Reliability Flagship Projects in NoE PATENT-DfMM

Ingrid De Wolf, IMEC

Nov-06

Focus on reliability

- How to test reliability
  - Stress based testing vs knowledge/application driven testing
  - Test structures
  - Understanding failure mechanisms (physics of failure)
  - Networking required

DfMM NoE PATENT

4 reliability flagships

- RELMETH (Marius Bazu, IMT)
- VIBSHOCKT (Khiem Trieu, IMS: Ingrid De Wolf, IMEC)
- HUMIDITY (Claude Pellet, IXL)
- ACCELEROMETER (Alan Brown, QinetiQ)

Reliability flagship management:

Orla Slattery, Tyndall

RELMETH

„Methodology for accelerated testing and reliability analysis of MEMS”

Marius Bazu, IMT

QinetiQ

DIPARTIMENTO DI
INGEGNERIA STRUTTURALE

LANCASTER
UNIVERSITY

Nov-06

«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»
Network of Excellence funded by the European Commission (EC FP6: IST, Unit C2, Contract 507255)

- Focus on ALT:

  accelerated lifetime testing

  (stress factors: power cycling, vibration, humidi temperature cycling, temperatures, etc.)

Old scientist

- Two 'kinds' of ALT:
  - Qualitative testing: to identify design weaknesses (Accelerated Stress Testing – AST)
  - Quantitative testing: to quantify reliability parameters ((Q)ALT)
- Purpose:

  To set-up a one-stop-shop for accelerated testing and reliability analysis of MEMS.

RELMETH: Project details

Two sub-projects:

SP1: Comparing Patent-DfMM knowledge with the state of the art in accelerated tests & reliability analysis and identifying missing elements (IMT, POLIMI, BUTE, IMS, LIRMM, ULAN, HWU, QinetiQ)

SP2: Performing (new) accelerated tests & reliability analyses on MEMS devices supplied by industry (IMT, POLIMI, BUTE, IMS, CSL, LIRMM, ULAN, HWU)

Devices from ST and from QinetiQ

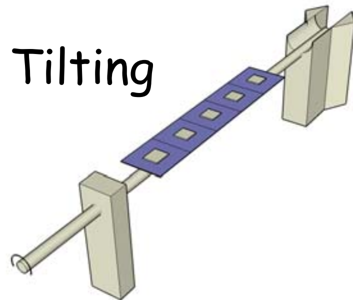
RELMETH: test plan

- The significant acceleration factors must be chosen depending on the main application of the tested MEMS (accelerometer):
  - Mechanical + thermal stress
  - Mechanical stress: shock, acceleration, vibration, tilt
  - Thermal stress: temperature, thermal cycling
  - Vibration: appropriated for MEMS with moving parts
  - Tilting: used for transportation (avionics, auto, railways, etc.)
- The test plan will simulate:
  - an environment composed by vibration and temperature
  - the use of accelerometers in transportation: tilting + temperature

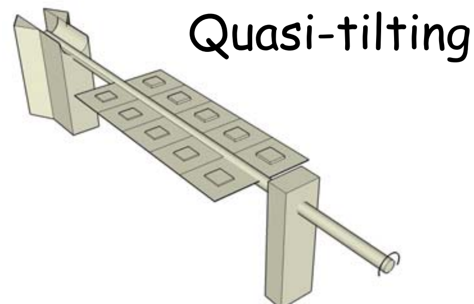
Example of a (new, application driven) ALT test: Tilting + Temperature

Mechanical stimulus –
(Quasi)tilting

Tilting



Quasi-tilting



RELMETH: goal 2006

- Life testing results on the accelerometers from ST Microelectronics
- A methodology for executing Accelerated Life Testing in the frame of Patent-DfMM (procedures, links, etc.)
- A study on the necessary projects for covering all the aspects of Reliability Analysis by Accelerated Testing
- A course on Reliability Analysis by Accelerated Testing

VIBshockT

Holistic Reliability Engineering for MEMS in harsh conditions

Khiem Trieu, IMS / Ingrid De Wolf, IMEC

Partners: IMS, IMEC, CSL, Polimi, Tyndall, BUTE, HWU, WUT, IMT, IZM

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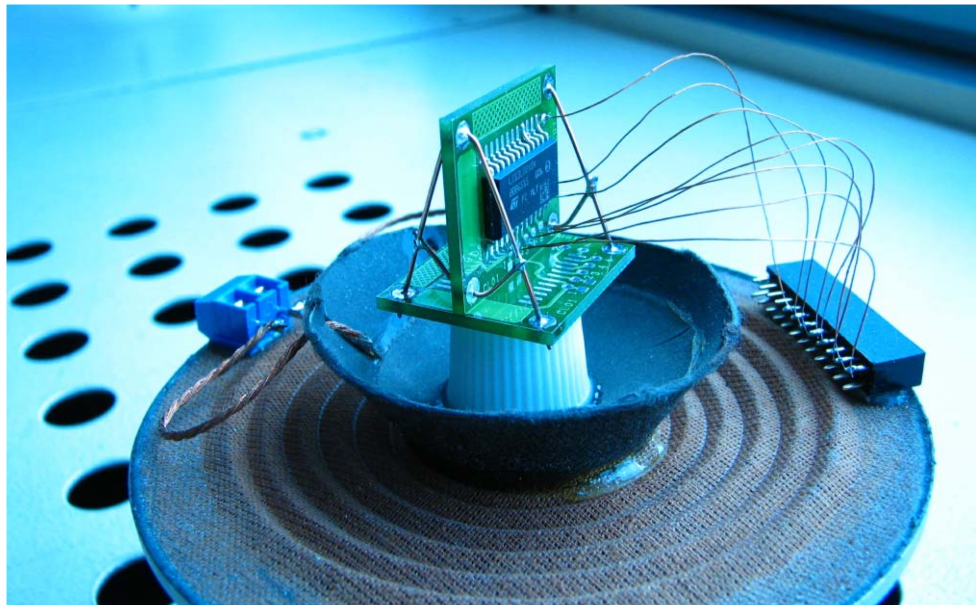
VIBshockT

