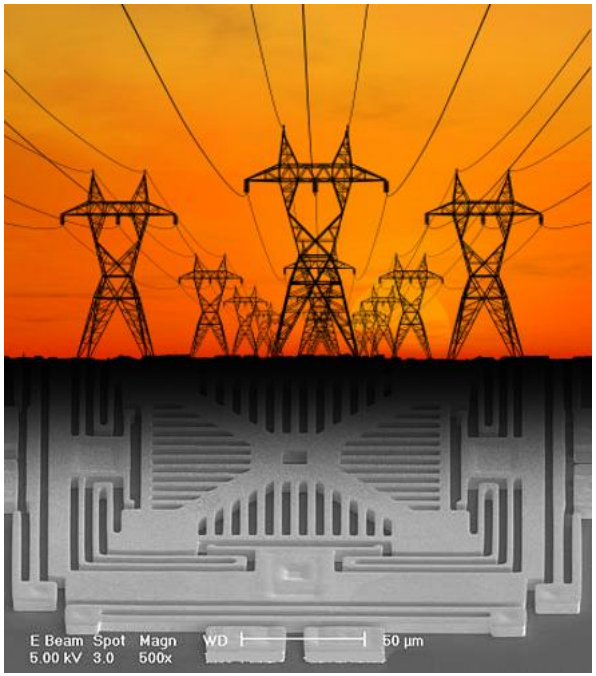
Business from technology



Potential Applications of MEMS Technology in Power Networks

D 6.3.2

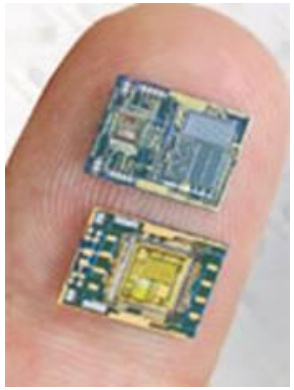
Henry Rimminen, Anu Kärkkäinen
VTT Technical Research Centre of Finland

MEMS (= MicroElectroMechanical Systems)

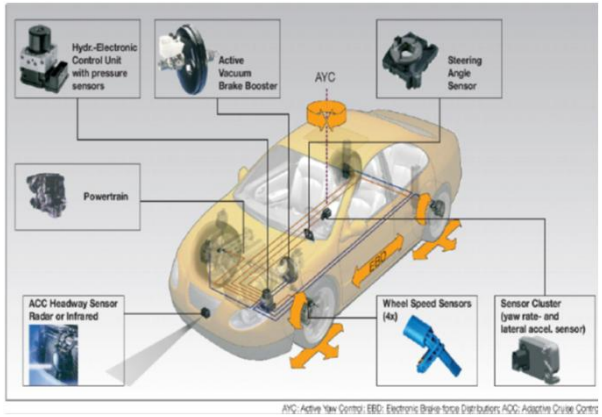
Cost effective technology to fabricate large number of small components processed on silicon wafer using integrated circuit production facilities

Benefits of MEMS are:

