Acoustic/Electronic stack design, interconnect, and assembly

Techniques available and under development

- supported by the European Commission
under support-no. IST-026461 e-CUBES

Maaike M. V. Taklo : SINTEF, Norway

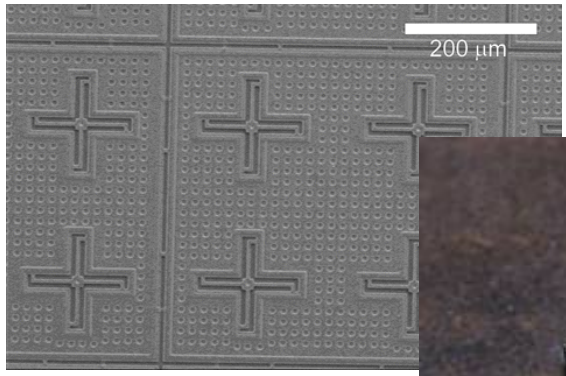
MI-lab Work-shop on future ultrasound probe technology

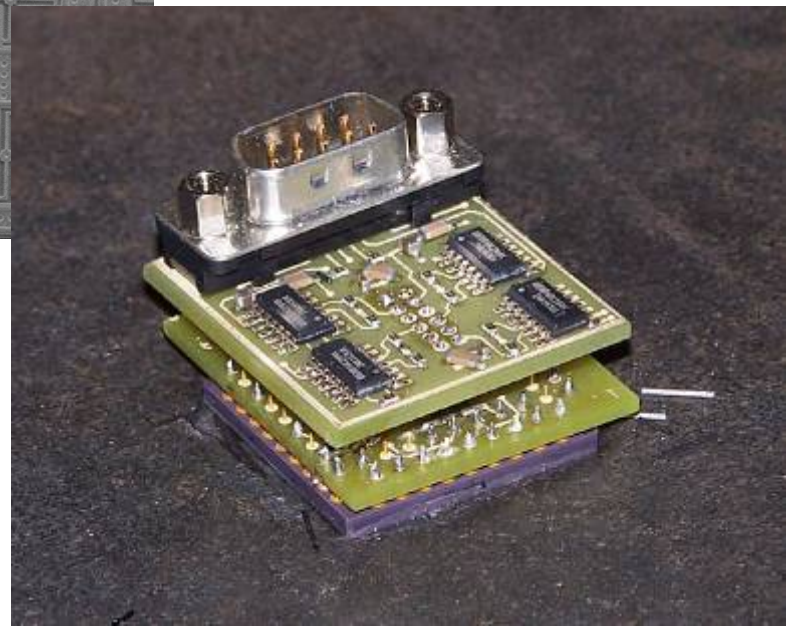
Trondheim, March 26. 2009

Outline

- 3D integration of MEMS/IC
- Solutions for through silicon vias
- Solutions for interconnects
- Examples of applied technologies
- Coming project
- Summary

MEMS: Micro electromechanical systems





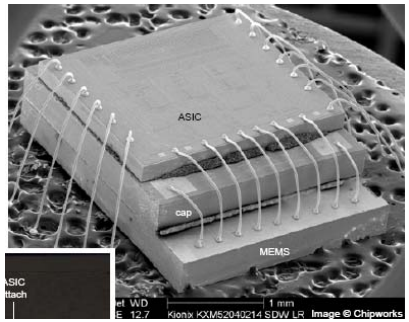
- Enables
  - Sensors
  - Actuators
    - cMUT: Both
- Demands
  - “Window” to the environment
  - ASICs for calibration and control
    - cMUT: Logic and memory

Source: www.ece.cmu.edu/~dwg/research/ae.html

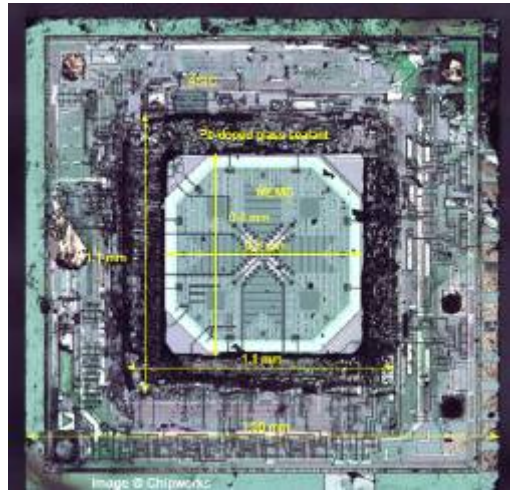
Existing packaging solutions

- Market driver examples
  - Nintendo Wii
  - Mobile phones
- The progress
  - Side by side, wire bonded
  - 3D stacked with wire bonds
  - Integrated in-plane
  - Interposer with through silicon vias (TSVs)
  - Wafer level packaging…