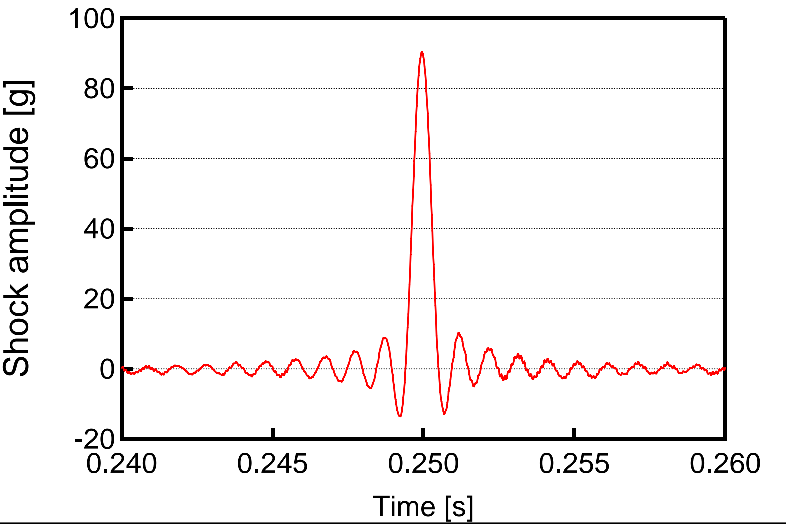
- Holistic Reliability Engineering for MEMS in harsh conditions
- Goal: Reliability testing and experimental and modeling analysis of MEMS devices (MEMS + package) in harsh conditions (vibration, shock, temperature).
- Perform ALT tests under standard conditions (T, P, shock,…) and compare with results under 'extreme' conditions
- Verification + prediction by modeling
- Devices from ST and from Qinetiq

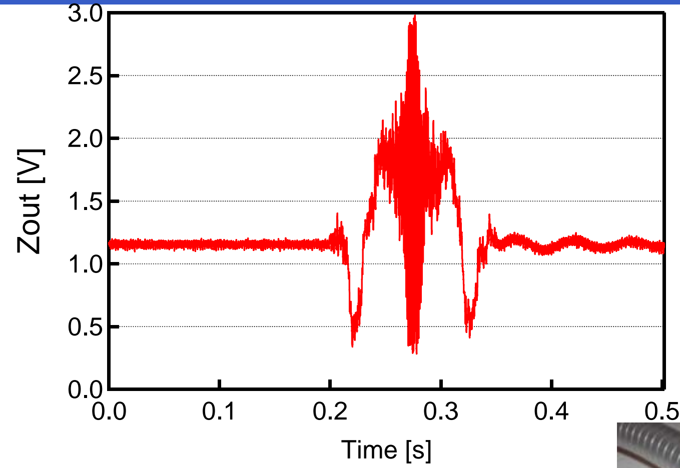
MIL-STD-883F-2005.2 vibration fatigue test method

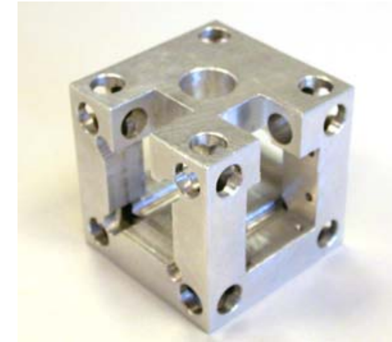
Standard tests (Bute and IMT):
no failures observed

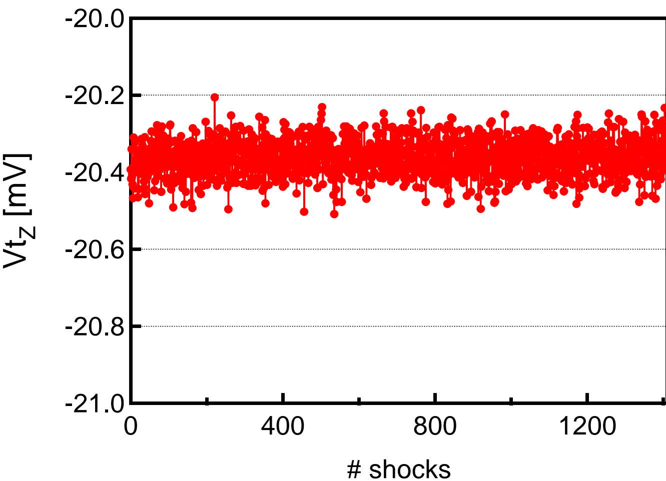


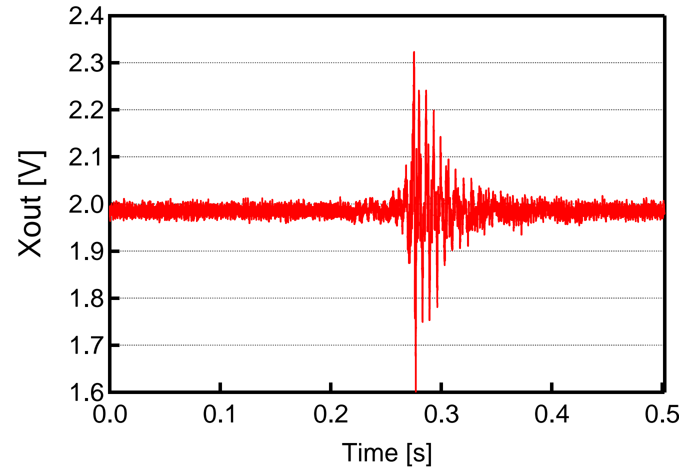
Shock test (low g, P=1 atm)





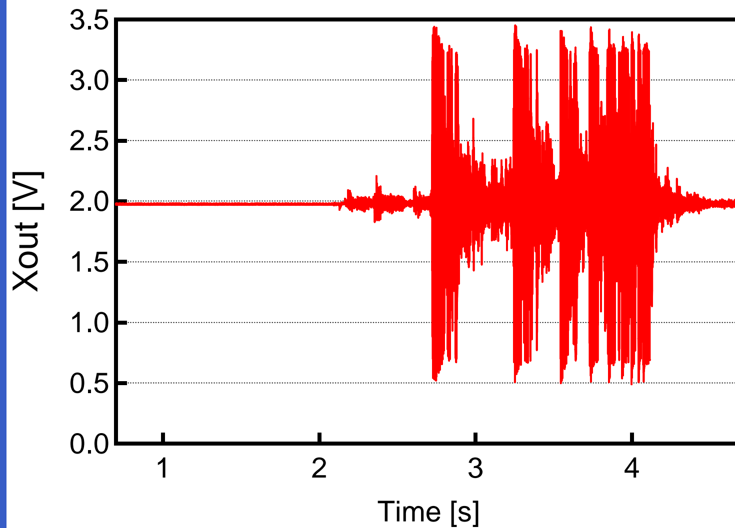






No failure (IMEC)