- small size
- low cost
- low power consumption
- integration with electronics

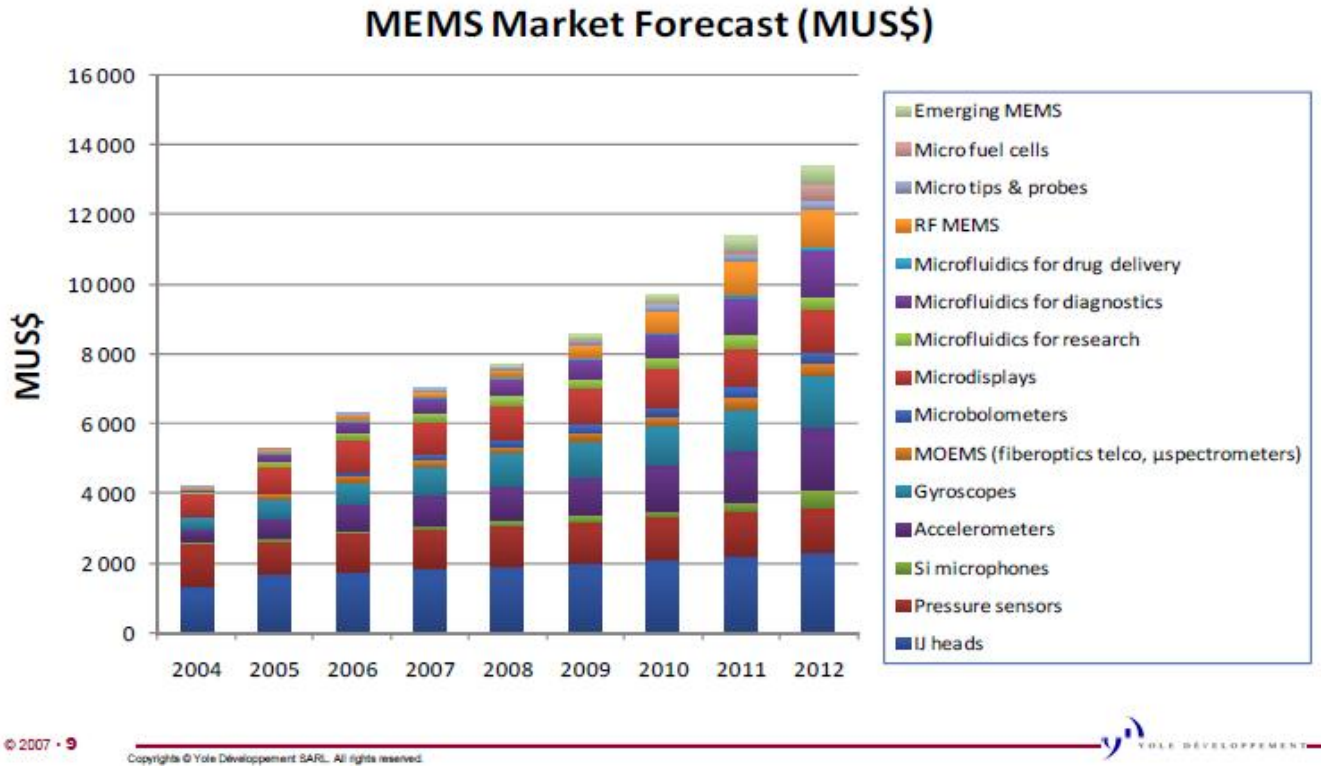


MEMS is established technology



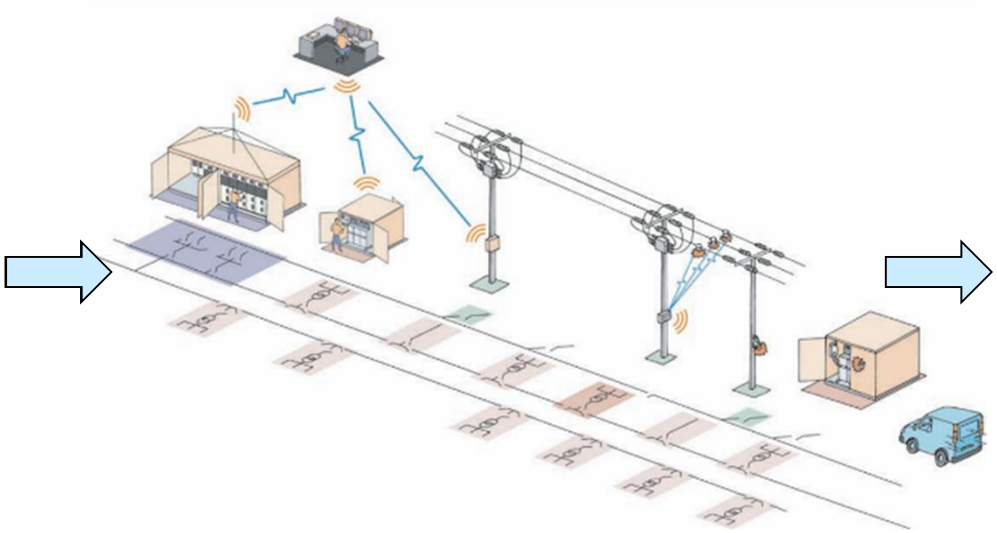
Automotive

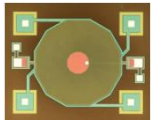
Consumer electronics

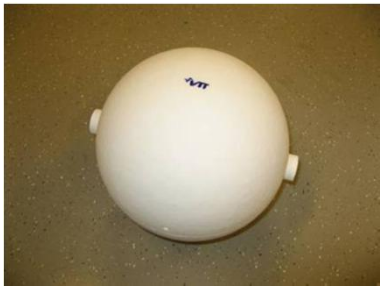


MEMS sensor potential in Smart Grid applications

- PD detection in power transformers
- PD detection in HV cable joints
- Line fault indicator for DC power lines
- Power meter
- Electrostatic Field Measurement
- High Power Switches
- Self Powered MEMS module for Smart Grid





