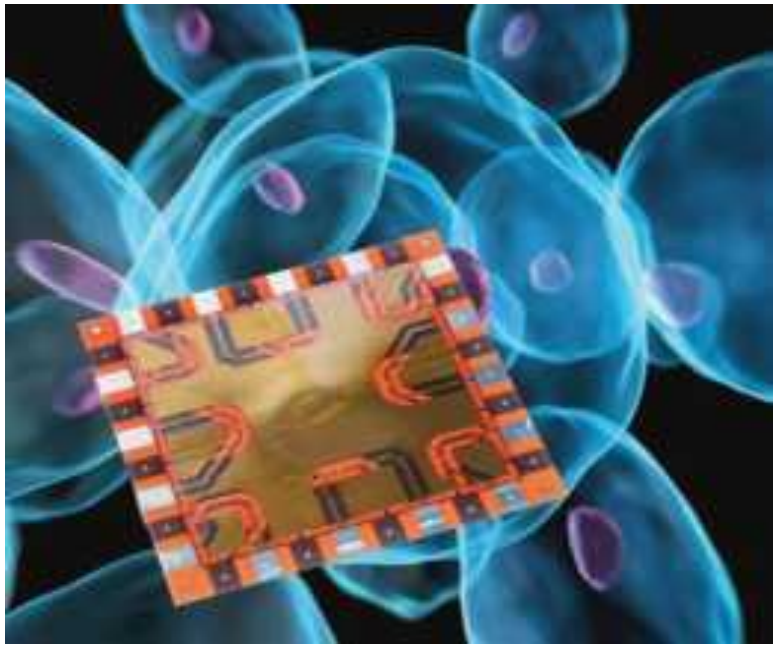
  - *Miniaturization improvement by flex and thin chip integration*



Images taken from Infineon, Phonak, Oticon and Fraunhofer IZM

Novel diagnostic applications using MEMS

- *Identification of tumor killer cells*
  - *Micro structuring in silicon*
  - *Microstructuring in polyimide*
  - *Layered metal deposition to form an electrostatic actuator*
  - *Cochise Project using DEP levitation to control cell position in 50µm micro wells*



Images taken from the COCHISE consortium w. IZM as partner

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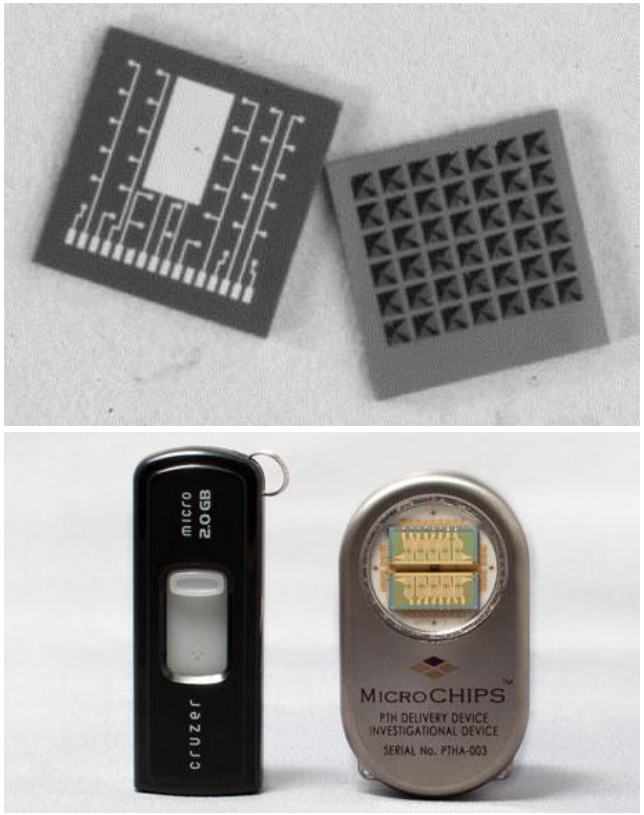
Novel therapeutic devices