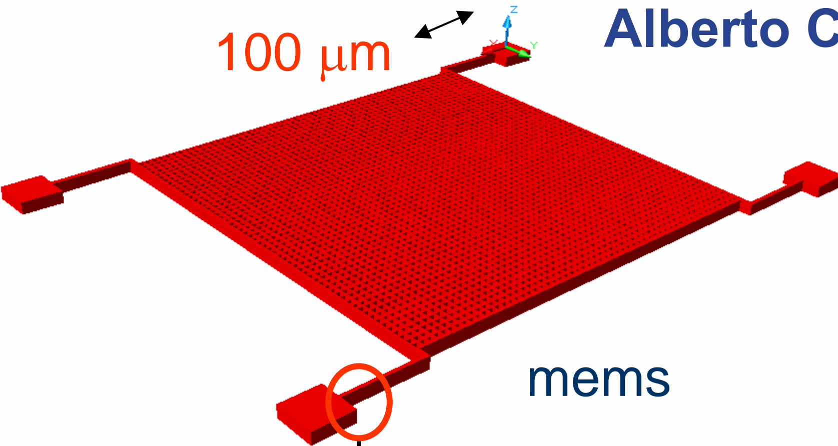
Shock test (high g, P=1 atm)

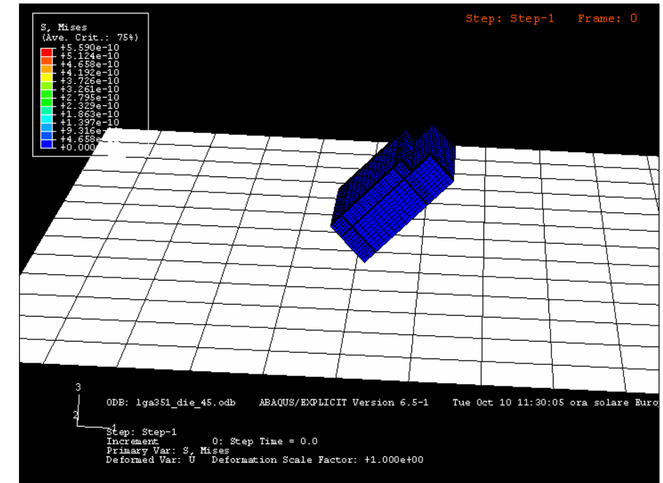


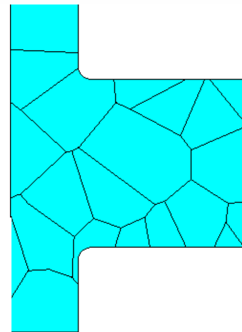
No failure observed (IMEC)

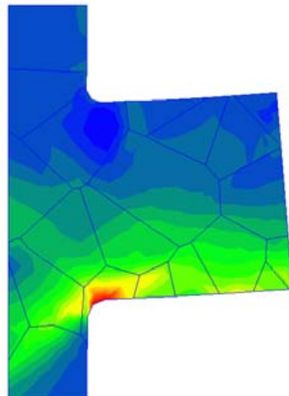
Simulations: impact/rupture

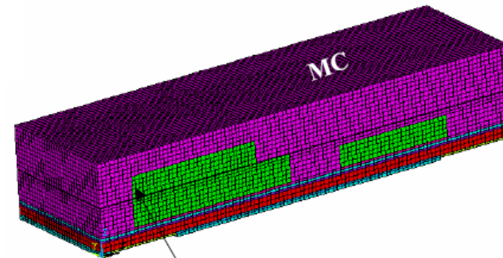
Alberto Corigliano, Fabrizio Cacchione. Polimi