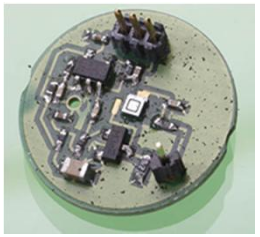


PD detection with AE

- Acoustic Emission (AE) is a known method for partial discharge detection
- Current sensors are based on piezo technology -> expensive, fatique, etc.
- VTT has developed a new MEMS based AE sensor
- MEMS AE sensor is
  - Affordable
  - Low power consumption
  - Small size
- Optimal for
  - Wireless applications (autonomous sensor nodes)
  - Product integration (auto diagnostics, smart machines)
- Application, see next slides

Different AE MEMS prototypes

SMD mountable component



OEM module

Traditional sensor head

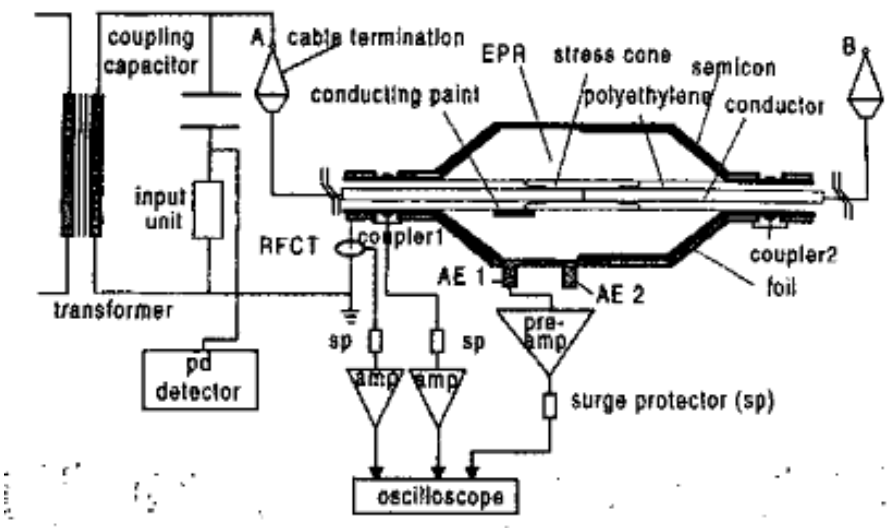
Wireless sensor including processing software

PD detection in power transformers by AE sensor

- Diagnostics of high voltage insulating systems
- Partial discharges (PD) deteriorate the insulation
- Advantages of AE detection
  - On-line method
  - Susceptibility to external disturbances
  - Location of PD possible when at least 3 sensors used
- Classification of PD harmfulness by frequency analysis [6]

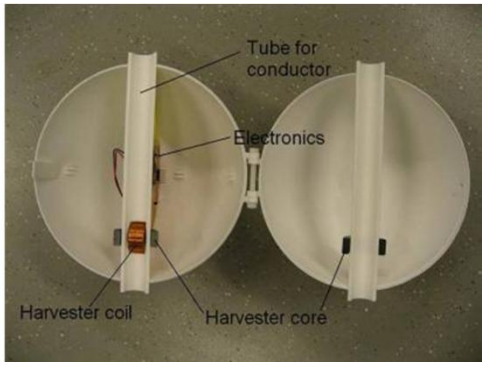
PD Detection of HV Cable Joints with AE

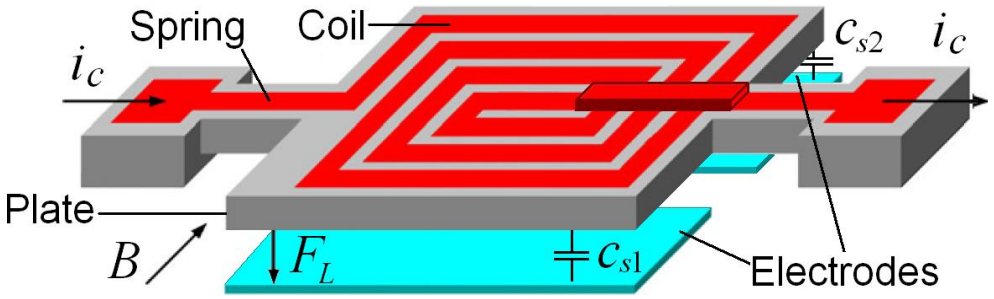
- Defects within polymeric insulation and cable joints can lead to PD activity [7]
- Advantages of AE detection
  - On-line method
  - Susceptibility to external disturbances
- No galvanic contact needed