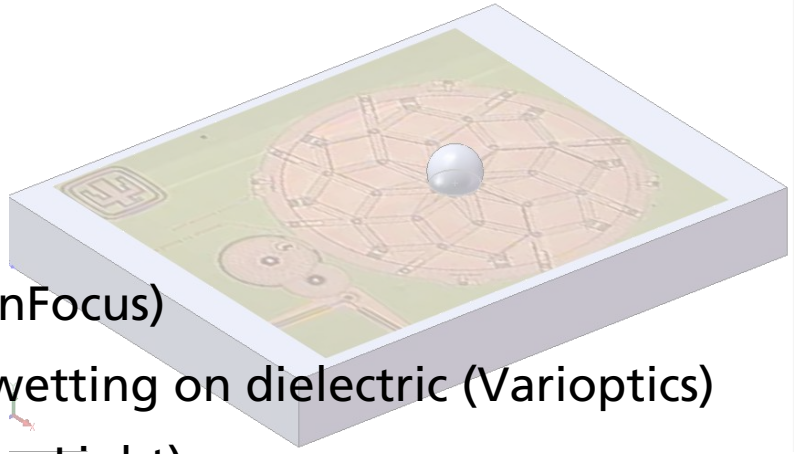
- *Individual drug reservoirs opened „on request“*
  - *Pain treatment*
  - *Hormone treatment*
  - *MEMS manufactured recesses*
  - *Individually adressable cover film*
  - *Subcutaneous implant*
  - *System MUCH larger than MEMS die…*



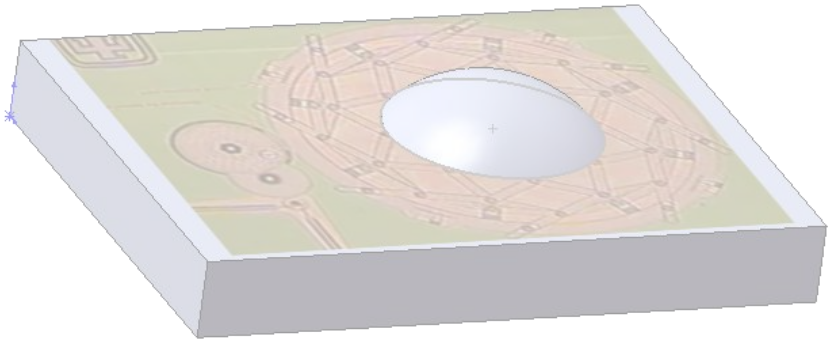
Images taken from MicroCHIPS Inc.

Novel therapeutic applications using MEMS/MOEMS

- *Intraocular Lens Replacement*
  - MEMS to control a deformable lens for intraocular lens replacement (nFocus)
  - Alternative approach: Electrowetting on dielectric (Varioptics)
  - Piezodeformable membrane (poLight)