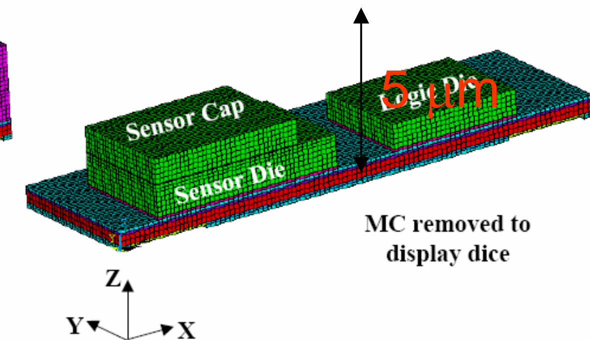




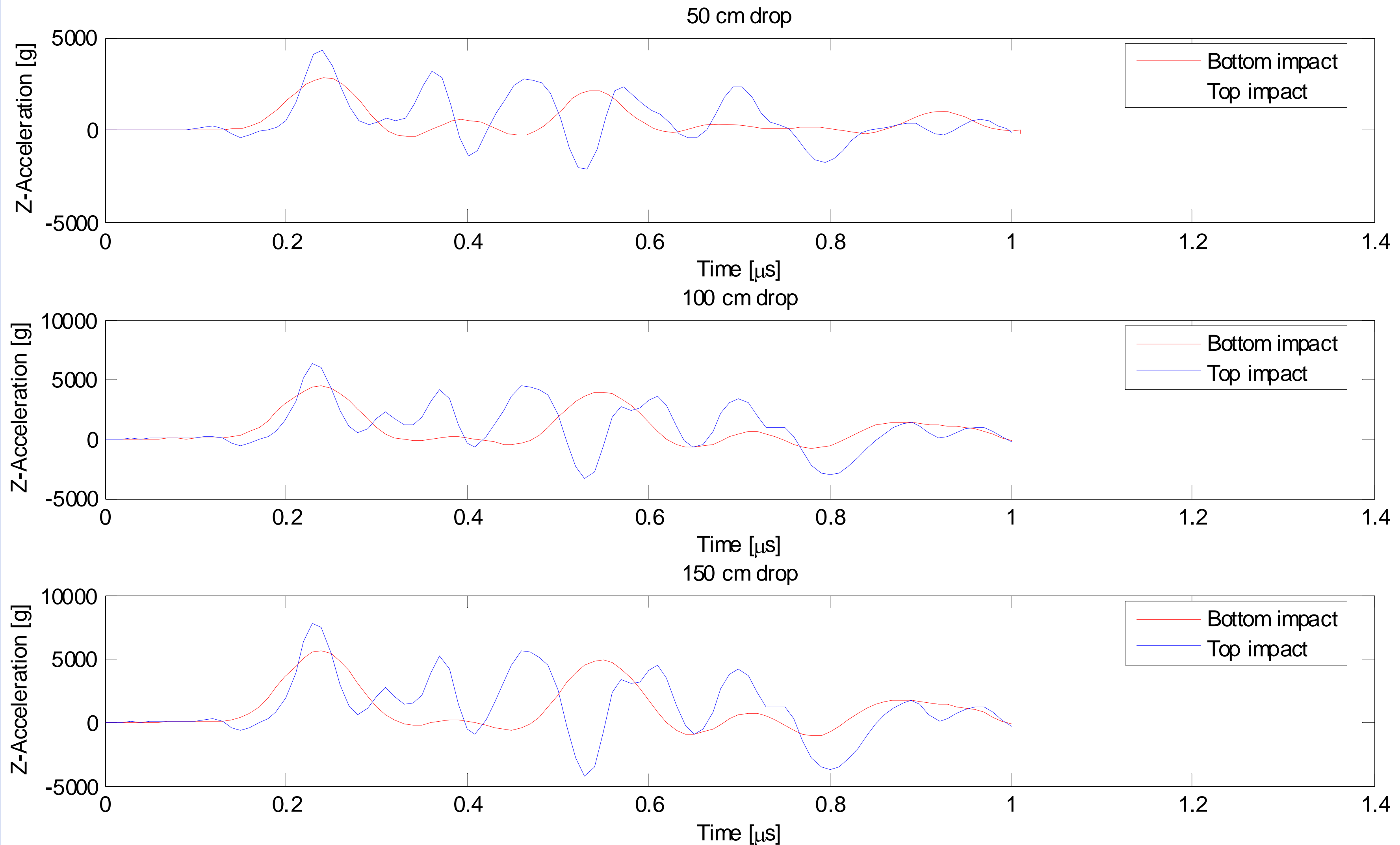








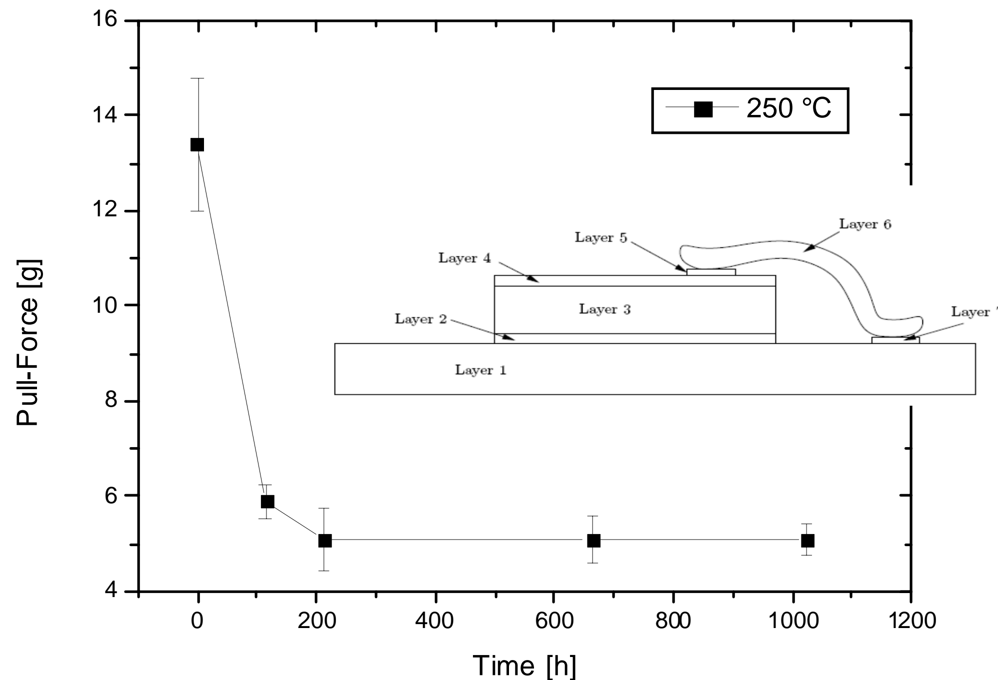
"bottom" and "top" z-acceleration history at different drop heights

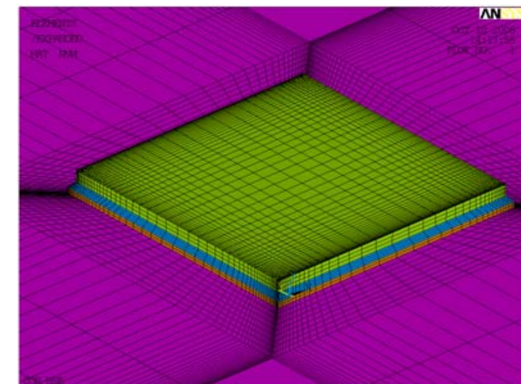


High T storage/cycling

- from RT to 250 or 300°C at pressures up to 100 bar (IMS)

Wire bond strength
after storage at 250 °C





- simulations

HERMETICITY

Clause Pellet, IXL

Partners: IXL, IEF, BUTE, LETI, Tyndall, IMEC, Qinetiq, Polimi, IMT

Nov-06

HERMETICITY

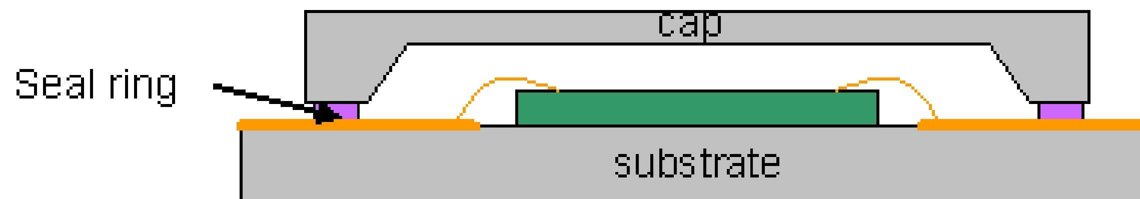
Aim : in-situ investigation of packaging hermeticity

Use a humidity microsensor as a device to demonstrate DfMM

Focus:

- wafer level packaging
- mainly polymer sealing ring

Gas diffusion simulations
In-situ monitoring of the atmosphere



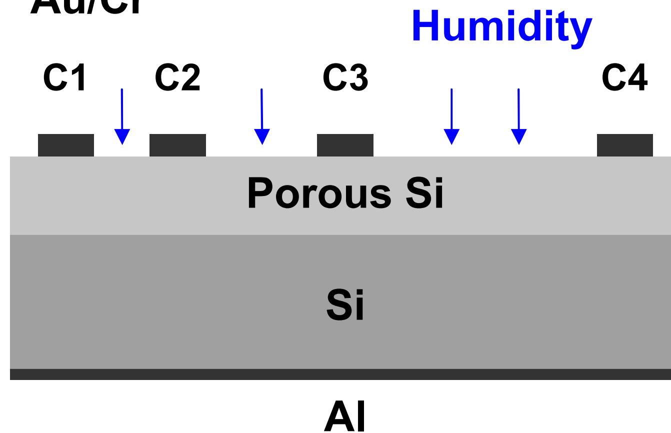
HERMETICITY: tasks

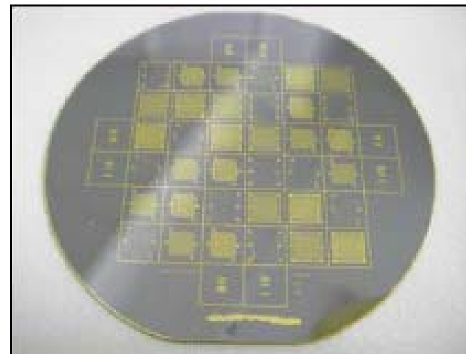
- design, fabricate and test a humidity microsensor to electrically detect traces of humidity
- characterize, measure and simulate reliability and packaging issues for the integration of the microsensor within a package
- analyse reliability and packaging concerns of wafer level packaging technologies for MEMS devices
- investigate the reliability measurement and modelling challenges associated with humidity, hermeticity and wafer level packaging for MEMS
- define mechanisms for bringing together partner knowledge obtained from activities and projects undertaken during the first 2 years of the PATENT NoE (across all technical workpackages), to demonstrate DfMM via a specific demonstrator of direct industrial benefit.

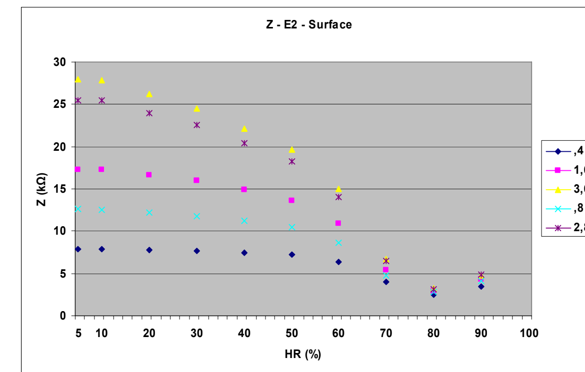
HERMETICITY: sensor

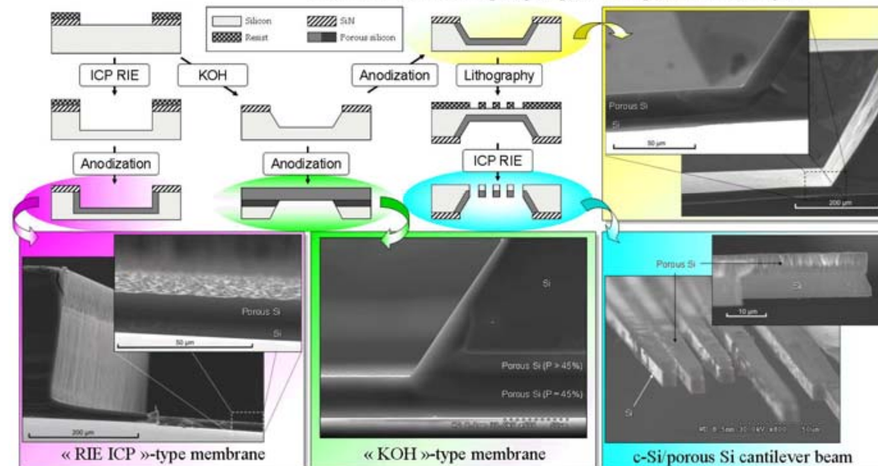
- Resistive / capacitive structure

Contacts Au/Cr





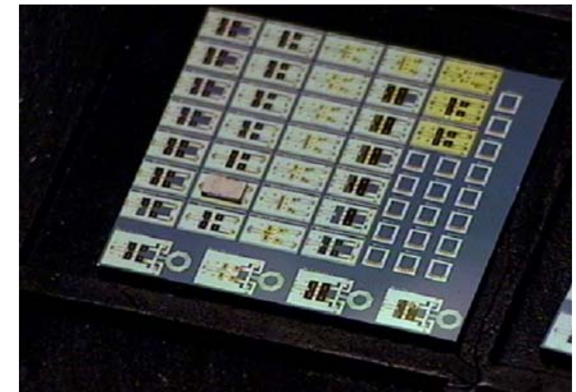




- Resonant structure

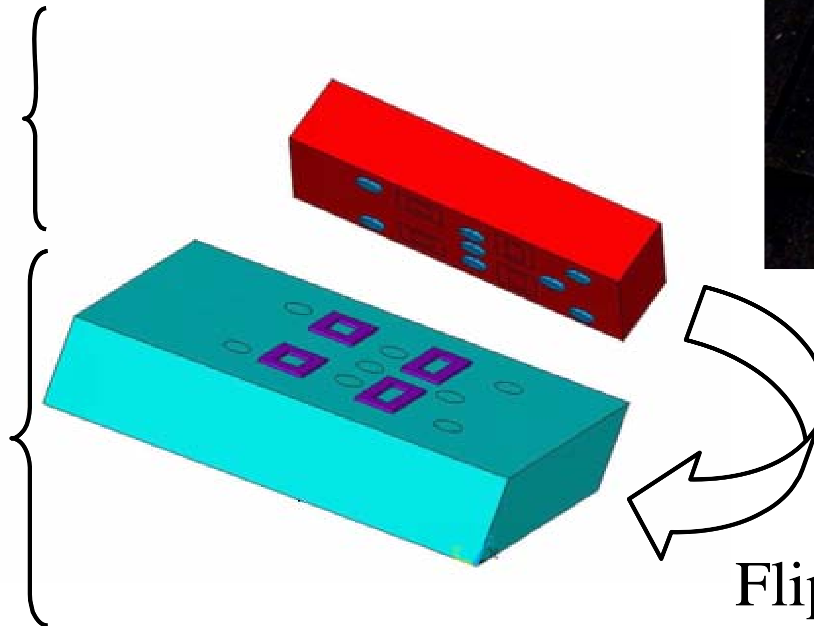
Test samples (NXP)

Integration of a die containing electro-mechanical component on a silicon substrate as a System in Package (SiP) solution