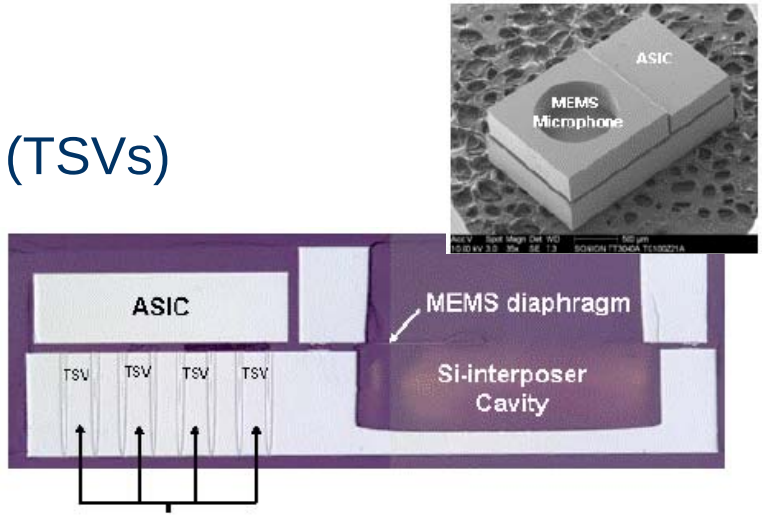
Kionix, KXPB5



Analog Devices Inc, ADXL330

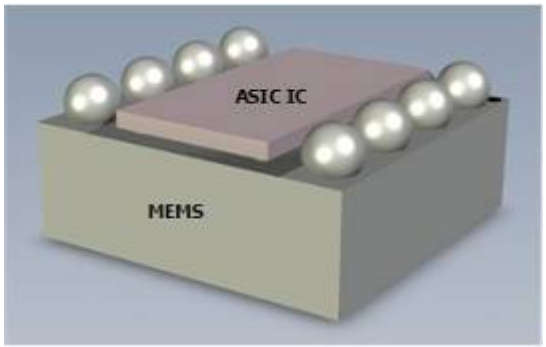


Source: CHIPWORKS

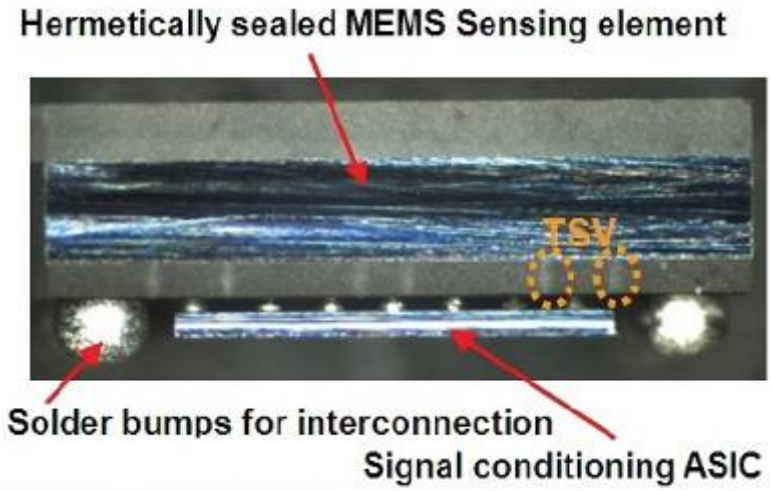


Wafer level packaging (WLP)

- No wire bonds
  - Through Silicon Vias (TSVs) required
  - Interconnects defined on wafer level
- Ready for surface mounting after final dicing



Source: VTI

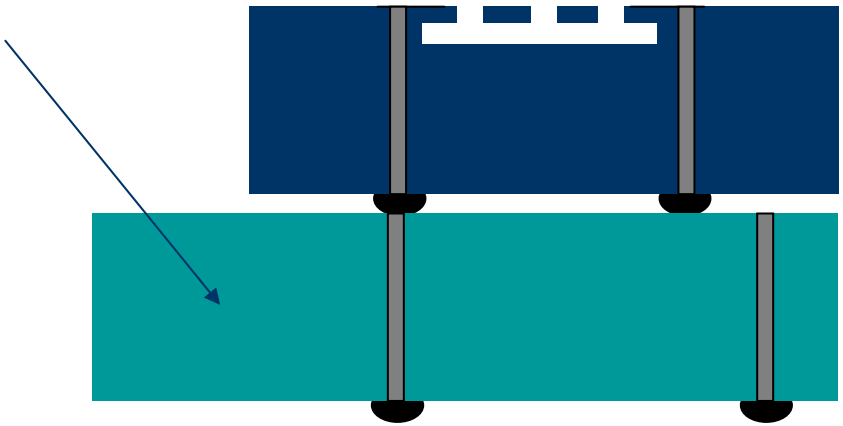


cMUTS: MEMS wafer TSVs / interposer

Surface micromachining or based on bonding

Interposer

RDL

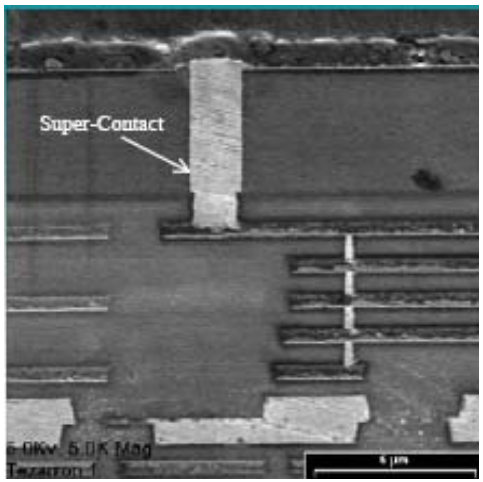


TSV technology choice

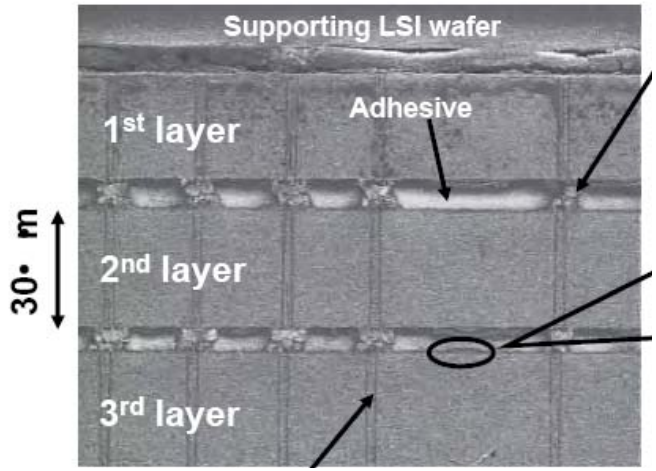
Pitch: 25 µm
Wafer thickness: 30-100µm
Aspect ratio: 10-20

TSVs

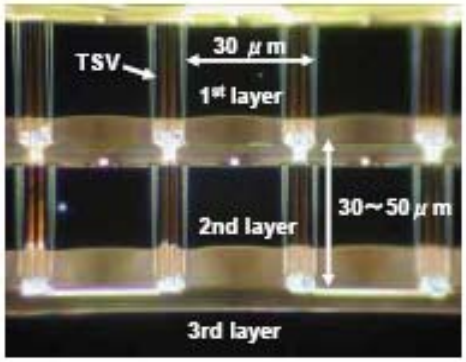
Pitch <50 µm, wafers <100 µm (ICs)