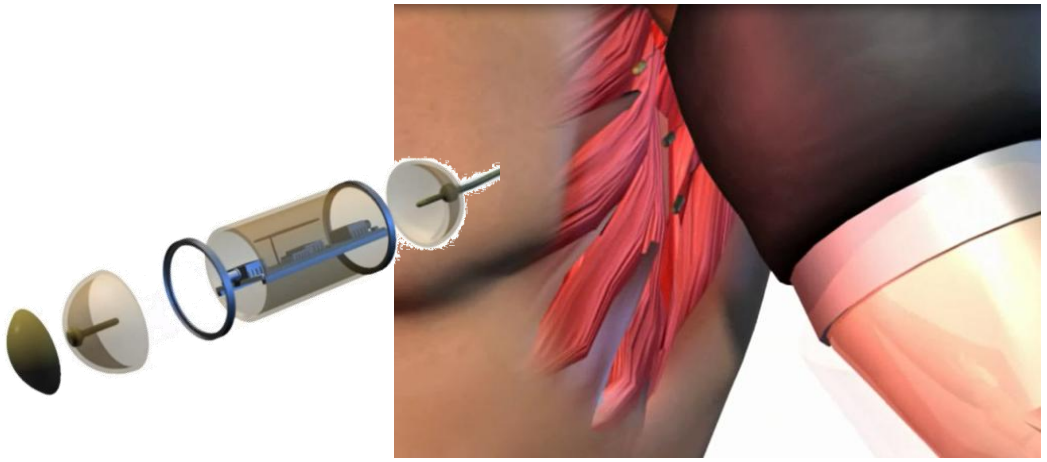
Closed LENS device



Open LENS device

Novel therapeutic devices

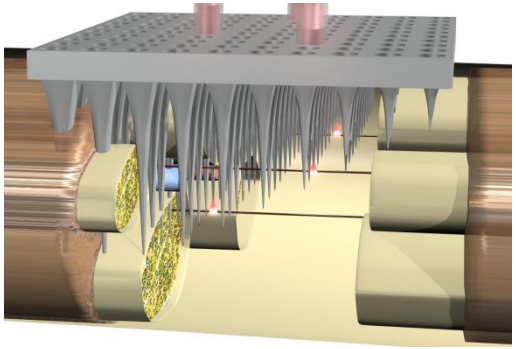
- ***Injectable muscle stimulators***
  - *RF ID adresseable*
  - *Inductive winding for external energy supply*
  - *Closed loop integration with neural recording interface*

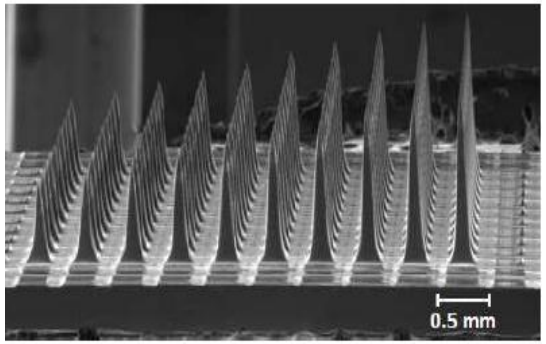


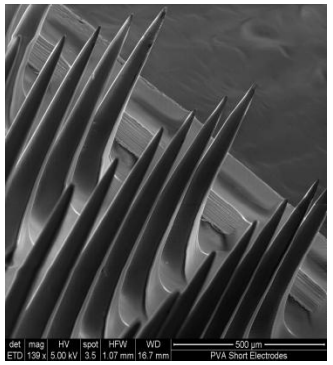
Images John Hopkins University, University of Utah and Fraunhofer IZM

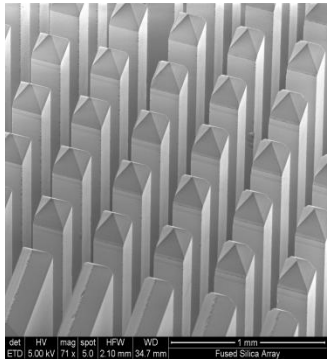
Novel therapeutic devices

- ***Optical stimulation in the cortex and peripheral nerve***
  - *Spasm treatment (parkinson, epilepsy) envisioned*
  - *VCSEL attachment to glass/polymer UEA*
  - *Direct (plasma) structuring as well as PIM replication*









Images taken from University of Utah

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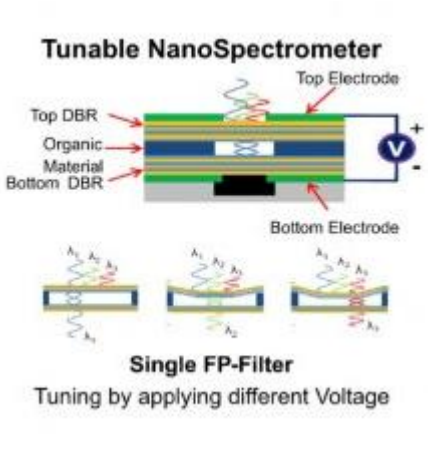
Novel diagnostic applications using N(?)EMS

- *Spectral response detection using a Fabry Perot Micro Resonator*
  - *Sub wavelength shift of FP resonator cavity*
  - *Continuous tuning of resonant frequency*
  - *Extremely high Q detection*