SAW filter with contact

PICS substrate with polymer seal rings

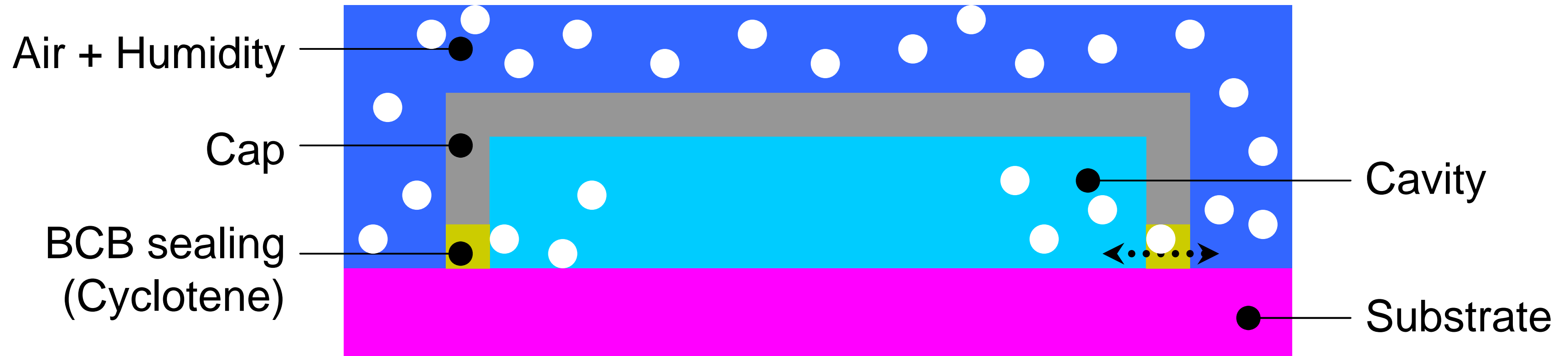


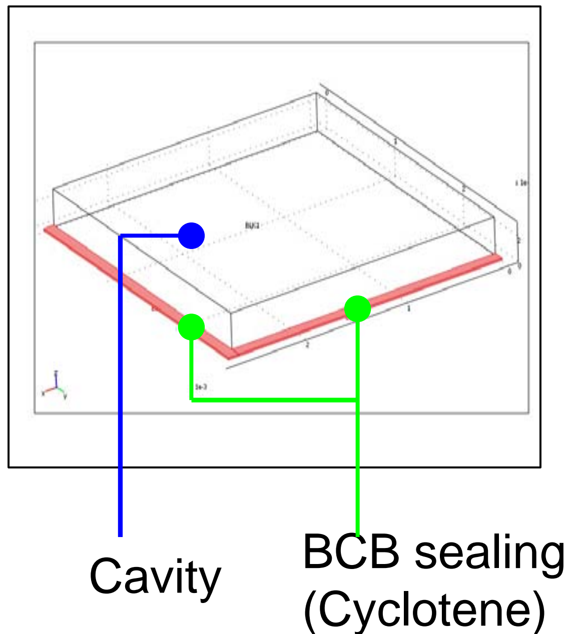
Flip-chip

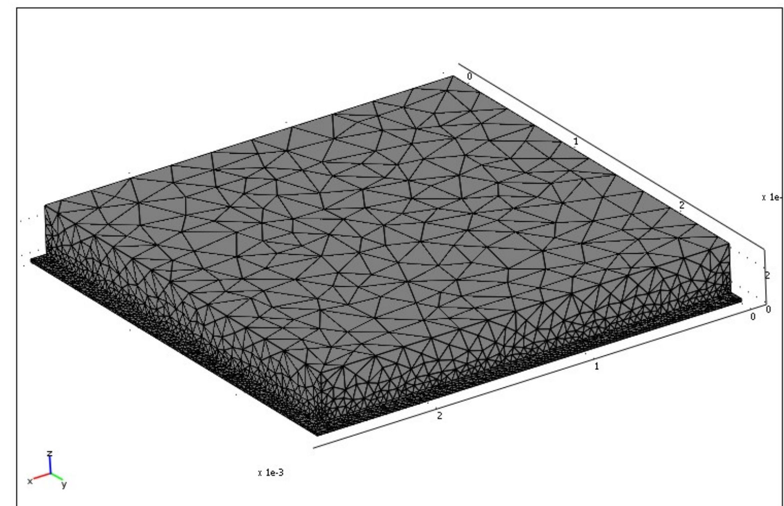
PICS = Passive Integration Connecting Substrate