Line fault indicator for DC power lines

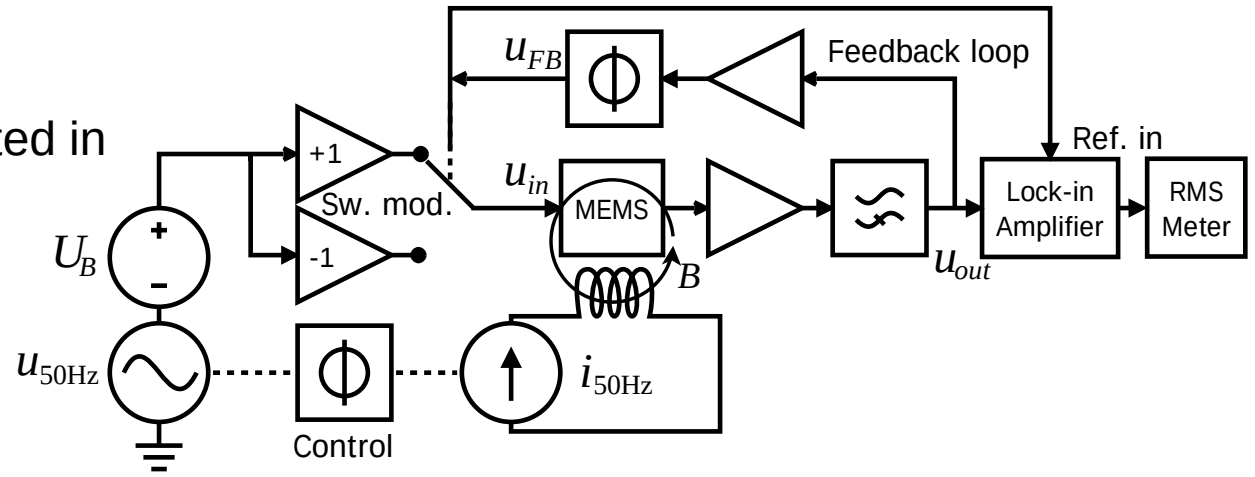
- VTT has developed a fault current indicator for 20 kV
  - The current measurement based a coil magnetometer
  - No battery changes needed because harvests operating energy from the power line using a current clamp
  - Radio communication provides flexibility and electrical isolation
  - Status: lab tests ok, field tests spring 2012
- Similar kind of indicator could be also implemented for DC lines using magnetometer
- Typical method for HVDC current measurement is to use a shunt transducer and transmit data and supply power optically [9]
- VTT has MEMS magnetometer
  - Based on Lorenz force
  - Small, low power, stable
  - Infrequent need for recalibration, no creep