Detection of frequency shifts e.g. with fluorescent samples

Multi frequency scan and probe measurement for skin cancer diagnosis

*(skin health monitor)**

Images by INA, Kassel and Opsolution GmbH

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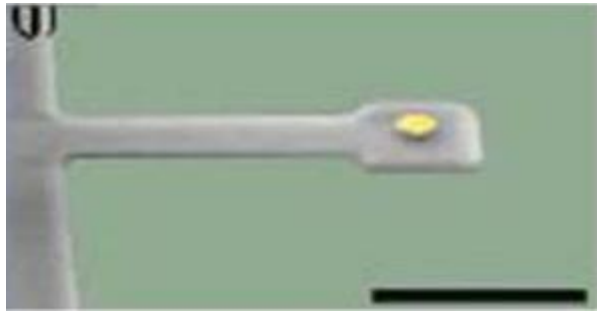
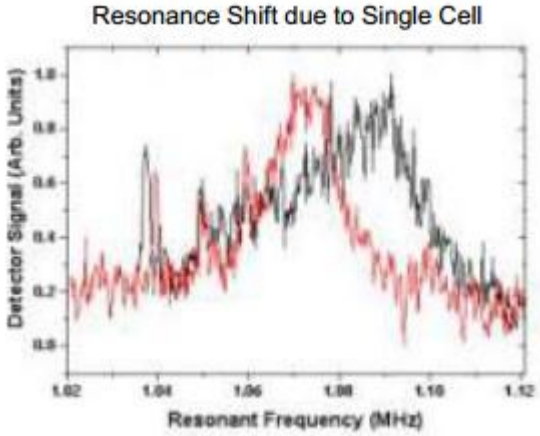
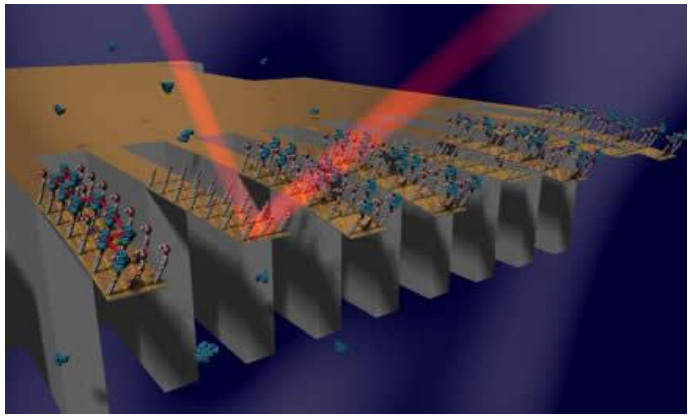
Novel diagnostic applications using NEMS

- *Single DNS strand detection and identification*
  - *Cantilever MEMS based detection platform*
  - *Functionalized nano-rod on the MEMS tip*
  - *Mass shift results in frequency shift -> detection of binding and mass of binding partner*



Au dot: 50nm





Images taken from Cornell University and BNC

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NEMS – special situation

- NEMS is no specific denominator
  - AFM/cantilever based concepts mingle with molecular based and self assembly concepts (top down/bottom up)
  - Nano-Materials associated with NEMS
  - NEMS concept are typically targeting the diagnostic regime
  - Nano-bots as envisioned by several researchers (flagellae movement, magnetic guidance, nano-actuators) are still not anywhere on the horizon of realism

Images taken from Zeitgeist AT and Nanobot Health

Visions and Pitfalls

- Vision
  - MEMS, MOEMS and NEMS will revolutionize the current way medicine technology is implemented
    - Miniaturization requirements
    - Sensing requirements
- Pitfalls
  - High expectations need to be matched agair requirements
  - Cost vs. Benefit needs to be demc
  - Cost often associated with econor patients and devices are not a good
  - Energy supply limits usability of micro/M(C, the field

Summary

- Microtechnology, specifically MEMS and MOEMS will continue to offer new devices and concepts for use in the medical regime
- MEMS/MOEMS will help to replace inadequate methods, but also offer novel, unforeseen opportunities
- Economy of scale considerations, regulatory issues, component-system-integration cylces may/will slow down the proliferation of MEMS/MOEMS into the medical field – compensated by the growing number of concepts

- NEMS more expected to be nanomaterials and structures integrated with MEMS/MOEMS than a class of their own with respect to the medical field.