Source: Tezzaron



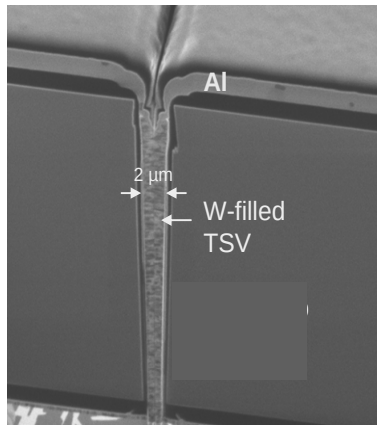
Source: ZyCube



Source: Honda

Poly Si, W, Cu, conductive paste

Source: Fraunhofer IZM-Munich



Definitions of TSVs

- Front-end-of-line (FEOL)
  - Before IC wiring
- Back-end-of-line (BEOL)
  - During IC wiring in IC foundry
- Post-BEOL
  - Following complete IC fabrication
- Vias First
  - Made before wafer bonding
- Vias Last
  - Made after wafer bonding and thinning

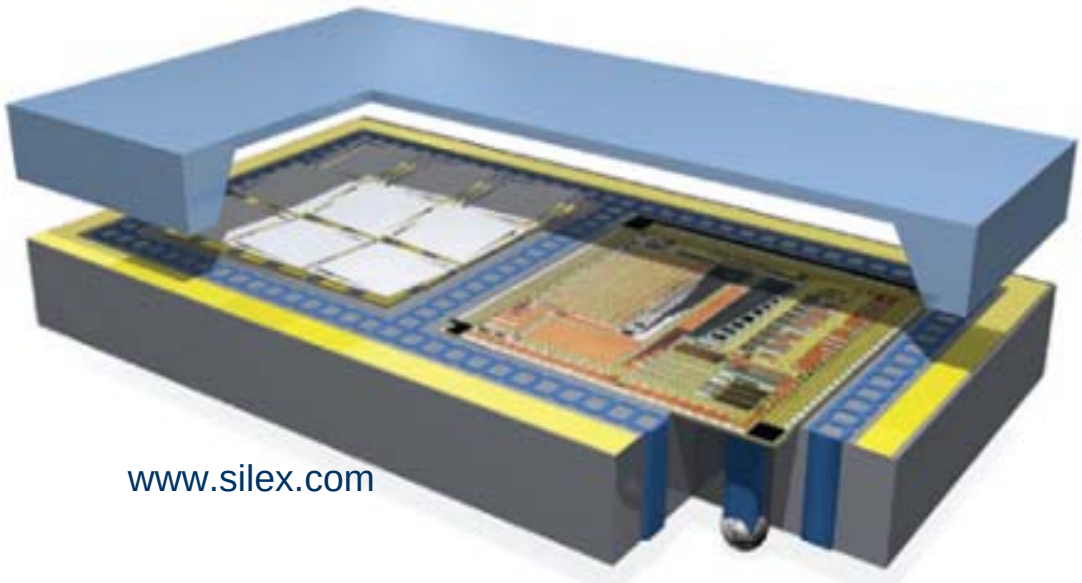
Source: Fraunhofer IZM

Handbook of 3D Integration (Garrou, Bower and Ramm)

TSVs

Pitch >50 µm, wafers >100 µm (MEMS)