Moisture diffusion simulation

Alberto Corigliano, Livio Domenella. Polimi



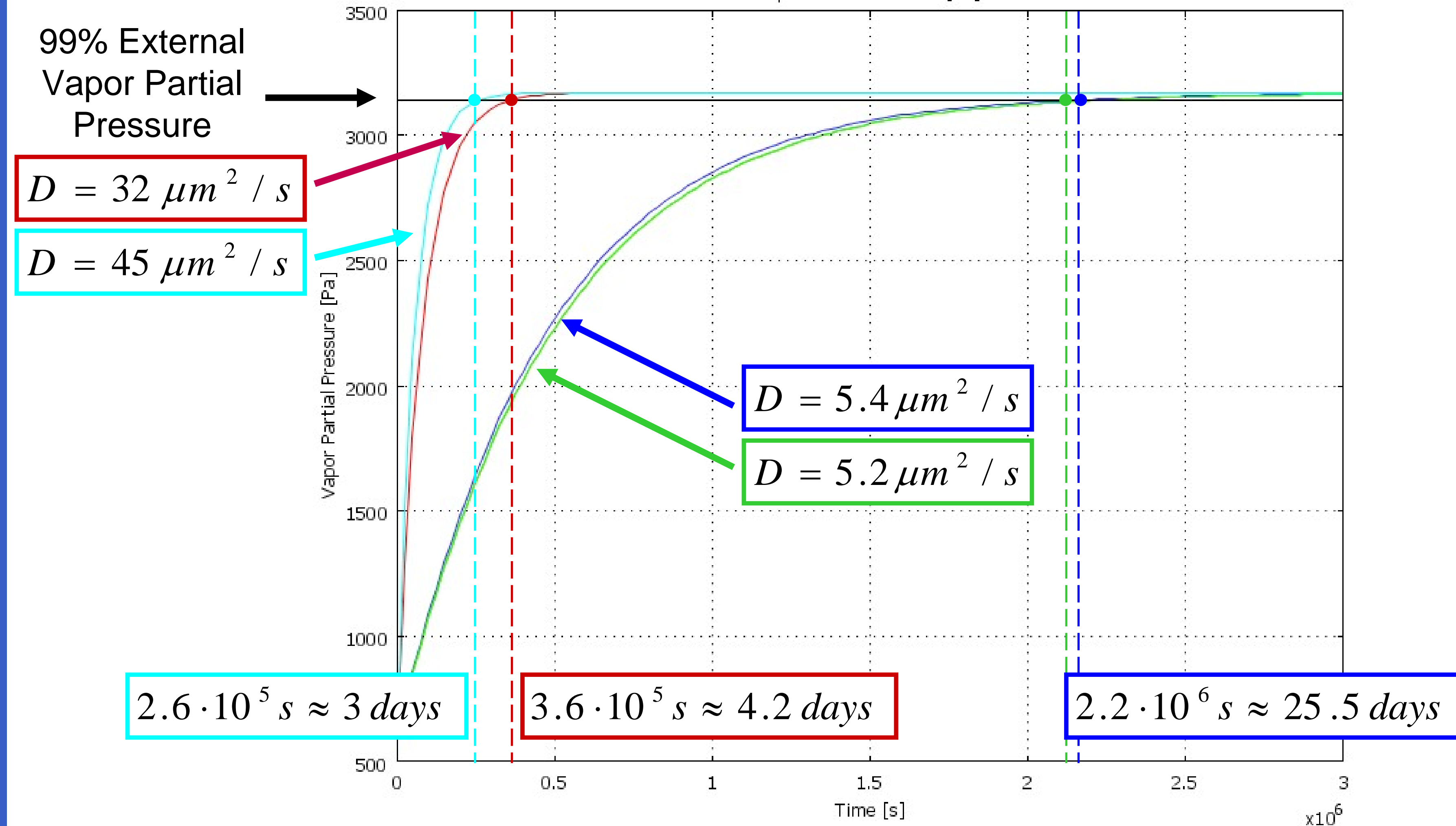




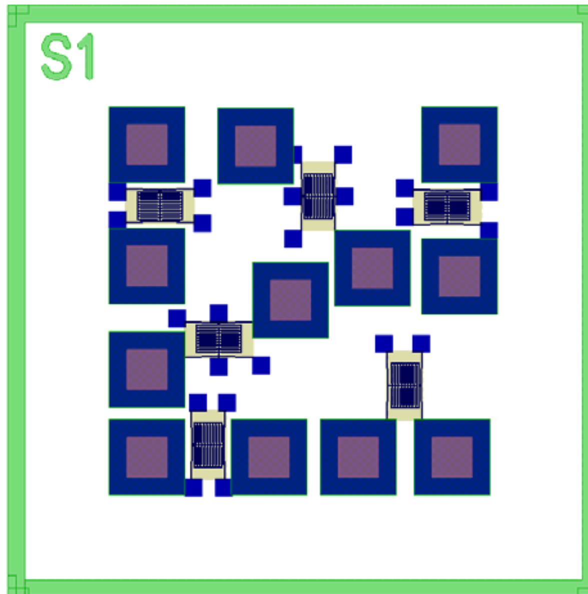
Moisture diffusion simulation

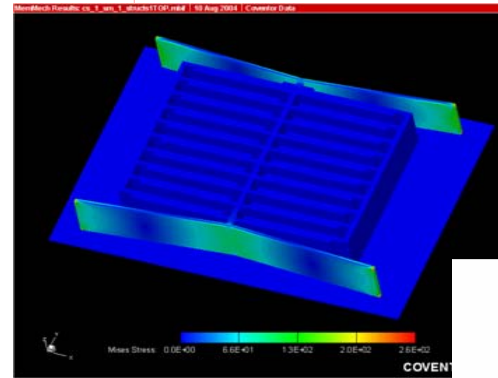
Partial pressure in the centre of the cavity

(External relative humidity: 100%)