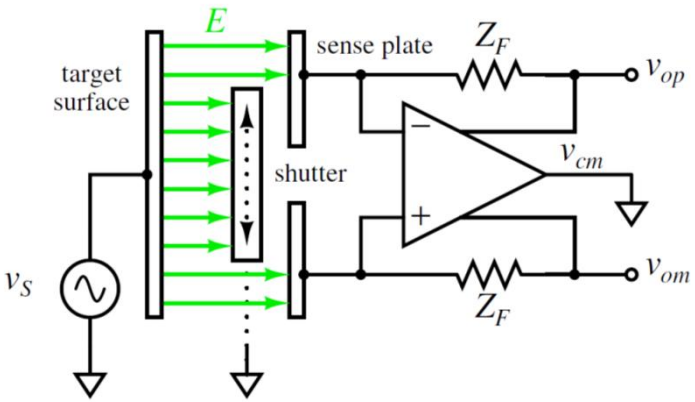
Power meter

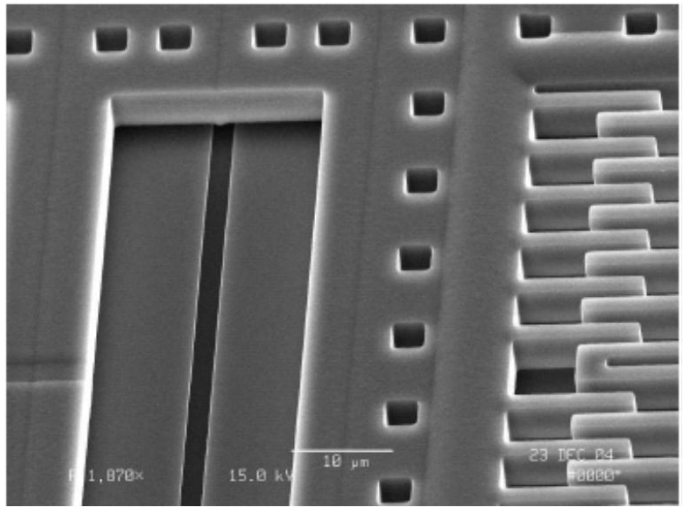
- VTT MEMS magnetometer has been demonstrated to measure 50 Hz active power [8]
- current coupling is magnetic and voltage coupling is galvanic
- the output is proportional to their product (~power)
- Power measurement with MEMS enables small size and autonomous operation
- These sensors could be planted in every household device



Electrostatic Field Measurement

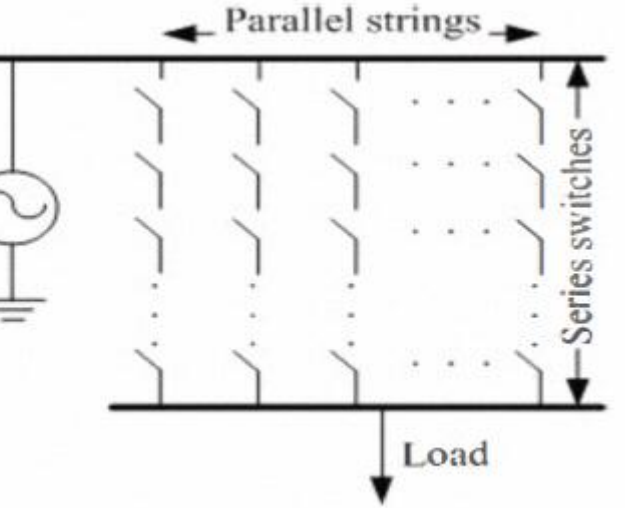
- MEMS enables accurate Electrostatic field measurement without bulky sensor electrodes [1, 2]
- A resonating plate with a hole (shutter) moves over two sensing electrodes
- The shutter blocks the electric field lines and due to its movement differential displacement current is generated to the electrodes
- A nonlinearity of 20 V/m over a range of 700 kV/m has been demonstrated
- A noise floor of 4 V/m/√Hz was also reached