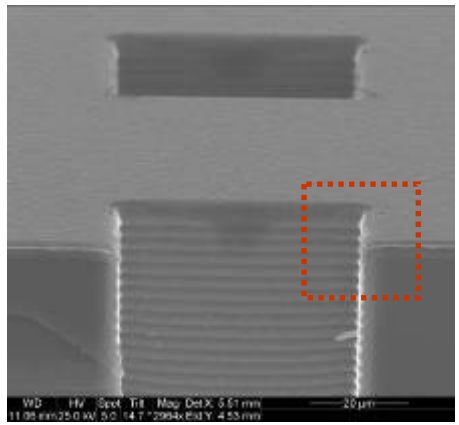
Si pins in Si



www.silex.com

Poly Si

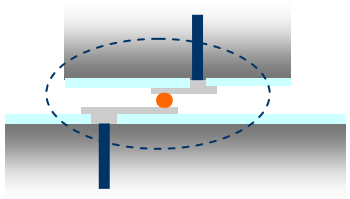
Hollow vias in Si



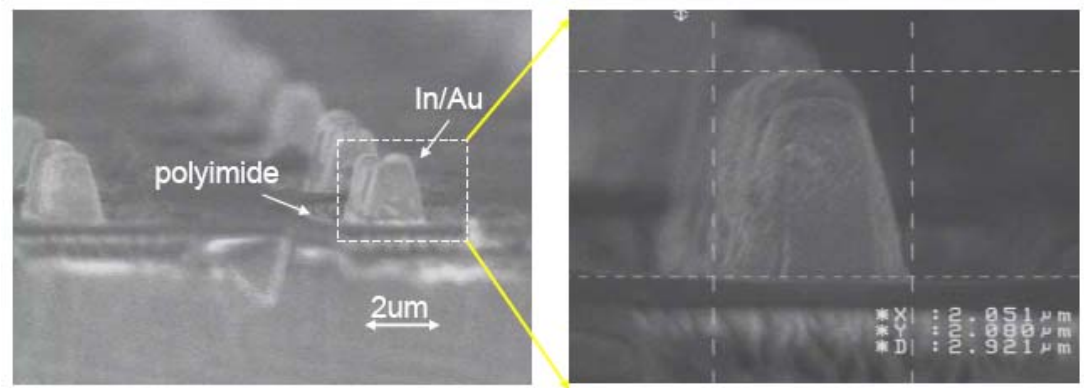
Source: SINTEF

Interconnects

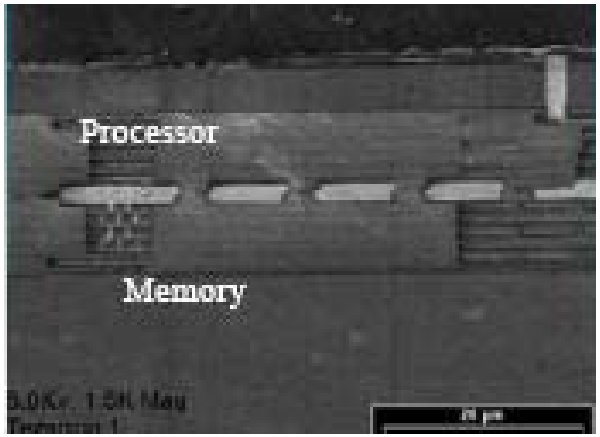
Pitch <50 µm, stand-off height ~5 µm



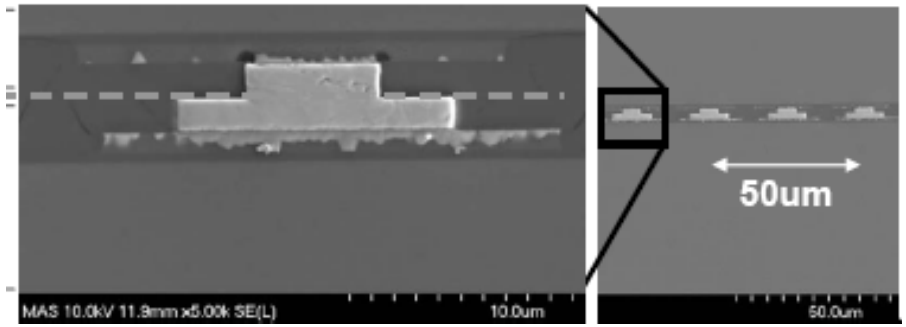
In/Au, Cu, Ni



Source: ZyCube



Source: Tezzaron

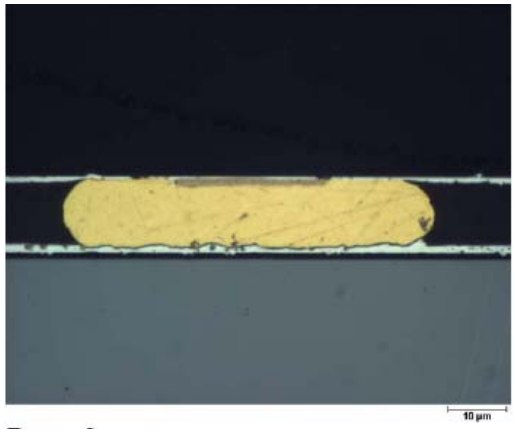


Source: Ziptronix

Interconnects

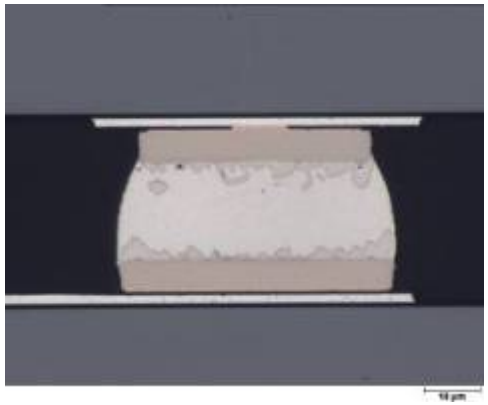
Pitch >50 µm, stand-off height ~10-20 µm

Au stud bump bonding (SBB)