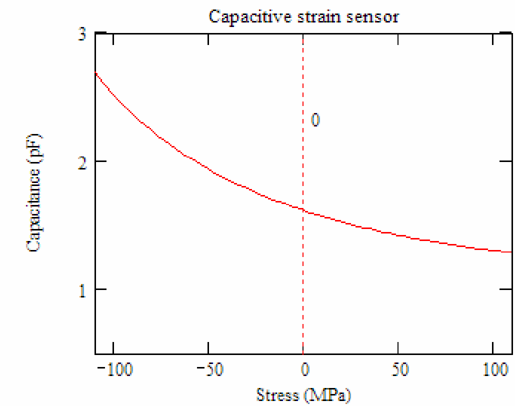


Strain sensor





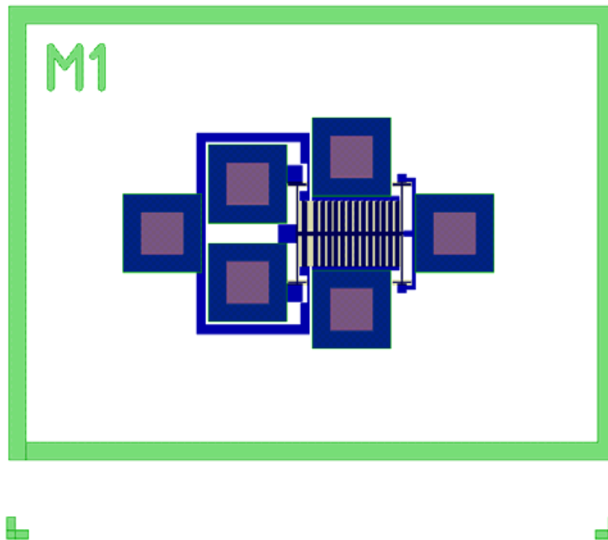
Qinetiq

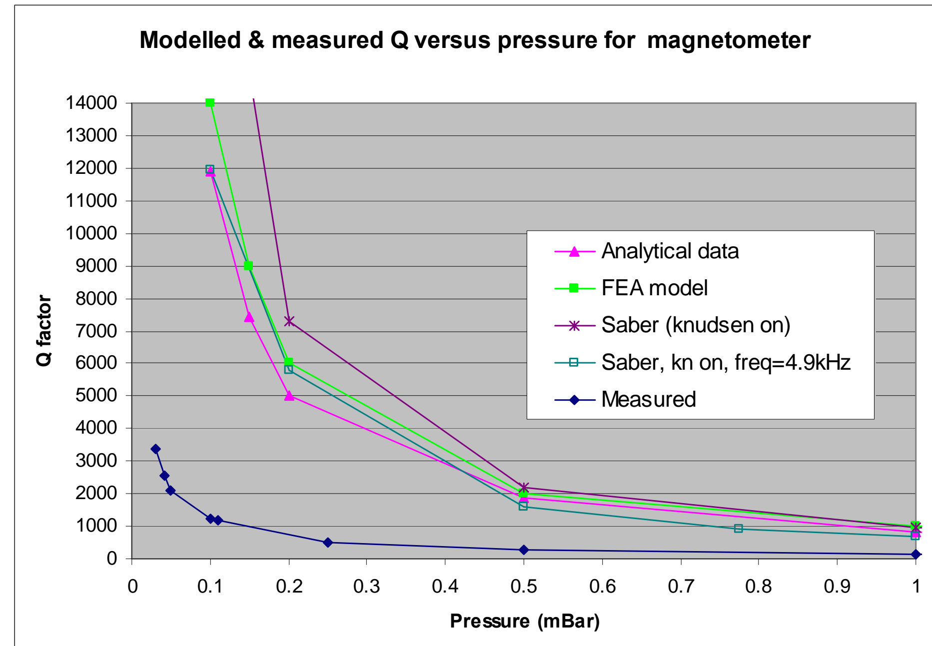


- Based on a pair on bent beam devices,
  - uses a capacitive readout
- Four devices to measure compressive and tensile stress in two orthogonal directions, and two orthogonal devices for control.

Resonant device

Qinetiq





- Magnetometer - vibrating structure to assess the resultant cavity hermeticity/ vacuum
  - Using Q versus pressure relationship from trials with non-sealed device in vacuum chamber

Accelerometer

Precursor activities to possible demonstrator project for PATENT-DfMM NoE

Alan Brown

QinetiQ

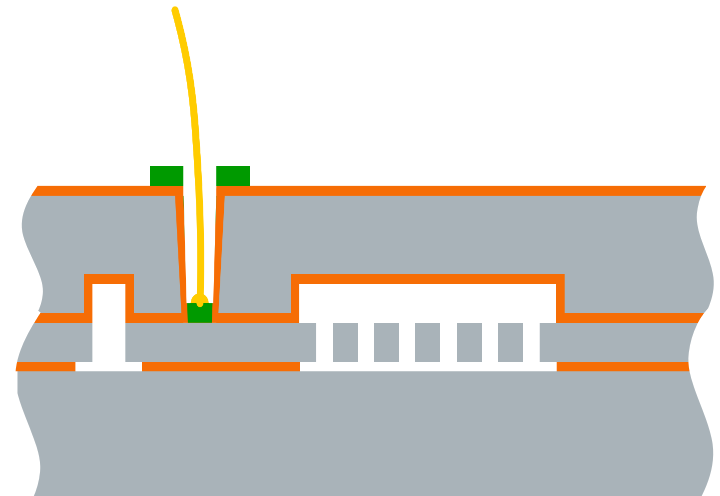
Nov-06

Part 1 - Scope demonstrator activity for 2007

- Scope: to demonstrate a testable, reliable low cost packaged accelerometer.
- The activity intends to build on previous work within PATENT.
- Based on the outcome a detailed proposal for the proposed demonstrator activity will be prepared for consideration as part of the call process for 2007 activities.

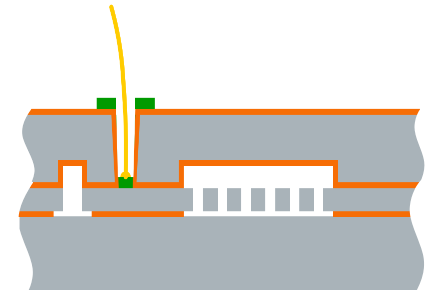
Part 2 - Precursor accelerometer packaging study

- QinetiQ to conduct a small precursor study on low cost packaging of SOI accelerometer devices.
  - A number of packaging options will be considered/ including, Chip on Board Assembly/Packaging and Wafer level packaging
  - Packaging trials will be conducted, and
  - if successful, samples will be supplied to the partners for initial reliability screening

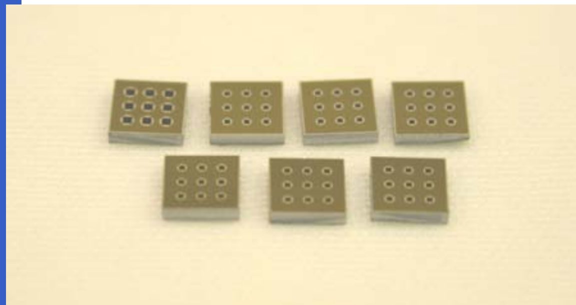


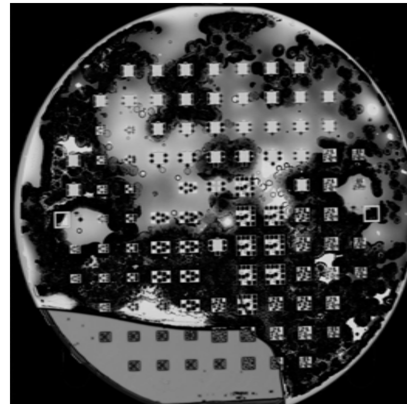
Part 2 - Precursor accelerometer packaging study

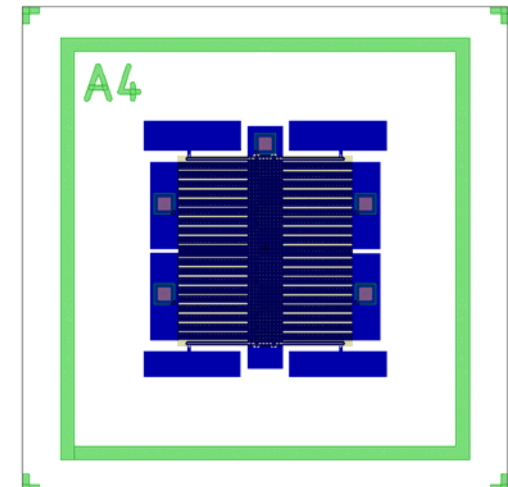
- Limitations of wire bonding in vias studied
  - using dedicated bonding tools (demonstrated for 300 micron vias)
  - With involvement of the tool company
  - With use of thinned wafers



- Study of wafer to wafer bonding
  - Test samples being fabricated
  - Tests are ongoing







Possible demonstrator project

- low cost (polymer intermediate bonding layer & Chip on Board mounting)
  - Full hermeticity not required for many applications
- Aim to pull together work on
  - CoB packaging
  - SU-8 bonding & associated reliability studies (or BCB)
  - Round robin modelling/ Die attach for stress sensitive devices
  - Accelerated testing study
  - SOI reliability work
  - Motionless testing at wafer level & Bias superposition

Conclusions

Reliability for MEMS is MEMS's best friend