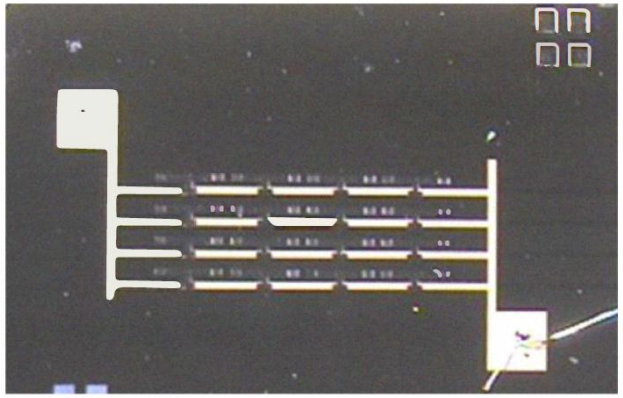




High Power Switches

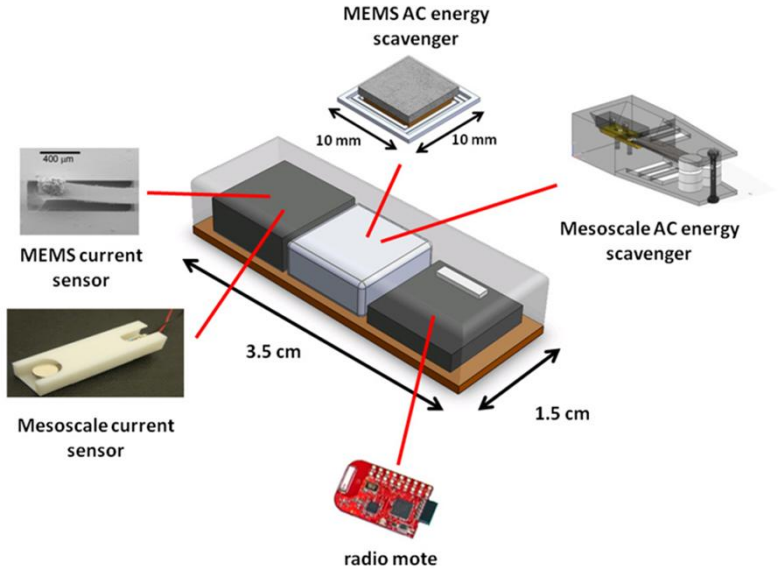
- MEMS switches are smaller and faster than conventional relays and can handle higher power densities than solid state switches [3]
- A matrix of small switches in series and in parallel enable high voltages and currents
- 4x4 arrays have been demonstrated [3,4]
- Actuation can be electrostatic, magnetic or pneumatic [3,4]
- A single switch can have 300-V insulation strength and 400-mA current handling capability [4]
- On- an off-resistances are *50* mΩ and 30 MΩ [4]

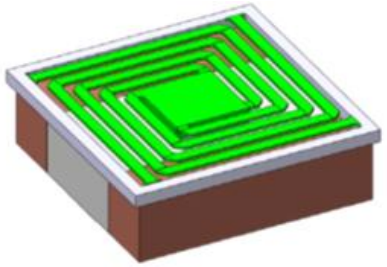


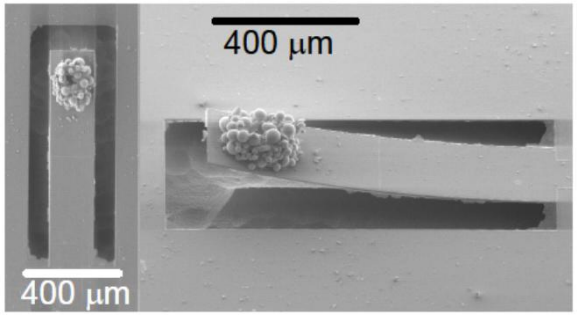


Self Powered MEMS module for Smart Grid

- Self powered module measures current and transmits results with radio [5]
- Current is measured with a MEMS component which has a piezo-coated cantilever (AlN) and a printed micro magnet on its tip
- Linearity is good (R^2 >0.99) and sensitivity is ≈1 mV/A in a range of 0-20 A_{RMS}
- Energy is scavenged from the ac line with a macro scale device, however a MEMS scavenger is under design
- The MEMS scavenger will have a permanent NdFeB-magnet mounted on a spring, which is piezo covered (AlN or PZT)







What VTT can do for you:

Company need ⇨ **Research and fabrication** ⇨ **Product prototype**

- Feasibility study
- Specifications
- IPR

- Modelling and simulation
- Prototype design and manufacturing
- Test setup development, test measurements
- Interface electronics design and implementation

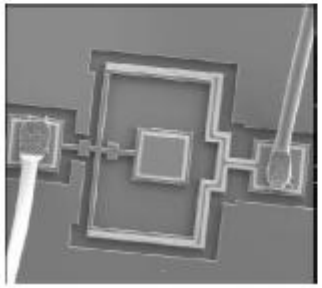
- Contract manufacturing
- Ramp up production
- Technology transfer
- Licensing

Micro- and nanotechnology center Micronova

- Largest research clean room facility in Northern Europe, class 10-100, 2600 m2
- 150 mm Si-process (mostly)
- CMOS-line, 0.6 µm linewidth
- More than 15 years of experience in MEMS design, manufacturing, electronics and testing
- Small scale production of several SOI based sensors

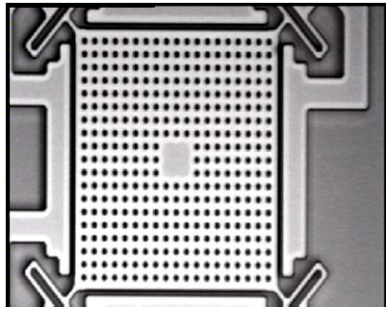
VTT Memsfab Oy
Contract manufacturing services

- A company founded within VTT group Jan 2011
- Seamless transition form research to production
- Provides contract manufacturing services
  - Piloting and ramp-up
  - Yearly volumes < 1M pcs
  - Technology transfer to high-volume manufacturers