Source: SINTEF/Datacon

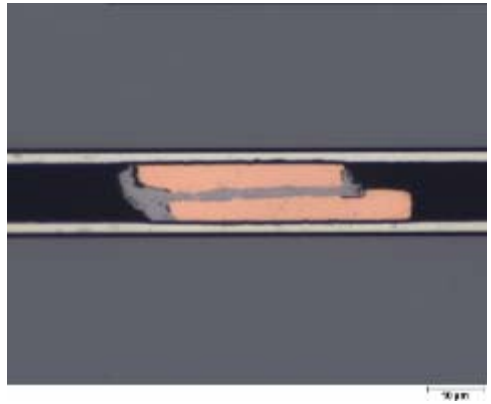
SnAg/AuSn microbumps



Source: SINTEF/Fraunhofer IZM-Berlin

Au, Cu/Sn, SnAg, AuSn

Cu/Sn SLID



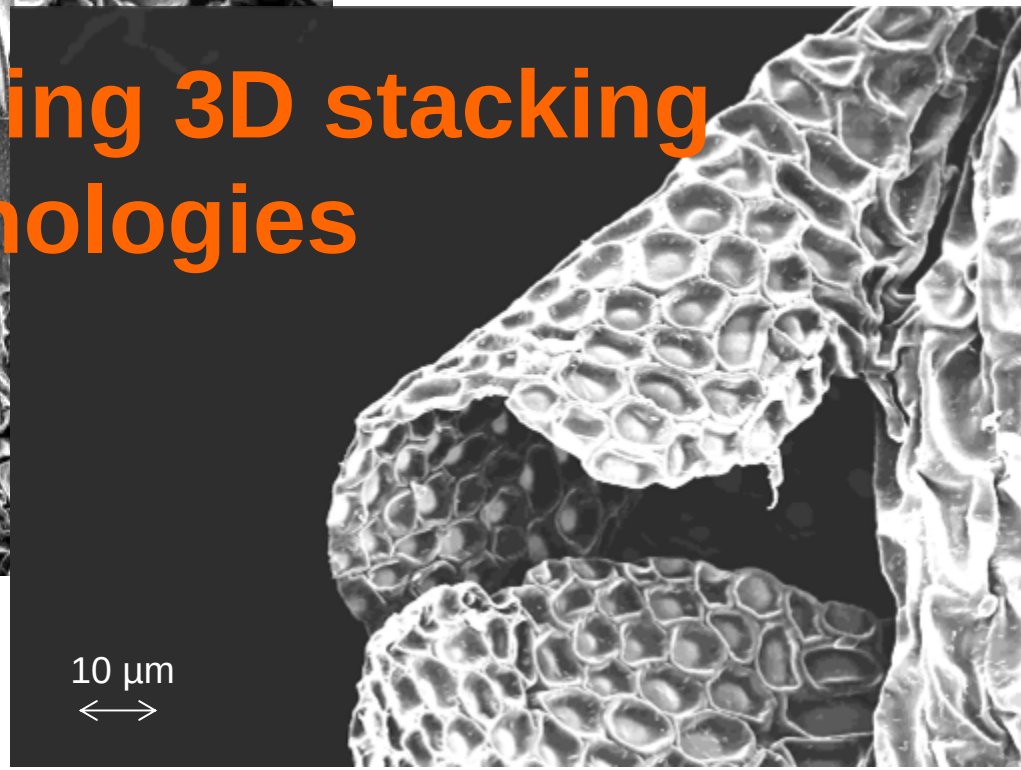
Source: SINTEF/ Fraunhofer IZM-Munich

Examples using 3D stacking technologies

High aspect ratio pillars on a leaf

Lesson learned from nature about 3D stacking

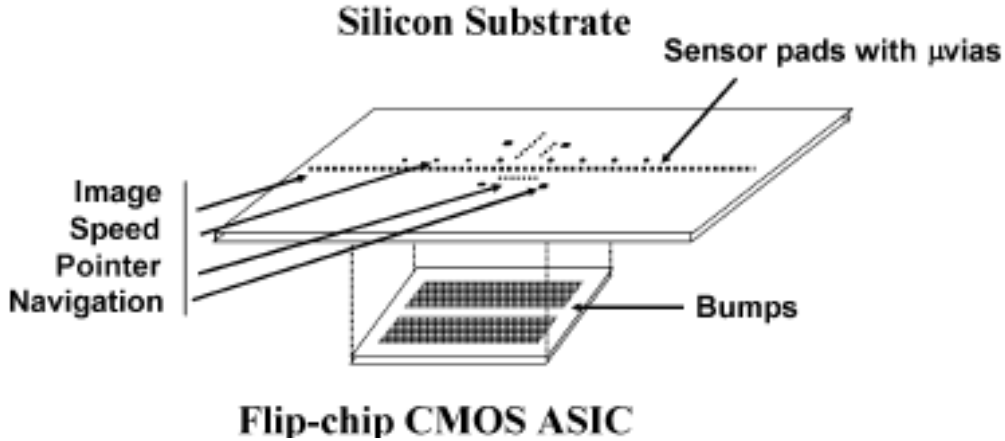
Moss, flexible by thinning

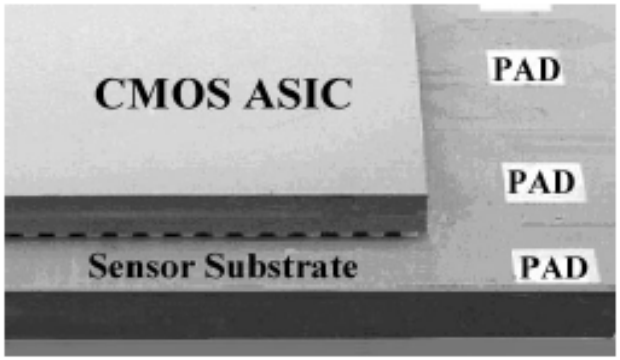


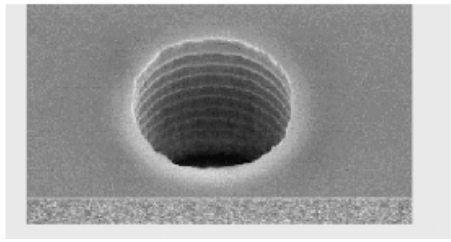
Source: MEMS-Point, Thomas Brunschwiler

3D integrated planar silicon sensor

- Fingerprint sensor
  - Navigation and pointer detection
  - TSVs through sensor
    - Pitch 50 µm
    - 20 µm wide
  - Bumps for interconnect
    - Routed out



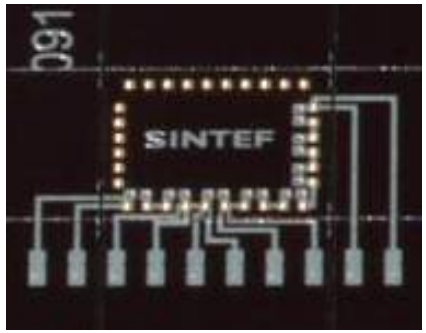


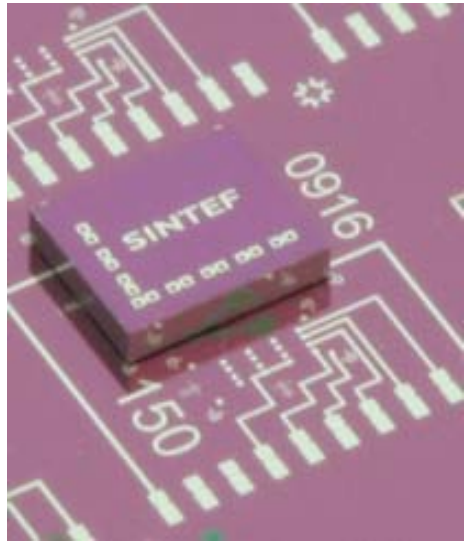


O. Vermesan et al, IEEE Journal of Solid-State Circuits, Vol. 38, No. 12, December (2003) / www.idex.no

Technology demonstrator

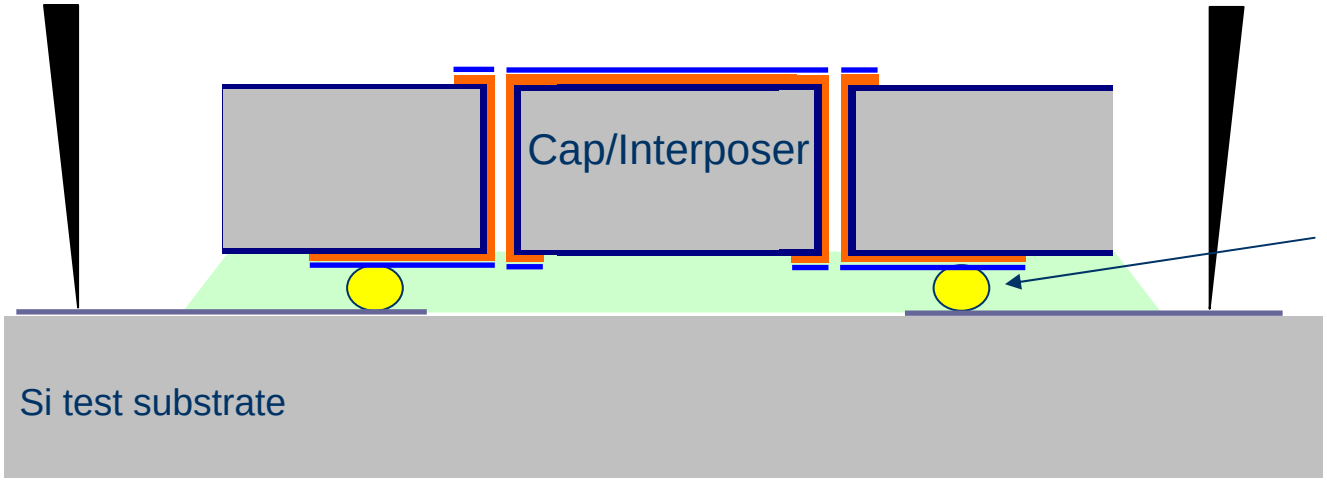
- Hollow vias with gold stud bumps (HoViGo)
  - High yield
  - Good reliability

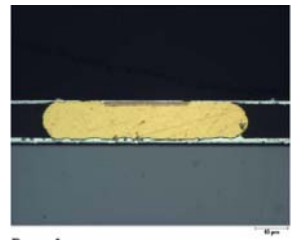




Source: SINTEF

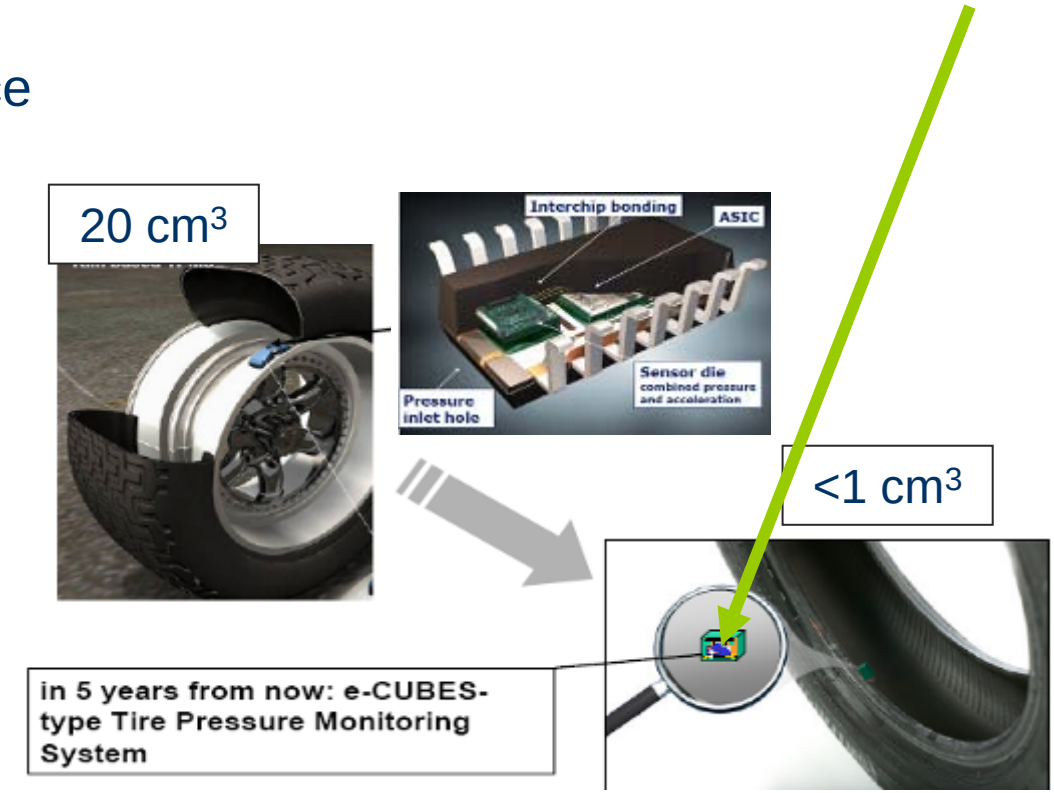
Pitch: 110 µm
Stand-off height: 10-15 µm





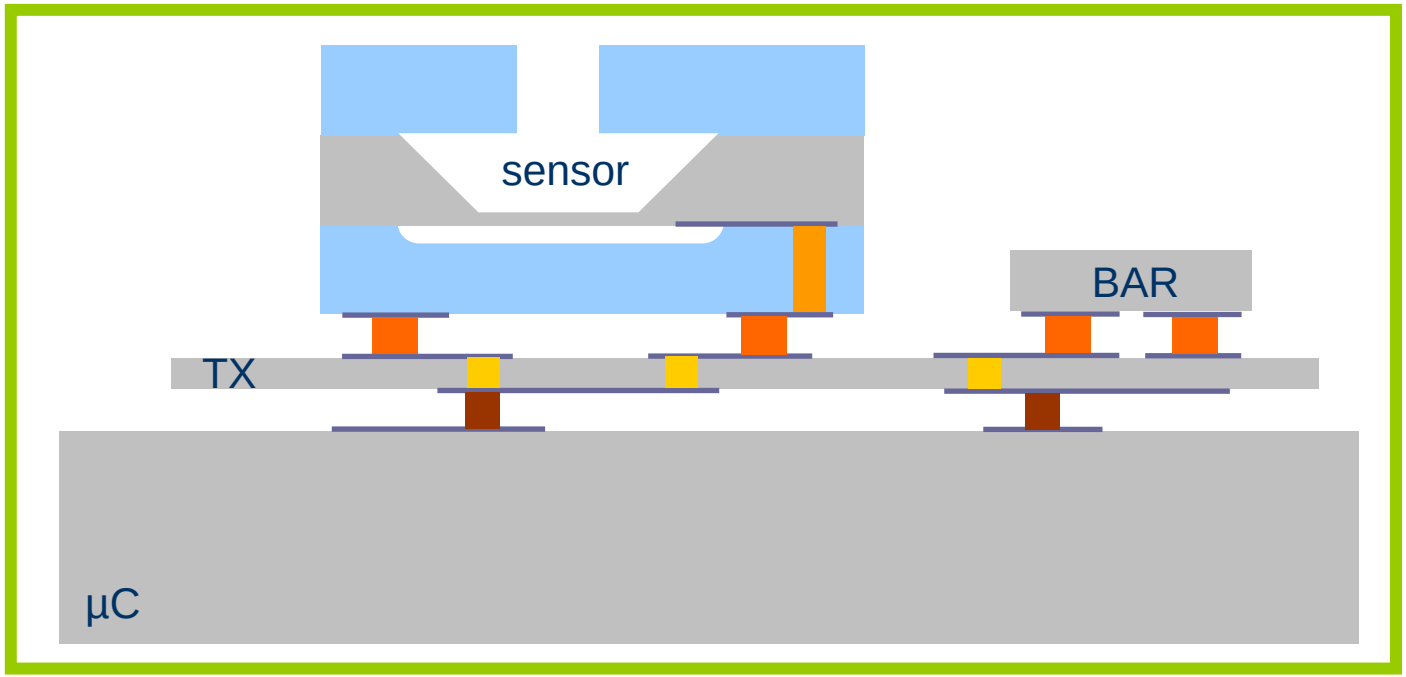
e-CUBES TPMS demonstrator

- Develop wireless sensor networks with miniaturized sensor nodes
- 3 demonstrators
  - Health and fitness
  - Aeronautics and space
  - Automotive
    - Tire Pressure Monitoring System (TPMS)