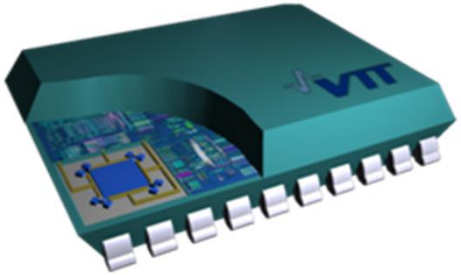


High-volume foundry

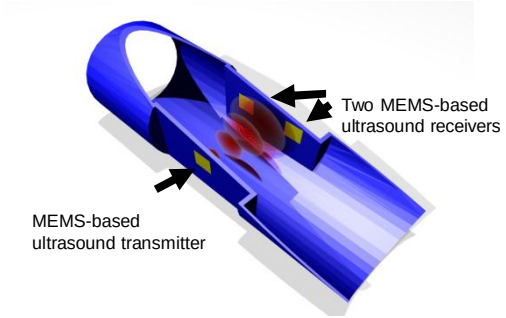
Reference projects



VTT has been a forerunner in developing low noise and temperature stable resonators since 1999.



VTT has a world record in MEMS sensor stability. Measured stability of the ac voltage reference was 2 ppm over one month.



VTT has invented a low cost flow meter based on ultrasound. Differential detection method eliminates errors due to contamination for example.

References

John Kao, Innovation Nation:

Otaniemi has also become a world leader in research into micro-electromechanical systems (MEMS), a technology that combines computers with tiny mechanical sensors, valves, gears, mirrors, and actuators embedded in semiconductor chips. For example, MEMS enable the clever Nintendo Wii

References

[1] Denison, T.; Jinbo Kuang; Shafran, J.; Judy, M.; Lundberg, K.; , "A Self-Resonant MEMS-based Electrostatic Field Sensor with 4V/m/Hz Sensitivity," *Solid-State Circuits Conference, 2006. ISSCC 2006. Digest of Technical Papers. IEEE International* , vol., no., pp.1121-1130, 6-9 Feb. 2006

[2] Lundberg, K.H.; Shafran, J.S.; Kuang, J.; Judy, M.; Denison, T.A.; , "A self-resonant MEMS-based electrostatic field sensor," *American Control Conference, 2006* , vol., no., pp.6 pp., 14-16 June 2006.

[3] Kim, B.C.; Kasim, R.; , "MEMS for sensing high current overload," *Mixed-Signals, Sensors and Systems Test Workshop (IMS3TW), 2010 IEEE 16th International* , vol., no., pp.1-6, 7-9 June 2010.

[4] Wong, J., "Analysis, Design, Fabrication, and Testing of a MEMS Switch for Power Applications," *Doctoral Thesis*, MIT, June 2000.

[5] Paprotny, I.; Leland, E.; Sherman, C.; White, R.M.; Wright, P.K.; , "Self-powered MEMS sensor module for measuring electrical quantities in residential, commercial, distribution and transmission power systems," *Energy Conversion Congress and Exposition (ECCE), 2010 IEEE* , vol., no., pp.4159-4164, 12-16 Sept. 2010.

[6] Sikorski, W.; Ziomek , W; Kuffel , J;. Kuffel, E.; and Siodla, K.;:" Recognition of partial discharge sources in power transformers using acoustic emission method with advanced signal processing," TPWRD-00790-2007

[7] Tian, Y.; Lewin, P.L.; and Davies, A.E.;:Comparison of On-line Partial Discharge Detection Methods for HV Cable Joints", IEE Transactions on Dielectrics and Electrical Insulation, Vol. 9, No. 4, August 2002.

[8] H.Rimminen, J. Hällström, P.Immonen, H. Seppä, A. Manninen, T. Latonen, J. Kyynäräinen, and A. Kärkkäinen, "Demonstration of 50-Hz Electrical Active Power Measurement using a Micromechanical Magnetometer," submitted to International Conference on Precision Electromagnetic Measurements, Washington DC, U.S., CPEM2012. (submitted)

[9] Case Study: LA Power Grid Marks 10 Years of Photonic Power Deployment, JDS Uniphase Corporation, http://www.jdsu.com/ProductLiterature/Intermountain-casestudy-FINAL.pdf

VTT creates business from technology