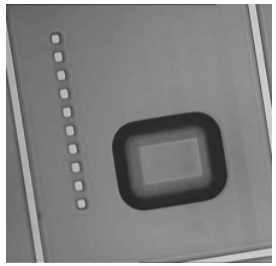
TPMS building blocks

- µ-controller ASIC (µC) : 4.3 x 3.8 mm^2
- Transceiver ASIC (TX): 3.8 x 3.3 mm^2
- MEMS pressure sensor: 1.8 x 2.1 mm^2
- MEMS bulk acoustic resonator (BAR): 0.8 x 1.3 mm^2
  - Antenna, battery, outer package



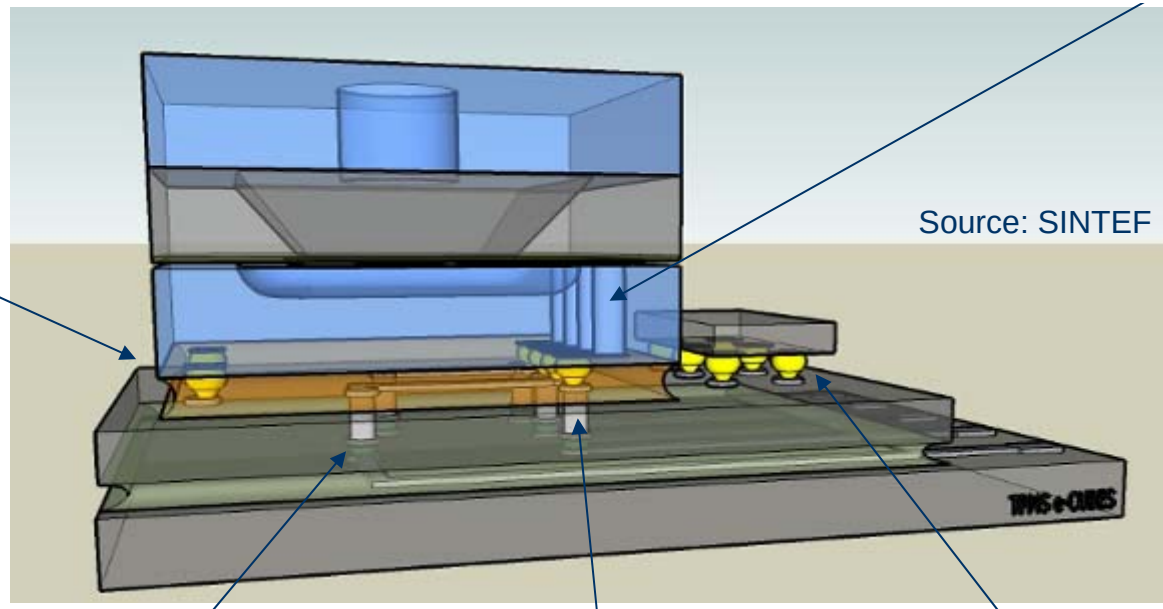
Technology choices

Silicon-glass compound wafer with TSVs (alternative : hollow TSVs)

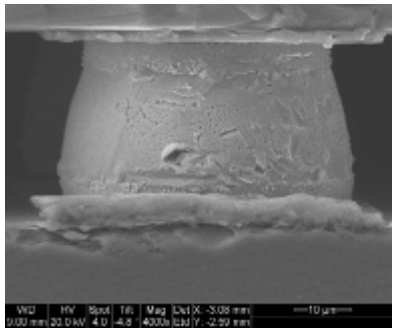


Source: SINTEF/ SensoNor/ PlanOptik

Au stud bumps with adhesive (alternative : SLID)

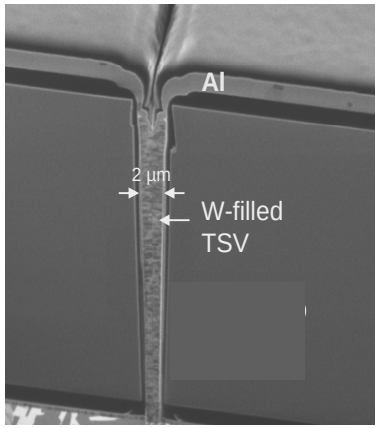


SnAg microbumps and underfiller



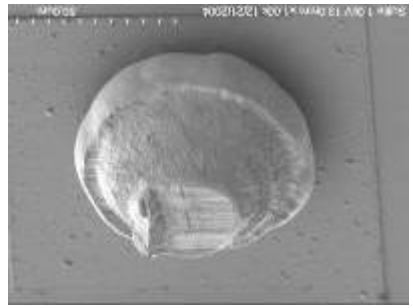
Source: SINTEF/ FhG IZM- Berlin

TSV with W



Source: Fraunhofer IZM-Munich

Au stud bumps only (alternative : SLID)

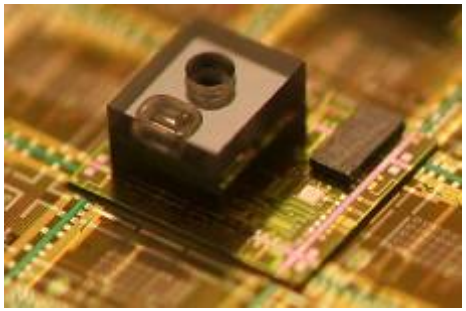


Source: Kulicke & Soffa

TPMS demonstrator results

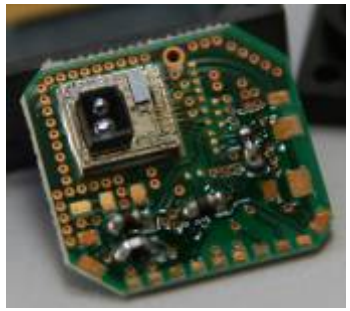
- Successful measurements on PCB level
  - Communication with TX
  - Communication with µC
  - BAR is running at correct frequency
- Sensor performance to be measured soon

MEMS / TX / µC 3D stack



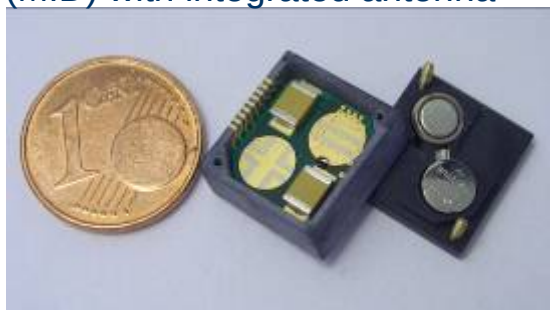
Source : SINTEF

Micro-PCB



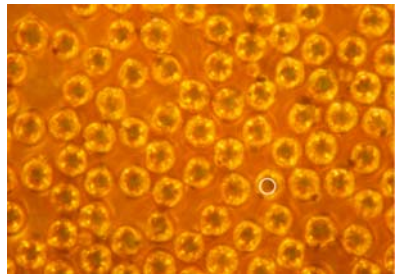
Source : Infineon Technologies

Molded Interconnect Device (MID) with integrated antenna

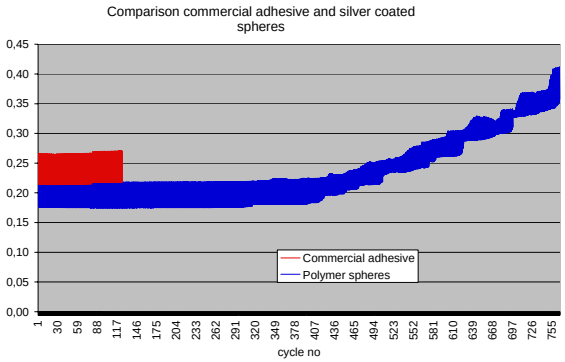


Miniaturized TPMS ~ 1 cm^3

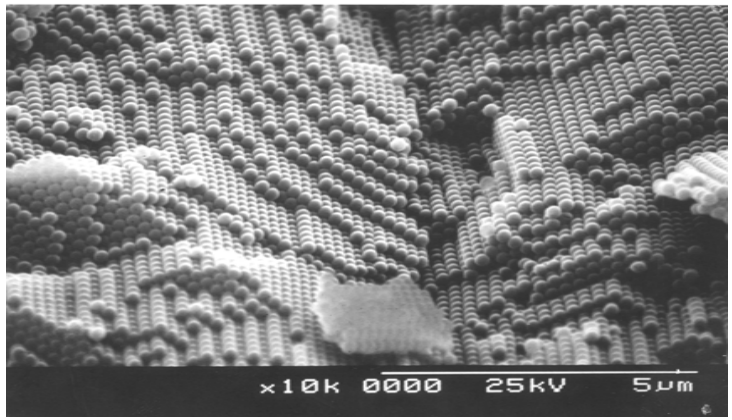
ReMi (KMB, BIA)



- Fine Pitch Interconnect of Microelectronics and Microsystems for use in Rough Environments
- 3 case studies
  - New or significantly improved devices for challenging environment applications
- SINTEF, VUC, FFI
- 6 Norwegian companies



Metal coated polymer spheres (ICA/ACA/ACF)

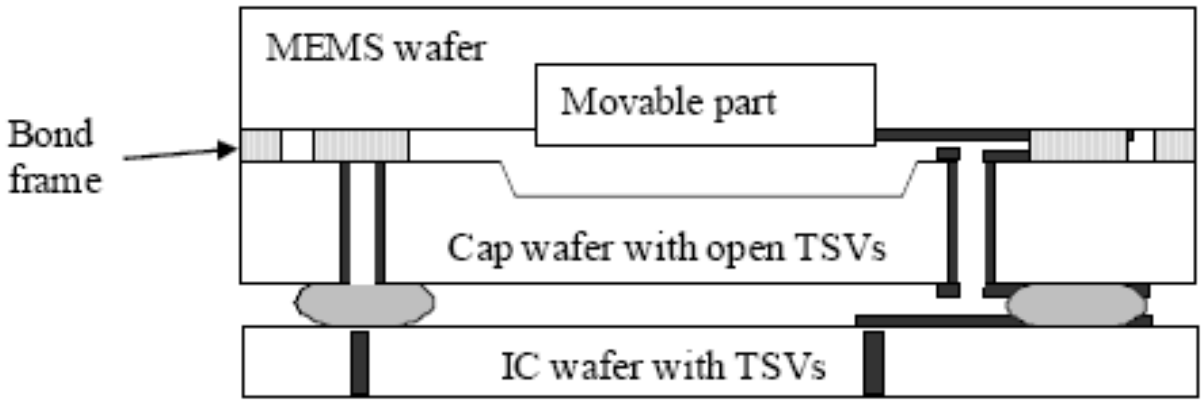


Source: Conpart

Coming:

JEMSiP 3D

- ENIAC
- SUB-PROGRAMME 8
  - Equipment & Materials for Nanoelectronics
- 20 partners
  - SUSS, FCI, FhG, LETI, Infineon, ALES, ASM…etc
- Kick-off: 2009-04-07



Summary

- A number of 3D stacking technologies are emerging
- Technology choice depends on required
  - Pitch
  - Aspect ratio
  - Stand-off height
  - Number of I/O counts
  - Compatibility of wafer/processes
- Research has come quite far, large activity
  - www.3dic-conf.org
- Industry coming
  - Optical devices
  - MEMS

Acknowledgements

- Colleagues of the e-CUBES project, especially
  - Werner Weber, Thomas Herndl and Josef Prainsack, Infineon Technologies
  - Timo Seppänen, Infineon Technologies SensoNor
  - Peter Ramm, Josef Weber and Lars Nebrich, Fraunhofer IZM-Munich
  - Jürgen Wolf and Matthias Klein, Fraunhofer IZM-Berlin
  - Nicolas Lietaer, Thor Bakke, Hannah Rosquist, Kari Schjølberg-Henriksen …, SINTEF
- Vincent McTaggart, Kulicke and Soffa Industrial (KNS)
  - For providing the bumping service
- Gerhard Hillmann, Datacon Technology GmbH
  - For providing the chip to wafer bonding service and process development